Validation of Test Weighing Protocol to Estimate Enteral Feeding Volumes in Preterm Infants

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Objective To evaluate the accuracy of pre- and postfeeding weights to estimate enteral feeding volumes in preterm infants.

Study design Single-center prospective cohort study of infants 28-36 weeks' corrected age receiving gavage feedings. For each test weight, 3 pre- and 3 postgavage feeding weights were obtained by study personnel, blinded to feeding volume, via a specific protocol. The correlation between test weight difference and actual volume ingested was assessed by the use of summary statistics, Spearman rho, and graphical analyses. The relationship between categorical predictive variables and a predefined acceptable difference (±5 mL) was assessed with the χ^2 or Fisher exact test.

Results A total of 101 test weights were performed in 68 infants. Estimated and actual feeding volumes were highly correlated (r = 0.94, $P < .001$), with a mean absolute difference of 2.95 mL (SD: 2.70; range: 0, 12.3 mL; 5th, 95th percentile: 0, 9.3); 85% of test weights were within ±5 mL of actual feeding volume and did not vary significantly by corrected age, feeding tube or respiratory support type, feeding duration or volume, formula vs breast milk, or caloric density. With adherence to study protocol, 89% of test weights (66/74) were within ±5 mL of actual volume, compared with 71% (19/27, $P = .04$) when concerns about protocol adherence were noted (eg, difficulty securing oxygen tubing).

Conclusions Via the use of a standard protocol, feeding volumes can be estimated accurately by pre- and postfeeding weights. Test weighing could be a valuable tool to support direct breastfeeding in the neonatal intensive care unit. *(J Pediatr 2016;■■:■■-■■).*

Test weighing, the practice of weighing a baby before and after feeding to estimate feeding volume, is a clinically accessible and noninvasive method for quantifying milk intake in breastfed infants. As a result of its positive correlation with successful breastfeeding,[1-3] test weighing is used by many medical providers[2,4,5] and is endorsed by the World Health Organization for term newborns.[6,7]

There are disparities in breastfeeding rates for preterm infants compared with term infants.[8-10] Test weighing has the potential to increase direct breastfeeding in the neonatal intensive care unit (NICU)[2] and to help maintain a mother's milk supply.[5,9,11,12] A few small studies support the use of test weighing in the NICU[2,13,14]; however, adoption of this technique have been limited by concerns about accuracy in preterm infants.[15] The aim of this study was to determine whether test weighing via the use of a standard protocol[16] could accurately estimate feeding volumes in a cohort of preterm infants. We hypothesized that test weighing with a standard protocol can accurately estimate feeding volume in preterm infants.

Methods

This was a prospective cohort study of infants admitted to the level III NICU at the University of New Mexico (UNM) Children's Hospital between October 1, 2014, and October 8, 2015. The study protocol was approved by the UNM Health Sciences Center Human Research Protections Office, and written informed consent was obtained from parents before participation.

Infants between 28 and 36 weeks' corrected age (CA) were included in this study if they were receiving only oro- or nasogastric tube feedings. Infants were excluded if they were intubated, hemodynamically unstable, required intravenous fluids, or had a congenital anomaly that would prevent swaddling. Three CA groups were defined: 28-31$^{6/7}$ weeks; 32-33$^{6/7}$ weeks; and 34-35$^{6/7}$ weeks CA. Each infant could be included once in each CA group.

CA	Corrected age
NICU	Neonatal intensive care unit
UNM	University of New Mexico

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Funding to purchase the infant scale and cart used for this study was provided by the resident and fellow union, the Committee for Interns and Residents (University of New Mexico Chapter), under the Patient Care Fund. The authors declare no conflicts of interest.

http://dx.doi.org10.1016/j.jpeds.2016.08.011

All weights were obtained with a single electronic scale (BabyWeigh II, Medela, Inc, McHenry, Illinois), based on previously published reports of improved accuracy and ease of use.[14,16,17] Before study initiation, the scale was calibrated by the clinical engineering department at UNM.

All weights were obtained by 1 of 3 research nurses who were blinded to the feeding volume for the infants. Before study initiation, all research nurses reviewed the published Hasse protocol and watched the attached video.[16] The principal investigator performed quality control observations of the research nurses at study initiation to ensure that the Hasse protocol was followed consistently.

Three consecutive weights were obtained and recorded within 30 minutes before beginning the feeding and again within 30 minutes of completing the feeding. To maintain blinding, the research nurse did not remain at the infant's bedside during the feeding. For each weight, monitor wires were disconnected from the monitor. The infant was diapered and swaddled in a receiving blanket, with the wires inside. Oxygen tubing (if present) was secured by the research nurse. The infant's diaper and clothing were not changed between the pre- and postweights. Weights were recorded by the research nurse on an index card, which was then placed in a sealed opaque envelope. A "comment" box was included on each index card to allow the research nurse to mention any concerns encountered in obtaining the weights, including unforeseen variables or concerns that could affect the measurement.

On a separate index card, the bedside nurse recorded the volume of milk administered in milliliters, the type of milk (formula vs human milk), caloric density (calories/ounce), route (orogastric or nasogastric tube), infusion time (minutes), and respiratory support (none, nasal cannula, high-flow nasal cannula, nasal continuous positive airway pressure, or noninvasive mechanical ventilation). A "comment" box also was included on this index card, to allow the bedside nurse to mention any concerns encountered in patient care during the feeding. This index card was placed in a separate sealed opaque envelope. Bedside nurses were blinded to the results of the pre- and postweights.

It was decided a priori to analyze data after the enrollment of 18 participants, to evaluate 2 methods of obtaining weights. Eight of the first 18 infants were weighed with monitor wires taped to the scale, and 10 were weighed with the monitor wires disconnected from the monitor and swaddled with the infant. When the first method was used, average difference was 6 mL, compared with 2 mL when the second method was used. Therefore, the remainder of the study was conducted with monitor wires disconnected and swaddled with the infant during weighing. Data from the 8 infants whose test weights were obtained with wires taped to the scale are not included in this analysis.

Statistical Analyses

We chose ±5 mL as a clinically acceptable difference between estimated and actual intake.[14] Test weight accuracy was assessed by determining the difference between test weight results (estimated volume, g) and actual volume (mL) based on a 1:1 relationship between weight change (g) and volume ingested (mL).[18] The mean, SD, and range of the absolute difference between estimated and actual volumes (mL), the percentage of estimates >5 mL from actual volume (%), and the mean percent error were used to determine the width of the frequency distribution between test weight and actual volume.

A sample size of 97 paired pre- and post-test weight measurements was required to detect a 5-g difference between the administered feeding volume and the test weight,[14] assuming a 15-g SD for repeated test weight measurements, 90% power, and an α of 0.05.[19] Sample size estimates and power calculations were on the basis of previous studies.[15,16] Stata SE 14 (StataCorp, College Station, Texas) was used for all statistical analyses.

Summary statistics were calculated for demographic variables and the absolute difference between the measured test weight and the actual volume delivered. Bland-Altman plots, correlation graphs, and Spearman correlation coefficients were generated to assess the correlation between test weights and actual volume.[20] The relationships between the categorical variable indicating acceptable difference (±5 g) and categorical variables indicating CA groups, respiratory support, formula vs breast milk, caloric density, route (oro- or nasogastric tube), feeding duration, feeding volume, research nurse, or protocol concerns (yes or no as indicated in "comments" on research nurse or bedside nurse index card) were assessed by use of the χ^2 test or Fisher exact test, as appropriate. In addition, percent of error was calculated as described in Meier et al, by "dividing the absolute difference between the actual and estimated volumes of intake by the actual volume of intake." The mean and range of the percent of error and the percentage of values with ≤10% error were reported.[14] One-way ANOVA was used to compare mean percent of error between CA groups, and a *t* test was used to compare mean percent of error between protocol concern categories (yes/no).

Results

Pre- and post-test weights were obtained on 101 occasions in 68 babies. Patient characteristics are shown in **Table I**. The mean actual feeding volume was 36.4 mL (SD: 9.2; range: 17, 62; 5th, 95th percentile: 21, 49) and the mean estimated volume was 34.9 mL (SD: 9.7; range: 8.7, 60.7; 5th, 95th percentile: 19.3, 53.3). Estimated and actual feeding volumes were highly correlated ($r = 0.94$, $P < .001$; **Figure 1**). The mean difference between estimated and actual volume was −1.47 mL (SD: 3.72; range: −10.7, 12.3; 5th, 95th percentile: −6.7, 4.3; **Figure 2**), and the mean absolute difference was 2.95 mL (SD: 2.70; range: 0, 12.3; 5th, 95th percentile: 0, 9.3).

Eighty-five percent of the test weights fell within ±5 mL of the actual volume. The percent of test weights within ±5 mL did not vary significantly by research nurse, CA group, use of orogastric vs nasogastric tube, type of respiratory support, feeding duration or volume, use of formula vs expressed breast milk, or higher calorie vs lower calorie feeds. Test weight estimates were more prone to error when a protocol concern was noted by either the research nurse or the bedside nurse

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Table I. Patient demographics, respiratory support, and feeding variables

Patient/feeding characteristics	Total N = 101 measurements (n = 68 infants)
Gestational age at birth, wk, median (range)	29.2 (26.6-34.2)
Birth weight, g, median (range)	1383 (700-2745)
Male, n (%)	36 (53)
Median CA at enrollment, wk (range)	34.2 (28.6-35.6)
Test weights by CA groups, n (%)	
28-31$^{6/7}$ wk	15 (15)
32-33$^{6/7}$ wk	30 (30)
34-35$^{6/7}$ wk	56 (55)
Respiratory support, n (%)	
Room air	36 (36)
Nasal cannula	42 (41)
High-flow nasal cannula	20 (19)
Noninvasive mechanical ventilation	4 (4)
Type of milk feeding, n (%)	
Formula	54 (53)
Human milk	48 (47)
Calorie content, n (%)	
20 kcal/ounce	2 (2)
22 kcal/ounce	26 (26)
> 24 kcal/ounce	74 (72)
Feeding volume, mL, median (range)	37 (17-62)
Feeding duration, min, median (range)	30 (30-60)

vs when no concern was noted: 71% (19/27) vs 89% (66/74) were within the acceptable range ($P = .04$), respectively. Protocol concerns are listed in **Table II**. There was a trend ($P = .09$) towards more protocol concerns for infants of younger CA.

In further analysis of variability, the mean percent of error was 8.9% (SD: 9.8; range: 0%-53.6%) with 73% of values ≤10% error, and 6% having >30% error. Mean percent of error did vary significantly by CA group (28-31$^{6/7}$ weeks: 13.6, 95% CI 6.8-20.4; 32-33$^{6/7}$ weeks: 11.3, 95% CI 6.8-15.8; 34-35$^{6/7}$ weeks: 6.3, 95% CI 4.6-8.0; $P = .01$) and protocol concerns (yes: 14.9, 95% CI 8.7-21.2 vs no: 7.4, 95% CI 5.6-9.1; $P = .001$).

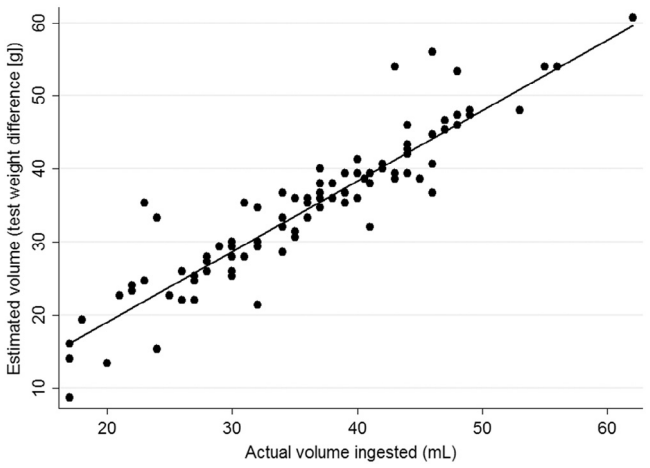

Figure 1. Correlation between the volume ingested (mL) and the difference in the test weight (g) for 101 measurement occasions (n = 68 preterm infants). Each dot indicates 1 measurement occasion.

Discussion

This study assessed test weighing in preterm infants and found that when the published Hasse protocol was used,[16] test weight measurements correlated well with volumes of gavage feeding even in small infants, regardless of type of feeding. The mean absolute difference (2.95 mL) was small for the overall population. The percent error was significantly greater in less mature infants and when protocol concerns were noted. This finding is not surprising, because more immature infants often require additional medical support and consume smaller volumes, potentially complicating the test weighing procedures. Four of the 6 babies who had >30% error were noted to have protocol concerns.

Our study results contrast with the high variability noted by Savenije and Brand,[15] who reported over- or underestimates of feeding volume by as much as 30 mL. We propose that their results reflect the use of "standard practice" for weighing preterm infants and not necessarily an inherent problem with the scales used. Our results support this because when concerns with the protocol were noted, the test weight was less likely to estimate the actual volume. Although our scale (BabyWeigh II, Medela, Inc) was different from those used in previous studies, we speculate that most electronic infant scales could yield accurate test weights, with proper technique.[14,16,21]

Our study could be repeated with different types of electronic scales, and in bottle-fed infants, to determine whether the method of feeding or type of scale would influence the accuracy of test weighing using a standard protocol. We did not include bottle feedings because our study was designed to assess whether rigorous adherence to a standard protocol would affect test weight results, bottle feedings can be incomplete because of loss of milk around the nipple, and because they are not generally used in the most immature infants.

Potential clinical limitations to translating our study to direct breastfeeding are that we did not include orally feeding infants and that infants <1800 g were gavage fed in their isolettes, possibly limiting evaporative water losses and falsely overestimate feeding volumes. Previous studies have demonstrated that these 2 issues are likely of minimal concern.[22] First, small studies have shown that the difference in energy expenditure between orogastric and orally fed preterm infants is about 0.42 kcal/kg/h, which would not be expected to have an impact on infant weight change over the course of a single feeding.[22-24] Second, all infants in this study were older than 1 week, minimizing transdermal losses of heat and water.

Additional limitations of our study were related to the difficulties in controlling external variables in a clinical setting. We cannot rule out the possibility of underascertainment of protocol deviations, because the research nurse was not present at bedside during feeding (30-60 minutes). The bedside nurses were not trained on the test weighing protocol, which is something that could be improved in future clinical or research practice. In addition, we did not check routinely the accuracy of

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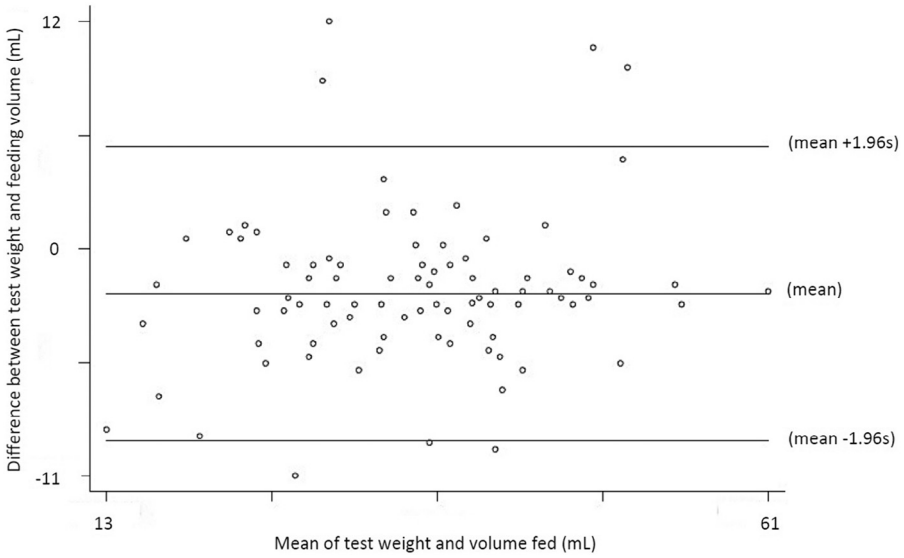

Figure 2. Bland-Altman plot of the agreement between the volume ingested (mL) and the difference in the test weight (g). Each dot indicates 1 measurement occasion (101 measurement occasions; n = 68 infants).

our scale using calibration weights throughout the study; future studies should consider including this important quality control practice.

A final limitation is that the study may not have been adequately powered to detect differences by the subgroups that we examined (CA group, use of orogastric vs nasogastric tube, type of respiratory support, feeding duration or volume, use of formula vs expressed breast milk, or higher calorie vs lower calorie feeds); the subgroup analysis should be interpreted as exploratory.

Resolving the debate over whether test weighing can accurately reflect intake for preterm infants is an important step in improving support for direct breastfeeding in the NICU environment. Often, clinicians are reluctant to allow preterm infants to directly breastfeed when feeding volumes are unknown, making it difficult to estimate how much milk should be supplemented after breastfeeding and difficult to determine whether suboptimal growth is related to inadequate calorie intake.[12] Adoption of pre- and postfeeding test weights may help promote direct breastfeeding in preterm infants.[2] Our results provide additional evidence for clinicians to support the use of test weights to estimate enteral feeding volume in a preterm population, especially infants beyond 34 weeks' CA. ■

Table II. Test weight protocol concerns

Protocol concerns, n (%)	Total n = 27 measurements
Difficulty securing oxygen tubing	10 (37)
Emesis/milk leaking from tubing	5 (19)
Delayed or incomplete feeding	4 (15)
Medication administered with feeding	3 (11)
Difficulty swaddling infant	2 (7)
Gastric residual refed or gastric tube vented between test weights	2 (7)
Diaper change	1 (4)

We acknowledge the valuable advice and guidance of Kristi Watterberg, MD, Robin Ohls, MD, Rebecca Moran, MD, Conra Lacy, RN, CCRC, Janell Fuller, MD, and Emilie Sebesta, MD, whose support was crucial in bringing this manuscript to fruition.

Submitted for publication Feb 26, 2016; last revision received Jul 14, 2016; accepted Aug 3, 2016

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References

1. Ericson J, Flacking R. Estimated breastfeeding to support breastfeeding in the neonatal intensive care unit. J Obstet Gynecol Neonatal Nurs 2013;42:29-37.
2. Funkquist EL, Tuvemo T, Jonsson B, Serenius F, Nyqvist KH. Influence of test weighing before/after nursing on breastfeeding in preterm infants. Adv Neonatal Care 2010;10:33-9.
3. Kent JC, Hepworth AR, Langton DB, Hartmann PE. Impact of measuring milk production by test weighing on breastfeeding confidence in mothers of term infants. Breastfeed Med 2015;10:318-25.
4. Butte NFL-AM, Garza C. World Health Organization and the United Nation's Children's Fund (UNICEF) [homepage on the internet]. Nutrient adequacy of exclusive breastfeeding for the term infant during the first six months of life. Geneva, Switzerland: World Health Organization; 2002. http://apps.who.int/iris/bitstream/10665/42519/1/9241562110.pdf. Accessed August 22, 2016.
5. Maastrup R, Hansen BM, Kronborg H, Bojesen SN, Hallum K, Frandsen A, et al. Factors associated with exclusive breastfeeding of preterm infants. Results from a prospective national cohort study. PLoS ONE 2014;9:e89077.
6. World Health Organization and the United Nation's Children's Fund (UNICEF) [homepage on the internet]. Evidence for the ten steps to successful breastfeeding. Geneva, Switzerland: World Health Organization;

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1998. http://www.who.int/nutrition/publications/evidence_ten_step_eng.pdf. Accessed August 22, 2016.
7. Gartner LM, Morton J, Lawrence RA, Naylor AJ, O'Hare D, Schanler RJ, et al. Breastfeeding and the use of human milk. Pediatrics 2005;115:496-506.
8. Davanzo R, Ronfani L, Brovedani P, Demarini S. Breast feeding very-low-birthweight infants at discharge: a multicentre study using WHO definitions. Paediatr Perinat Epidemiol 2009;23:591-6.
9. Pineda R. Direct breast-feeding in the neonatal intensive care unit: is it important? J Perinatol 2011;31:540-5.
10. Smith MM, Durkin M, Hinton VJ, Bellinger D, Kuhn L. Initiation of breastfeeding among mothers of very low birth weight infants. Pediatrics 2003;111:1337-42.
11. Wilson E, Christensson K, Brandt L, Altman M, Bonamy AK. Early provision of mother's own milk and other predictors of successful breast milk feeding after very preterm birth: a regional observational study. J Hum Lact 2015;31:393-400.
12. Nyqvist KH, Haggkvist AP, Hansen MN, Kylberg E, Frandsen AL, Maastrup R, et al. Expansion of the baby-friendly hospital initiative ten steps to successful breastfeeding into neonatal intensive care: expert group recommendations. J Hum Lact 2013;29:300-9.
13. Meier PP, Engstrom JL, Fleming BA, Streeter PL, Lawrence PB. Estimating milk intake of hospitalized preterm infants who breastfeed. J Hum Lact 1996;12:21-6.
14. Meier PP, Lysakowski TY, Engstrom JL, Kavanaugh KL, Mangurten HH. The accuracy of test weighing for preterm infants. J Pediatr Gastroenterol Nutr 1990;10:62-5.
15. Savenije OE, Brand PL. Accuracy and precision of test weighing to assess milk intake in newborn infants. Arch Dis Child Fetal Neonatal Ed 2006;91:F330-2.
16. Haase B, Barreira J, Murphy PK, Mueller M, Rhodes J. The development of an accurate test weighing technique for preterm and high-risk hospitalized infants. Breastfeed Med 2009;4:151-6.
17. Meier PP, Engstrom JL, Crichton CL, Clark DR, Williams MM, Mangurten HH. A new scale for in- home test-weighing for mothers of preterm and high risk infants. J Hum Lact 1994;10:163-8.
18. Coward WA. Measuring milk intake in breast-fed babies. J Pediatr Gastroenterol Nutr 1984;3:275-9.
19. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39:175-91.
20. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1:307-10.
21. Meier PP, Engstrom JL. Test weighing for term and premature infants is an accurate procedure. Arch Dis Child Fetal Neonatal Ed 2007;92:F155-6.
22. Karlsson V, Heinemann AB, Sjors G, Nykvist KH, Agren J. Early skin-to-skin care in extremely preterm infants: thermal balance and care environment. J Pediatr 2012;161:422-6.
23. Grant J, Denne SC. Effect of intermittent versus continuous enteral feeding on energy expenditure in premature infants. J Pediatr 1991;118:928-32.
24. Lubetzky R, Vaisman N, Mimouni FB, Dollberg S. Energy expenditure in human milk- versus formula-fed preterm infants. J Pediatr 2003;143:750-3.

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