The predictive value of childhood body mass index values for overweight at age 35 y\(^1\)\(^{-3}\)

Shumei S Guo, Alex F Roche, W Cameron Chumlea, Jane D Gardner, and Roger M Siervogel

ABSTRACT Larger body mass index values (BMI in kg/m\(^2\)) are associated with increased morbidity and mortality in adulthood and there are significant correlations between BMI values in childhood and in adulthood. The present study addresses the predictive value of childhood BMI for overweight at 35 ± 5 y, defined as BMI > 28 for men and > 26 for women. Analyses of data for 555 white children indicated that overweight at 35 y can be predicted from BMI at younger ages. The prediction is excellent at age 18 y, good at 13 y, but only moderate at ages younger than 13 y. For 18-y-olds with a BMI value exceeding the 60th percentile, the odds of overweight at 35 y are 34% for men and 37% for women. A clinically applicable method is provided to assign an overweight child to a group with a known probability of high BMI values in adulthood. Am J Clin Nutr 1994;59:810–9.

KEY WORDS Overweight, children, adults, risk analysis

Introduction

Overweight is of considerable public concern because it is related to cardiovascular disease, hypertension, and diabetes in adulthood and these are leading causes of death in the United States (1–5). Overweight in childhood is related to morbidity and mortality rates in adulthood (6), because body weight during childhood is an important determinant of adulthood overweight (7). Despite this importance, the predictive value of overweight in childhood for overweight in adulthood has not been established. Such predictive values would assist the identification of children with a high probability of being overweight in adulthood. The management of overweight in these children should not be delayed until adulthood when the pathophysiological changes associated with overweight are more likely to be established (8) and it is more difficult to accomplish changes in lifestyle (9, 10).

Weight and stature are the most common measurements in clinical settings and in health-related surveys. A simple way to assess overweight is to combine these measurements in the body mass index (BMI), which is defined as weight (kg) divided by stature squared (m\(^2\)). This index adjusts weight for stature and larger values are associated with increased mortality rates in adulthood.

Among published studies, the emphasis has been on correlations between childhood and adulthood BMI values. Little is known about the extent to which childhood BMI values are associated with adulthood values that have significant health risk for morbidity and mortality, ie, values that exceed the recommended range. Establishment of these relationships would facilitate the selection of cutoff points for childhood BMI values and assist public health programs that aim to detect and manage children with increased odds of being overweight in adulthood. To establish these relationships, the predictive values of childhood BMI for adulthood BMI values above the recommended range have been determined and a simple method was developed for their clinical and public health application.

There are numerous reports that BMI values > 28 for men and > 26 for women are associated with increased risks of fatal and nonfatal coronary heart disease, other cardiovascular diseases, gallstones, and non-insulin-dependent diabetes mellitus and increases in all-causes mortality rates (1–4, 8, 11–14). There are some contrary reports of only slight associations between adult BMI values and the prevalence of cardiovascular diseases 10 y later (15).

Methods

Sample

The data were obtained from 277 male and 278 female white participants in the Fels Guidance, Harvard, and Oakland longitudinal studies who were born between 1929 and 1960 (16–18). The Fels Longitudinal Study was approved by the Institutional Review Board of Wright State University; the other studies were conducted before ethical approval was required. Data for those who were pregnant or with known diseases were excluded. Participants from a wide range of socioeconomic groups were enrolled at or soon after birth and were not selected in regard to factors known to be associated with obesity. Annual data for stature or recumbent length and for weight from 1 to 18 y and at 35 ± 5 y were included in the analysis. Recumbent length was

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used in place of stature from 1 to 3 y of age. The measurements were made by using procedures closely similar to those recommended in the Anthropometric Standardization Reference Manual (19). Reliability data for these measurements are excellent (20) and secular trends for weight and stature were not significant in these data (20–22). Pooling of data from the four studies for the present analyses was justified by the absence of significant differences among the coefficients of the study-specific logistic regressions that related BMI percentiles in childhood to the presence of overweight at 35 y. The sample sizes from the four longitudinal studies are given in Table 1 where they are separated depending on whether the BMI values at 35 y exceed the recommended values. These values were exceeded by 12.6% of men and 11.2% of women.

Statistical methods

Data recorded at annual target ages from 1 to 18 y and from 30 to 39 y were analyzed. Childhood BMI values were computed and converted to percentiles, to the nearest integer, for age and sex by using data from the Second National Health and Nutrition Examination Survey for whites (NHANES II, 23). A BMI value at 35 y for an individual was obtained by averaging all available BMI values from 30 to 39 y.

For the present analyses, the upper limits of the desirable range of BMI values at 35 y were needed for each sex. The values selected were 28 for males and 26 for females after considering the recommendations of others and reports from long-term follow-up studies beginning at ≈35 y. In these studies, mortality rates are related to BMI values at entry. The increases in mortality rates with increases in BMI begin at ≈25, but these increases are small and irregular until larger BMI values (> 28 for males and > 26 for females) are reached (24–26). These studies and others have been the subject of critical reviews (11, 27) that have led to the recommendation of ranges for BMI at ≈35 y that have upper limits similar to the cutoff values chosen for the present analyses.

It is not possible to establish consensus values for the upper limit of the desirable ranges of BMI at 35 y because the studies vary in design regarding the exclusion of smokers and of deaths soon after entry, screening for disease at entry, and length of follow-up. Furthermore, comparisons among studies are made difficult by the common practice of grouping BMI values for analysis by quintiles of the study distributions. As a result, the range of values within quintiles differs among studies. Finally, the relationship between a particular BMI value at entry to a study and longevity is influenced by biological variations in the effects of BMI values on pathophysiological processes, changes in BMI after entry, and intervening variables.

Model fitting

A logistic regression of overweight at 35 y (BMI > recommended range) on BMI percentiles at each annual childhood age was performed separately for males and females by using the LR program in the BMDP package (28). This related the logarithm of the odds (logit) of overweight at 35 y to the BMI percentile at each specified childhood age. The functional relationship is described in the following equation:

\[
\log \left( \frac{p}{1 - p} \right) = \alpha + \beta x + \epsilon
\]

where \(p\) is the proportion of overweight in the group, \(x\) is the BMI percentile at the specified childhood age, \(\alpha\) and \(\beta\) describe the intercept and slope of the logistic regression, and \(\epsilon\) is an error term. Goodness of fit was assessed by using Hosmer-Lemeshow chi-square statistics (29). Lack of fit would imply that the chosen model was not valid for the data.

Prediction

The probability of overweight at 35 y, \(\hat{p}\), was predicted from childhood BMI percentiles for each annual age from the fitted model:

\[
\hat{p} = \frac{e^{\hat{\alpha} + \hat{\beta}x}}{1 + e^{\hat{\alpha} + \hat{\beta}x}}
\]

The probabilities of overweight at 35 y were calculated for childhood BMI values at the 50th, 75th, 85th, and 95th percentile levels. After adjusting the probability values for the effects of multiple tests (30), the fit was good for each sex at all ages.

Odds ratio

The odds of overweight at age 35 y for children with BMI values at the 95th percentile level were calculated relative to the odds of overweight for children with BMI values at the 50th and 75th percentile levels. The odds of overweight at age 35 y for children with BMI values at the 75th percentile level were calculated relative to the odds for those at the 50th percentile level.

Cutoff points in childhood in relation to overweight at 35 y

Each childhood cutoff point was defined as the BMI percentile at a childhood age from which a participant can be predicted to be in an overweight group or the remaining group at 35 y. The cutoff points were derived from the following equation:

\[
\hat{X} = \left( \ln \frac{p}{1 - p} - \hat{\alpha} \right) / \hat{\beta}
\]

The sensitivity (Se) and specificity (Sp) were evaluated for selected childhood cutoff points. Sensitivity refers to the percentage of participants who were correctly predicted to be in the overweight group.

### Table 1

<table>
<thead>
<tr>
<th>Study</th>
<th>Males ≤ 28</th>
<th>Males &gt; 28</th>
<th>Females ≤ 26</th>
<th>Females &gt; 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fels (16)</td>
<td>92</td>
<td>20</td>
<td>93</td>
<td>18</td>
</tr>
<tr>
<td>Guidance (17)</td>
<td>53</td>
<td>2</td>
<td>52</td>
<td>3</td>
</tr>
<tr>
<td>Harvard (17)</td>
<td>43</td>
<td>8</td>
<td>46</td>
<td>6</td>
</tr>
<tr>
<td>Oakland (17)</td>
<td>54</td>
<td>5</td>
<td>54</td>
<td>4</td>
</tr>
<tr>
<td>Totals</td>
<td>242</td>
<td>35</td>
<td>247</td>
<td>31</td>
</tr>
</tbody>
</table>

* BMI in kg/m²; reference numbers for studies in parentheses.
TABLE 2
BMI values at ages 3, 8, 13, 18, and 35 y by sex and by absence or presence of adulthood overweight*

<table>
<thead>
<tr>
<th>Age</th>
<th>Males</th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>(n = 242)</td>
<td>(n = 35)</td>
<td>(n = 247)</td>
<td>(n = 31)</td>
</tr>
<tr>
<td>3 y</td>
<td>16 ± 1.2</td>
<td>17 ± 1.0</td>
<td>16 ± 1.4</td>
<td>17 ± 1.3</td>
</tr>
<tr>
<td>8 y</td>
<td>16 ± 1.9</td>
<td>17 ± 2.0</td>
<td>16 ± 1.6</td>
<td>18 ± 2.6</td>
</tr>
<tr>
<td>13 y</td>
<td>18 ± 2.4</td>
<td>22 ± 3.5†</td>
<td>19 ± 2.6</td>
<td>22 ± 3.8</td>
</tr>
<tr>
<td>18 y</td>
<td>21 ± 2.1</td>
<td>25 ± 3.4†</td>
<td>21 ± 2.1</td>
<td>26 ± 5.0†</td>
</tr>
<tr>
<td>35 y</td>
<td>24 ± 2.2</td>
<td>30 ± 2.9†</td>
<td>21 ± 2.0</td>
<td>30 ± 4.6†</td>
</tr>
</tbody>
</table>

*± SD. Adulthood overweight: BMI > 28 for males, BMI > 26 for females. BMI in kg/m².
† Significantly different from remaining group, \( P = 0.05 \).

\[
Se = \frac{\text{p}(x_i < \text{cutoff point and } x_o < c) + \text{p}(x_i > \text{cutoff point and } x_o > c)}{\text{p}(x_o > c)}
\]

where \( x_i \) is the BMI percentile at age \( r \) for the \( i \)th individual, \( x_o \) is the BMI value at 35 y for the same individual, and \( c \) is the criterion for adulthood overweight. Specificity refers to the percentage of participants who were correctly predicted to be in the remaining group.

\[
Sp = \frac{\text{p}(x_i < \text{cutoff point and } x_o < c)}{\text{p}(x_i > c)}
\]

Receiving operating curves (ROCs) were plotted to select the cutoff points. These ROCs are plots of sensitivity by the false positive rate (1-specificity). An ROC curve shows excellent predictability if the sensitivity increases rapidly as the false positive rate increases. For a given cutoff BMI percentile, sensitivity is the proportion of participants with BMI percentiles greater than the cutoff point at the childhood age who are overweight at 35 y. Odds ratios and their SDs for the selected childhood cutoff points, in relation to adulthood risks, were calculated for males and females (31).

Results

The sample sizes and means and SDs of BMI values at ages 3, 8, 13, 18, and 35 y for participants categorized by the absence or presence of overweight at 35 y are given in Table 2. These ages have been selected to represent early and late childhood, pubescence, postpubescence, and adulthood.

Pearson correlation coefficients between BMI at 35 y and BMI at ages 1 to 18 y are presented in Figure 1. The correlations for males increased from 1 to 4 y, remained generally stable from 4 to 9 y, and then increased. The correlations for females increased from 1 to 18 y except from 1 to 3 y and from 10 to 13 y. The correlation coefficients were ≤ 0.3 to 0.9 y in males and 4 y in females; after 4 y these correlations were greater for females than males, reaching ≤ 0.6 and 0.7 at 18 y for males and females, respectively.

Prediction

The predicted probabilities of overweight at 35 y for those with childhood BMI values at the 50th, 75th, and 95th percentile levels are presented in Table 3. For childhood BMI values at 75th and at 95th percentiles, the probabilities of overweight at 35 y increased with age. The probabilities were higher for males than for females until ≤ 8 y for childhood BMI values at the 50th, 75th, and 95th percentiles. The sex-associated differences in the

![FIG 1. Correlation coefficients between body mass index at age 35 y and childhood body mass index from 1 to 18 y.](image-url)
probability of overweight at 35 y were slight after 8 y but varied by age.

**Odds ratio**

The odds ratios for adulthood overweight were similar in the two sexes except toward the end of the childhood age range when some very large odds ratios occurred for the 95th-50th comparison that were more frequent for females than for males (Table 4 and Table 5). The odds ratios of overweight for males at 35 y for childhood BMI values at the 95th percentile, relative to those at the 75th percentile, varied with age and they doubled after approximately 10 y. The corresponding odds ratios for females were doubled after approximately 8 y. For male and female participants aged 8–18 y at the 75th percentile, the odds of overweight at 35 y were at least double those for participants with BMI values at the 50th percentile. The odds ratios of overweight at 35 y for male participants with BMI values at the 95th percentile, relative to those for participants at the 50th percentile, were doubled after 1 y, reached approximately 4.6 at 7 y, and exceeded 6.0 at ages >10 y. The corresponding odds ratios for females reached approximately 3.0 at 7 y and ≥5.0 thereafter.

**Cutoff points in childhood in relation to overweight at 35 y**

The ROCs in Figures 2 and 3 show sensitivity (percentage true positive), in relation to the false positive rate, for childhood BMI percentiles at 3, 8, 13, and 18 y for prediction of overweight at 35 y for males and females separately. The height of each curve increased with age indicating that the false positive rate decreased for a particular level of sensitivity, eg, 80%. For example, at age 18 y, at the 80% level of sensitivity, the false positive rates were 18% in males and 17% in females and the corresponding BMI value was at the 60th percentile. These analyses of sensitivity and specificity showed the prediction was excellent at age 18 y, good at 13 y, and only moderate at ages <13 y.

**TABLE 3**

Probability of overweight at 35 y predicted from childhood BMI percentile

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th>Girls</th>
<th>Boys</th>
<th>Girls</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50th percentile</td>
<td>75th percentile</td>
<td>95th percentile</td>
<td>50th percentile</td>
<td>75th percentile</td>
<td>95th percentile</td>
</tr>
<tr>
<td>1 y</td>
<td>0.12</td>
<td>0.10</td>
<td>0.16</td>
<td>0.15</td>
<td>0.21</td>
<td>0.20</td>
</tr>
<tr>
<td>2 y</td>
<td>0.12</td>
<td>0.11</td>
<td>0.18</td>
<td>0.16</td>
<td>0.25</td>
<td>0.20</td>
</tr>
<tr>
<td>3 y</td>
<td>0.12</td>
<td>0.10</td>
<td>0.16</td>
<td>0.15</td>
<td>0.21</td>
<td>0.20</td>
</tr>
<tr>
<td>4 y</td>
<td>0.12</td>
<td>0.11</td>
<td>0.18</td>
<td>0.16</td>
<td>0.25</td>
<td>0.21</td>
</tr>
<tr>
<td>5 y</td>
<td>0.10</td>
<td>0.11</td>
<td>0.19</td>
<td>0.18</td>
<td>0.29</td>
<td>0.27</td>
</tr>
<tr>
<td>6 y</td>
<td>0.12</td>
<td>0.11</td>
<td>0.17</td>
<td>0.18</td>
<td>0.24</td>
<td>0.27</td>
</tr>
<tr>
<td>7 y</td>
<td>0.12</td>
<td>0.07</td>
<td>0.24</td>
<td>0.13</td>
<td>0.39</td>
<td>0.19</td>
</tr>
<tr>
<td>8 y</td>
<td>0.11</td>
<td>0.08</td>
<td>0.23</td>
<td>0.20</td>
<td>0.37</td>
<td>0.39</td>
</tr>
<tr>
<td>9 y</td>
<td>0.10</td>
<td>0.13</td>
<td>0.19</td>
<td>0.33</td>
<td>0.30</td>
<td>0.57</td>
</tr>
<tr>
<td>10 y</td>
<td>0.11</td>
<td>0.07</td>
<td>0.25</td>
<td>0.21</td>
<td>0.43</td>
<td>0.44</td>
</tr>
<tr>
<td>11 y</td>
<td>0.07</td>
<td>0.09</td>
<td>0.21</td>
<td>0.19</td>
<td>0.40</td>
<td>0.32</td>
</tr>
<tr>
<td>12 y</td>
<td>0.09</td>
<td>0.10</td>
<td>0.24</td>
<td>0.26</td>
<td>0.44</td>
<td>0.48</td>
</tr>
<tr>
<td>13 y</td>
<td>0.07</td>
<td>0.09</td>
<td>0.21</td>
<td>0.19</td>
<td>0.40</td>
<td>0.32</td>
</tr>
<tr>
<td>14 y</td>
<td>0.09</td>
<td>0.05</td>
<td>0.25</td>
<td>0.22</td>
<td>0.45</td>
<td>0.51</td>
</tr>
<tr>
<td>15 y</td>
<td>0.07</td>
<td>0.09</td>
<td>0.22</td>
<td>0.23</td>
<td>0.44</td>
<td>0.41</td>
</tr>
<tr>
<td>16 y</td>
<td>0.07</td>
<td>0.03</td>
<td>0.20</td>
<td>0.17</td>
<td>0.39</td>
<td>0.45</td>
</tr>
<tr>
<td>17 y</td>
<td>0.08</td>
<td>0.07</td>
<td>0.25</td>
<td>0.37</td>
<td>0.50</td>
<td>0.74</td>
</tr>
<tr>
<td>18 y</td>
<td>0.06</td>
<td>0.07</td>
<td>0.37</td>
<td>0.32</td>
<td>0.78</td>
<td>0.66</td>
</tr>
</tbody>
</table>

**TABLE 4**

Odds ratios and their 95% CIs of overweight at 35 y for males with BMI values at higher percentiles compared with the risk for those with BMIs at lower percentiles

<table>
<thead>
<tr>
<th>Age</th>
<th>95th:75th</th>
<th>75th:50th</th>
<th>95th:50th</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 y</td>
<td>1.37 (0.99, 1.89)</td>
<td>1.48 (0.99, 2.21)</td>
<td>2.02 (0.98, 4.17)</td>
</tr>
<tr>
<td>2 y</td>
<td>1.48 (1.03, 2.11)</td>
<td>1.63 (1.04, 2.54)</td>
<td>2.40 (1.08, 5.37)</td>
</tr>
<tr>
<td>3 y</td>
<td>1.37 (0.99, 1.89)</td>
<td>1.48 (0.99, 2.21)</td>
<td>2.02 (0.98, 4.17)</td>
</tr>
<tr>
<td>4 y</td>
<td>1.55 (1.14, 2.13)</td>
<td>1.74 (1.17, 2.57)</td>
<td>2.70 (1.33, 5.46)</td>
</tr>
<tr>
<td>5 y</td>
<td>1.79 (1.24, 2.59)</td>
<td>2.08 (1.31, 3.29)</td>
<td>3.73 (1.63, 8.51)</td>
</tr>
<tr>
<td>6 y</td>
<td>1.46 (1.05, 2.03)</td>
<td>1.60 (1.06, 2.42)</td>
<td>2.34 (1.12, 4.90)</td>
</tr>
<tr>
<td>7 y</td>
<td>1.97 (1.34, 2.88)</td>
<td>2.33 (1.45, 3.76)</td>
<td>4.59 (1.94, 10.82)</td>
</tr>
<tr>
<td>8 y</td>
<td>2.03 (1.39, 2.99)</td>
<td>2.43 (1.50, 3.92)</td>
<td>4.94 (2.08, 11.72)</td>
</tr>
<tr>
<td>9 y</td>
<td>1.83 (1.24, 2.70)</td>
<td>2.13 (1.31, 3.46)</td>
<td>3.89 (1.62, 9.33)</td>
</tr>
<tr>
<td>10 y</td>
<td>2.22 (1.51, 3.28)</td>
<td>2.71 (1.67, 4.41)</td>
<td>6.03 (2.52, 14.45)</td>
</tr>
<tr>
<td>11 y</td>
<td>2.57 (1.76, 3.75)</td>
<td>3.26 (2.03, 5.23)</td>
<td>8.39 (3.59, 19.61)</td>
</tr>
<tr>
<td>12 y</td>
<td>2.51 (1.66, 3.78)</td>
<td>3.16 (1.89, 5.28)</td>
<td>7.93 (3.15, 19.98)</td>
</tr>
<tr>
<td>13 y</td>
<td>2.57 (1.76, 3.75)</td>
<td>3.26 (2.03, 5.23)</td>
<td>8.39 (3.59, 19.61)</td>
</tr>
<tr>
<td>14 y</td>
<td>2.52 (1.75, 3.63)</td>
<td>3.18 (2.02, 5.01)</td>
<td>8.02 (3.54, 18.19)</td>
</tr>
<tr>
<td>15 y</td>
<td>2.79 (1.93, 4.23)</td>
<td>3.60 (2.13, 6.07)</td>
<td>10.03 (3.92, 25.71)</td>
</tr>
<tr>
<td>16 y</td>
<td>2.55 (1.74, 3.74)</td>
<td>3.22 (1.99, 5.20)</td>
<td>8.22 (3.47, 19.47)</td>
</tr>
<tr>
<td>17 y</td>
<td>2.97 (1.98, 4.47)</td>
<td>3.91 (2.35, 6.50)</td>
<td>11.62 (4.64, 29.09)</td>
</tr>
<tr>
<td>18 y</td>
<td>6.05 (3.03, 12.08)</td>
<td>9.49 (4.00, 22.51)</td>
<td>57.46 (12.15, 271.84)</td>
</tr>
</tbody>
</table>

* Odds ratio, 95% CI in parentheses.

The BMI values at the 60th percentile for age 18 y was chosen as a cutoff point for identifying overweight at 35 y because it had greater sensitivity and specificity than other percentile levels (Table 6). The probability of overweight at 35 y predicted from BMI values at or above the 60th percentile at age 18 y was 0.34 for males and 0.37 for females. The sensitivities were 0.81 for
males and 0.86 for females and the specificities were 0.77 for males and 0.81 for females. By using the cutoff point of the 60th percentile at 18 y, the odds ratios of overweight at 35 y were $\approx 15$ for males and 28 for females. The corresponding SEs were 1.9 for males and 3.5 for females.

**Application of findings**

Figures 4 and 5 display reference percentiles (75th, 85th, and 95th) from NHANES II data for BMI at ages from 2 to 18 y for white boys and girls, respectively. In each sex, the reference percentiles change only slightly from 2 to 5 y and then increase in an almost straight-line fashion to $\approx 16$ y, after which the changes are less regular. The levels of corresponding percentiles are similar for the two sexes except that the 95th percentile is considerably higher in girls. The 95th percentiles are less regular than the 85th and 75th percentiles, even after smoothing, due to the limited sample sizes in NHANES II.

Figures 4 and 5 also show the likelihood of overweight at 35 y dependent on the BMI percentile during childhood. The lines that indicate the 75th, 85th, and 95th percentile levels in these figures are shaded differentially to indicate age ranges during which the probability of overweight at 35 y was either $< 20\%$, $20-29.9\%$, $30-39.9\%$, or $40-80\%$. For example, it can be seen in Figure 5 that a girl aged 12 y with a BMI of 26.5 is at the 95th percentile for national data. Her BMI value is toward the upper end of the distribution for the general US population of white girls. Only 5 of 100 girls her age have BMI values $> 26.5$ and this group of overweight girls has a $40-80\%$ probability of overweight at 35 y.

For corresponding BMI percentiles, the probabilities of overweight at 35 y increased with childhood age and percentile level, but they were similar in the two sexes. For children with BMI at the 75th percentile level, the probability of overweight at 35 y was $< 20\%$ from 2 to 9 y for boys and from 2 to 10 y for girls after which the probability was $20-29.9\%$ until 18 y for boys and 16 y for girls; after 16 y the probability was $30-39.9\%$ for girls. At the 85th percentile level, the probability for boys was $30-39.9\%$ except at ages $< 7$ y ($20-29.9\%$) and $> 17$ y (40–80%). For girls, the probability at the 85th percentile was $20-29.9\%$ to 10 y, then $30-39.9\%$ to 16 y, after which the probability was 40–80%. The probability of overweight at 35 y for those with a BMI at the 95th percentile was $20-29.9\%$ from 2 to 6 y for boys and from 2 to 8 y for girls, then the probability was $30.0-39.9\%$ until 9 y for boys and 10 y for girls after which the probability was 40–80% for both sexes.

**Discussion**

The most widely used ratio to assess overweight is the BMI. Values for this index can be compared with national reference data from NHANES II. The 85th percentile for BMI in these data during young adulthood has been recommended as the upper limit of normal for adults (12, 32). This corresponds to 27.8 for males and 27.3 for females. This is not a suitable choice because the criterion is related to a specific set of reference data, which makes it difficult to compare the prevalence of overweight between sexes, ethnic groups, and national populations, and to evaluate possible secular changes in these prevalences. Most importantly, the choice of the 85th percentile is not based on evidence that this is a threshold beyond which high BMI values are more closely associated with disease.
Others have suggested upper limits for BMI in adulthood beyond which increases in morbidity and mortality rates are said to occur (33, 34). The present analyses considered adults aged 35 y to be overweight if their BMI values exceeded 28 for men and 26 for women. These values were chosen after a thorough literature review but, for the reasons discussed earlier, although these choices are defensible, the literature does not allow precise judgments of the BMI values beyond which morbidity and mortality rates are significantly increased.

Most reports of the relationships between childhood BMI values and adulthood values are based on age-to-age correlations. There are low correlations between BMI or relative weight (weight relative to the median for age and sex) in infancy and corresponding values in young adulthood (35, 36). Rolland-Cachera et al (36) reported that correlations between BMI at each age from 1 to 16 y with values at 18 y of age increase rapidly in each sex to =0.6 at 7 y. After 7 y, the correlations increase slowly in each sex until 13 y and then increase rapidly until the correlation between values at 16 y and at 35 y is 0.8. In agreement with the present findings others have reported lower correlations, particularly in males (37, 38).

There are reports of a greater tendency for obese individuals to remain obese during childhood and adolescence than for the lean to remain lean (39), but Rolland-Cachera et al (40) found that those initially obese and those initially lean had equal tendencies to retain group membership from ages 1 to 16 y. Some have found more consistency in BMI from infancy or childhood to young adulthood for females than males (35-37, 41, 42), but contrary findings have been reported (36, 43). Analyses of the present data showed higher age-to-age correlations between BMI in childhood and at 18 y for females than for males after 4 y; at younger ages the sex differences in these correlations were small and inconsistent.

Age-to-age correlations for a total study sample provide estimates of the extent to which status at one age is related to status at a later age. Estimates of the degree to which individuals retain group membership from one age to another, with groups defined as parts of the distributions of childhood BMI values, can help identify groups with a high probability of overweight in adulthood for which intervention programs may be implemented.

![Graph showing false positive rate vs. sensitivity for BMI at different ages for females.](https://academic.oup.com/ajcn/article-abstract/59/4/810/4715794)

**FIG. 3.** Receiving operating curves for ages 3, 8, 13, and 18 y smoothed by third-degree polynomials for females.
FIG 4. Selected percentiles for body mass index (BMI, in kg/m²) in males from the Second National Health and Nutrition Examination Survey. Segments of the 75th, 85th, and 95th percentile lines are differentially shaded to indicate differences in the probability that BMI at 35 y will be > 28.

FIG 5. Selected percentiles for body mass index (BMI, in kg/m²) in females from the Second National Health and Nutrition Examination Survey. Segments of the 75th, 85th, and 95th percentile lines are differentially shaded to indicate differences in the probability that BMI at 35 y will be > 28.
Such reports show that most children change group membership from infancy to young adulthood (40), but children with high values for BMI or relative weight at ages from 1 to 11 y show a distinct tendency to retain group membership during 7–10-y periods (44–47). This tendency extends from childhood to young adulthood or beyond (48–51), although most obese children do not become obese adults (45, 46).

We have demonstrated the predictive value of childhood BMI percentiles derived from NHANES II data for overweight at 35 y when overweight is categorized as BMI values > 28 for men and > 26 for women. Our findings indicate that the probability of overweight, dependent on childhood values, increases with childhood age. The increases in probability with age at each percentile show high BMI values at ages < 8 y are a less important risk factor for overweight at 35 y than high BMI values at older ages. These findings differ from those of Stark et al (49) who concluded there is no optimal age during childhood for the prediction of overweight in adulthood. These differences may reflect variations between studies in sampling and in the criterion for overweight.

The odds of overweight in adulthood for those with childhood BMI values at the 75th percentile were \( \approx 1.0–10.0 \) times as great as for those with BMI values at the 50th percentile for males and 1.5–8.0 times for females. The corresponding risks for the 95th percentile compared with those for the 75th percentile were 1.3–6.1 for males and 1.4–4.9 for females.

The sensitivity and specificity of selected childhood cutoff points in relation to adulthood overweight were analyzed for ages 3, 8, 13, and 18 y; the same method could be applied to establish the cutoff points for other ages. The sensitivity and specificity of the chosen cutoff point (60th percentile) were excellent for predicting overweight at 35 y from BMI values at age 18 y. At ages 3, 8, and 13 y, the sensitivity and specificity were less than at 18 y for the chosen cutoff point and they were less in males than in females. This cutoff point could facilitate public health screening programs by detecting children with a high probability of being overweight at age 35 y.

The present study has shown that overweight during childhood is an important risk factor for overweight at 35 y with its attendant risks for some serious and common diseases. The importance of the present findings is derived from the relationships between high BMI values at \( \approx 35 \) y and increased risks of selected diseases and increased mortality rates. The predictability of adulthood overweight from childhood BMI values in the present study has limitations. The present study used the data from four large longitudinal studies. The data in these studies were collected between 1929 and 1991. There is a potential cohort effect or secular trend that needs to be taken into account when
applying the present results in a clinical or public health assessment.

It is recommended that the findings reported here be applied in a clinical or public health assessment of white US children with weights greater than the 95th percentile for age. The present findings could be applied to children of other US ethnic groups but the probabilities may differ from those for white children. To apply the present findings, a child's stature and weight must be measured with the child wearing light indoor clothing and without shoes. A nomogram, such as that provided in Figure 6, can be used to calculate BMI from weight and stature or a calculator can be used to divide weight in kilogram by the square of stature in meter. The BMI value should be plotted on Figure 4 or 5, depending on the sex of the child, to determine the percentile level of the child's BMI relative to other white US children.

If the child's BMI percentile is the 75th, 85th, or 95th, the probability that the BMI at 35 y will be greater than the recommended value is indicated by the differential shading of the percentile lines in Figures 4 and 5. For example, a girl aged 12 y with a BMI at the 95th percentile belongs to a group with a probability of 40–80% that her BMI at 35 y will exceed 26. The probability applies to the group to which the girl belongs—not to the individual girl. The probability of overweight at 35 y should be judged relative to whichever of the 75th, 85th, and 95th percentiles is nearest to the child's percentile level.

It is probable that the accuracy of the prediction in the present study could be improved by incorporating parental data, dietary patterns, smoking behavior, obesity, and physical activity. The degree of maturity might also assist the prediction of adulthood status from childhood data. The covariates that may influence the prediction of adulthood overweight from childhood BMI will be investigated later. Decisions about entering the child into a management program will be influenced by the health risk for the individual as judged by current BMI values, recent changes in BMI, blood pressure and total cholesterol concentrations, psychosocial stress, the family history of non-insulin-dependent diabetes mellitus and cardiovascular diseases, and values for skinfold thicknesses. Skinfold thicknesses should be measured at the triceps and subscapular sites and compared with national data (23). There should not be concern about high BMI value if the skinfold thicknesses are less than the reference medians. The age of the child should be considered because the probabilities of overweight at 35 y are not high enough to justify entry into a management program at ages < 9 y, even for those with BMI values > 95th percentile.

A long-term management program is necessary to achieve and retain the set goals. Intensive approaches with very-low-energy diets may be appropriate for adults (52) but not for children because they retard growth (53). A detailed description of the management of overweight during childhood is outside the scope of this report but a few comments will be made. Success depends on the extent to which the child, the parents, and the health-care provider consider that the management will reduce the rate of weight gain (34). The desirability of a reduced rate of gain in weight should be apparent to the health-care provider, the child, and the parents when they are aware of the probability of overweight at 35 y and its associations with an increased prevalence of serious diseases and a reduced life span.

Health-care professionals may be pessimistic about long-term results of weight-management programs because of numerous reports of failures. Epstein et al (54), however, reported a treatment program for children that resulted in the maintenance of weight control for $\geq 10$ y. In this program, and in some other successful programs, parents and children were seen separately and each contracted to change dietary and other behaviors. In this approach, the health-care provider must encourage and advise the patient over a long period; this may be difficult logistically and expensive. Therefore, it is important that programs be applied only to those at high risk of overweight in middle age with its negative health-related effects.

References


