Crossing Growth Percentiles in Infancy and Risk of Obesity in Childhood

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Objective: To examine the associations of upward crossing of major percentiles in weight-for-length in the first 24 months of life with the prevalence of obesity at ages 5 and 10 years.

Design: Longitudinal study.

Setting: Multisite clinical practice.

Participants: We included 44 622 children aged from 1 month to less than 11 years with 122 214 length/height and weight measurements from January 1, 1980, through December 31, 2008.

Main Exposure: The number of major weight-for-length percentiles crossed during each of four 6-month intervals, that is, 1 to 6 months, 6 to 12 months, 12 to 18 months, and 18 to 24 months.

Main Outcome Measures: Odds and observed prevalence of obesity (body mass index [calculated as weight in kilograms divided by height in meters squared] ≥95th percentile) at ages 5 and 10 years.

Results: Crossing upwards 2 or more weight-for-length percentiles was common in the first 6 months of life (43%) and less common during later age intervals. Crossing upwards 2 or more weight-for-length percentiles in the first 24 months was associated with elevated odds of obesity at ages 5 years (odds ratio, 2.08; 95% CI, 1.84-2.34) and 10 years (1.75; 1.53-2.00) compared with crossing less than 2 major percentiles. Obesity prevalence at ages 5 and 10 was highest among children who crossed upwards 2 or more weight-for-length percentiles in the first 6 months of life.

Conclusions: Crossing upwards 2 or more major weight-for-length percentiles in the first 24 months of life is associated with later obesity. Upward crossing of 2 weight-for-length percentiles in the first 6 months is associated with the highest prevalence of obesity 5 and 10 years later. Efforts to curb excess weight gain in infancy may be useful in preventing later obesity.

previous studies have examined whether crossing major percentiles in the CDC growth charts during the first 24 months of life is associated with later obesity.

The purpose of this longitudinal study was to examine associations of upward crossing of major percentiles in weight-for-length in the first 24 months of life with the prevalence of obesity at ages 5 and 10 years.

METHODS

SETTING AND SUBJECTS

We culled longitudinal data from a clinical database of 1649123 well-child visits by 244562 children. The study population consisted of children younger than 11 years of age who were seen for well-child visits at any of the 14 health centers of Harvard Vanguard Medical Associates/Atrius Health in eastern Massachusetts from January 1, 1980, through December 31, 2008. Throughout the study period, Harvard Vanguard Medical Associates used a completely electronic medical record system that contained demographic and growth data. Details of the data collection methods have been previously published.2,13 To be included in the analyses, children needed at least 2 measurements within at least 1 of 4 6-month intervals in the first 24 months of life, from which we could calculate the number of weight-for-length percentiles they crossed. Of the 244562 children, 100447 had at least 2 measurements within 1 of these 6-month intervals. Of these 100447 children, 44622 had either 5- or 10-year anthropometric outcomes. The sample size for our final analyses included these 44622 children with 122214 weight-for-length measures between the ages of 1 and 24 months and height/weight measurements at 5 or 10 years. An individual child could contribute to each of the four 6-month intervals. Of note, because birth weight and especially length were not universally recorded in the outpatient electronic medical record, we could not use birth as a starting age. Instead, we used a well-child visit anytime in the first month of life, and we called this time point “1 month.” The study protocol was approved by the institutional review board of Harvard Pilgrim Health Care.

MEASUREMENTS

Medical assistants at Harvard Vanguard Medical Associates health centers measured length or height and weight according to the written standardized protocol of the health centers. Weight was measured to the nearest 0.25 lb on a calibrated pediatric scale. Using a paper-and-pencil technique, medical assistants measured recumbent length in children younger than 24 months. In this technique, the child lies supine on a piece of paper atop an examination table with his or her face looking downwards 2 major percentiles (the 90th and 75th) in weight-for-length percentiles at ages 6 and 12 months were 14th and 45th, respectively, then he or she crossed upwards 1 major percentile (the 25th) in weight-for-length in that 6-month interval. If another child's weight-for-length percentiles at ages 6 and 12 months were 94th and 55th, respectively, then he or she crossed downwards 2 major percentiles (the 90th and 75th) in weight-for-length in the 6-month interval. Details of the sample sizes in each interval are presented in Table 1.

In secondary analyses, we also examined ever crossing upwards 2 or more weight-for-length percentiles during any of the 4 intervals. For the secondary analyses, we included 17322 participants with 86610 weight-for-length measurements during all four 6-month intervals and outcome data at ages 5 or 10 years and complete covariate information.

OUTCOME MEASURES

From heights and weights at ages 5 and 10 years, we calculated body mass index. Our main outcome at ages 5 and 10 years was prevalence of obesity, defined as an age- and sex-specific body mass index at the 95th percentile or higher.16 OTHER MEASURES

From enrollment records, we extracted information on each child's date of birth, sex, visit dates, and race/ethnicity. Parental or clinician report of child's race/ethnicity was documented in the record using the categories white, black, His-
panic, American Indian/Alaska Native, Asian, and other. Race/ethnicity was missing for 10,206 participants (22.9%). Comparison of them with the 34,416 participants with nonmissing race/ethnicity data showed that the 2 groups did not differ by number of percentiles crossed upwards: 64% of children with nonmissing race/ethnicity data vs 65% of children with missing race/ethnicity data crossed upwards 2 or more weight-for-length percentiles in any of the four 6-month intervals in the first 24 months of life.

**STATISTICAL ANALYSIS**

In the primary analyses of crossing percentiles within each 6-month interval, we ran the observed prevalence of obesity at ages 5 and 10 years. We stratified the analyses according to starting weight-for-length percentile interval, we ran the observed prevalence of obesity at ages 5 and 10 years associated with crossing upwards 2 or more weight-for-length percentiles. Fewer children crossed upwards 2 or more weight-for-length percentiles after 6 months of age: 20% from 6 to 12 months, 14% from 12 to 18 months, and 11% from 18 to 24 months (Table 3). We observed similar crossing patterns for boys and girls (Table 3).

**Table 2** summarizes the number of children who crossed less than 0 (ie, moved downward across major percentiles), 0, 1, and 2 or more percentiles. Obesity prevalence was 11.6% at age 5 and 16.1% at age 10 years. In the first 6 months of life, 43% of participants crossed upwards 2 or more weight-for-length percentiles. Fewer children crossed upwards 2 or more weight-for-length percentiles after 6 months of age: 20% from 6 to 12 months, 14% from 12 to 18 months, and 11% from 18 to 24 months (Table 3). We observed similar crossing patterns for boys and girls (Table 3).

**Table 4** shows the observed prevalence of obesity at ages 5 and 10 years according to the number of percentiles crossed in each of the four 6-month intervals, stratified by starting weight-for-length percentile. As expected, starting at a higher percentile at any time between 1 and 24 months was associated with higher obesity prevalence at 5 or 10 years than starting at a lower percentile (Table 4). For example, a 6-month-old child starting at the 75th to 90th percentile who crossed upwards 2 or more percentiles in the next 6 months had an observed prevalence of obesity of 29.7% at age 5 years, much higher than the 7.4% in a 6-month-old child who instead started at less than the 25th percentile.

Crossing upwards 2 or more percentiles in the first 6 months of life was associated with a higher prevalence of obesity at ages 5 and 10 years. For example, at age 5, the prevalence was 32.9% for 1-month-old infants whose weight-for-length started at the 75th to 90th percentile and crossed 2 or more percentiles by age 6 months. This prevalence was higher, compared with the prevalence of 29.7% for those crossing between 6 and 12 months of age, 32.0% for 12 to 18 months, and 31.8% for 18 to 24 months (Table 4). At age 10 years, we also observed a high prevalence of obesity in children with upward crossing of 2 or more percentiles in the first 6 months of life.

**Table 3** shows the sex, race/ethnicity, and obesity prevalence among the 44,622 participating children, and
and who were in the 75th to 90th percentile at baseline (34.6%) (Table 4 and Figure).

In secondary analyses, we found that 11 090 (64.4%) of 17 233 children had ever crossed upwards 2 or more percentiles in the first 24 months of life. In covariate-adjusted regression analyses, we found elevated odds of obesity at ages 5 years (odds ratio, 2.08; 95% CI, 1.84-2.34) and 10 years (1.75; 1.53-2.00) among children who crossed 2 or more percentiles in the first 24 months of life. In covariate-adjusted regression analyses, we found elevated odds of obesity at ages 5 years (odds ratio, 2.08; 95% CI, 1.84-2.34) and 10 years (1.75; 1.53-2.00) among children who crossed 2 or more percentiles in the first 24 months of life. Nevertheless, it remains to be seen whether interventions based on such early identification result in improvements in child health.

With few exceptions, these frequencies were higher, albeit not always significantly, than those associated with crossing during any of the other 6-month intervals. Within each interval, crossing at least 2 lines was associated with higher risks than crossing fewer lines. In addition, similar to a study predicting obesity at age 12 years from measures at 2 to 5 years of age, we observed that having ever crossed upwards 2 or more major weight-for-length percentiles in the first 24 months of life was associated with 2-fold higher odds of obesity at age 5 years and 75% higher odds at age 10 years.

Our findings extend a growing body of literature indicating that weight gain in the first few months of life contributes to the development of obesity. Previous studies of both contemporary and historical cohorts and 2 recent systematic reviews of infant growth and obesity have concluded that infants at the highest end of the weight or body mass index distribution, and infants who grew most rapidly (usually measured as weight gain), were more likely to be obese later in life. Many of these studies, however, have been limited by their relatively small sample sizes, to be obese later in life. Many of these studies, however, have been limited by their relatively small sample sizes, by lack of data among children younger than 24 months, or by reliance on weight measures alone without length measurements. Our large sample size of children with weight and length measures who were younger than 24 months allowed precise estimates within strata defined both by starting weight-for-length percentiles and number of percentile lines crossed.

One feature of our study lends itself to potential clinical application. Assessing how many percentiles a child crosses has more clinical utility and is more practical than calculating an epidemiologic exposure measure, such as change in weight-for-length z score, as many studies have done. Because pediatric clinicians routinely document serial measures of weight and length and screen for abnormalities in weight status using the published CDC growth charts, crossing percentiles could be used to assess early risk of obesity in pediatric primary care of infants younger than 24 months. Nevertheless, it remains to be seen whether interventions based on such early identification result in improvements in child health.

Table 4. Prevalence of Obesity at Ages 5 and 10 Years According to Starting Weight-for-Length Percentile and the Number of Weight-for-Length Percentile Lines Crossed

<table>
<thead>
<tr>
<th>Age, mo</th>
<th>≤25th</th>
<th>25th-50th</th>
<th>50th-75th</th>
<th>75th-90th</th>
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<tbody>
<tr>
<td>1-6</td>
<td>4.8</td>
<td>4.1</td>
<td>6.4</td>
<td>11.5</td>
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<tr>
<td>6-12</td>
<td>1.6</td>
<td>3.0</td>
<td>5.1</td>
<td>7.4</td>
</tr>
<tr>
<td>12-18</td>
<td>1.5</td>
<td>3.1</td>
<td>3.4</td>
<td>4.9</td>
</tr>
<tr>
<td>18-24</td>
<td>1.7</td>
<td>2.0</td>
<td>2.3</td>
<td>5.3</td>
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Obesity at age 5 years

<table>
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<tr>
<th>Age, mo</th>
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<th>25th-50th</th>
<th>50th-75th</th>
<th>75th-90th</th>
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<tbody>
<tr>
<td>1-6</td>
<td>10.0</td>
<td>9.2</td>
<td>12.2</td>
<td>16.7</td>
</tr>
<tr>
<td>6-12</td>
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<td>18-24</td>
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Obesity at age 10 years

<table>
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<tr>
<th>Age, mo</th>
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<th>25th-50th</th>
<th>50th-75th</th>
<th>75th-90th</th>
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<tr>
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<td>1.7</td>
<td>2.0</td>
<td>2.3</td>
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<td>6-12</td>
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<td>4.0</td>
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<tr>
<td>18-24</td>
<td>3.8</td>
<td>2.0</td>
<td>3.8</td>
<td>4.4</td>
</tr>
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a Excluded children whose starting weight-for-length percentile was ≥90th because they could not cross upwards 2 major percentile lines. Obesity is defined as a body mass index ≥90th percentile for age and sex.

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used weights and lengths in the first month of life. Thus, we examined infrequently contained birth weight. Rather, we be considered. First, the ambulatory care records we ex-lined whether these factors also predict weight gain in early infancy, especially in the first 6 months of life, is as-sociated with high rates of obesity at ages 5 and 10 years. Our results may not be gen-eralizable to more disadvantaged populations with less access to primary care.

Even if crossing weight-for-length percentiles can serve as a tool for pediatric clinicians to identify excess gain-ers in infancy, there is still the need to identify modifi-cable determinants of excess gain in adiposity and what the proper response should be. A robust literature has emerged regarding prenatal and perinatal predictors of childhood adiposity, but few studies have exam-ined whether these factors also predict weight gain in early infancy. Furthermore, there is a need to examine trade-offs of more rapid vs less rapid weight gain for different outcomes. At least among infants born preterm, more rapid weight gain in early infancy predicts better neurocognitive outcomes in childhood. Whether this same situation holds with term infants is less clear. Thus, the amount of weight gain that optimizes both neurocognitive and obesity risk may differ by gestational age. In vestigating these potential determinants of excess in-fant adiposity gain could lead to intervention strategies in clinical and public health settings to prevent childhood obesity and its consequences.

When interpreting our study, several limitations should be considered. First, the ambulatory care records we ex-amined infrequently contained birth weight. Rather, we used weights and lengths in the first month of life. Thus, our estimates of crossing percentiles in the first 6 months of life do not reflect any shifts that may have occurred between birth and the first well-child care visit. Second, we used clinically measured lengths, which tend to overestimate actual length. To overcome this limitation, we used the regression estimate from our previous validation study to statistically correct for this systematic over-estimation. Third, race/ethnicity was missing for approxi-mately 20% of the children in this study, although we did not observe differences in rates of crossing percentiles among children with and without complete race/ethnicity data. Finally, all participants in this study had health insurance and access to primary care during the first 24 months of life (1-24 months) and during childhood (5- or 10-year visit). Our results may not be generalizable to more disadvantaged populations with less access to primary care.

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Upward crossing of major weight-for-length percentiles in infancy, especially in the first 6 months of life, is associated with high rates of obesity at ages 5 and 10 years. These results raise the possibility of using this metric as a practical tool to identify children who may be at high risk of obesity in pediatric settings where clinicians already weigh, measure, and plot growth for infants at regular intervals. Our findings and those of the growing literature in this area support the need to identify modifiable determinants of excess gain in adiposity in infancy that can inform the design of clinical and public health interventions to modify these determinants.

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REFERENCES