Growth Curves and Z-Scores: Sorting It All Out

Rita A. Chrivia, RD, CSP, LD

EDITOR

Patricia Nash, MSN, NNP

"HOW MUCH DOES MY baby weigh?" and "How long is my baby?" are two of the most frequently asked questions in the delivery room. From that point on, growth is followed closely by parents and primary care providers alike. Anthropomorphic measurements (height/length, weight, head circumference) are obtained routinely and are compared with standardized references to follow the growth pattern compared with the norm.

Two of the most common tools used to describe growth in the neonatal and pediatric populations are percentiles and *z*-scores.[1] Although both use normalized curves, *z*-scores are more sensitive and standardized across populations. This column will discuss and describe what *z*-scores are, how they are determined, how their use compares to and complements that of standardized growth curves, and how they are used to assess growth in neonatal and pediatric patients.

GROWTH CURVES

Intrauterine and postnatal growth curves are used in the neonatal intensive care unit (NICU). Intrauterine curves such as Fenton, Babson and Benda, Olsen, and Lubchenko are based on cross-sectional measurements from infants of varying gestational ages at birth.[2–5] These charts vary as to the size of the database, the years in which the data was collected, and the geographic location and ethnicity of the sample, and do not take into account the initial weight loss after birth. They are also limited as to the length of time they can be used after birth, with some available for use as little as 40 days and others out to 168 days.[6] Postnatal curves such as Dancis, Hall/Shaffer, Shaffer/Wright, Wright, Lair and Kennedy, and Ehrenkranz are generally based on a large sample of infants from a broad geographic area and usually reflect the initial weight loss after birth.[7–11] They are limited, though, in that they were likely influenced by the medical and nutritional practices at the time the data was collected and that they do not show growth relative to that of the fetus.[6]

WHAT IS A Z-SCORE?

A *z*-score is a statistical measure that describes how much a point deviates from the mean; that is, it quantifies the distance of a data point—measured in standard deviations—away from the mean of the data set (see sidebar).

There are *z*-score charts and spreadsheets available for various growth curves so that these numbers do not have to be generated each time; two examples are the Fenton, and Centers for Disease Control and Prevention (CDC) curves.[2,13] The *z*-scores are derived from the data sets used to generate the growth curves, so a *z*-score chart is applicable only to its particular curve. For example, the Fenton *z*-score spread sheet would not be appropriate to use with the CDC curves because they describe different populations and are based on different measured values.

In nutritional assessment, *z*-scores are not only used to compare a population but also to compare progress in a particular patient over time, with a more positive *z*-score typically indicating an improvement in status.[14] The most commonly used cutoff to define malnutrition with *z*-scores is two standard deviations below the mean, regardless of the indicator used (weight, length, or head circumference).[15]

USING Z-SCORES IN THE NICU

Z-scores, being numerical values, are more sensitive than percentiles and allow a more precise assessment of growth as well as allowing for a description of growth outside of the 3rd and 97th percentiles.[14] Thus, *z*-scores can pick up subtle changes from week to week and give a better overall picture of growth than looking at daily weight changes, for example. Consequently, there can be a fall in the *z*-score for weight in spite of an average gain of 20–25 g/day. In the NICU at the time of discharge, many infants have a *z*-score for weight two standard deviations below their birth score; that is, birth *z*-score

Determining a Z-Score

A z-score is determined by subtracting the mean of the population from the actual value of the individual and dividing by the standard deviation of the population.[12]

$$z = (a - b)/c$$

Where *a* is the actual measured value (e.g., weight); *b* is the mean of the population; and *c* is the standard deviation of the population.

A *z*-score is negative when the actual score is below the mean and positive when it is above the mean. Because it is impossible to measure every individual to determine the true population standard deviation, a random sample allows for an estimation of the deviation. Unless there is access to all the raw data used to determine the curve, the practitioner would be unable to derive these numbers.

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− discharge z-score ≥ −2; this is not a desirable outcome as it reflects growth failure.[16] By monitoring z-scores throughout admission, nutrients delivered can be adjusted as needed to maintain growth closer to the birth score.

Decreased morbidity and mortality have been associated with normal birth weight z-scores and with catch-up to birth scores by two years of age.[16,17] When using the z-score, the goal is to achieve and maintain growth at or above the birth z-score in almost every case. This does not mean that every infant can or should achieve the 50th percentile for growth. It does mean that with an infant born at the 10th percentile, the goal is to achieve and maintain growth along the 10th percentile. It is important to note that z-scores do not differentiate between the causes of weight change such as changes in fluid status, lean body mass, or adiposity. Therefore, continuing to analyze weight for length is important in identifying both malnutrition and overnutrition. As with any anthropomorphic measure, the information that can be derived is only as good as the information received; inaccurate measures will not provide accurate z-scores.

PRACTICAL USE OF THE Z-SCORE

An example of how the z-score can be a more sensitive indicator of growth velocity changes in a 24-week gestation male infant can be seen in Table 1 and Figures 1 and 2. Both Table 1 and Figure 1 in this example are based on the Fenton

TABLE 1 ■ Data of a 24-Week Gestation, 690-Gram Infant

Weeks	Measure (Weight in Grams)	*Z*-Score	Percentile
24	690	0.16	56
25	725	−0.30	38
27	940	−0.25	40
28	1,100	−0.11	46
29	1,200	−0.26	40
30	1,375	−0.21	42
31	1,520	−0.32	38
32	1,670	−0.45	33
33	1,750	−0.78	22
34	1,970	−0.79	22
35	2,360	−0.43	33
36	2,175	−1.37	9
37	2,370	−1.32	9
38	2,390	−1.64	5
42	3,590	−0.60	27
43	3,745	−0.61	27
44	3,890	−0.64	26
45	4,185	−0.44	33

Note: Data are based on the Fenton growth curve demonstrating weight measures at various weeks gestation compared with the z-score for that weight at that age and the percentile at which the weight would plot.

FIGURE 1 ■ A graph of the weights for the 24-week gestation male infant presented in Table 1 as plotted on the Fenton growth curve. Note that he received significant fluid on day of life 2 as reflected by a weight plot at the 90th percentile.

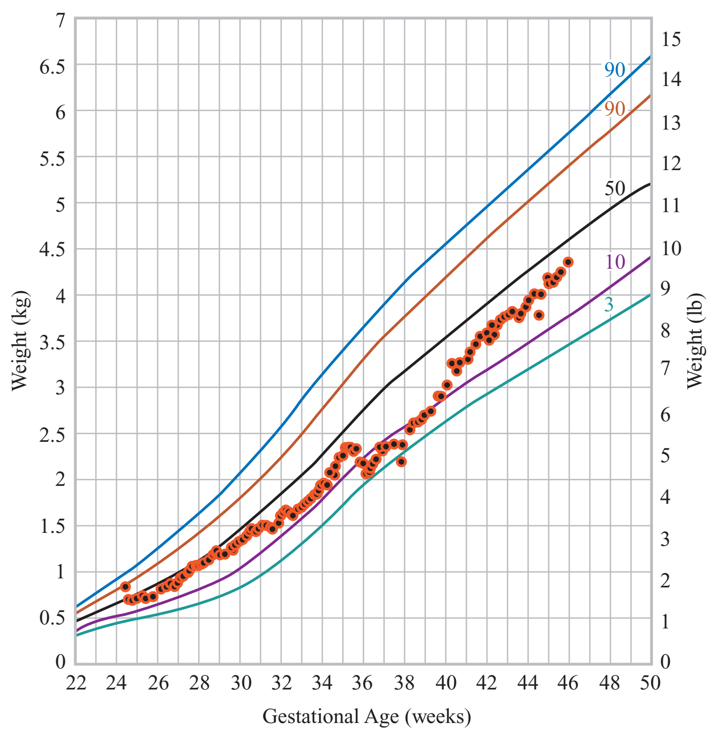
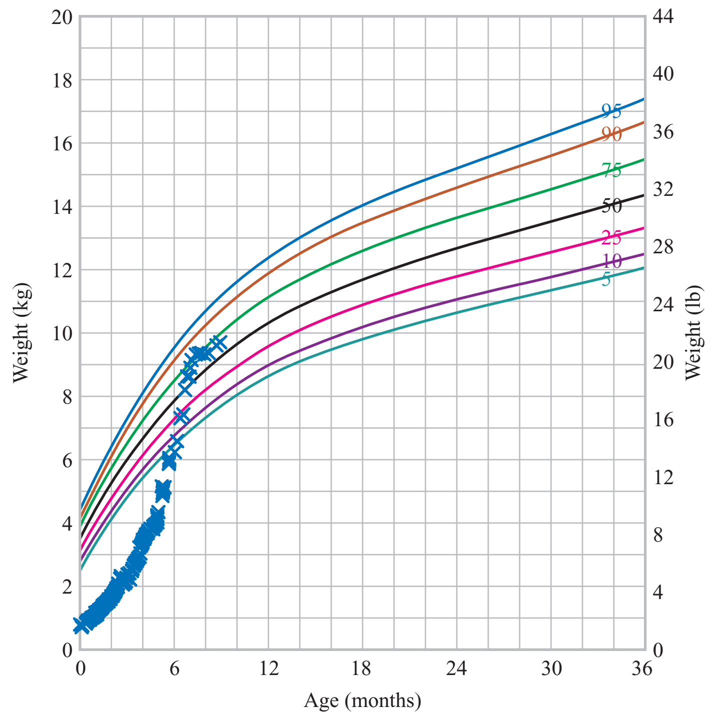


FIGURE 2 ■ **A graph of the weights for the 24-week gestation male infant presented in Figure 1 as plotted on the CDC growth curve. This demonstrates the importance of choosing the correct chart to obtain the most useful information.**



National Center for Health Statistics, National Center for Chronic Disease Prevention and Health Promotion. Weight-for-age percentiles. Boys, birth to 36 months. In: *My First Health Record: Growth Charts*. Atlanta, GA: Centers for Disease Control and Prevention; 2000.

data and illustrate weight changes over time. The patient is a 24-week gestation male with a birth weight of 690 g. Data are available through 45-weeks gestational age, by which time he weighs 4,185 g. His birth data as shown in both the *z*-score chart and the Fenton weight curve place him at the 56th percentile. Note that he received significant fluid on day of life 2 as reflected by a weight plot at the 90th percentile. On the Fenton growth curve, for the time period through 31 weeks gestation, he appears to be growing at the 50th percentile, and most practitioners would say he is following his curve. The *z*-score chart, however, shows a decrease in the *z*-score over this same period from his birth value of 0.16 to a value of −0.32, which is almost one half of a standard deviation difference. By week 44, he has demonstrated some catch-up growth from his low point but is now almost a full standard deviation away from where he began. If *z*-scores were not being followed and nutrition wasn't adjusted to maintain those *z*-scores, he would likely have continued to fall further behind in his growth.

SUMMARY

In conclusion, growth curves do not always visually capture the distance that an infant's growth is from the birth percentile. *Z*-scores offer a more precise assessment of growth by assigning a numerical description and a value for the distance from the goal birth weight score and percentile. The *z*-score, therefore, in conjunction with the growth curve, is a valuable tool in the neonatal population in particular, where growth is associated with developmental and medical outcomes.

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About the Author

Rita A. Chrivia, RD, CSP, LD received her BS in Dietetics at the University of California, Davis and completed her qualifying experience for dietetic registration at Harborview Medical Center, Seattle, Washington. She is licensed as a dietitian in the state of Missouri and is a Board Certified Specialist in Pediatric Nutrition through the Academy of Nutrition and Dietetics (formerly the American Dietetic Association). Rita has practiced for the past 14 years as a neonatal dietitian in the Level III NICU at SSM Cardinal Glennon Children's Medical Center, St. Louis, Missouri where she also serves as dietitian for the nursery follow up clinic. Rita has presented lectures throughout the Midwest to physicians, nurse practitioners, nurses, dietitians, and pharmacists on neonatal and infant nutrition.

For further information, please contact:
Rita A. Chrivia, RD, CSP, LD
E-mail: Rita_Chrivia@ssmhc.com