Classification of Body Fatness by Body Mass Index–for-Age Categories Among Children

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**Objective:** To examine the ability of various body mass index (BMI)–for-age categories, including the Centers for Disease Control and Prevention’s 85th to 94th percentiles, to correctly classify the body fatness of children and adolescents.

**Design:** Cross-sectional.

**Setting:** The New York Obesity Research Center at St Luke’s–Roosevelt Hospital from 1995 to 2000.

**Participants:** Healthy 5- to 18-year-old children and adolescents (N=1196) were recruited in the New York City area through newspaper notices, announcements at schools and activity centers, and word of mouth.

**Main Outcome Measures:** Percent body fat as determined by dual-energy x-ray absorptiometry. Body fatness cutoffs were chosen so that the number of children in each category (normal, moderate, and elevated fatness) would equal the number of children in the corresponding BMI-for-age category (<85th percentile, 85th-94th percentile, and ≥95th percentile, respectively).

**Results:** About 77% of the children who had a BMI for age at or above the 95th percentile had an elevated body fatness, but levels of body fatness among children who had a BMI for age between the 85th and 94th percentiles (n=200) were more variable; about one-half of these children had a moderate level of body fatness, but 30% had a normal body fatness and 20% had an elevated body fatness. The prevalence of normal levels of body fatness among these 200 children was highest among black children (50%) and among those within the 85th to 89th percentiles of BMI for age (40%).

**Conclusion:** Body mass index is an appropriate screening test to identify children who should have further evaluation and follow-up, but it is not diagnostic of level of adiposity.

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**HIGH LEVELS OF BODY MASS INDEX (BMI) AMONG CHILDREN ARE ASSOCIATED WITH ADVERSE LEVELS OF VARIOUS RISK FACTORS,\(^1\) AND LONGITUDINAL STUDIES INDICATE THAT HIGH CHILDHOOD BMI IS RELATED TO Atherosclerosis,\(^2\) ADULT OBESITY,\(^3,4\) AND TOTAL MORTALITY.\(^5,6\) HOWEVER, MANY OF THESE ASSOCIATIONS ARE EVIDENT ONLY AFTER DECADES OF FOLLOW-UP, AND IT IS DIFFICULT TO CLASSIFY CHILDHOOD BMI ACCORDING TO HEALTH-RELATED RISKS. THE 2 MOST WIDELY USED CLASSIFICATION SYSTEMS EXPRESS A CHILD’S BMI RELATIVE TO THOSE AMONG CHILDREN OF THE SAME SEX AND AGE IN NATIONALLY REPRESENTATIVE SAMPLES FROM EITHER THE UNITED STATES\(^7\) OR BRAZIL, GREAT BRITAIN, HONG KONG, THE NETHERLANDS, SINGAPORE, AND THE UNITED STATES.\(^8,9\)

According to Centers for Disease Control and Prevention (CDC) growth charts, children with BMI-for-age levels at or above the 95th percentile of the 1963-1994 reference population were originally considered overweight, and those between the 85th and 94th percentiles were considered at risk of overweight.\(^10,11\) Although the BMI-for-age cutoffs (85th and 95th percentiles of the CDC reference population) have not changed, the terms overweight (85th-94th percentile) and obese (≥95th percentile) have recently been suggested to describe these groups.\(^12\) It has also been recommended\(^11\) that the approximately 17% of US schoolchildren who have a BMI for age at or above the 95th percentile\(^13\) be referred for an in-depth medical assessment. Another 16% of US schoolchildren have a BMI for age between the 85th and 94th percentiles,\(^13\) and it has been suggested\(^11\) that these children also be referred for medical assessment if there is a family history of obesity or weight-related medical problems, they have adverse levels of lipids or blood pressure, or they have had large increases in BMI. However, the accuracy of childhood BMI as an indicator of adiposity increases with the degree of body fatness,\(^14,15\) and a child with a BMI for age between the 83rd and 94th percentiles could...
METHODS

SAMPLE

Between 1995 and 2000, 1166 healthy volunteers (ages, 5-18 years) were recruited in the New York City area for the Pediatric Rosetta Body Composition project through newspaper notices, announcements at schools and activity centers, and word of mouth. The institutional review board of St Luke’s–Roosevelt Hospital Center approved the study protocol, and consent was obtained from each volunteer’s parent or guardian. When appropriate, assent was also obtained from each volunteer.

As previously described, a questionnaire was used to establish ethnicity; the criterion was consistent ethnic background (white, black, Hispanic, or Asian) for both parents and all grandparents. Subjects with grandparents of different racial or ethnic groups (n=92) were not included in analyses that focused on race/ethnic differences. Most Hispanic participants were of Dominican or Puerto Rican ethnicity.

ANTHROPOMETRY

Body weight was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a stadiometer with subjects wearing a hospital gown and foam slippers. Body mass index, calculated as weight in kilograms divided by height in meters squared, was used as an index of relative weight, with BMI-for-age z scores and percentiles calculated from CDC growth charts. These standardized levels express the BMIs of children in the current study (ages 5-18 years) relative to those of the same sex and age in the CDC reference population, who for the most part, were examined between 1963 and 1980.

Because of possible confusion resulting from the use of the terms at risk of overweight, overweight, and obesity to describe various BMI-for-age categories, we refer to these categories using the percentile ranges from the CDC reference population (eg, children with a BMI for age within the 85th and 94th percentiles rather than children who are overweight). Because these percentiles are calculated to several decimal places, the actual percentiles among children between the 85th and 94th percentiles range from 85.000 to 94.999.

DUAL-ENERGY X-RAY ABSORPTIOMETRY

Whole-body dual-energy x-ray absorptiometry scans were performed using Lunar DPX, with pediatric software version 3.8G, and DPX-L, with pediatric software 1.5G (GE Lunar Corporation; Madison, Wisconsin). The scan mode was chosen according to the weight guidelines provided by the manufacturer, and each scan gave an estimate of percent body fat. As has been reported, various aspects of quality control for the dual-energy x-ray absorptiometry instruments were performed daily, monthly, and at all maintenance visits.

Because of concerns about additional radiation exposure, the reproducibility of these scans was not assessed among children. However, among adults in the New York Obesity Research Center, the coefficient of variation for percent body fat was 3.3% and the intraclass correlation coefficient was 0.994. The use of 2 different pencil-beam dual-energy x-ray absorptiometry systems in the current study likely resulted in additional errors, but a previous analysis found good agreement (coefficient of variation, 4.4%) between estimates of fat mass by each system among adults.

CLASSIFICATION OF BODY FATNESS

We focus on the ability of 3 categories of BMI for age (<85th percentile, 85th-94th percentile, and ≥95th percentile) to correctly classify the body fatness of children. Because there is little agreement on the classification of excess body fatness among children (or adults), we constructed 3 categories of body fatness (normal, moderate, and elevated) that correspond to the 3 BMI-for-age categories. Within each sex and age group (<9, 9-11.9, 12-14.9, and ≥15 years), percent body fat cutoffs were chosen so that (1) the number of children with elevated fatness would equal the number of children who had a BMI for age at or above the 95th percentile, (2) the number of children with moderate levels of fatness would equal the number who had a BMI for age between the 85th and 94th percentiles, and (3) the number of children with a normal fatness would equal the number who had a BMI for age lower than the 85th percentile. If there was a perfect correlation between BMI for age and body fatness (on a continuous scale), this type of classification would result in perfect correspondence of categories of BMI for age and body fatness.

Among 12- to 14-year-old girls (n=132), for example, levels of percent body fat were ranked from low (1) to high (132). Of these girls, 26 had a BMI for age at or above the 95th percentile, and we therefore classified the 26 girls with the highest levels of percent body fat (ranks 107-132) as having elevated body fatness. Because another 22 girls had a BMI for age between the 85th and 94th percentiles, the 22 girls with the next highest levels of percent body fat (ranks 85-106) were considered to have moderate body fatness. Girls with lower levels of percent body fat (ranks of ≤84) were considered to have a normal body fatness. A similar process was applied to levels of body fatness in the other sex-age groups.

The derived cutoffs for body fatness are presented in Table 1. Because of the sex and age differences in body fatness, a body fatness of 35% among girls would be considered elevated (coefficient of variation, 4.4%) between estimates of fat mass by each system among adults.
Table 2. Demographic Characteristics by Sex and Age

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Boys 5-11.9 y (n=316)</th>
<th>Boys 12-18 y (n=310)</th>
<th>Girls 5-11.9 y (n=311)</th>
<th>Girls 12-18 y (n=259)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI, median (interquartile distance)</td>
<td>17.5 (4)</td>
<td>21.5 (5)</td>
<td>17.4 (5)</td>
<td>22.0 (6)</td>
</tr>
<tr>
<td>BMI for age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>z Score, mean (SD)</td>
<td>0.6 (1.1)</td>
<td>0.4 (1.1)</td>
<td>0.5 (1.1)</td>
<td>0.5 (1.0)</td>
</tr>
<tr>
<td>Percentile, %</td>
<td>85th-94th</td>
<td>16</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>&gt;95th</td>
<td>18</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Percent body fat, median (interquartile distance)</td>
<td>17.6 (16)</td>
<td>15.0 (16)</td>
<td>22.6 (14)</td>
<td>28.1 (14)</td>
</tr>
<tr>
<td>Race/ethnicity, %b</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>28</td>
<td>23</td>
<td>26</td>
<td>24</td>
</tr>
<tr>
<td>Black</td>
<td>18</td>
<td>24</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>Hispanic</td>
<td>11</td>
<td>19</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Asian</td>
<td>32</td>
<td>29</td>
<td>31</td>
<td>27</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).  
a Twenty-five percent of children had a BMI between the 85th and 94th percentiles and another 21% higher among children with a BMI for age at or above the 95th percentile (P < .001). (These differences were adjusted in regression models for sex and age.)  
b There were 92 children whose race/ethnicity was unclassified; these children had grandparents of different racial or ethnic groups.

Statistical Analysis

All analyses were performed using R (R Project for Statistical Computing, Vienna, Austria). Summary statistics are shown by sex and age group, and because the distributions of BMI and percent body fat were skewed, we present the median and interquartile (75th-25th percentile) distance for these characteristics. To visually examine the classification of body fatness by BMI for age, each child’s body fatness was plotted vs age, and lowess smoothing regression (locally weighted scatterplot smoother)24 was used to indicate trends in body fatness by age within each BMI group. We estimated mean differences in percent body fat between the 3 categories of BMI for age in regression models that included sex and age as covariates.

We cross-classified the 3 categories of both BMI for age and body fatness (normal, moderate, and elevated) and focused on the positive predictive values of BMI for age. Stratified analyses examined whether the proportion of children who had a BMI for age from the 85th to the 94th percentile with normal body fatness varied by age or race/ethnicity; statistical significance was assessed using Cochran-Mantel-Haenszel tests (controlling for sex)24 and logistic regression models.

We also examined the ability of 7 narrower categories of BMI for age to correctly identify corresponding levels of body fatness. Cutoffs for percent body fat in this analysis were constructed as previously described, so that the number of children in each BMI for age and fatness category would be equal.

Results

Table 2 presents demographic, BMI, and body fatness characteristics by sex and age among the 1196 children. Compared with the CDC reference population, the examined children were relatively heavy, with mean BMI-for-age z scores of 0.4 to 0.6. Overall, about 17% of the children had a BMI for age between the 85th and 94th percentiles and another 16% had a BMI for age at or above the 95th percentile. There were large differences in body fatness by sex and age, with median levels of percent body fat ranging from 15% (older boys) to 28% (older girls). Overall, 23% of the examined children were black, 14% were Hispanic, and 30% were Asian.

Compared with the body fatness of children who had a BMI for age lower than the 85th percentile, the mean level of percent body fat was 11% higher among those with a BMI for age between the 85th and 94th percentiles and 21% higher among children with a BMI for age at or above the 95th percentile (P < .001). (These differences were adjusted in regression models for sex and age.) Furthermore, as assessed by various interaction terms, differences in body fatness across the 3 BMI groups did not significantly vary by sex or age.

The Figure shows the children’s body fatness by sex and age, along with smoothed levels of body fatness among children in the 3 BMI groups. Despite the large differences in mean body fatness across the BMI categories, the body fatness of individual children overlapped substantially. (Perfect classification of body fatness by BMI for age would result in 3 completely distinct groups of symbols.) Among both boys and girls, many children with a BMI for age between the 85th and 94th percentiles had more body fatness than did some children with higher levels of BMI for age, whereas other children with a BMI for age between the 85th to 94th percentiles had body fatness comparable with that of children with lower BMIs. As assessed visually, this misclassification did not markedly differ by sex or age.

The cross-classification of categories of BMI for age (<85th, 85th-94th, and ≥95th percentile) and percent body fat (normal, moderate, and elevated) is summarized in Table 3. Overall, BMI was a fairly good indicator of body fatness among most children: 82% of boys and 84% of girls were in comparable categories (along the diagonal) of the 2 characteristics. Of the 187 children with a BMI for age at or above the 95th percentile, 75% of boys and 80% of girls had an elevated body fatness. There was more misclassification among children who had a BMI for age between the 85th and 94th percentiles, with only about one-half of these 200 children having a moderate body fatness. Of the 98 boys with a BMI for age between the 85th and 94th percentiles, 21% had an elevated level of percent body fat and 32% had a

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Figure. Percent body fat by age among boys and girls who have body mass index (BMI)–for-age levels lower than the 85th percentile, between the 85th and 94th percentiles, and at or above the 95th percentile. Each point represents an individual boy or girl, and the 3 lines represent smoothed (Lowess) levels of body fatness by age in each BMI group.
normal level. Misclassification was fairly similar among the 102 girls who had a BMI for age in this range: 16% had an elevated body fatness and 29% had a normal level.

Stratified analyses (Table 4) examined whether the distribution of body fatness levels among the 200 children who had a BMI for age between the 85th and 94th percentiles varied by age or race/ethnicity. (Results among boys and girls were similar, and the 2 groups have been combined in Table 4.) The prevalence of normal body fatness among these children did not significantly differ (P = .33) by age, but there were substantial differences by race/ethnicity. Whereas only 20% of Asian children who had a BMI for age in this range had a normal body fatness, the prevalence reached 50% among black children (P = .03, for race/ethnicity difference).

We then examined the ability of narrower BMI categories (a total of 7) to correctly identify corresponding levels of body fatness among all 1196 children (Table 5). Whereas none of the 36+ children with a BMI for age lower than the 50th percentile had an elevated body fatness, 112 of 120 children (93%) who had a BMI for age at or above the 97th percentile had an elevated level. Furthermore, within each of the 3 major BMI groups, a higher BMI for age was associated with increased body fatness. For example, the prevalence of elevated body fatness increased from 9% (8 of 88) among children who had a BMI for age between the 85th and 89th percentiles to 26% (29 of 112) among children between the 90th and 94th percentiles. Furthermore, children with a BMI for age at or above the 97th percentile were more likely to have an elevated body fatness than those with BMIs between the 95th and 96th percentiles (93% vs 48%).

There was also substantial misclassification of the body fatness of the thinnest children, but this was limited to categories of normal body fatness. For example, although only 61 of 144 children (42%) with a BMI for age lower than the 25th percentile had a correspondingly low level of body fatness, none had a moderate or elevated body fatness.

### Table 3. Classification of Children by BMI-for-Age and Body Fatness Categories

<table>
<thead>
<tr>
<th>BMI-for-Age Percentile</th>
<th>Normal (%)</th>
<th>Moderate (%)</th>
<th>Elevated (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;85th</td>
<td>392 (92)</td>
<td>28 (7)</td>
<td>5 (1)</td>
</tr>
<tr>
<td>85th-94th</td>
<td>31 (32)</td>
<td>46 (47)</td>
<td>21 (21)</td>
</tr>
<tr>
<td>≥95th</td>
<td>2 (2)</td>
<td>24 (23)</td>
<td>77 (75)</td>
</tr>
<tr>
<td>Total</td>
<td>425</td>
<td>98</td>
<td>103</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index.

### Table 4. Body Fatness Among Children Who Had a BMI for Age Between the 85th and 94th Percentiles by Age and Race/Ethnicity

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Normal (%)</th>
<th>Moderate (%)</th>
<th>Elevated (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;9</td>
<td>8 (22)</td>
<td>18 (50)</td>
<td>10 (28)</td>
</tr>
<tr>
<td>9-11</td>
<td>20 (28)</td>
<td>41 (57)</td>
<td>11 (15)</td>
</tr>
<tr>
<td>12-14</td>
<td>15 (31)</td>
<td>25 (52)</td>
<td>8 (17)</td>
</tr>
<tr>
<td>≥15</td>
<td>18 (41)</td>
<td>18 (41)</td>
<td>8 (18)</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>12 (27)</td>
<td>24 (55)</td>
<td>8 (18)</td>
</tr>
<tr>
<td>Black</td>
<td>18 (50)</td>
<td>11 (31)</td>
<td>7 (19)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>12 (33)</td>
<td>20 (56)</td>
<td>4 (11)</td>
</tr>
<tr>
<td>Asian</td>
<td>16 (23)</td>
<td>39 (57)</td>
<td>14 (20)</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index.

### Table 5. Classification of Children by BMI-for-Age and Body Fatness Categories

<table>
<thead>
<tr>
<th>BMI-for-Age Percentile</th>
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<th>Moderate (%)</th>
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</tr>
<tr>
<td>≥95th</td>
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<td>24 (23)</td>
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<tr>
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<td>425</td>
<td>98</td>
<td>103</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index.

### COMMENT

The magnitude of the association between childhood levels of BMI and body fatness (determined by dual-energy x-ray absorptiometry, densitometry, and other methods) has varied substantially across studies, and relatively modest (r, approximately 0.5) associations have been reported.26-28 In the current study, of the 200 children who had a BMI for age between the 85th and 94th percentiles, about 20% had a body fatness that was comparable with levels among children with higher BMIs, while about 30% had a body fatness within the range of children with normal weight (<85th percentile). Although the misclassification of body fatness among children who had a BMI for age between the 85th and 94th percentiles did not vary significantly by sex or age, black children with BMIs in this range were more likely to have a normal body fatness than were other children. In addition, children with BMI for age between the 85th and 89th percentiles were more likely to have normal body fatness than those with levels between the 90th and 94th percentiles.

Although a high BMI (for a child’s sex and age) is a good indicator of elevated body fatness,29 BMI has been considered to be “almost useless as an estimator of percentage of body fat in normal-weight children.”15 We have previously reported14 that BMI differences among children with normal weight can largely reflect variability in fat-free mass, and our current results indicate that there is substantial misclassification of body fatness by BMI for age among thin children. For example, only 42% of the 144 children who had a BMI for age lower than the 25th percentile had a cor-
respondingly low body fatness, but 93% of the 120 children with very high levels of BMI for age (≥97th percentile) had an elevated body fatness. We have previously shown that skinfold thickness measurements can substantially improve the prediction of body fatness in children with a BMI for age lower than the 95th percentile, and it is likely that these measurements could identify children with moderately elevated BMIs who truly have elevated body fatness.

In addition to the variability in levels of fat-free mass, the misclassification of body fatness by BMI for age may also reflect the differing scales for BMI and BMI for age. Among boys at age 12 years, for example, the difference between the 50th (BMI, 17.8) and 97th (BMI, 26.0) percentiles of BMI for age is 8.2, whereas the difference in BMI between the third (BMI, 14.7) and 50th percentiles (also a 47-point percentile difference) is only 3.1. The asymmetry arises from the skewed distribution of BMI levels. Because BMI-for-age categories among heavy children span greater BMI ranges than do categories among thinner children, one might expect BMI for age to be a better indicator of the body fatness of relatively heavy children. We have previously reported that the combination of age, race/ethnicity, and BMI for age is a good predictor of percent body fat, with multiple $R^2$ values of 0.81 (boys) and 0.82 (girls).

About 70% of children in the current study with a BMI for age between the 85th and 94th percentiles had a high (moderate or elevated) level of body fatness; this positive predictive value did not significantly vary by sex or age. Black children with BMIs in this range (both boys and girls), however, were less likely to have high body fatness than other children (white, Asian, and Hispanic). These results are in agreement with our previous report that at similar levels of BMI for age, the mean body fatness of black children is about 3% lower than that of white children. Other investigators have also reported racial differences in body composition, with black individuals having a higher fat-free body density and less body fatness than white individuals.

All classification systems of body fatness are somewhat arbitrary, and there is little agreement on the classification of excess body fatness among adults or children. We used cutoffs for percent body fat that were consistent (in terms of identifying similar numbers of children within each sex-age group) with various categories of BMI for age, and other studies have used similar approaches. Although some investigators have attempted to base fatness cutoffs on cross-sectional associations with cardiovascular disease risk factors, this approach may not be optimal. The underlying associations between risk factors and body fatness are continuous without obvious inflection points, and some of the proposed cutoffs do not account for the large age and sex differences in body fatness. Furthermore, it is possible that various risk factors are as strongly correlated with levels of BMI as with body fatness.

Table 5. Classification of Body Fatness by Narrower BMI-for-Age Categories

<table>
<thead>
<tr>
<th>BMI-for-Age Percentile</th>
<th>No. (%) of Participants per Body Fatness Categorya</th>
</tr>
</thead>
<tbody>
<tr>
<td>25th-29th, first category</td>
<td>144 (61 Normal, 54 First Category, 29 Second Category)</td>
</tr>
<tr>
<td>25th-29th, second category</td>
<td>220 (56 Normal, 80 Second Category, 82 Third Category)</td>
</tr>
<tr>
<td>25th-29th, third category</td>
<td>445 (27 Normal, 84 Second Category, 272 Third Category)</td>
</tr>
<tr>
<td>25th-29th, fourth category</td>
<td>88 (0 Normal, 2 Second Category, 20 Third Category)</td>
</tr>
<tr>
<td>25th-29th, fifth category</td>
<td>112 (0 Normal, 0 Second Category, 26 Third Category)</td>
</tr>
<tr>
<td>25th-29th, sixth category</td>
<td>67 (0 Normal, 0 Second Category, 3 Third Category)</td>
</tr>
<tr>
<td>25th-29th, seventh category</td>
<td>120 (0 Normal, 0 Second Category, 8 Third Category)</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index.

aCategories of body fatness and BMI for age correspond by ordinal numbers. For example, there were 144 children with a BMI for age lower than the 25th percentile (first category), and body fatness cutoffs were selected so that there would also be 144 children in the lowest category of body fatness.
ness that was comparable with levels among children with lower levels of BMI for age.

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Author Contributions: Dr Freedman had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Freedman, Sophie, and Horlick. Acquisition of data: Thornton, Mei, Sophie, Pierson, and Horlick. Analysis and interpretation of data: Freedman, Sophie, and Horlick. Critical revision of the manuscript for important intellectual content: Freedman, Wang, Mei, Pierson, Dietz, and Horlick. Statistical analysis: Freedman, Thornton, and Mei. Obtained funding: Pierson and Horlick. Administrative, technical, and material support: Wang, Sophie, Pierson, and Horlick. Study supervision: Dietz and Horlick.

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REFERENCES


