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Annex 1. Growth Charts: Plotting Measurements and Interpreting Growth Patterns

(Adapted from WHO 2008 and Cogill 2003)

To fully understand whether a child is growing at a healthy pace, his/her growth must be examined over time. To do this, health workers will typically plot a child's measurements (length/height-for-age, weight-for-age, weight-for-length/height, and BMI-for-age) across multiple visits, using growth charts to track the child's growth. The growth chart has z-score lines that serve as a reference of where the child's individual measurements fall (e.g., above or below -2 z-score), presenting a clear visual display of nutritional status in that moment and how a child is growing over time in comparison to expectations. This can help identify problems such as poor growth, undernutrition, risk of undernutrition, or overweight/risk of overweight.

Plotting growth is a key part of growth monitoring and promotion programs that typically target children under 5 years of age, using growth charts that are usually based on the WHO Child Growth Standards. It is also possible—and useful—to plot the growth of children and adolescents 5–19 years of age; charts based on the WHO Growth Reference are available for that age group. This annex provides guidance on how to accurately plot children's measurements on a growth chart and interpret growth patterns.

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How to Plot and Interpret Measurements

When interpreting plotted growth, remember that children's growth should track with the median and normal z-score lines on the growth charts. Whenever a child's growth line crosses a z-score line (i.e., if the child's curve increases or decreases at a more rapid pace or a much slower pace than the median), the health worker should look at the trends of the child's other growth indices, interpret the trends as a whole, and ask about recent or chronic illnesses, food shortages, or other possible causes that may impact a child's growth. Growth patterns that may cause concern include:

Sharp Declines in Growth Pattern

A sharp decline in weight is always of concern, even among overweight children. Normal and undernourished children who are gaining height should consistently gain weight; those who lose weight are at risk of becoming moderately or severely malnourished. Overweight children should not lose weight rapidly. Rather, they should maintain a steady weight while continuing to grow taller, "growing into their weight." A sharp decline in height indicates a measurement error as children are unlikely to lose height.

Sharp Inclines in Growth Pattern

Sharp inclines in weight must be carefully investigated. If a child has gained weight rapidly, the health care provider should look also at changes in height. If the child grew in weight and height proportionately, this is probably catch-up growth from previous illness or undernutrition or a growth spurt. In such a situation, the weight-for-age and height-for-age charts will show steeper-than-expected inclines, while the weight-for-height growth line tracks steadily along the z-score curves. However, if the child gained weight without gaining height, this may be a cause for concern.

Flat Growth Pattern

A flat (stagnant) growth line indicates that a child is not gaining height or weight (depending on the measurement being charted). This may indicate undernutrition and should be explored. Flat growth is of less concern when an overweight or obese child maintains the same weight over time while growing in height, which would bring the child closer to a healthy weight-for-height. This can be verified by consulting both the weight-for-height and height-for-age growth curves.

When weight and height are both stagnant, the child's overall growth and development may have been compromised by undernutrition and/or illness. For children in age groups that grow rapidly (i.e., with steep growth curves), such as during the first 6 months of life, even one month of flat growth is cause for concern because it is hard to recover that lost growth.

The following examples show how to plot and interpret measurements on growth charts for length/height-for-age, weight-for-age, weight-for-length/height, and body mass index (BMI)-for-age. For plotting growth, be sure to select the appropriate growth chart(s) based on the child's sex, age, and the measurements to be taken.

Each chart has a line showing the median value, which is equal to a z-score of 0 (green), and +2 and -2 (red), and +3 and -3 (black). The weight-for-length/height, BMI-for-age, and head circumference-for-age charts also include orange lines for z-scores of +1 and -1.

Length/Height-for-Age

In the charts for length/height-for-age, the x-axis shows age and the y-axis shows length or height in centimeters. Age is plotted in completed weeks from birth until age 3 months, in completed months from age 3 to 12 months, and then in completed years and months.

To plot length/height-for-age:

- Find the child's age in *completed* weeks, months, or years and months on the x-axis (e.g., a child 5.5 months of age would be 5 completed months). A vertical line will extend from the child's completed age.
- Find the child's length/height on the y-axis. The length/height will fall on a horizontal line or between horizontal lines.
- Find the point on the graph where the vertical line extending from the child's age would meet a horizontal line extended from the child's length/height. Make a small dot on the graph at that point. This is the plotted point showing the child's length/height-for-age.
- When points are plotted for two or more visits, connect the points with a straight line to better observe the trend.

BOX 1. USEFUL DEFINITIONS

Plotting refers to drawing a dot (point) on the chart indicating the value of the measurements taken. Plotting points requires understanding the following terms:

X-axis is the horizontal reference line at the bottom of the graph. In a growth chart, an x-axis may show age or length/height. Points are plotted on the vertical lines that extend from the x-axis, corresponding to completed age (in weeks, months, or years and months) or to length or height rounded to the nearest whole centimeter.

Y-axis is the vertical reference line at the far left of the graph. In a growth chart, the y-axis may show length/height, weight, or body mass index. Points are plotted as precisely as possible on or between horizontal lines that extend from the y-axis, corresponding to length/height, weight, or BMI.

Plotted point is the point on a graph where a line extended from a measurement on the x-axis (e.g., age) intersects with a line extended from a measurement on the y-axis (e.g., weight).

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Figure 1, on the next page, shows the correctly plotted points for a girl's height-for-age measurements over time. The horizontal lines extending from the y-axis represent 1 cm increments. At the first visit, the child was 2 years and 4 months of age and was 92 cm tall. This first point falls between 0 and +2 z-scores, a normal height for her age. At the second visit, the girl was 3 years and 3 months of age and 98 cm tall. At the third visit, she was 103 cm tall at 4 years and 2 months of age. Although her height-for-age falls within the normal range at the additional plotted points, her pace of growth has slowed and is no longer tracking with a normal z-score line. By her third measurement, she has crossed the median, moving from a positive to a negative z-score. This indicates a risk of undernutrition if her growth continues to falter.

Table 1. Length/Height-for-Age Z-Score Cutoffs (Birth to 19 Years)

Nutritional status	Z-score range
Normal	≥ -2 to ≤ +3
Moderately stunted	≥ -3 to < -2
Severely stunted	< -3

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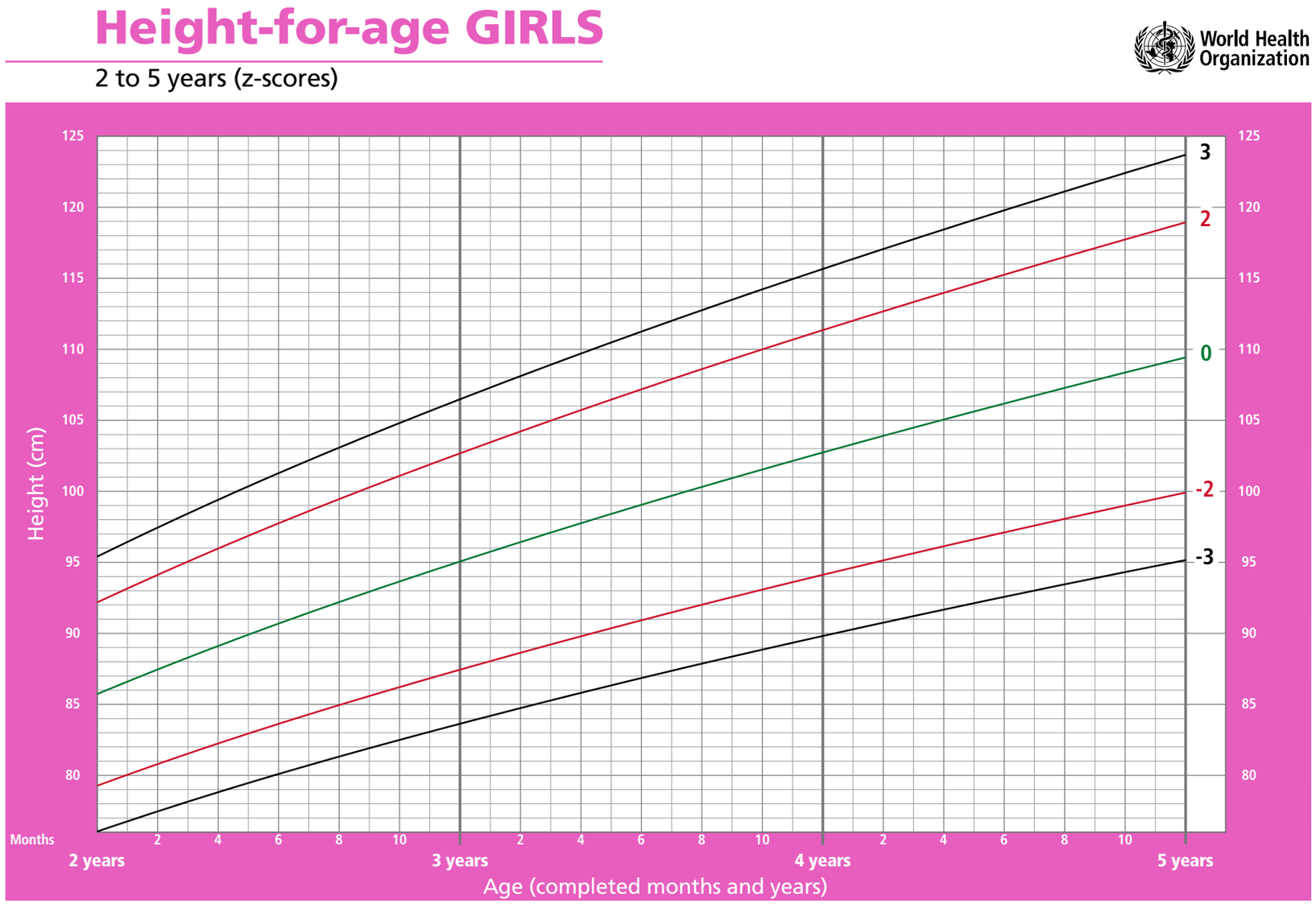
Figure 1. Example of Plotting Height-for-Age



Source: WHO. 2008. *Training Course on Child Growth Assessment. Interpreting Growth Indicators.* Geneva: WHO.

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Weight-for-Age

In the charts for weight-for-age, the x-axis shows age and the y-axis shows weight in kilograms. Age is plotted in completed weeks from birth until age 3 months, in completed months from age 3 to 12 months, and then in completed years and months.

To plot weight-for-age:

- Find the child's age in *completed* weeks, months, or years and months on the x-axis (e.g., a child 5.5 months of age would be 5 completed months). A vertical line will extend from the child's completed age.
- Find the child's weight on the y-axis. The exact weight may fall on a horizontal line or between horizontal lines. Find the point on the graph where the vertical line extended from the child's age on the x-axis would meet a straight line extended from the child's weight on the y-axis. Make a dot on the graph where the two lines meet. That dot is a plotted point.
- When points are plotted for two or more visits, connect the points with a straight line to better observe the trend.

Figure 2, on the next page, shows correctly plotted points for a boy's weight-for-age at three visits. The horizontal lines extending from the y-axis represent 0.1 kg increments. At the first visit, he was 9 months of age and weighed 8 kg. His z-score is in the normal range. At the second visit, the child was 1 year and 1 month of age and weighed 8.8 kg and his measurement tracks on the same z-score line, indicating normal growth. At the third visit, the child was 1 year and 6 months of age and weighed just over 9.2 kg. His growth has slowed. Although his z-score is not yet below -2, this trend is of concern. It will be helpful to investigate potential causes of this slowed growth during counseling sessions with the mother/caregiver and provide support and guidance as needed.

Table 2. Weight-for-Age Z-Score Cutoffs (Birth to 10 Years)

Nutritional status	Z-score range
Normal	≥ -2 to ≤ +1
Moderately underweight	≥ -3 to < -2
Severely underweight	< -3

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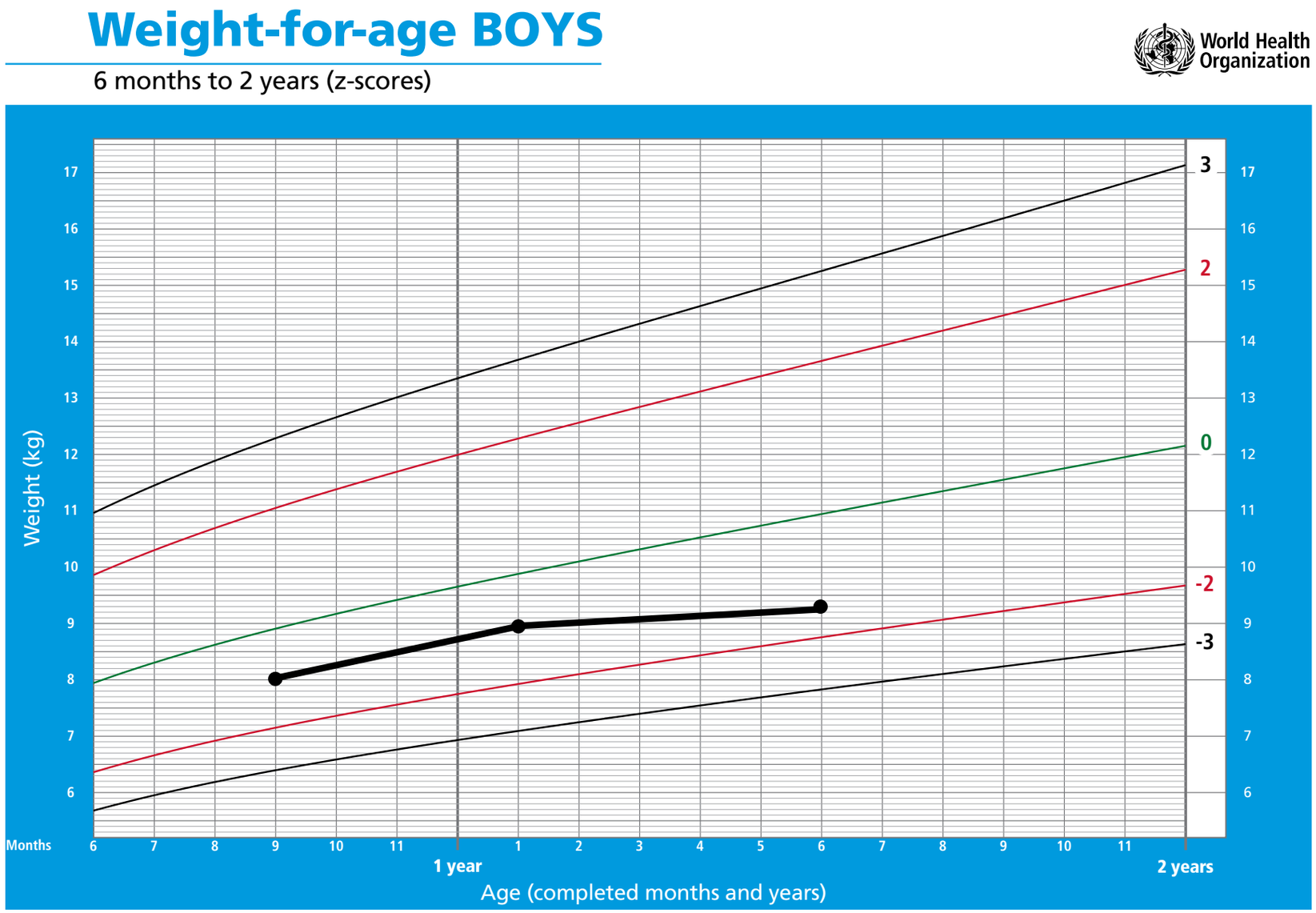
Figure 2. Example of Plotting Weight-for-Age



Source: WHO. 2008. *Training Course on Child Growth Assessment. Interpreting Growth Indicators.* Geneva: WHO.

Weight-for-Length/Height

In the charts for weight-for-length/height, the x-axis shows length/height in centimeters and the y-axis shows weight in kilograms in 0.5 kg increments.

To plot weight-for-length/height:

- Round the child's length/height to the nearest whole centimeter. Round down 0.1–0.4 and round up 0.5–0.9 (e.g., 78.7 cm would round to 79 cm).
- Find that length/height on the x-axis. A vertical line will extend from this point on the x-axis.
- Find the child's weight on the y-axis. This may fall on a horizontal line or between horizontal lines (e.g., 10.5 kg would be midway between 10 kg and 11 kg).
- Find the point on the graph where the vertical line extended from the child's height on the x-axis would meet a horizontal line extended from the child's weight on the y-axis. Make a dot on the graph where the two lines meet. That dot is a plotted point.
- When points are plotted for two or more visits, connect the points with a straight line to better observe the trend.

Figure 3, on the next page, shows correctly plotted points for a child's weight-for-height at two visits. At the first visit, the child was 85 cm tall and weighed 13 kg. His weight-for-height is just above +1 z-score line, which is classified as normal. At the second visit, the child was 97 cm tall and weighed 16 kg. He maintains healthy growth, which still tracks along the +1 z-score line.

Table 3. Weight-for-Length/Height Z-Score Cutoffs (Birth to 5 Years)

Nutritional status	Z-score range
Obese	> +3
Overweight	> +2 to ≤+3
Risk of overweight	> +1 to ≤ +2
Normal	≥ -2 to ≤ +1
Moderately wasted	≥ -3 to < -2
Severely wasted	< -3

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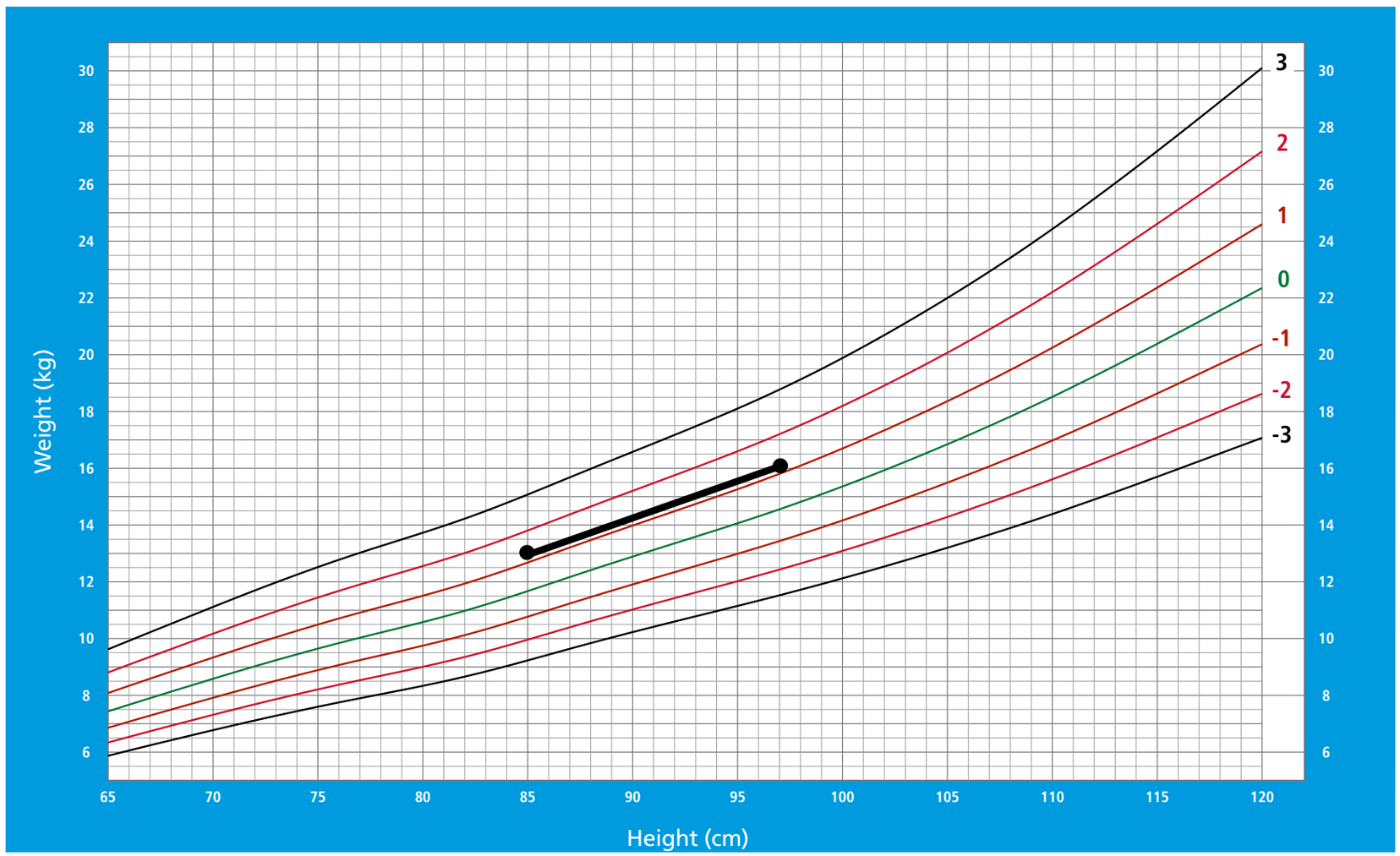
Figure 3. Example of Plotting Weight-for-Height



Source: WHO. 2008. *Training Course on Child Growth Assessment. Interpreting Growth Indicators.* Geneva: WHO.

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BMI-for-Age

In the charts for BMI-for-age, the x-axis shows age in completed months or years and months, and the y-axis shows BMI. Age is plotted in completed months from birth to 12 months and then in completed years and months.

To plot BMI-for-age:

- Find the child's age in *completed* months or years and months on the x-axis (e.g., a child 3.5 months of age would be 3 completed months). A vertical line will extend from the child's completed age.
- Find the child's BMI on the y-axis (e.g., 14, 14.2). This may fall on a horizontal line or between horizontal lines. If a calculator was used to determine BMI, it may be recorded and plotted to one decimal place.
- Find the point on the graph where the vertical line extended from the child's age on the x-axis would meet a horizontal line extended from the child's BMI on the y-axis. Make a dot on the graph where the two lines meet. The dot is a plotted point.
- When points are plotted for two or more visits, connect the points with a straight line to better observe the trend.

Figure 4, on the next page, shows correctly plotted points for a girl's BMI-for-age at two visits. The horizontal lines extending from the y-axis represent 0.2 BMI units. At the first visit, she was 7 months of age and had a BMI of 17. This BMI falls on the median and within the normal BMI-for-age range. At the second visit, the child was 1 year and 2 months of age and had a BMI of 18. She is not tracking along the median z-score line and now falls between +1 and +2 z-scores. She is at risk of overweight.

Table 4. BMI-for-Age Z-Score Cutoffs (Birth to 5 Years)

Nutritional status	Z-score range
Obese	> +3
Overweight	> +2 to ≤+3
Risk of overweight	> +1 to ≤ +2
Normal	≥ -2 to ≤ +1
Moderately wasted	≥ -3 to < -2
Severely wasted	< -3

Table 5. BMI-for-Age Z-Score Cutoffs (5 to 19 Years)

Nutritional status	Z-score range
Obese	> +2
Overweight	> +1 to ≤ +2
Normal	≥ -2 to ≤ +1
Moderately wasted	≥ -3 to < -2
Severely wasted	< -3

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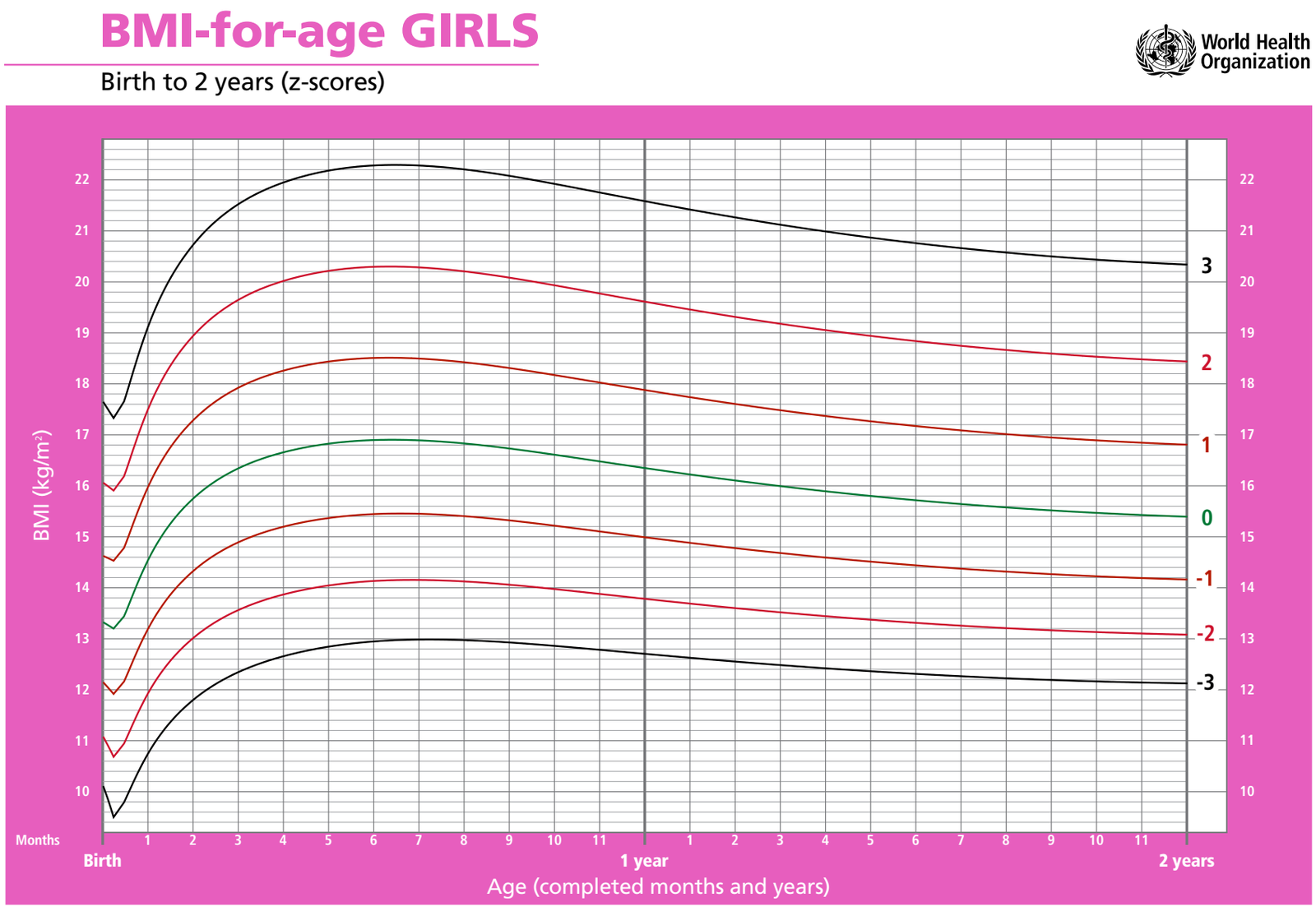
Figure 4. Example of Plotting BMI-for-Age



Source: WHO. 2008. *Training Course on Child Growth Assessment. Interpreting Growth Indicators.* Geneva: WHO.

Head Circumference-for-Age

The chart on the next page tracks a boy's head circumference-for-age from 1 month to 1 year of age. Age is on the horizontal (x) axis and head circumference (cm) on the vertical (y) axis. At 1 month of age, this boy had a head circumference of 36.5 cm, within the normal range between -1 z-score and the median. At 6 months of age, his head circumference was 43 cm, still within the normal range and following a healthy trajectory. His healthy pace of growth continued to age 1 year, when his head circumference was 45.5 cm, and there are no concerns about his head circumference.

Table 6. Head Circumference-for-Age Z-Score Cutoffs (Birth to 5 Years)

Nutritional status	Z-score range
Large head circumference	> +2
Normal	≥ -2 to ≤ +2
Small head circumference	≥ -3 to < -2
Very small head circumference	< -3

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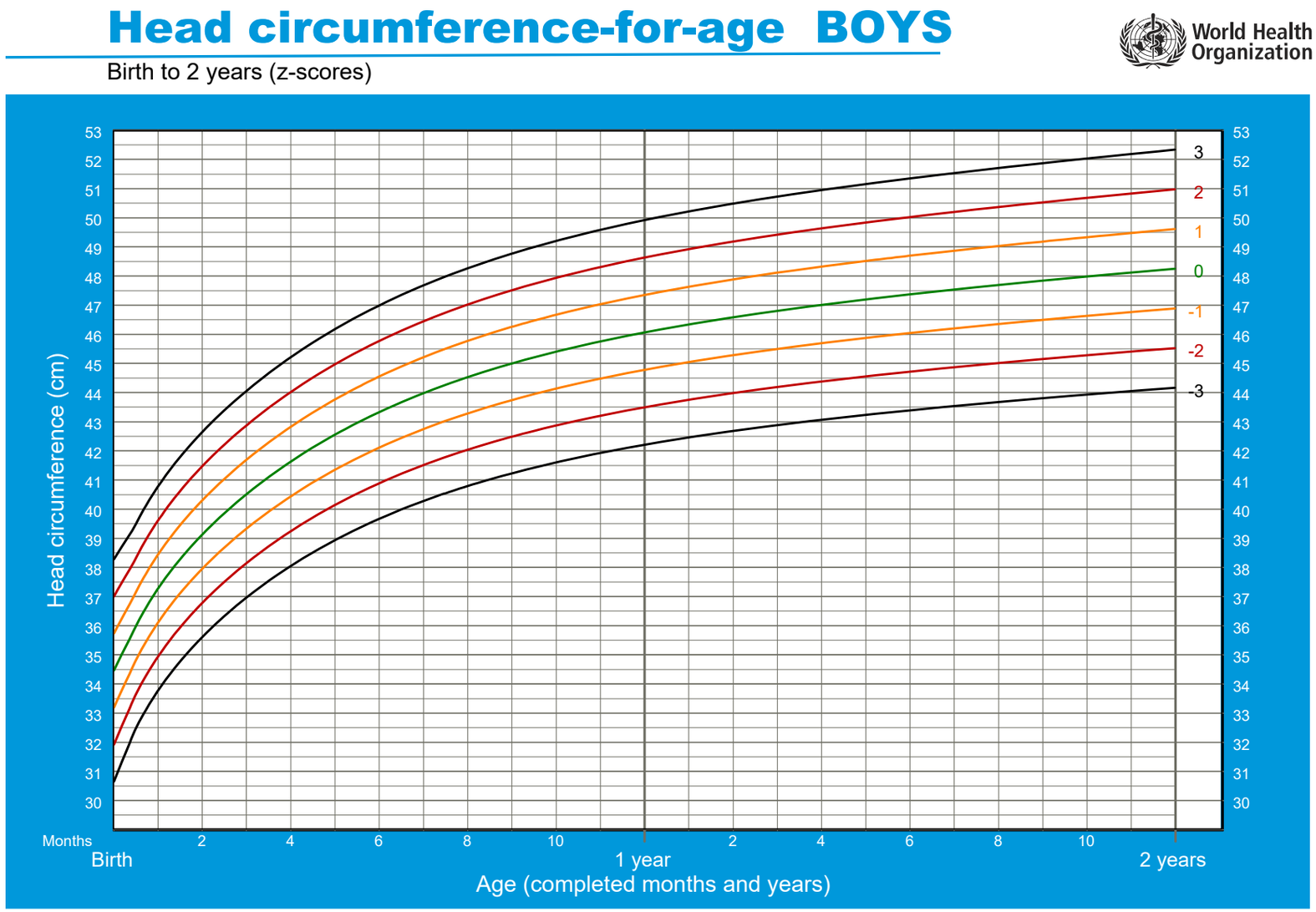
Figure 5. Example of Plotting Head Circumference-for-Age



Source: WHO. 2008. *Training Course on Child Growth Assessment. Interpreting Growth Indicators.* Geneva: WHO.

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Annex 2. How Is a Z-Score Calculated?

(Adapted from WHO 2008.)

Z-scores are calculated differently for measurements that are distributed normally and non-normally in the reference population. Z-scores can be easily calculated by software available on the WHO website. Hand calculation, which is described below, is possible but not recommended.

Measurements that Are Normally Distributed in the Reference Population

In a normally distributed population, such as the height measurement reference population in the WHO Child Growth Standards and the WHO Child Growth Reference, about 68 percent of the values fall within 1 standard deviation (z-score) of the median, about 95 percent within 2 z-scores, and more than 99 percent within 3 z-scores. As shown in the Figure 1, in this normal distribution, there is equal distance between the standard deviations.

The z-score for an individual measurement based on a normal distribution is calculated using this formula:

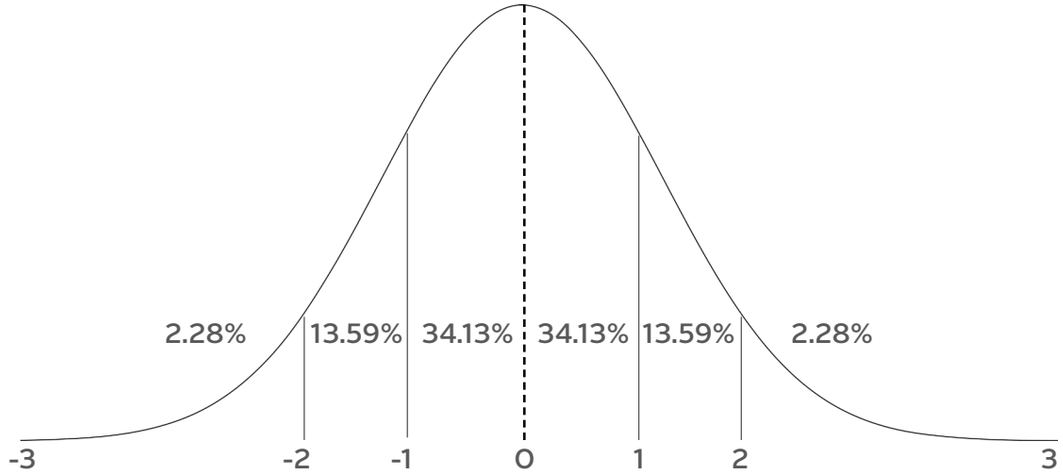
$$\text{Z-score} = \frac{\text{(observed measurement)} - \text{(median reference value)}}{\text{Standard deviation of reference population measurement}}$$

Observed measurement refers to the *actual measurement taken* of that individual.

Median reference value is the *median measurement of all individuals of that age and sex* (i.e., the height measurement that has a z-score of 0 for that age and sex on the WHO Child Growth Standards or WHO Growth Reference charts and tables).

"Standard deviation of a measurement in the reference population can be described as the average of differences in that measurement for each child from the median in the reference population. To find the standard deviation of a particular measurement, refer to the WHO Child Growth Standards tables (0-5 years) or WHO Growth References tables (5-19 years), which provide standard deviations based on age and sex.

Figure 1. Normally Distributed Population



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EXAMPLE CALCULATION

A health worker measures the height of a boy named Sam. He is 2 years and 4 months of age. His height is 96.1 cm. The standard deviation of boys' heights at age 2 years and 4 months is 3.3.

To calculate Sam's **height-for-age z-score**:

Observed value = 96.1 cm.

Median reference value = 90.4 cm (the median height of all boys measured who are age 2 years and 4 months), which is taken from the WHO Child Growth Standards height-for-age tables for boys 2–5 years of age.

Standard deviation: 3.3, taken from the WHO Child Growth Standards height-for-age tables for boys 2–5 years of age.

Inserting the above numbers in the formula, Sam's height-for-age z-score is calculated as follows:

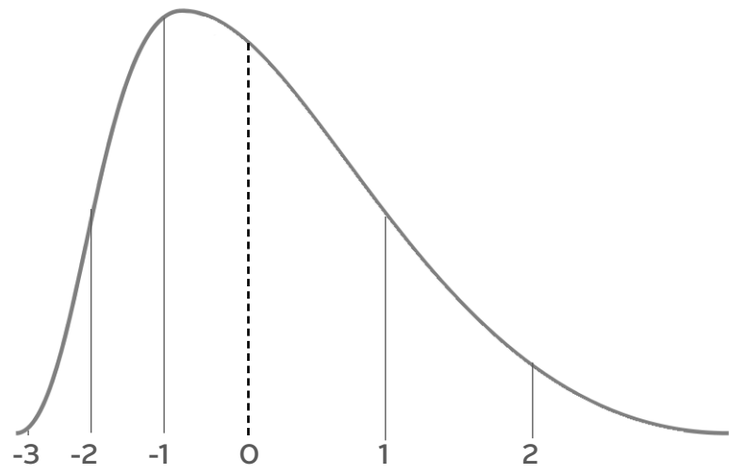
$$\frac{96.1 - 90.4}{3.3} = 1.73$$

Sam's **z-score for height-for-age** is **1.73**, or above 1, indicating that his height currently is normal.

Measurements that Are Non-Normally Distributed in the Reference Population

Not all measurements have a normal distribution. Some measurements, like weight, have a distribution that is "skewed," with one side (tail) longer than the other. In the WHO Child Growth Standards, the weight distribution is "right-skewed," meaning the right side is longer than the left (Figure 2). Although the percentages of individuals falling within each z-score are the same as those in the normal distribution (e.g., 34.13 percent between 0 and 1), the distance between the standard deviations varies and the differences between the standard deviations below the median are shorter than the differences between the standard deviations above the median. This makes it more complicated to calculate an individual's z-score. This applies to the weight-for-age, weight-for-length/height, and BMI-for-age z-scores.

Figure 2. Right-Skewed Distribution



To calculate the z-score for a non-normally distributed measurement, use the following formula:

$$\text{Z-score} = \frac{(\text{observed value} \div M)^{L} - 1}{L \times S}$$

M is the reference median value

L is the power needed to transform the data in order to make it normal (remove the skewness)

S is the coefficient of variation

For the WHO Child Growth Standards, the L, M, and S values can be found in the z-score growth tables for each measure, age, and sex and in the WHO Child Growth Standards Methods and Development documents on the WHO website: http://www.who.int/childgrowth/standards/en/. For the WHO Growth Reference, the L, M, and S values are included in the z-score tables for each measure, age, and sex on the WHO website: http://www.who.int/growthref/en/.

EXAMPLE CALCULATION

Sam is 2 years and 4 months of age and weighs 11.9 kg. For boys age 2 years and 4 months, the M, L, and S values are as follows (note: this will vary according to age and sex):

Observed value = 11.9

M = 12.9303 (Median weight-for-age for boys age 2 years and 4 months.)

L = -0.0337 (power to normalize the data)

S = 0.11664 (coefficient of variation)

$$\frac{(11.9 \div 12.9303)^{-.03} - 1 = -0.63}{-0.0337 \times 0.11664}$$

Sam's weight-for-age z-score is -0.63, which is below the median but still within the normal range of weight-for-age.

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References

Cogill, B. 2003. *Anthropometric Indicators Measurement Guide.* Washington, DC: FHI 360/FANTA.

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