

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

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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.

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THE PREVALENCE OF OBESITY and its related morbidity are increasing in industrialized countries worldwide.¹⁻⁴ In obese children, interventions rarely show satisfying long-term results.⁵ Therefore, identifying children at risk and appropriate for possible prevention at an early age is a major challenge.

Several studies⁶⁻⁸ 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 weight⁹⁻¹² or length^{13,14} 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.

METHODS

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.

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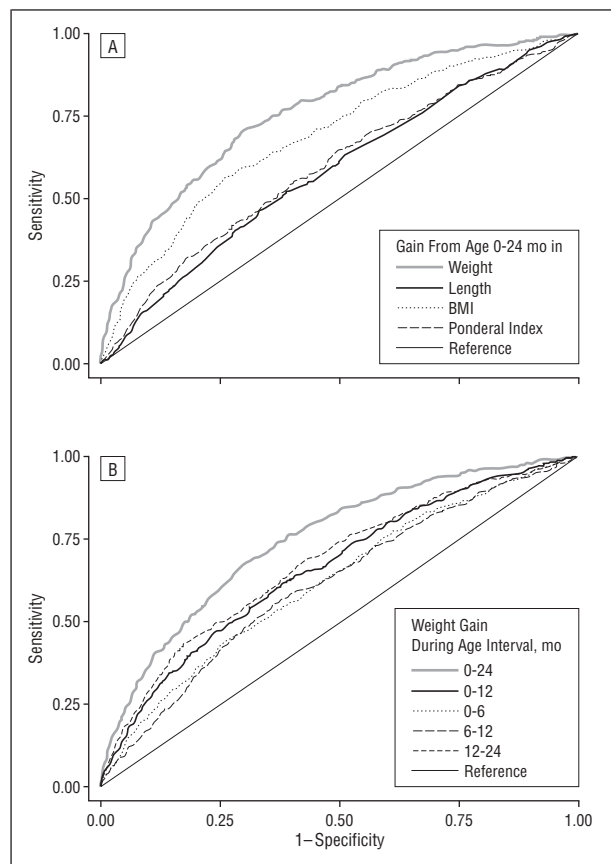
Table 1. Weight, Length, Body Mass Index (BMI), and Ponderal Index During the First 2 Years of Life*

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

*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.¹⁵ 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 cutpoints, based on the widely used cutoff point of 25 for adult overweight as proposed by the International Obesity Task Force.¹⁶

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.¹⁷ To compare predictability of different gains, the area under the curve was estimated and tested using the algorithm suggested by DeLong et al.¹⁸ Best possible cutpoints were defined at the highest Youden index ([sensitivity plus specificity] minus 1),¹⁹ and the confidence interval (CI) of the best positive likelihood ratio (sensitivity divided by false positives) was calculated as suggested by Simel et al.²⁰ Predictive values were calculated based on the prevalence of overweight at school entry found in our study population of 4235 children.¹⁹

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

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

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

*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.

(74% of initial value) (**Table 1**). The highest growth velocities were observed during the first 6 months, with 4.6 kg per 6 months for weight (mean increase, 23% of birth weight per month), 17.6 cm for length (6% per month), 4.1 for BMI (5% per month), and -0.4 for ponderal index (-0.3% per month).

At school entry, 382 children (9%) were overweight. Weight gain from birth to 2 years was associated with the largest area under the receiver operating characteristic curve, the highest Youden index of 41%, and the greatest positive likelihood ratio of 2.39 (95% CI, 2.20-2.59) at a cutpoint of 9764 g (**Figure** and **Table 2**). Weight gain was the best predictor for later overweight at all cutpoints, compared with length gain, BMI gain, and ponderal index gain, reflecting an overall superiority. The 2-year interval was a better predictor compared with shorter intervals.

A weight gain greater than 9764 g from birth to 24 months was observed in 1400 children (33%) (**Table 3**). The odds ratio for weight gain greater than 9764 g and later overweight was 5.7 (95% CI, 4.5-7.1). The calculation of the corresponding sensitivity and specificity yielded 70% (95% CI, 65%-75%) and 71% (95% CI, 69%-72%), respectively. The probability of establishing overweight at school entry after a positive test result is called *positive predictive value* and was 19% (95% CI, 17%-21%) in the general population, while the *negative predictive value* (probability of not establishing overweight at school entry after a negative test result) was 96% (95% CI, 95%-97%).

COMMENT

Weight gain greater than 9764 g from birth to 24 months was the best predictor of overweight at school entry. The odds ratio for overweight at school entry associated with weight gain greater than 9764 g was 5.7 (95% CI, 4.5-7.1). This contrasts with a corresponding low positive likeli-

Table 3. Overweight at School Entry by Weight Gain Greater Than 9764 g at Age 2 Years*

Weight Gain >9764 g	Overweight at School Entry		Total
	Yes	No	
Yes	268	1132	1400
No	114	2721	2835
Total	382	3853	4235

*Odds ratio, $(268 \times 2721)/(1132 \times 114) = 5.7$ (95% confidence interval [CI], 4.5-7.1); sensitivity, $268/(268 + 114) = 70\%$ (95% CI, 65%-75%); specificity, $2721/(2721 + 1132) = 71\%$ (95% CI, 69%-72%); positive predictive value, $268/(268 + 1132) = 19\%$ (95% CI, 17%-21%); and negative predictive value, $2721/(2721 + 114) = 96\%$ (95% CI, 95%-97%).

hood 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 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

What This Study Adds

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.

as a marker for identification of children at risk for later overweight should be early enough for application of intervention strategies, with possible modification of underlying risk behavior.

The weight data at birth and during the first 2 years were copied from physicians' documentation at the time of the respective well-child checkup visit. Misclassification might result in biased estimates. Any decision making based on large weight gain, however, is based on documentation in a routine setting. Therefore our data provide estimates that are likely to reflect the degree of prediction attainable in physicians' practices.

It is unlikely that the poor positive likelihood ratio and positive predictive value of early weight gain for later overweight found in this analysis are specific for weight gain patterns in Bavaria. The Euro-Growth Study²¹ could not detect differences in growth patterns among populations of European infants, and an association between early weight gain and later overweight of similar magnitude was found in different populations.⁹⁻¹²

Although a large weight gain during the first 2 years increases the risk for later overweight, the practical usefulness as a single clinical variable for early identification of children at risk for overweight is limited in the general population. A likelihood ratio of 2:5 may indicate small (but sometimes important) changes in disease probability.²² However, in a population with an overweight prevalence of 9% (pretest probability), the positive predictive value (posttest disease probability for positive results) was only 19%, implying that 81% of children with large infant weight gain would undergo an unnecessary intervention, with potential adverse effects if intervention was based on large early weight gain.

Even though the predictive potential of a large weight gain may be higher among high-risk populations, other markers need to be considered to allow for early identification of children at high risk for later overweight with sufficient precision.

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