Pediatric RESEARCH www.nature.com/pr

CORRESPONDENCE

Variability in the use of growth curves between preterm and term infants in NICUs and newborn nurseries

Pediatric Research (2021) 89:711–713; https://doi.org/10.1038/s41390-020-0972-9

"Low birth weight" was first defined in 1977 by the World Health Organization (WHO) as "<2500 g".[1] Since then, this terminology has mostly been abandoned in favor of "small for gestational age (SGA)" representing birth weight (BW) <10th percentile for gestational age. At the other end of the growth spectrum, "large for gestational age (LGA)" represents newborns with BW >90th percentile for gestational age.[2,3] Today, SGA and LGA designations have served as tools to measure risk of morbidity in term infants, which may affect immediate management after birth. For example, infants deemed SGA will have serial screening for hypoglycemia and other conditions (e.g., cytomegalovirus infection), as it is assumed that this weight cutoff will differentiate high- from low-risk newborns. However, the validity of these cutoffs has been questioned.[4,5]

To further complicate matters, various growth curves were developed using different methodologies and populations, such as cross-sectional vs. longitudinal data, international vs. United States, and preterm vs. term newborns.[6–13] Growth curves differ especially at the extreme lower and upper percentiles, where major decisions are made.[14] The delineation of SGA/LGA, therefore, varies based on the specific growth curve used.

The electronic medical record is another factor that confuses growth designations. Many hospitals' electronic medical record systems default to only one type of growth curve rather than having an array of growth curves based on gestational age and often lag in updating them (e.g., Fenton 2003 vs. 2013). This further hinders appropriate clinical practice and uniformity among units and institutions.

Recently at our own institution, the newborn nursery (NBN) began using the Fenton preterm growth curve[6] for *term* infants for the purpose of categorizing size for dates at birth, while the level IV neonatal intensive care unit (NICU) continued to use the WHO growth curve.[12] This growth curve switch resulted in different term newborns being screened for hypoglycemia based upon which unit they were admitted to at the same institution.

While newborns delivered at 39 weeks gestation have similar 10th and 90th percentile weights on the WHO and Fenton growth curves, as gestational age decreases closer to early term, such as at 37 weeks gestation, the Fenton growth curve cutoffs for SGA and LGA status are 300–400 g lower than the WHO growth curve values regardless of sex (Fig. 1). A similar but opposite gap is observed between the WHO and Fenton growth curves as gestational age increases. Therefore, when using the Fenton vs. the WHO growth curve, fewer newborns delivered at 37 weeks gestation are deemed SGA, whereas at 41 weeks gestation, more infants are labeled as SGA.

Since term newborns at our institution have growth parameters identified differently based upon the care unit of admission, we sought to evaluate current practices at other U.S. University hospitals with the hypothesis that there is significant variation in the use of growth curves both within (NICU vs. NBN) and between hospitals.

To evaluate the usage of growth curves in NICUs and NBNs across the nation, we surveyed NICU Chiefs and Medical Directors in University institutions with a Neonatal-Perinatal Medicine fellowship program via e-mail (using Neonatology Chief and NICU Medical Director list serves) from September to December 2019. Those who did not respond to the initial survey received up to two e-mail reminders. Chiefs and NICU Medical Directors were asked to identify which growth curves were used in their NICUs and NBNs, for preterm infants (<37 weeks gestation) and term newborns, and at birth to determine size for gestational age and for longitudinal growth. Each question was accompanied by the following growth curves as choices: INTERGROWTH-21st (2015),[9] Fenton Preterm Growth Chart (2013),[6] Olsen (2010),[13] WHO (2006),[12] Other (specify), and <2500 g (SGA) and >4000 g (LGA). For the questions about NBNs, additional answer choices included "no preterm infants in NBN" and "do not have a NBN" (Supplementary Appendix S1 (online)).

Based on our survey, the WHO (2006),[12] Fenton Preterm Growth Chart (2013),[6] and Olsen (2010)[13] growth curves were the most commonly used growth curves in NICUs and NBNs around the country. To demonstrate differences in the 10th and 90th percentile BW cutoffs, data from these growth curves were either obtained from the original publication (Olsen 2010)[13] or web-based electronic supplements (WHO).[15] For the Fenton 2013 growth curve cutoffs, the Actual Age Calculator v8, championed by the original author on the University of Calgary website,[6,16] was used to determine the closest weight in grams, which corresponded to 10th percentile (z-score of -1.3) or 90th percentile (z-score of $+1.3$). The Actual Age Calculator v8 uses the actual age of the infant at the time the anthropometric data was obtained, specific to the day (i.e., 37 weeks and 1 days) rather than averaging data into completed weeks.[16] This calculator is most appropriate for clinical applications, where gestational weeks and days are available, and most accurately reflects the goals of our research.

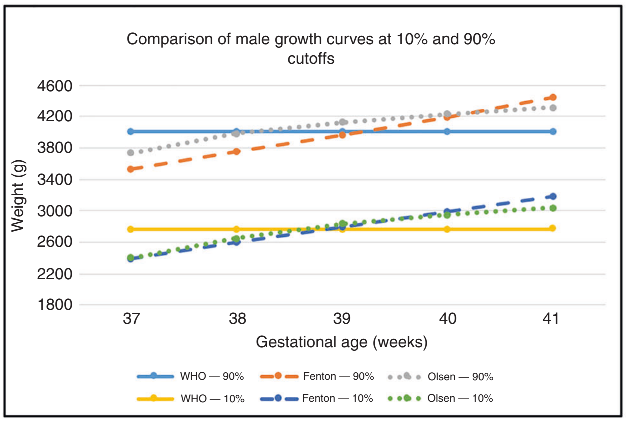
One hundred institutions with a Neonatal-Perinatal Medicine fellowship program were contacted through the e-mail list serves. Eighty-one institutions responded to the survey. Of those, 79 responded to the questions regarding their NBNs. Five institutions did not have NBNs and three institutions did not have preterm infants in their NBNs. For *preterm* infants, 100% of NICUs use a preterm growth curve (93% use the Fenton growth curve) to categorize size for dates at birth, compared to 86% of NBNs (77% use the Fenton growth curve, Fig. 2).

However, for *term* infants at birth, there was a divide between which growth curve was used in NICUs and NBNs. Fifty-one percent (41/81) of NICUs and 50% (37/74) of NBNs use a term growth curve (i.e., the WHO growth curve) for term infants, followed by 41% (33/81) and 35% (26/74) of NICUs and NBNs, respectively, use the Fenton preterm growth curve (Fig. 2). Intra-institutional agreement between NICUs and NBNs was only 76% (i.e., 24% of NICUs and their associated NBNs used different growth curves at birth).

Received: 16 January 2020 Revised: 6 May 2020 Accepted: 9 May 2020
Published online: 22 May 2020

10% and 90% of weight-to-gestational age cutoffs for males on varying growth curves					
	GA (weeks)				
	37	38	39	40	41
WHO — 90%	4011	4011	4011	4011	4011
Fenton — 90%	3530	3750	3970	4195	4450
Olsen — 90%	3736	3986	4129	4232	4319
WHO — 10%	2758	2758	2758	2758	2758
Fenton — 10%	2390	2595	2795	2990	3190
Olsen — 10%	2401	2652	2833	2950	3039

10% and 90% of weight-to-gestational age cutoffs for females on varying growth curves					
	GA (weeks)				
	37	38	39	40	41
WHO — 90%	3853	3853	3853	3853	3853
Fenton — 90%	3460	3700	3910	4110	4310
Olsen — 90%	3651	3847	3973	4070	4142
WHO — 10%	2678	2678	2678	2678	2678
Fenton — 10%	2290	2487	2662	2822	3985
Olsen — 10%	2260	2526	2724	2855	2933



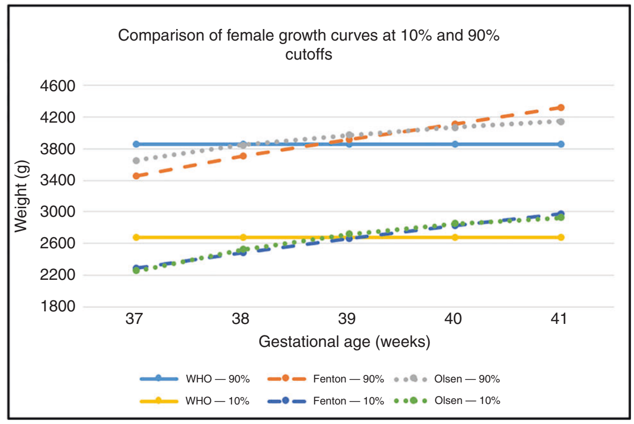


Fig. 1 Comparison of weight-to-gestational age cutoffs (grams) for 10th and 90th percentile of WHO, Fenton, and Olsen growth curves. The left and right graphs show comparisons for the 10th and 90th percentile weight cutoffs for males and females, respectively, for different growth curves.

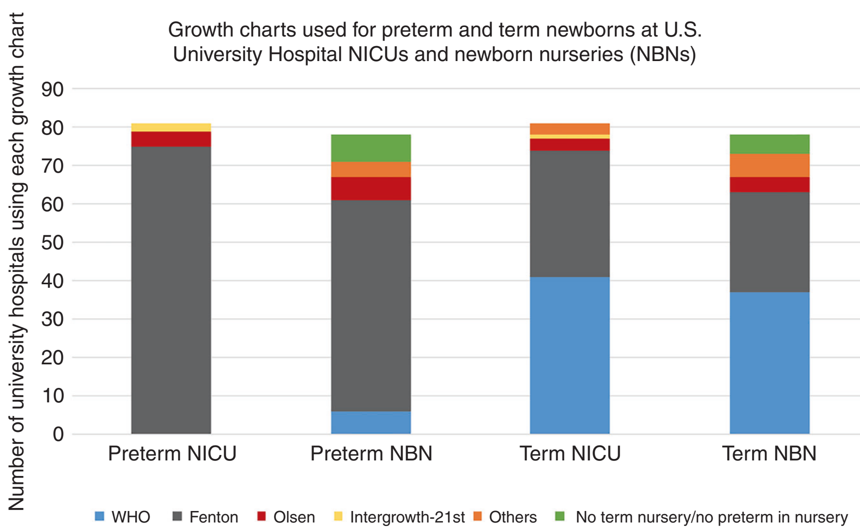


Fig. 2 Comparison of growth curves used in NICUs and newborn nurseries for preterm and term infants.

No surveyed NICUs use the criteria of "<2500 g and >4000 g" for SGA/LGA categorization. For NBNs, only two institutions use the specific BW cutoffs for term infants.

There was no difference between the growth curves used for size-for-dates purpose vs. for measuring longitudinal growth for both preterm and term newborns (data not shown).

This survey of U.S. institutions with Neonatal-Perinatal Medicine fellowship programs found that most *preterm* newborns have birth parameters plotted on preterm growth curves (most used the Fenton growth curve) irrespective of care unit admitted to. In contrast, for *term* infants, only half of the surveyed hospitals use term growth curves (mostly the WHO growth curve) in the NICU. Despite that most admissions to NBNs are term infants, still only half of term newborns were plotted on term growth curves, similar to NICUs. This inconsistency in using preterm growth curves for half of term newborns is less of a problem at 50 weeks gestation when the 2013 Fenton growth curve essentially matches the WHO growth curve.[6] On the other hand, for infants born at 37 and 41 weeks gestation, there are very large BW discrepancies identifying SGA/LGA status between the Fenton growth curve, plotted based on gestational age, and the WHO growth curve, which does not distinguish between gestational age at birth (Fig. 1). For example, a male newborn at 38 weeks gestation with a BW of 3800 g would be considered LGA if plotted on the Fenton growth curve, but not if plotted on WHO growth curve. Moreover, if this infant was to be transferred inter-institutionally from NICU to NICU, there is only a 50% chance that the LGA diagnosis will remain.

Based on our survey, there is no consensus on the appropriate growth curve to use for term infants in the U.S. The variability in the type of growth curve used at birth for term newborns and the inherent difference between the Fenton growth curve, which adjusts for gestational age, in comparison to the WHO growth curve, which does not, can significantly alter whether a newborn is considered small or large for gestational age. Strong historical support for the use of the 2500 and 4000 g cutoffs for the definition of low birth weight and LGA, respectively,[17,18] and their continued use in subsequent studies[19] suggest that using these BW cutoffs may be a convenient surrogate for defining SGA and LGA. For the purpose of stratifying postnatal morbidity and mortality, we call upon the AAP Committee on Fetus and Newborn and other governing bodies to opine on which growth curve to use for term infants at birth. While a consensus is pending regarding abnormal growth status in term infants, perhaps eliminating growth curves as a confounder and use BW cutoffs of <2500 g and >4000 g, respectively, to determine SGA and LGA status may be in order.[18,20]

ACKNOWLEDGEMENTS

We thank the participating neonatologists for their correspondence.

AUTHOR CONTRIBUTIONS

Substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data—J.R.K., Y.L.M. Drafting the article or revising it critically for important intellectual content—Y.L.M., J.R.K., S.Z.T., I.M.P., J.R.M. Final approval of the version to be published—Y.L.M., J.R.K., S.Z.T., I.M.P., J.R.M.

ADDITIONAL INFORMATION

The online version of this article (https://doi.org/10.1038/s41390-020-0972-9) contains supplementary material, which is available to authorized users.

Competing interests: The authors declare no competing interests.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Yuanyi L. Murray[1], Ian M. Paul[2], Jennifer R. Miller[2], Sherry Z. Thrash[3] and Jeffrey R. Kaiser[1,4]

[1]Department of Pediatrics, Neonatal-Perinatal Medicine, Penn State College of Medicine, Hershey, PA, USA; [2]Department of Pediatrics, Academic General Pediatrics, Penn State College of Medicine, Hershey, PA, USA; [3]Department of Clinical Nutrition, Penn State Health Children's Hospital, Hershey, PA, USA and [4]Department of Obstetrics and Gynecology, Penn State College of Medicine, Hershey, PA, USA

Correspondence: Jeffrey R. Kaiser (jkaiser2@pennstatehealth.psu.edu)

REFERENCES

1. World Health Organization. *International Conference for the Ninth Revision of the International Classification of Diseases. Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death: Based on the Recommendations of the Ninth Revision Conference, 1975, and Adopted by the Twenty-Ninth World Health Assembly* (World Health Organization, 1977).
2. World Health Organization. *Physical Status: The Use and Interpretation of Anthropometry: Report of a WHO Expert Committee*. Technical Report Series No. 854 (World Health Organization, 1995).
3. ICD-11 for Mortality and Morbidity Statistics. *World Health Organization*. https://icd.who.int/browse11/l-m/en#/http://id.who.int/icd/entity/784073668 (2019).
4. Kohn, M. A., Vosti, C. L., Lezotte, D. & Jones, R. H. Optimal gestational age and birth-weight cutoffs to predict neonatal morbidity. *Med. Decis. Mak.* **20**, 369–376 (2000).
5. Beune, I. M. et al. Consensus based definition of growth restriction in the newborn. *J. Pediatr.* **196**, 71–76 (2018).
6. Fenton, T. R. & Kim, J. H. A systematic review and meta-analysis to revise the Fenton growth chart for preterm infants. *BMC Pediatr.* **13**, 59–72 (2013).
7. Lubchenco, L. O., Hansman, C., Dressler, M. & Boyd, E. Intrauterine growth as estimated from liveborn birth-weight data at 24 to 42 weeks of gestation. *Pediatrics* **32**, 793–800 (1963).
8. Villar, J. et al. International standards for newborn weight, length, and head circumference by gestational age and sex: the newborn cross-sectional study of the INTERGROWTH-21st Project. *Lancet* **384**, 857–868 (2014).
9. Villar, J. et al. Postnatal growth standards for preterm infants: the preterm postnatal follow-up study of the INTERGROWTH-21(st) Project. *Lancet Glob. Health* **3**, e681–e691 (2015).
10. Villar, J. et al. INTERGROWTH-21st very preterm size at birth reference charts. *Lancet* **387**, 844–845 (2016).
11. Haschke, F. & Van't Hof, M. A. Euro-Growth references for length, weight, and body circumferences. *J. Pediatr. Gastroenterol. Nutr.* **31**, S14–S38 (2000).
12. WHO Multicentre Growth Reference Study Group. WHO child growth standards based on length/height, weight and age. *Acta Paediatr.* **450**(Suppl.), 76–85 (2006).
13. Olsen, I. E., Groveman, S. A., Lawson, L., Clark, R. H. & Zemel, B. S. New intrauterine growth curves based on United States data. *Pediatrics* **125**, e214–e224 (2010).
14. Kozuki, N. et al. Comparison of US birth weight references and the international fetal and newborn growth consortium for the 21st century standard. *JAMA Pediatr.* **169**, e151438 (2015).
15. WHO Growth Charts. *Centers for Disease Control and Prevention*. https://www.cdc.gov/growthcharts/who_charts.htm (2010).
16. 2013 Growth Chart. *University of Calgary*. https://www.ucalgary.ca/fenton/2013chart (2017).
17. Blencowe, H. et al. National, regional, and worldwide estimates of low birthweight in 2015, with trends from 2000: a systematic analysis. *Lancet Glob. Health* **7**, e849–e860 (2019).
18. Boyd, M. E., Usher, R. H. & McLean, F. H. Fetal macrosomia: prediction, risks, proposed management. *Obstet. Gynecol.* **61**, 715–721 (1983).
19. McCormick, M. C. The contribution of low birth weight to infant mortality and childhood morbidity. *N. Engl. J. Med.* **312**, 82–90 (1985).
20. Hughes, M. M., Black, R. E. & Katz, J. 2500-g Low birth weight cutoff: history and implications for future research and policy. *Matern. Child Health J.* **21**, 283–289 (2017).