Identifying Children at High Risk for Overweight at School Entry by Weight Gain During the First 2 Years

Andre Michael Toschke, MD, MPH; Veit Grote, MD, MSc; Berthold Koletzko, MD; Rüdiger von Kries, MD, MSc

Objective: To assess the best anthropometric predictor from birth to 2 years for later overweight, based on recent studies reporting that large infant weight or length gain predicts subsequent overweight.

Design: Retrospective cohort study.

Setting: Southern Germany.

Participants: German children (n=4235) aged 5.0 to 6.9 years.

Main Outcome Measures: Overweight at school entry was defined according to sex- and age-specific body mass index cutpoints proposed by the International Obesity Task Force. Weight, length, body mass index, and ponderal index differences between birth, 6 months, 12 months, and 24 months of age were compared by receiver operating characteristic curves and predictive values.

Results: For all variables, the largest area under the receiver operating characteristic curve was observed with a 24-month follow-up: 0.76 (95% confidence interval [CI], 0.74-0.79) for weight, 0.70 (95% CI, 0.67-0.72) for body mass index, and 0.58 (95% CI, 0.55-0.61) for length gain. The highest Youden index ([sensitivity plus specificity] minus 1) for weight gain from birth to 24 months (41%) was attained for a cutpoint of 9764 g, with a corresponding positive likelihood ratio of 2.39 (95% CI, 2.20-2.59) and positive predictive value of 19% (95% CI, 17%-21%), despite an odds ratio of 5.7 (95% CI, 4.5-7.1).

Conclusions: Weight gain from birth to 24 months was the best overall predictor of later overweight compared with other anthropometric markers and intervals. However, the corresponding poor positive predictive value suggests that only 1 of 5 children with a large weight gain in the first 2 years is overweight at school entry and reflects an insufficient predictability in the general population.


The prevalence of obesity and its related morbidity are increasing in industrialized countries worldwide. In obese children, interventions rarely show satisfying long-term results. Therefore, identifying children at risk and appropriate for possible prevention at an early age is a major challenge.

Several studies have shown that high birth weight is an important risk factor for later overweight, indicating the role of genetics and early priming by intrauterine environment. In addition, recent studies pointed to further priming of childhood overweight in the first 2 years of life by a high postnatal weight or length gain. A large early weight or length gain might be a first indicator of a risk behavior for overweight and therefore be a first hint for counseling parents.

To identify the best anthropometric predictor for childhood overweight, we used standardized methods such as receiver operating characteristic curve analysis to identify optimal cutpoints and to compare weight gain with length gain and other anthropometric measures to predict childhood overweight.

STUDY POPULATION AND DATA SOURCES

This was a retrospective cohort study of children participating in the obligatory school entry health examination in 1999-2000 in 6 Bavarian communities (Germany). Data on height and weight at birth, 6 months, 12 months, and 24 months were obtained by pediatricians or general practitioners performing the examinations of the well-child preventive health program offered to all children in Germany. Parents were asked to copy the data from the well-child checkup booklets to questionnaires.
Table 1. Weight, Length, Body Mass Index (BMI), and Ponderal Index During the First 2 Years of Life*

<table>
<thead>
<tr>
<th>Measure</th>
<th>Birth</th>
<th>6 mo</th>
<th>12 mo</th>
<th>24 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight, kg</td>
<td>3.3 ± 0.5</td>
<td>8.0 ± 0.9</td>
<td>9.6 ± 1.1</td>
<td>12.3 ± 1.4</td>
</tr>
<tr>
<td>Length, cm</td>
<td>51.2 ± 2.6</td>
<td>68.7 ± 2.9</td>
<td>75.5 ± 2.9</td>
<td>87.4 ± 3.4</td>
</tr>
<tr>
<td>BMI†</td>
<td>12.7 ± 1.3</td>
<td>16.8 ± 1.6</td>
<td>16.8 ± 1.5</td>
<td>16.1 ± 1.4</td>
</tr>
<tr>
<td>Ponderal index‡</td>
<td>24.9 ± 2.7</td>
<td>24.5 ± 2.6</td>
<td>22.4 ± 2.3</td>
<td>18.4 ± 1.8</td>
</tr>
</tbody>
</table>

*Data are given as mean ± SD.  
†Calculated as weight in kilograms divided by the square of height in meters.  
‡Calculated as weight in kilograms divided by length in meters cubed.

Receiver operating characteristic curves. A, For gain of weight, length, body mass index (BMI) (calculated as weight in kilograms divided by the square of height in meters), and ponderal index (calculated as weight in kilograms divided by length in meters cubed) from birth to 2 years of life. B, For weight gain during different intervals.

In the communities participating in this study, the distributions of body mass index (BMI), sex, and number of siblings were similar in the 1997 compulsory school entry health examination to those in all regions of Bavaria, suggesting that the study region is representative for Bavarian children. The region consists of one densely populated area (847 inhabitants/km²)—the city of Ingolstadt, a population in the outskirts of the city of Augsburg (214 inhabitants/km²)—and 4 rural areas (Miesbach, Günzburg, Kitzingen, and areas surrounding Regensburg), all with fewer than 200 inhabitants/km². The overall questionnaire return rate, including non-German children and children younger than 5.0 and older than 6.9 years, was 75.9% (7386/9731).

The analysis was confined to the 5.0- to 6.9-year-old German children (n=6862). Repeated measurements and exact points in time are required to determine an anthropometric gain. Only complete data sets for anthropometric measures at any point in time were used, to allow for comparison of gains during different intervals within the same population. Information on the anthropometric measures at birth, at the pediatric preventive health care examinations at ages 6 months, 12 months, and 24 months (well-child checkups), and at the school entry examination, was available for 4235 children (38% [2627/6862] of anthropometric measures were missing at any point in time). Children with complete information were similar to children with incomplete information with regard to mean BMI (calculated as weight in kilograms divided by the square of height in meters) at school entry (15.5 vs 15.2) and mean birth weight (3350 vs 3343 g).

OUTCOME AND EXPLANATORY VARIABLES

Stature and weight of all children without shoes and with light clothing only were measured as part of the routine school entry health examination with balances and fixed stadiometers, or portable scales and stadiometers in case of examinations in kindergartens. Overweight was defined according to sex- and age-specific BMI cutoffs, based on the widely used cutoff point of 25 for adult overweight as proposed by the International Obesity Task Force.

Gains in weight, length, BMI, or ponderal index (calculated as weight in kilograms divided by length in meters cubed) were defined as differences between observation times: 0 to 6 months, 6 to 12 months, 12 to 24 months, 0 to 12 months, and 0 to 24 months.

STATISTICAL ANALYSIS

Sensitivity and specificity of weight gain, length gain, BMI gain, and ponderal index difference were determined at each cutpoint following distribution of respective gains. Positive likelihood function (receiver operating characteristic curve) analysis was performed using sensitivity and false positives (1 minus specificity) at all cutpoints as suggested by Choi. To compare predictability of different gains, the area under the curve was estimated and tested using the algorithm suggested by DeLong et al. Best possible cutoff points were defined at the highest Youden index ([sensitivity plus specificity] minus 1), and the confidence interval (CI) of the best positive likelihood ratio (sensitivity divided by false positives) was calculated as suggested by Simel et al. Predictive values were calculated based on the prevalence of overweight at school entry found in our study population of 4235 children.

All calculations were carried out with the software packages SAS version 8.2 (SAS Institute Inc, Cary, NC) and Stata version 8.0 (StataCorp LP, College Station, Tex).

RESULTS

Between birth and age 2 years, the mean weight increased from 3.3 to 12.3 kg (373%), length from 51.2 to 87.4 cm (171%), and BMI from 12.7 to 16.1 (127%), whereas the ponderal index decreased from 24.9 to 18.4
The potential to predict overweight at school entry was higher for weight gain from birth to 24 months than for other intervals within the first 2 years. Weight gain during a longer period and closest to the time of diagnosis of overweight appears more likely to be a better predictor. The use of weight gain during 2 years after birth would be overweight at school entry. The odds ratio for weight gain greater than 9764 g from birth to 24 months was 5.7 (95% CI, 4.5-7.1). This contrasts with a corresponding low positive likelihood ratio of 2.39 (95% CI, 2.20-2.59) and a positive predictive value of 19% (95% CI, 17%-21%), indicating that in the general population only 1 in 5 children presumed to be at risk for overweight because of a large weight gain will be overweight at school entry.

Analysis of receiver operating characteristic curves is a standardized tool to compare different predictors over the range of values. In addition to visual estimation, calculations of the corresponding areas under the curve and test algorithms allow for detecting the most powerful predictor. In our data, the curves of weight and length gain did not cross. Weight gain was a better predictor for childhood overweight than length gain or other anthropometric markers at every cutpoint, confirming the results of recent studies9-12 pointing to the effect of early weight gain. The odds ratio, (268/2721)/(1132/11003) = 5.7 (95% confidence interval [CI], 4.5-7.1); sensitivity, 268/(268 + 114) = 70% (95% CI, 65%-75%); specificity, 2721/(2721 + 1132) = 71% (95% CI, 68%-72%); positive predictive value, 268/(268 + 1132) = 19% (95% CI, 17%-21%); and negative predictive value, 2721/(2721 + 114) = 96% (95% CI, 95%-97%).

Table 2. Area Under Receiver Operating Characteristic (ROC) Curves and Cutpoints, Sensitivity, and Specificity at Highest Youden Index for Anthropometric Measures*

<table>
<thead>
<tr>
<th>Measure</th>
<th>Area Under ROC Curve</th>
<th>Cutpoint at Highest Youden Index (Youden Index)†</th>
<th>Sensitivity at Highest Youden Index, %</th>
<th>Specificity at Highest Youden Index, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 0-6 mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>0.63 (0.60-0.66)</td>
<td>5100 g (19)</td>
<td>45 (40-50)</td>
<td>74 (73-76)</td>
</tr>
<tr>
<td>Length</td>
<td>0.51 (0.48-0.55)</td>
<td>20 cm (4)</td>
<td>21 (17-25)</td>
<td>83 (81-84)</td>
</tr>
<tr>
<td>BMI†</td>
<td>0.60 (0.57-0.63)</td>
<td>5 (15)</td>
<td>43 (38-48)</td>
<td>72 (70-73)</td>
</tr>
<tr>
<td>Ponderal index§</td>
<td>0.59 (0.53-0.60)</td>
<td>0.2 (11)</td>
<td>32 (27-37)</td>
<td>78 (76-79)</td>
</tr>
<tr>
<td>Age 0-12 mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>0.68 (0.65-0.70)</td>
<td>6933 g (27)</td>
<td>68 (63-72)</td>
<td>59 (58-61)</td>
</tr>
<tr>
<td>Length</td>
<td>0.55 (0.52-0.58)</td>
<td>26 cm (9)</td>
<td>66 (61-71)</td>
<td>43 (42-45)</td>
</tr>
<tr>
<td>BMI‡</td>
<td>0.63 (0.60-0.66)</td>
<td>4 (20)</td>
<td>66 (62-71)</td>
<td>53 (51-55)</td>
</tr>
<tr>
<td>Ponderal index§</td>
<td>0.57 (0.54-0.60)</td>
<td>−0.3 (11)</td>
<td>64 (59-69)</td>
<td>47 (45-48)</td>
</tr>
<tr>
<td>Age 0-24 mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>0.76 (0.74-0.79)</td>
<td>9764 g (41)</td>
<td>70 (65-75)</td>
<td>71 (69-72)</td>
</tr>
<tr>
<td>Length</td>
<td>0.58 (0.55-0.61)</td>
<td>39 cm (13)</td>
<td>45 (40-50)</td>
<td>68 (66-69)</td>
</tr>
<tr>
<td>BMI†</td>
<td>0.70 (0.67-0.72)</td>
<td>4 (31)</td>
<td>57 (52-62)</td>
<td>74 (73-75)</td>
</tr>
<tr>
<td>Ponderal index§</td>
<td>0.61 (0.58-0.64)</td>
<td>−0.5 (17)</td>
<td>44 (39-49)</td>
<td>72 (71-74)</td>
</tr>
</tbody>
</table>

*Data are given as value (95% confidence interval) unless otherwise indicated. †(Sensitivity + specificity) − 1. §Calculated as weight in kilograms divided by the square of height in meters. Calculated as weight in kilograms divided by the length in meters cubed.
Recent studies have shown an association between infant weight gain and overweight later in life, but until now a comparison with other anthropometric measures in infancy, their best cutpoints, and calculation of predictive values has been lacking. Weight gain was the best overall anthropometric predictor in infancy for later overweight. However, low corresponding poor likelihood ratio and positive predictive value suggest that infant weight gain will not allow prediction of childhood overweight with sufficient power as a single variable.

What This Study Adds

This study was supported in part by the Commission of the European Communities and by the Research and Technology Development Quality of Life and Management of Living Resources Programme, Brussels, Belgium; and by grant QLK1-2001-00389 from the Childhood Obesity-Programming by Infant Nutrition (CHOPIN) and by the Bayerisches Staatsministerium für Arbeit, Sozialordnung, Familie, Frauen und Gesundheit, Democ Mauermeyer Foundation, and Child Health Foundation, Munich.

This article does not necessarily reflect the views of the Commission of the European Communities and in no way anticipates its future policy in this area.

Corresponding author: Andre Michael Toschke, MD, MPH, Division of Pediatric Epidemiology, Institute of Social Pediatrics and Adolescent Medicine, Ludwig-Maximilians-University, Heiligstrasse 63, 81377 Munich, Germany (e-mail: michael.toschke@LRZ.uni-muenchen.de).

REFERENCES