ORIGINAL ARTICLE

Accuracy and precision of test weighing to assess milk intake in newborn infants

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Background: Test weighing is commonly used to estimate milk intake in newborn infants.

Objective: To assess the accuracy and precision of test weighing in clinical practice.

Methods: Infants fed by bottle, cup, or nasogastric tube were weighed before and immediately after feeding by a blinded investigator. Actual milk intake was determined by reading the millilitre scale of the milk container before and after feeding. The accuracy and precision of test weighing was assessed by examining the frequency distribution of the difference between weight change and actual milk intake.

Results: Ninety four infants completed the study. The mean difference between weight change and actual milk intake was 1.3 ml, indicating good accuracy. The precision of test weighing, however, was poor: 95% of differences between weight change and actual milk intake ranged from -12.4 to 15 ml. The maximum difference was 30 ml. Imprecision was not influenced by the presence of monitor or oxygen saturation wires, intravenous lines, or vomiting of the infant.

Conclusions: Test weighing is an imprecise method for assessing milk intake in young infants. This is probably because infant weighing scales are not sensitive enough to pick up small changes in an infant's weight after feeding. Because of its unreliability, test weighing should not be used in clinical practice.

Test weighing (weighing before and after feeding) is the easiest method to assess milk intake in breast fed infants.¹⁻³ This method is commonly used during the first weeks of life, during the build-up phase of breast feeding and when newborn infants are ill, both at home and in hospital.^{3,4} It is assumed that the increase in the baby's weight after feeding (in grams) reflects the amount of milk (in millilitres) drunk by the infant.³ The World Health Organization considers test weighing to be a useful method of assessing milk intake in breast fed infants.⁵ This is based on several studies that examined the reliability of test weighing in bottle fed infants, comparing the difference in weight with the amount of milk drunk from the bottle.^{1-4,6-10} In these studies, conclusions were based on highly significant correlations between weight change and milk intake, which indicate association but not necessarily agreement between two methods.¹¹ In particular, a strong association does not exclude poor accuracy or precision. Accuracy is defined as the ability of a measurement technique to measure the true value of a property. Lack of accuracy means systematic error. It has been shown that test weighing is slightly inaccurate because of evaporative water loss (EWL), but this inaccuracy is too small to be clinically relevant.^{1,7} Precision, on the other hand, is related to the spread of results obtained with repeated measurements. If a procedure such as test weighing is imprecise, its clinical usefulness is hampered considerably. We therefore designed a study to assess the accuracy and precision of test weighing in a clinical setting.

METHODS

We studied 100 infants, fed by bottle, cup, or nasogastric tube, admitted to the newborn and infant ward of the Princess Amalia Children's Clinic in a large district general hospital in the Netherlands. Critically ill or haemodynamically unstable patients were excluded. Each infant took part in the study only once. Babies were weighed three times: before feeding, immediately after feeding, and 15 minutes later. Study measurements were made under conditions that reflected regular clinical procedures as closely as possible.

Each weight measurement was made with the baby fully dressed, wearing a nappy, and, if applicable, with intravenous lines, splints, and monitor wires on the scale. Weight measurements and the presence of intravenous lines, splints, and monitor wires were recorded on a weighing sheet.

All weighing was performed by the same investigator (OS), who was unaware of the baby's milk intake. Two identical Avery Berkel Pesa ERR330 electronic balances were used (Avery Berkel, Breda, the Netherlands). These scales are designed for infant weighing and have a digital display in single grams, without decimals. They were calibrated and maintained annually, according to the Dutch Weights and Measures Act, by the manufacturer. To assess the weighing performance of the scales, we weighed calibrated standard weights of 1.5 and 4 kg (reflecting weights of small and large infants in the study) 20 times within 30 minutes on each of the scales. We repeated this procedure on four consecutive days. The standard deviation of these repeated measurements was then calculated. According to Dutch standards, a scale is appropriate for weighing objects that weigh at least 100 times as much as the standard deviation of repeated measurements with that scale.¹²

Babies were fed by the ward's nursing staff, who were unaware of the measured weights. The amount of milk drunk by each baby was measured in two ways: by emptying the milk container in 20 or 50 ml syringes and reading from the millilitre scale of these syringes, and by weighing the milk container before and after feeding. These values were recorded on a feeding sheet, which was kept separate from the weighing sheet until completed. On the feeding sheet, the nursing staff also recorded whether milk had been spilled or whether the child had regurgitated or vomited milk between feeding and weighing.

Statistical analysis

The increase in weight of the infant after feeding was calculated (as assessed by test weighing, V_{tw}) and expressed

Abbreviations: EWL, evaporative water loss; IQR, interquartile range

in millilitres because it was intended to reflect milk intake. This was compared with the actual milk intake as assessed by reading the millilitre scale on the milk syringes (V_{ml}) in a Bland-Altman plot.¹¹ The frequency distribution of the difference between V_{tw} and V_{ml} was calculated. Its mean represents the inaccuracy of test weighing: a mean of zero indicates that test weighing is accurate. The width of this frequency distribution represents the precision of test weighing.

The difference between the weight immediately after feeding and 15 minutes later was considered to reflect EWL.

Statistical analyses were performed using SPSS for Windows, version 12.0, on a personal computer.

On the basis of a standard deviation of repeated weight measurements of 10 g, a sample size of 84 paired measurements was needed to detect a difference of 5 g between V_{tw} and V_{ml} (considered to be clinically relevant) with 90% power and α of 0.05.

Ethical considerations

The study protocol was approved by the hospital's ethics review board, acting as a recognised subsidiary of the Dutch Central Committee on Research Involving Human Subjects. All parents of participating children gave written informed consent.

RESULTS

Study subjects

One hundred infants were recruited, six of whom were withdrawn because they had been weighed on a different scale. As a result, feeding and weighing data were available for 94 infants (48 male). Median (interquartile range (IQR)) age, gestational age, and birth weight were 3 (2 to 8) days, 257 (243 to 278) days, and 2747 (2045 to 3470) g respectively. The median (IQR) amount of formula (or expressed breast milk) given to the infant was 37.5 (24.5 to 45) ml. Thirty seven infants were weighed with monitor or oxygen saturation wires (39%), and 26 with intravenous lines and splints (28%). Regurgitation and vomiting occurred with 14 infants (15%), and milk spilling with 20 (21%). The median (IQR) difference between the weight immediately after feeding and 15 minutes later, representing EWL, was 1 (–1 to 2) g.

Figure 1 presents a Bland-Altman plot comparing V_{tw} with V_{ml} . The mean difference between V_{tw} and V_{ml} (representing the accuracy of test weighing) was 1.3 ml, and the standard deviation was 7.0 ml; 95% of the differences between V_{tw} and V_{ml} ranged from –12.4 to 15 ml. The correlation between the mean of V_{tw} and V_{ml} and their difference was weak ($r = -0.18$) and not significant ($p = 0.09$). Comparable results were obtained when using the change in weight of the milk canister before and after the feeding as the amount of milk intake, when using data adjusted for EWL, or when limiting the analysis to cases where no milk was spilled.

The difference between V_{tw} and V_{ml} was not influenced significantly by the presence of intravenous lines and splints, monitor, or oxygen saturation wires (all $p > 0.2$), nor by regurgitation/vomiting by the infant ($p = 0.98$). When milk was spilled, the mean difference between V_{tw} and V_{ml} was slightly higher than when no milk was spilled (95% confidence interval for difference 1.1 to 7.9 g).

The standard deviations of the repeated measurements of 1.5 kg and 4 kg standard weights were 0.25 g and 0.82 g for the first scale and 0.97 and 0.57 g for the second scale.

DISCUSSION

This study shows that test weighing of infants is an accurate, but imprecise method of assessing milk intake in young infants. Differences between milk intake as estimated by test

weighing and the actual amount of milk drunk by the infant amounted to 30 ml (fig 1). In 95% of the cases, test weighing underestimated or overestimated the actual amount of milk drunk by up to 15 ml, or 40% of the median milk intake in this group of infants. Because of this large imprecision, test weighing cannot be used to estimate milk intake in young and sick infants drinking small amounts of milk.

This study was designed to reflect the actual clinical situation in which test weighing is used in practice. In contrast with earlier studies, the scales were not calibrated daily, but were maintained according to usual regulatory guidelines.^{7,8} Babies were weighed with clothes, nappies, wires, and splints, exactly as would be done in the clinical situation. The imprecision of test weighing was not influenced by the presence of wires and splints, nor by vomiting or regurgitation. Imprecision was slightly higher when milk was spilled, but after exclusion of cases where milk was spilled, 95% of test weighings still showed imprecision of up to 14 ml. The imprecision did not improve when adjusted for insensible water loss.

Our results appear to differ from earlier studies in which it was concluded that test weighing is a reliable method for assessing milk intake in infants.^{1,3,4,6–10} The latter conclusions were based on highly significant correlations between test weighing and milk intake. However, when the results of these studies are examined in more detail, differences of up to 30 ml were reported in all. By using a more appropriate method to express the agreement between milk intake as assessed by test weighing and the actual amount of milk drunk,¹¹ we have shown that these earlier conclusions were, in fact, incorrect, and that test weighing is too imprecise to be of clinical value.

The most likely reason for the imprecision of test weighing is that the scales used are designed to measure infant weight reliably, but not to pick up small changes in infant weight after a single feed. Following the rules of the Royal Dutch Pharmaceutical Society,¹² the scales used in this study are appropriate for measuring weights larger than 97 g (the largest standard deviation found with repeated measurements of standard weights multiplied by 100). This weighing performance is insufficient for reliable measurement of small increments in weight, as is required for test weighing.

Figure 1 Bland-Altman plot of the agreement between the difference in weight of the infant before and after feeding (V_{tw}) and the actual milk intake recorded by the feeding nurse by reading the millilitre scale on the milk canister before and after feeding (V_{ml}). Each dot represents one child in the study. The spread of the scatter on the y axis indicates the imprecision of test weighing.

What is already known on this subject

- Test weighing (weighing before and after feeding) is a common method for estimating (breast) milk intake in infants, endorsed by the World Health Organization
- Previous studies estimated the accuracy of test weighing in highly standardised situations, not comparable to daily clinical practice, or by assessing the correlation between weight difference and quantity of milk drunk

What this study adds

- Test weighing is an imprecise method for assessing milk intake; overestimation and underestimation of up to 30 ml are possible, probably caused by the use of insensitive scales, which are satisfactory for assessing a baby's weight, but not for measuring small changes in weight
- Test weighing is too imprecise to be of use in clinical practice

Although more sensitive scales should show smaller standard deviations with repeated measurements, the delicate handling required to operate them makes their use unfeasible for test weighing purposes.

Alternative methods for estimating milk intake have been examined, including computerised measurements of breast volume and deuterium tracer studies.^{5–13} These methods are too complicated, however, for practical clinical use. Indirect test weighing (measuring weight changes in the mother rather than the child) can be assumed to suffer from the same measurement imprecision as the method of test weighing assessed in this study.^{9–14–15} Because weight changes over 24 hours in infants are larger than weight changes after a single feed, the imprecision of daily weighing should be smaller, and the reliability higher, than the imprecision of single feed test weighing.¹⁵ One study suggested that repeated test weighing after every feed during 24 hours was more reliable in predicting milk intake than test weighing of an isolated feed, but these findings are difficult to generalise because the study involved only six subjects and was never confirmed.⁹ Clinical indices such as good suckling and baby

contentedness after feeding have also been shown to be unreliable in predicting milk intake.²

It appears therefore that there is no reliable, simple, clinically useful method for assessing milk intake in breast fed infants. Our results suggest that test weighing of a single feed is too imprecise to be of clinical use and should be discouraged.

CONTRIBUTORS

OS performed all weight measurements and data analyses and wrote the initial report. PB designed the study, wrote the protocol, supervised data analysis, and edited the report.

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Competing interests: none declared

REFERENCES

- 1 Arthur PG, Hartmann PE, Smith M. Measurement of the milk intake of breast-fed infants. *J Pediatr Gastroenterol Nutr* 1987;**6**:758–63.
- 2 Meier PP, Engstrom JL, Fleming BA, et al. Estimating milk intake of hospitalized preterm infants who breastfeed. *J Hum Lact* 1996;**12**:21–6.
- 3 Scanlon KS, Alexander MP, Serdula MK, et al. Assessment of infant feeding: the validity of measuring milk intake. *Nutr Rev* 2002;**60**:235–51.
- 4 Whitfield MF, Kay R, Stevens S. Validity of routine clinical test weighing as a measure of the intake of breast-fed infants. *Arch Dis Child* 1981;**56**:919–21.
- 5 Butte NF, Lopez-Alarcon MG, Garza C. *Nutritional adequacy of exclusive breastfeeding for the term infant during the first six months of life*, Geneva, World Health Organization, 2002.
- 6 Borschel MW, Kirksey A, Hannemann RE. Evaluation of test-weighing for the assessment of milk volume intake of formula-fed infants and its application to breast-fed infants. *Am J Clin Nutr* 1986;**43**:367–73.
- 7 Meier PP, Lysakowski Y, Engstrom JL, et al. The accuracy of test weighing for preterm infants. *J Pediatr Gastroenterol Nutr* 1990;**10**:62–5.
- 8 Meier PP, Engstrom JL, Crichton CL, et al. A new scale for in-home test weighing for mothers of preterm and high risk infants. *J Hum Lact* 1994;**10**:163–8.
- 9 Neville MC, Keller R. Accuracy of single- and two-feed test weighing in assessing 24-hr breast milk production. *Early Hum Dev* 1984;**9**:275–81.
- 10 Stevens S, Whitfield MF. How accurate is clinical test weighing of the newborn? *Midwives Chron* 1980;**93**:148–9.
- 11 Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;**1**:307–10.
- 12 Laboratorium Nederlandse Apothekers. *Procedure balans, bedieningsvoorschrift*, The Hague, Royal Dutch Pharmaceutical Society, 2005.
- 13 Daly SEJ, Kent JC, Huynh DQ, et al. The determination of short-term breast volume changes and the rate of synthesis of human milk using computerized breast measurement. *Exp Physiol* 1992;**77**:79–87.
- 14 Woolridge MW, Jackson DA, Imong SM, et al. Indirect test weighing: a non-intrusive technique for estimating night-time breast milk intake. *Hum Nutr* 1987;**41C**:347–61.
- 15 Michaelsen KF, Larsen PS, Thomsen BL, et al. The Copenhagen Cohort Study on infant nutrition and growth: breast milk intake, human milk macronutrient content, and influencing factors. *Am J Clin Nutr* 1994;**59**:600–11.