Health of Children Classified as Underweight by CDC Reference but Normal by WHO Standard

WHAT'S KNOWN ON THIS SUBJECT: Many US children aged 6 to 24 months who would be classified as low weight-for-age by the Centers for Disease Control and Prevention 2000 reference will be classified as normal weight-for-age by the World Health Organization 2006 standard.

WHAT THIS STUDY ADDS: Children who will be reclassified from underweight by either criteria, the aORs for adverse health outcomes than children who are not low weight-for-age by the Centers for Disease Control and Prevention reference.

OBJECTIVE: To ascertain measures of health status among 6- to 24-month-old children classified as below normal weight-for-age (underweight) by the Centers for Disease Control and Prevention (CDC) 2000 growth reference but as normal weight-for-age by the World Health Organization (WHO) 2006 standard.

METHODS: Data were gathered from children and primary caregivers at emergency departments and primary care clinics in 7 US cities. Outcome measures included caregiver rating of child health, parental evaluation of developmental status, history of hospitalizations, and admission to hospital at the time of visit. Children were classified as (1) not underweight by either CDC 2000 or WHO 2006 criteria, (2) underweight by CDC 2000 but not by WHO 2006 criteria, or (3) underweight by both criteria. Associations between these categories and health outcome measures were assessed by using multiple logistic regression analysis.

RESULTS: Data were available for 18,420 children. For each health outcome measure, children classified as underweight by CDC 2000 but normal by WHO 2006 had higher adjusted odds ratios (aORs) of adverse health outcomes than children not classified as underweight by either; children classified as underweight by both had the highest aORs of adverse outcomes. For example, compared with children not underweight by either criteria, the aORs for fair/poor health rating were 2.54 (95% confidence interval: 2.20–2.93) among children underweight by CDC but not WHO and 3.76 (3.13–4.51) among children underweight by both.

CONCLUSIONS: Children who are reclassified from underweight to normal weight in changing from CDC 2000 to WHO 2006 growth charts may still be affected by morbidities associated with underweight. Pediatrics 2013;131:e1780–e1787
In September 2010, the US Centers for Disease Control and Prevention (CDC) recommended that World Health Organization (WHO) growth charts replace the previously recommended CDC growth charts for children younger than 24 months. In contrast to recommendations for adult BMI, which were based on mortality data, the anthropometric cutoff values used to define normal growth for children in both CDC and WHO growth charts are statistical constructs and not based on health outcome data. This article examines selected measures of health status among children whose classification as either underweight (below normal weight-for-age*) or normal weight depends on which growth chart is used. The CDC published updated growth charts in 2000, based on growth variables of representative cross-sectional samples of US children, which thus constitute a growth reference, reflecting the genetic and environmental conditions of the reference population at the time it was measured, which may not represent how children would grow under optimal conditions. For example, although exclusive breastfeeding for the first 6 months of life is recommended by the American Academy of Pediatrics, the CDC 2000 data were gathered at a time when only approximately one-third of US infants breastfed for $\geq$3 months.

An alternative to the growth reference chart is a growth standard chart based on the growth of healthy children under optimal nutritional and environmental circumstances. This approach was adopted by the WHO, which in 2006 published growth charts “that would document how children should grow in all countries rather than merely describing how they grew at a particular time and place.” on the basis of the WHO Multicentre Growth Reference Study. Term singleton infants born between 1997 and 2003 to healthy, nonsmoking mothers were followed longitudinally from birth to 2 years in 6 countries: Brazil, Ghana, India, Norway, Oman, and the United States. The mothers of children selected for study were of sufficiently high socioeconomic status so that environmental conditions should not constrain child growth. Three-quarters of the infants were exclusively or predominantly breastfed for at least 4 months, 99.5% began complementary foods by 6 months, and 68.3% were partially breastfed to at least age 12 months, as recommended for the study. The 2.3rd and 97.7th percentiles (equivalent to $\pm 2$ SDs from the mean) define the lower and upper bounds of normal on the WHO charts, as opposed to the 5th and 95th percentiles used by the CDC reference; because the variability of growth in the WHO data set was smaller than that in the CDC data, the “commonly used statistical cutoffs ($\pm 2$ SD)” were recommended “to identify children at significant risk for either inadequate or excessive growth.”

There are important differences between the normal height and weight ranges for the WHO standard and the CDC reference, which vary by age and growth variable; these differences are especially important for weight-for-age during infancy, reflecting differences in rate of weight gain associated with infant feeding practices. From birth to 6 months of age, healthy breastfed infants typically gain weight more rapidly than do formula-fed infants; thus, the WHO charts show a more rapid rate of weight gain than do the CDC charts from birth to age 6 months. From age 6 to 24 months, breastfed infants typically gain weight more slowly than do formula-fed infants, which is reflected in the CDC sample’s being heavier, as a group, than the WHO sample after age 6 months. As a result, more children will be classified as low weight-for-age by the CDC reference (ie, weight below the fifth percentile for age and gender) than by the WHO standard (weight below the 2.3rd percentile) after age 6 months. The CDC found that among US children aged 6 to 23 months, $<3\%$ would be classified as low weight-for-age by the WHO standard but 7% to 11% would be so classified by using the CDC reference. Similar findings have been reported for children in the United Kingdom, Belgium, and Norway. Thus, depending on their age, between 4% and 8% of US children ages 6 to 23 months will be classified as low weight-for-age by the CDC reference but as normal weight-for-age by the WHO standard, as shown in Fig 1.

The classification of a child as low weight-for-age is clinically important, because it may reflect undernutrition, which can jeopardize the child’s growth, impair immunocompetence, and contribute to concurrent and long-term deficits in cognition and socioaffective competence. The CDC report notes that “the clinical consequences of using the WHO standards compared with the CDC reference should be evaluated over time to identify . . . unforeseen adverse consequences of the use of the WHO standards.” Clinically important differences have been described in the classification of undernutrition in low-income countries by using the WHO standards as opposed to the CDC reference, which may affect referral to therapeutic feeding programs. There are currently no data available reflecting the health status of children who will be reclassified from “low weight-for-age” (underweight) to “normal weight-for-age” in the shift from the CDC reference to the WHO standard.

---

*The CDC’s Pediatric Nutrition Surveillance System defines the term “underweight” as weight-for-length less than the fifth percentile (http://www.cdc.gov/pednss/what_is/pednss_health_indicators.html). We use the term “underweight” throughout this report to mean less than the fifth percentile weight-for-age solely for economy of language.
In this report we use data from an ongoing multisite study to examine the health status of a large cohort of predominantly low-income US children aged 6 to 24 months with respect to their weight-for-age classification. We hypothesized that children who are identified as not underweight by both CDC and WHO criteria would have the best health outcomes, that children identified as underweight by both criteria would have the worst outcomes, and that children identified as underweight by the CDC reference but as not underweight by the WHO standard would have outcomes that are intermediate but still indicative of higher health risk than for children who are not identified as underweight by either CDC or WHO criteria.

**METHODS**

Data were obtained by Children’s HealthWatch, an ongoing, multisite, sentinel surveillance study that gathers interview and clinical data from emergency departments (EDs) and primary care sites. For this study, data from the University of Maryland Medical Center (Baltimore, MD), Boston Medical Center (Boston, MA), Arkansas Children’s Hospital (Little Rock, AR), UCLA Medical Center (Los Angeles, CA), Hennepin County Medical Center (Minneapolis, MN), St Christopher’s Hospital for Children (Philadelphia, PA), and Mary’s Center for Maternal and Child Care (Washington, DC) from June 1998 through December 2010 were analyzed. All sites were approved by their institutional review boards to collect data by using the Children’s HealthWatch survey instrument (available at www.childrenshealthwatch.org). Trained research assistants interviewed caregivers of children younger than age 36 months during visits to primary care sites or EDs for nonurgent illness or injury. The survey included demographic characteristics, housing status, participation in public benefits programs, and the US Food Security Scale. Participants self-identified their race/ethnicity by using US Census Bureau definitions. The breastfeeding variable reflects whether the child was ever breastfed or is still breastfeeding. Since 2000 the survey has included a validated screen for caregivers’ depressive symptoms. Four health outcome measures were included: parental...
rating of child health (“excellent” or “good” versus “fair” or “poor”), Parental Evaluation of Developmental Status (PEDS),25 history of hospitalizations, and hospital admission at time of interview (for ED sites only). The PEDS instrument, introduced into the Children’s HealthWatch survey in 2004 and administered to children >4 months of age, is a screening measure of child developmental status based on the parent/caregiver’s response to 10 questions related to the child’s abilities; ≥2 concerns is considered a positive result.25

Potential respondents were excluded if they were not the child’s primary caregiver; did not speak English, Spanish, or (in Minneapolis only) Somali; did not live with the child; were not knowledgeable about the child’s household; lived out of state; or did not provide informed consent. Caregivers of critically ill or injured children were not approached. For children with multiple study visits, only the first was included. Schedules of data collection varied by site.

At the time of the interview, the child’s weight was measured and recorded by on-site clinical staff by using standard procedures. To account for the possible effect of dehydration on weight, the diagnosis of dehydration was recorded from the clinical record. Weight-for-age z scores were calculated for both the 2000 CDC age- and gender-specific reference values by using Epi Info Epinut software26 and for the 2006 WHO algorithms by using Igrowup software.27 Children were categorized into 3 mutually exclusive groups: (1) not underweight by CDC or by WHO criteria, (2) not underweight by WHO criteria but underweight by CDC criteria, or (3) underweight by both CDC and WHO criteria. Health outcomes among the 3 groups were then compared.

Descriptive statistics were obtained for demographic characteristics, program use, low birth weight, dehydration status, and the child health outcome measures. Bivariate associations were assessed via χ² analyses or analysis of variance as appropriate. To assess associations between the 3 exposure groups and dichotomous child health outcomes, multiple logistic regression analyses adjusted for demographic characteristics (study site, mother’s birth country, race/ethnicity, child gender, mother’s employment, and child’s age) were conducted. Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) are reported for logistic regression models. All analyses were conducted by using 2-sided tests and a significance level of 0.05. Statistical analyses were performed by using SAS software (version 9.2; SAS Institute, Cary, NC).

RESULTS

Of 20,513 children aged 6 to 24 months seen at 7 US urban medical centers, weight data were available for 18,420 (90%). The mothers of children missing weight data were more likely to be immigrants, Hispanic, not married or partnered, and with less than a high school education and were more likely to have been seen at the Boston or Minneapolis sites. Of these, 13,845 (75.2%) were interviewed in an ED. Characteristics of the children in the 3 weight-for-age categories are shown in Table 1. Ninety percent were not underweight by either criteria, 3% were underweight by both criteria, and 7% were underweight by the CDC reference but not by the WHO standard. Significant differences in the characteristics of these 3 groups were noted in site of visit, US- versus foreign-born, age, race/ethnicity, history of low birth weight, and caregiver employment status. Mean weight-for-age z score of the children in the 3 categories is shown in Table 2. For those who were underweight by the CDC reference but not by the WHO standard, mean weight-for-age was −2.07 (range: −3.12 to −1.64) according to the CDC reference and −1.39 (−2.00 to −0.78) according to the WHO standard.

Unadjusted analysis of outcome measures by underweight classification status was conducted separately for children with and without a history of low birth weight (<2500 g), because low birth weight children will be overrepresented in the group that is underweight by both CDC and WHO criteria. Results for 15,389 children without a history of low birth weight are shown in Fig 2. For each measure, children classified as not underweight by either CDC or WHO criteria had better outcomes than did children classified as underweight by both criteria, and children classified as underweight by the CDC reference but not underweight by the WHO standard had an intermediate outcome. For example, caregiver-rated child health status was fair or poor for 10% of children classified as not underweight by either CDC or WHO criteria, for 22% of children classified as underweight by CDC but not by WHO criteria, and for 27% of children classified as underweight by both criteria (P < .001). A similar pattern (P < .001) was found for 2557 children who had a history of low birth weight (Fig 3). Multivariable analysis with adjustment for site, US-born versus immigrant mother, race/ethnicity, gender, caregiver employment status, child age, and child history of low birth weight is shown in Table 3. The following covariates were missing for 139 subjects (<1% of total sample): US-born mother (n = 31), ethnicity (n = 64), and caregiver employment (n = 53). aORs for child health as fair/poor, developmental risk on PEDS, history of hospitalizations, and hospital admission at time of interview were lowest for children classified as not underweight on both the CDC reference and the WHO standard, highest for children classified as underweight by both criteria, and intermediate for children classified as underweight by the CDC reference but
TABLE 1 Characteristics by Classification of Underweight

<table>
<thead>
<tr>
<th></th>
<th>Not Underweight by CDC or WHO</th>
<th>Underweight by CDC/Not WHO by WHO</th>
<th>Underweight by CDC and WHO</th>
<th>P (χ²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total participants (n = 18 420), n (%)</td>
<td>16 555 (90)</td>
<td>1245 (7)</td>
<td>620 (5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Dehydration (n = 13 471), n (%)</td>
<td>426 (4)</td>
<td>76 (8)</td>
<td>37 (8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Female gender, n (%)</td>
<td>7709 (47)</td>
<td>557 (45)</td>
<td>241 (39)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Insurance, n (%)</td>
<td>Public</td>
<td>13 700 (82)</td>
<td>1036 (84)</td>
<td>.124</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>859 (5)</td>
<td>51 (4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Private</td>
<td>1888 (11)</td>
<td>150 (12)</td>
<td>.13</td>
</tr>
<tr>
<td>Child age, mean ± SD, mo</td>
<td>13.5 ± 5.1</td>
<td>14.8 ± 4.6</td>
<td>12.9 ± 4.9</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Race/ethnicity, n (%)</td>
<td>Hispanic</td>
<td>4089 (28)</td>
<td>316 (25)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Black, non-Hispanic</td>
<td>8231 (50)</td>
<td>619 (50)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>White, non-Hispanic</td>
<td>2939 (18)</td>
<td>219 (18)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>741 (4)</td>
<td>83 (7)</td>
<td></td>
</tr>
<tr>
<td>Breastfed, n (%)</td>
<td>9195 (58)</td>
<td>684 (56)</td>
<td>325 (53)</td>
<td>.320</td>
</tr>
<tr>
<td>Low birth weight, n (%)</td>
<td>1839 (11)</td>
<td>364 (30)</td>
<td>354 (58)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Mother US-born, n (%)</td>
<td>11 953 (72)</td>
<td>916 (74)</td>
<td>485 (78)</td>
<td>.002</td>
</tr>
<tr>
<td>Mother married or living with partner</td>
<td>7168 (43)</td>
<td>522 (42)</td>
<td>283 (46)</td>
<td>.222</td>
</tr>
<tr>
<td>Mother’s age, mean ± SD, y</td>
<td>26.1 ± 5.9</td>
<td>26.3 ± 6.0</td>
<td>26.5 ± 6.2</td>
<td>.140</td>
</tr>
<tr>
<td>Mother smoked in past year (n = 5745), n (%)</td>
<td>1417 (27)</td>
<td>92 (26)</td>
<td>38 (21)</td>
<td>.196</td>
</tr>
<tr>
<td>Maternal education, n (%)</td>
<td>Never/elementary/some high school</td>
<td>4810 (29)</td>
<td>364 (23)</td>
<td>.614</td>
</tr>
<tr>
<td></td>
<td>High school</td>
<td>6545 (39)</td>
<td>478 (33)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technical school/college graduate/Master’s degree</td>
<td>5318 (32)</td>
<td>397 (32)</td>
<td></td>
</tr>
<tr>
<td>Caregiver employed, n (%)</td>
<td>7734 (47)</td>
<td>534 (43)</td>
<td>232 (37)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Maternal depression, n (%)</td>
<td>3479 (24)</td>
<td>258 (24)</td>
<td>143 (26)</td>
<td>.378</td>
</tr>
</tbody>
</table>

* Refers to χ² test of no differences across the 3 study groups.

TABLE 2 Comparison of Weight-for-Age z Score Means According to the CDC Reference and WHO Standard for the 3 Weight-for-Age Categories

<table>
<thead>
<tr>
<th>Weight-for-Age</th>
<th>Not Underweight by CDC or WHO (n = 16 555)</th>
<th>Underweight by CDC/Not WHO by WHO (n = 1245)</th>
<th>Underweight by CDC and WHO (n = 820)</th>
<th>CDC reference</th>
<th>WHO standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.217 ± 1.03 (−1.64 to 4.60)</td>
<td>−2.07 ± 0.34 (−3.12 to −1.645)</td>
<td>−3.48 ± 0.89 (−3.25 to −1.95)</td>
<td>0.648 ± 0.99 (−1.72 to 4.98)</td>
<td>−1.39 ± 0.31 (−2.00 to −0.780)</td>
</tr>
</tbody>
</table>

Data are means ± SD; ranges in parentheses.

DISCUSSION

In this large multicenter study of predominantly low-income urban children, those classified as underweight by the CDC 2000 reference but as normal weight-for-age by the WHO 2006 standard had significantly worse outcomes on 4 health indicators than children not classified as underweight by either criteria but better outcomes than children classified as underweight by both criteria.

The clinical significance of this finding lies in the diagnosis of low weight-for-age (sometimes referred to as “failure to thrive”) in children. Because underweight in infancy is associated with concurrent susceptibility to infection and short- and long-term adverse developmental outcomes, screening, identification, and treatment of this condition have been prioritized in primary health care. There previously has been no universal agreement as to which criteria define this clinical condition but weight-for-age below the fifth percentile of the CDC 2000 growth charts has been widely accepted and recommended. It has been suggested that the methodologic problems in defining underweight lead to an overestimation of its clinical significance and overreferral of children for additional evaluation and management, with consequent expenditure of limited resources and unnecessary anxiety among the affected families. However, underidentification may deprive children of important nutritional and medical assessments and interventions that might protect them from short- and long-term morbidity in growth, health, and developmental potential. Because young children in...
low-income families, particularly those of ethnic/racial minorities, are at particularly high risk of underweight, such underidentification could exacerbate existing health and developmental disparities among ethnic/racial groups.

One of the major differences between the populations sampled for the CDC 2000 reference and the WHO 2006 standard is the rate of breastfeeding. We were not able to determine the duration of exclusive or predominant breastfeeding in our sample; however, data from the CDC National Immunization Survey show that only approximately one-fourth of mothers who participate in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and/or who have incomes below the poverty level breastfeed exclusively for at least 3 months. Thus, on this important nutritional characteristic, our sample likely resembles the CDC 2000 population more than the WHO 2006 population.

This study has several limitations. The data are drawn from a clinical sentinel sample and cannot be considered representative of the general US population; however, the sample comprises largely low-income urban children who are known to be at higher risk of a number of adverse outcomes and may be representative of this population. Our finding that 7% of the study population is classified as underweight by the CDC reference but as normal weight by the WHO standard is consistent with the CDC’s report that 4% to 8% of children aged 6 to 23 months fall into this category. The health outcome measures available are limited, and some rely on parental report. However, parental rating of child health has been shown to be reliable and valid and has been used in national surveys including the National Survey of Children’s Health and the NHANES. The Peds instrument has been validated as an indicator of developmental risk, and maternal recall of child hospitalization history has been shown to be reliable. The adoption of the WHO growth standard, as currently recommended, will redefine the lower limit of normal weight-for-age, resulting in the reclassification of a large number of infants and toddlers from “low weight-for-age” to “within normal limits.” It is not known whether or how many of these children will not receive the focused medical and nutritional assessment and intervention that are often prompted by their being identified as underweight. This study reveals that the adverse clinical correlates of underweight occur along a gradient rather than being confined to those falling below a statistically defined threshold, in this case the WHO...
standard. Clinical judgment in assessing the nutritional status of individual children is essential and should include such factors as breastfeeding history; clinicians may wish to compare the growth trajectories of individual children on both graphs or to choose the WHO standard to assess growth for exclusively breastfed infants and the CDC reference for others. To avoid communication errors, it should always be specified which criteria are used to determine nutritional status and growth trajectory. In addition, there may be policy effects on the assignment of priority categories for children who are categorically eligible for WIC after the program’s change, implemented on October 1, 2012, from the CDC 2000 reference to the WHO 2006 standard for children aged 0 to 24 months.44

CONCLUSIONS
Clinicians should be aware that some young children who fall above the cutoff for underweight on the WHO 2006 growth charts may still be affected by morbidities associated with underweight; thus, caution is warranted in using the WHO standards to identify underweight among children aged 6 to 24 months in low-income populations in the United States.

**REFERENCES**

**ACKNOWLEDGMENTS**
Children’s HealthWatch includes Boston University School of Medicine, Boston, MA; Boston University School of Public Health Data Coordinating Center, Boston, MA; Drexel University School of Public Health, Philadelphia, PA; Hennepin County Medical Center, Minneapolis, MN; University of Arkansas for Medical Sciences, Little Rock, AR; University of Maryland School of Medicine, Baltimore, MD, and the following staff: Justin Pasquaariello, Ingrid Weiss, Cerlyn Cantave, Grace Paik, Kathleen Barrett, Tu Quan, and Amanda Breen.

**TABLE 3** Association Between Underweight Classification and Child Health Outcomes

<table>
<thead>
<tr>
<th>Health outcome</th>
<th>Not Underweight by CDC/WHO (n = 16,555)</th>
<th>Underweight by CDC/WHO (n = 1245), aOR (95% CI)</th>
<th>Underweight by CDC and WHO (n = 620), aOR (95% CI)</th>
<th>Overall P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child health fair/poor (n = 18,234)</td>
<td>1.00</td>
<td>2.54 (2.20–2.93)</td>
<td>3.76 (3.13–4.51)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hospitalizations (n = 17,951)</td>
<td>1.00</td>
<td>1.66 (1.47–1.88)</td>
<td>2.57 (2.18–3.04)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Peds: ≥2 significant concerns* (limited to those aged ≥4 months; n = 11,402)</td>
<td>1.00</td>
<td>3.23 (2.63–3.95)</td>
<td>7.21 (5.68–8.14)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Admit from ED on day of interview* (n = 11,121)</td>
<td>1.00</td>
<td>1.84 (1.50–2.25)</td>
<td>2.79 (2.19–3.57)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Data were adjusted for site, US-born mother versus immigrant, race/ethnicity, child gender, caregiver employment, and child’s age.
* Administration of Peds instrument began in 2004.
* These data only gathered from ED sites.


Health of Children Classified as Underweight by CDC Reference but Normal by WHO Standard

Alan Meyers, Katherine Joyce, Sharon M. Coleman, John T. Cook, Diana Cutts, Stephanie Ettinger de Cuba, Timothy C. Heeren, Ruth Rose-Jacobs, Maureen M. Black, Patrick H. Casey, Mariana Chilton, Megan Sandel, Deborah A. Frank and on behalf of Children's HealthWatch

*Pediatrics*; originally published online May 20, 2013;
DOI: 10.1542/peds.2012-2382

The online version of this article, along with updated information and services, is located on the World Wide Web at:
/content/early/2013/05/15/peds.2012-2382