**Additional information about gradual growth chart/z-score data tables and code**

2025-08-07

The method to produce gradual z-scores and growth chrts is primarily a simple weighted average, but some details can affect implementation. We try to address as many details as possible below.

**Please cite this publication whenever using these charts in your work.**

Daymont et al., Pediatrics, 2025 (citation details to come when available)

**INDIVIDUALS or ANALYSES**

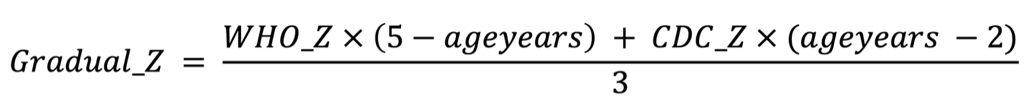
**To make gradual (smoothed) z-scores for an individual measurement or group of measurements**

Example a: You wish to show gradual z-scores for measurements on individual children in an EHR.

Example b: You are doing research on children 1-10 years old and have their age in days and their weight.

**Do not smooth percentiles or LMS parameters. You must smooth z-scores specifically.**

1. Obtain WHO and CDC z-scores if you do not have them already: WHO for ≤5 years (1825 days) and CDC ≥2 years (731 days) using the CDC whoanthro and cdcanthro packages or another method.\*
   1. whoanthro: <https://github.com/CDC-DNPAO/WHOanthro>
   2. cdcanthro: <https://github.com/CDC-DNPAO/CDCAnthro>
2. Option A to create gradual z-scores from WHO and CDC z-scores: Download and use the provided R or Stata code
3. Option B: Use the equation and text in the equation-gradual.pdf document to implement in another language/environment. The equation is reproduced below. (ageyears = age in days / 365.25, unrounded.)
4. The R and Stata code will produce z-scores from these sources at the listed ages. If you are implementing the code yourself, use these ages. We use age in days here to ensure consistency, and we use age in years in the equation for interpretability.
   1. WHO ≤730 days
   2. Gradual (smoothed using equation) 731-1825 days
   3. CDC ≥1826 days



\*We recommend using the R packages whoanthro and cdcanthro from the CDC website. Alternately, use another method that you know accounts for all of the recommended adjustments to the z-scores to avoid excessive influence of skew correction. These include the switch to extended BMI z-scores by the CDC in 2022. The whoanthro and cdcanthro software packages account for these adjustments.

*Visualizations on next page*

**CUSTOM VISUALIZATIONS**

To make visualizations for EHR integration, analysis, or other purposes. This is specifically for visualizations of the percentile curves. The information above describes how to obtain the gradual z-score for an individual point.

**Information about necessary data files**

1. The file names are datatable-gradual-months and datatable-gradual-days. They are compressed .csv files.
2. The gradual charts are identical to WHO from birth to 2 years, use smoothed values from 2 to 5 years, and are identical to CDC from 5 to 20 years.
3. When using age in days, the last day of WHO is 730, the gradual charts are from 731-1825 days, and the first day of CDC is 1826.
4. There are charts by age in days and age in months. The month tables include whole months (e.g., 2 months = 2 months and 0 days, as used by WHO) and half-months (e.g., 2.5 months which is approximately 2 months and 15 days, as used by CDC).
5. The tables include a variety of percentiles and z-scores of +1/-1, +/-2 (referred to in our printable charts as either 2nd/98th or 2.3rd/97.7th) as well as the 0.1 and 99.9%iles, which are very similar to z-scores +3/-3.
6. The .csv data tables contain percentiles/z-scores for the following charts by age and sex
   1. Gradual growth charts
   2. WHO
   3. CDC -- what we refer to as “CDC-2000” in the paper, the CDC charts before incorporation of the WHO charts.
      1. We refer to these charts as CDC-2000 because they do not include the subsequent changes in 2010. However, they do incorporate the extended BMI z-score changes made in 2022. In hindsight, I would have chosen a different name, but I keep this name here because it is used in the publication.
   4. Sudden - (what we refer to as “CDC-recommended” in the paper, the current CDC recommendations switching abruptly from WHO to CDC at 2 years of age.
7. Notes re outer z-scores
   1. What is listed in the data tables as z = -2/+2 corresponds to what is printed on the chart as the 2nd and 98th percentiles. Z-scores of -2/+2 correspond to approximately the 2.3rd and 97.7th percentile.
   2. The 0.1th and 99.9th percentiles are very similar to z-scores of -3/+3.
8. If you use the 95th and 50th percentiles to estimate a standard deviation and use that to determine other percentiles or z-scores, the results will be inaccurate. (This is also true for the 5th and 50th, etc.)
9. Information about the variables is in the next section

**Data tables: Variable naming conventions**

1. Age variables are agedays or agemonths
2. Percentiles or z-score values are named using
   1. First: gradual, who, cdc, or sudden
   2. Second: m or f to indicate sex
   3. Third: wt, ht, or bmi to indicate growth parameter (ht is used for length and height)
   4. Fourth: one of the suffixes described in #3
3. Suffixes indicating value provided
   1. p# where # is a specific percentile: 01 (0.1st %ile), 1, 5, 10, 25, 50, 75, 90, 95, 99, 99.9
   2. z#(neg) where # is the magnitude of a z-score and neg is present if it is negative: z2/z2neg, z1/z1neg, z0 (same as p50)
   3. We also provide LMS values for WHO and the extended CDC z-scores and sigma for CDC extended BMI z-scores. These are labeled l, m, s, or sigma. Care must be taken when using these to create extreme z-scores/percentiles because of recommended adjustments by the WHO and CDC (in addition to the extended BMI z-scores).

**To plot a percentile/z-score that is in the .csv file**

If the percentile/z-score is in the .csv file, you can plot the values directly from the datatable-gradual-days file.

Available percentiles: 0.1, 1, 5, 10, 25, 50, 75, 90, 95, 99, 99.9

Available z-scores: -2, -1, -, +1, +2

For example, if you want to plot the 90th percentile for boys for weight-for-age for children 2 to 5 years of age, you would use the values in the gradual\_m\_wt\_p90 column in the rows for agedays 731 to 1825.

**Note about mechanics of creating visualizations**

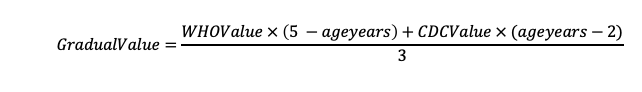
For visualizations, I typically use values for each day and plot ~ every 3rd day for infants and ~ every 10th day for older children, making sure to plot the first day and last day of the age range as well as days 730 and 731 if they are in the age range. Using measurements by month will not capture all the changes in slope in infants and young children. Using measurements from every day creates jagged lines. Using smoothing functions can cause unpredictable and often nonreproducible effects on the shapes of the percentiles -- these may or may not be of significance.

**If the percentile/z-score is not in the .csv file**

The overall goal is to make weighted averages of the values corresponding to the percentile or z-score for the appropriate sex over the desired age range. You can then plot the values created by the weighted average. Note that in the manuscript and in the Individuals or Analyses section above we made a weighted average of z-scores, not the corresponding values.

Creating a weighted average of values

1. If you have the WHO and CDC values that correspond to the percentile or z-score of interest over the age range of interest, proceed with this section. If you do not have the values, see the “Obtaining values” sections below, then return to step 2.
2. Use the equation below to make a weighted average of the WHO and CDC values. The equation is a slightly modified version of the equation used to make gradual z-scores. The only modification is that we are taking a weighted average of values, rather than z-scores.
3. Use WHO values ≤730 days, gradual values 731-1825 days, and CDC values ≥1826 days when plotting.



GradualValue: The gradual growth chart value for a given percentile or z-score. A weighted average of the WHO and CDC values from 2 to 5 years.

WHOValue: The weight, length/height, or BMI corresponding to the percentile or z-score of interest according to the WHO 2006 Growth Standards.

CDCValue: The weight, length/height, or BMI corresponding to the percentile or z-score of interest according to the CDC Growth Reference.

ageyears: Age in days divided by 365.25. For example, 1000 days is an ageyears of 2.7378508.

Obtaining values for a z-score or percentile

1. If you are interested in a percentile, you must first determine the z-score that corresponds to that percentile (generally using statistical software or Excel). For example, the 40th percentile corresponds to a z-score of -0.2533471.
2. Calculate values corresponding to the WHO z-score
   1. For WHO z-scores within >-3 and <+3, you can calculate the values corresponding to the z-score of interest using the z-score, the LMS parameters in the provided data tables (or another source), and the equation found on the CDC website: <https://www.cdc.gov/growthcharts/cdc-data-files.htm>. A PDF version of the site is uploaded here, titled lms-formula-from-cdc-site.pdf.
   2. For WHO percentiles/z-scores ≤-3 or ≥+3 z-scores, the WHO provides a correction for skew. Information that would allow you to calculate values for these z-scores starts on page 301 of the WHO Child Growth Standards development document, which can be found at this site: <https://www.who.int/publications/i/item/924154693X>.
3. Calculate CDC values
   1. For weight and height, you can use the LMS parameters in the provided data tables (or another source) and the equation found on the CDC website (see above).
   2. For BMI ≤95th percentile, you can use the LMS parameters.
   3. For BMI >95th percentile, you need to use the formula for the extended BMI z-scores, which includes LMS parameters as well as an additional parameter, sigma. These parameters are included in the data tables. The formula is available at this site: <https://www.cdc.gov/growthcharts/extended-bmi-data-files.htm>.
4. Use these values in step 2 of the “Creating a weighted average of values” section above

**Tip**: For those newer to working with these data: If your statistical software is not recognizing the age variables in our datatable as matching your data, there may miniscule deviations from displayed values. For example, depending on your software and settings, 7.000000001 may be displayed as 7, but it will not match with integer 7. Rounding or converting to an integer variable type may fix this matching issue.

Please see the manuscript, the supplemental methods, and additional documentation on this site for more information. The Stata code used to create the data tables is available in a .txt file: documentation-code-datatable-gradual-2025-04-25.txt. It is annotated (better in some places than others) and contains more details about choices made during their development.

**If you have additional questions about the growth charts, equation, or how to use these files, please email Carrie Daymont at** [**cdaymont@pennstatehealth.psu.edu**](mailto:cdaymont@pennstatehealth.psu.edu)**.**