Clinicians, Consumers, Evidence
Centre for Clinical Effectiveness

Evidence Request 2007-006

Test weighing of healthy, full-term newborns

Date November 2007

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Abstract

Background

An Evidence-Based Practice Guideline for the Management of Feeding in Newborn Services at Southern Health is currently in development. Management of newborns includes assessment of their feeding ability.

Test weighing is sometimes used to assess the volume of milk consumed by breast feeding infants. An infant is weighed before and after a feed and the calculated difference in weight is assumed to be equivalent to the volume intake of milk in millilitres.

The Guideline Development Group assessed the use of test weighing in pre-term newborns to assess milk transfer; however the evidence to assess the accuracy of test weighing in this population was limited.

In order to provide supplementary information for the guideline an evidence review on the accuracy of test weighing in healthy, full-term newborns was requested. Studies were sought where newborn infants were fed either formula or expressed beast milk by means of a bottle, cup, syringe, dropper or gavage. Artificially fed infants were examined as in order to properly examine the accuracy of test weighing the amount of weight gained needs to be compared to a known volume of milk.

Clinical Question

In healthy, full-term newborns, is test weighing an accurate measure of milk intake?

Methods

We searched The Cochrane Library, including The Cochrane Database of Systematic Reviews, DARE, CENTRAL, HTA and NHS EED in May 2007. We also searched Medline and CINAHL.

We included all trials published in English.

Studies were selected and appraised by one reviewer in consultation with colleagues, using inclusion, exclusion and appraisal criteria established a priori.

Results

Our search identified 1500 potentially relevant titles. Of these, four articles were identified which met all our inclusion and exclusion criteria, all published between 1979 and 1986.

The methodological quality of the identified studies was medium to low with poor descriptions of study population and selection criteria. Lack of blinding and independence of outcomes are likely to have introduced bias.

All four studies considered test weighing to be a useful and sufficiently accurate method of assessing volume intake of milk for the method to be used in further studies or in clinical practice. Correlation coefficients between volume of milk intake and change in infants weight reported in the studies ranged from 0.66 to 0.99. However, we have concerns about the appropriateness of this method of statistical analysis.

A high correlation does not necessarily equate to high agreement in values. Correlation shows that there is a relationship between two factors and this is reported as a figure between -1 and +1, with figures close to +1 or -1 indicating a strong relationship. If two variables have a consistent relationship the measurements, plotted against each other, will lie along a straight line, and the correlation will be close to +1 or -1. A study in which milk volume was consistently under or over-estimated by test weighing could still report a perfect correlation between test weighing and actual milk volume.

The studies did not discuss the variation of measurements found in their studies in enough detail to assess the accuracy of test weighing. Data presented in the papers showed test weighing to differ by up to 70ml from a known volume ingested by the infant.

It would be preferable if the authors had expressed some measurement of variation such as the standard deviation of differences between the two methods. This would enable a more

	valid assessment of the accuracy of the test weighing technique.
Conclusions	There is no strong evidence supporting the accuracy of test weighing as a method for determining volume of milk intake in this population.

Background

An Evidence-Based Practice Guideline for the Management of Feeding in Newborn Services at Southern Health is currently in development.[1] Management of newborns includes assessment of their feeding ability. While indicators such as the infants duration of sucking, contentment, and the mother's assessment of emptying of the breast may be used to measure the success of breast feeding these do not measure the actual volume of milk the newborn has consumed.

Test weighing is sometimes used to assess the actual volume intake of milk in breast feeding babies and infants. An infant is weighed before and after a feed and the calculated difference in weight is assumed to be equivalent to the volume intake of milk in millilitres.

The Guideline Development Group assessed the use of test weighing in pre-term newborns to assess milk transfer. One study that assessed test weighing in 50 pre-term, bottle fed babies (<38 weeks gestation) was appraised. The paper examined the difference between test weighing before and after feeds on an electronic scale and compared this amount to the actual intake as measured by bottle. The mean absolute difference between test weights and volume intake was 1.97ml, the mean percentage error was 5.96% and the Pearson's correlation was 0.97. Fifty-four percent of differences were less than or equal to 5ml. However the study was considered methodologically flawed and thus difficult to interpret.[1]

In order to provide supplementary information for the guideline an evidence review on the accuracy of test weighing in healthy, full-term newborns was requested. Artificially fed infants were examined as in order to properly examine the accuracy of test weighing the amount of weight gained needs to be compared to a known volume of milk.

Clinical Question

In healthy, full-term newborns, is test weighing an accurate measure of milk intake?

Methods

Study Selection Criteria

Patient	**Inclusion:** Full-term, healthy, newborn (≤ one month of age), bottle-fed or gavage-fed babies receiving a known volume of either formula or expressed breast milk. **Exclusion:** Premature (less than 38 weeks gestation), very low (<1500 grams) or extremely low (<1000 grams) birthweight babies; babies with congenital abnormalities; infants greater than one month of age; animal studies; mixed population studies where data could not be extracted for population of interest (ie. mixed gestation at birth or mixed age at time of study)				
Intervention	**Inclusion:** Volume intake as determined by test weighing of baby before and after a feed **Exclusion:** Volume intake as determined by test weighing of mother before and after feeding or overnight test weighing of infant.				
Comparison	**Inclusion:** Volume intake of formula or milk from bottle as determined by: • Weighing of bottle before and after feeding • Reading of volume from scale of bottle before and after feeding • Measuring of volume by measuring cup, syringe or other similar scale before and after feeding. **Exclusion:** Any other method of determining volume intake such as isotope labelling of fluid				
Outcomes	Accuracy				
Study Type	Diagnostic cohort studies	**Publication Date**	Any	**Language**	English

Search Strategy

Evidence Source	Date of Search or Issue searched
All EBM (Ovid) *	4 May 2007
The Cochrane Library (HTA and NHS EED)	4 May 2007
Medline (Ovid)	4 May 2007
CINAHL (Ovid)	4 May 2007

*(including The Cochrane Database of Systematic Reviews, DARE, CENTRAL and ACP Journal Club)

Search Terms in Medline*

Patient	1. (neonat$ or newborn$ or infant$ or infancy or baby or babies).mp. or exp Infant, Newborn or exp neonatology/ or exp neonatal nursing/
	2. bottle$.mp. or exp bottle feeding/ or gavage.mp. or (oral$ and feed$).mp. or (nasogastric or naso-gastric or orogastric or oro-gastric).mp.
	3. ((formula or milk).mp. or exp milk, human/ or exp infant formula)
	4. (intake or transfer or volume or amount).mp.]
	5. #3 and #4
	6. [(nasal and oral).mp. and exp Intubation, Gastrointestinal/]
	7. #1 or #2 or #5 or #6
Intervention	8. (weigh$ and test$).mp. or (weigh$ and before and after).mp. or (weigh$ and pre$ and post$).mp. or (weigh$ and change$).mp. or exp body weight changes/
Comparison	-
Outcomes	-
Search strategy	#7 and #8

*Syntax adapted as appropriate for other databases

Data Collection & Analysis

Studies were selected and appraised by one reviewer in consultation with colleagues using study selection and appraisal criteria established a priori. Appraisal was undertaken using standard criteria and is presented in Appendix A.

Results

Our search identified 1500 potentially relevant titles. Initial review of titles reduced this number to 121 references for which abstract, and if necessary, full text were examined.

Study populations and inclusion criteria were only briefly described in most papers. No papers fully described the study populations in terms of gestation and birthweight. Descriptions such as 'healthy, full-term, formula-fed infants' and some indication infants age being less than or equal to one month were considered sufficient for inclusion. Equally, when no description of gestation or birthweight was given but terms such as premature, very low birth weight, extremely low birthweight or special care nursery were used, this was considered sufficient for exclusion.

A systematic review by Scanlon et al[2] on the assessment of infant feeding was located however the inclusion criteria did not match our inclusion criteria and the methodology of included papers was not well appraised. Thus we have not included this review in our results but rather used the review as an additional source of papers. One paper in the review which we have included in our report was not identified in our initial search.[3] There was no abstract for this paper in the health databases and the subject headings and title were insufficient for the paper to be identified by our search strategy.

Four articles were identified which met all our inclusion and exclusion criteria. These were all older articles, published between 1979 and 1986. All articles compared test weighing of infants before and after feeding to either test weighing formula bottles before and after feeding or reading the volume of milk consumed off a scale on the bottle. No articles were found where healthy, newborn infants were test weighted before and after gavage feeding.

Culley et al evaluated 115 infants each for a single feed.[2] The study by Woolridge et al was the smallest study including only 18 infants and analysing 20 pairs of measurements.[4] Hendrikson et al analysed 188 pairs of measurements obtained from an unknown number of infants.[5] Borschel et al included 20 infants and analysed 71 pairs of measurements.[6]

Two of the included papers conducted preliminary validation studies of test weighing prior to using test weighing in breast-fed babies.[3,4] The validation of test weighing was not the major focus of the papers and they did not fully describe the population used for validation of the test-weighing technique. The study subjects were described as less than or equal to one month of age and it was assumed that the population used for validation was of a similar age.

In two of the four studies the same person was responsible for both weighing the baby and calculating the volume of milk taken from the bottle thus introducing an important source of bias.[3,6] In only one study were these measurements assessed independently[4] and in one study this was unclear.[4]

None of the studies adjusted for evaporative water loss. Evaporative water loss is the loss of water through the skin which may affect weight. This could be accounted for using a correction factor but at least one paper suggests that the amount is so small that it is not clinically relevant.[7]

All four studies concluded that test weighing is a useful and sufficiently accurate method of assessing volume intake of milk for the method to be used in further studies or in clinical practice. Correlation coefficients reported were 0.83,[3] 0.99,[4] 0.82[5] and 0.66.[6] The lowest correlation coefficient, reported by Borschel et al, was obtained from

a study in a home setting where it is likely that conditions were less strictly controlled compared to a hospital setting.[6] We have concerns about the use of the correlation coefficient for statistical analysis of test weighing.

Correlation shows that there is a relationship between two factors. Correlation is normally reported as a figure between -1 and +1 with figures close to +1 indicating a strong positive relationship and figures close to -1 indicating a strong negative relationship. If two variables have a consistent relationship the measurements, plotted against each other, will lie along a straight line and the correlation will be close to +1 or -1. A study in which milk volume was consistently under or over-estimated by test weighing could still report a perfect correlation between test weighing and actual milk volume.

The included studies did not discuss the variation of measurements found in their studies in enough detail to properly assess the accuracy of test weighing. For example, though Culley et al[2] and Hendrickson[5] reported high correlation, data indicates wide variation in measurements of the same volume in different babies. Culley at al present a graph showing that when newborns were fed a 60ml volume of formula test-weighing indicated that between 20 and 90 ml had been taken.[3] Presentation of population means and standard deviation in the Hendrickson paper enable us to calculate that the volumes measured by weight may have varied by as much as ±30 ml from the actual volume consumed.[5] Borschel et al showed that the overall mean difference in intake per feed was 16±2 ml though this is for the entire population studied, who ranged from one month to six months of age. Data presented graphically in the paper by Borschel et al also shows a wide variation in measurement of the same volume of formula in different infants.[6]

Data presented by Woolridge et al showed very little spread of results and a very high correlation however in this study babies were weighed repeatedly until two measurements within 0.5g were obtained.[4] This, along with the possibility that the same person performed the weighing of both the baby and the bottle may have introduced a substantial bias as the person performing the weighing may have had preconceived ideas about the value to be expected.

Discussion

To examine the accuracy of test weighing in healthy, full-term newborns we searched for studies that compared test-weighing to a known intake of milk as determined by volume fed from a bottle.

This was a difficult search as we were searching using terms that are not necessarily indexed in the databases. Thus we relied on mention of various combinations of terms such as ‘test’ and ‘weigh’ in title, abstract and key-word fields. As mentioned in the results section, one of our included studies was found through the reference list of another article. This study was not identified in the database searches as there was no abstract in the databases and the title and subject headings did not fully represent the content of the article. It is standard practice at the Centre for Clinical Effectiveness to examine reference lists of key articles, however although the article in question was identified we cannot be certain that we have identified all relevant articles.

We identified four articles that met our inclusion and exclusion criteria. The methodological quality of these studies was medium to low with poor descriptions of study population and selection criteria. In only one of the four studies was it clear that assessors were blinded to the outcome of the other measurement. Potential lack of blinding in the other studies may have introduced an important source of bias.

Studies reported correlations from 0.66 in a home setting[6] to 0.99 in a more controlled hospital setting.[4] However studies did not adequately describe the range of readings obtained for known volumes. It is well known that a high correlation does not necessarily equate to high agreement in values. It would be preferable if the authors had expressed some measurement of variation such as the standard deviation of differences between the two methods.

No paper addresses repeatability. Repeatability may be an important consideration in test weighing of active, wriggling infants. Woolridge et al took two measurements of babies and if the measurements were not within ±0.5 grams a third measurement was taken.[4] However, no data is presented on the number of times a third measurement had to be taken and rather than being used to analyse the repeatability of the method this procedure may have artificially increased the correlation of the test weighing method through minimising the variation (correlation in this study was 0.99).

The scale used for test weighing may also be important. In Woolridge et al, the scale was programmed to take an average of 10 weights 0.5 seconds apart. Woolridge et al recommend the use of electronic scales as being more accurate than spring loaded or mechanical scales.[4] Some of the papers included in this review did not describe the scale used[5] or did not sufficiently explain calibration of the scales[6] thus we are unsure of the ability of the scales used to detect small differences in weight.

One limitation of this review is that we concentrated on healthy, full-term, newborn infants. This excluded some studies that used a mixed population of term and pre-term infants or a mixed age population with data not presented in a manner that enabled us to extract the data for our population of interest.

Conclusions

There is no strong evidence for the use of test-weighing as a method for determining volume of milk intake in this population.

References

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Disclaimer

Appendix A: Critical appraisal of included studies

Characteristics of included studies

Study	Study Type	N (total)	Setting	Patients	Intervention	Comparison	Outcomes
Culley et al, 1979	Diagnostic cohort study	115 infants, single feed measure ment	Birmingham Hospital, UK.	Newborn infants. Gestation unclear but no suggestion that babies were premature or unwell. Actual age of the infants used for the preliminary validation study is unclear however, subjects used for the second part of study were observed from the 3rd to 5th day after birth.	Test weighing of infant before and after feeding in a hospital setting. Measurements were performed on an Avery balance scale accurate to 5g. It is unclear whether the mother or the nurse was responsible for the weighing of the infant. The paper states that the process was supervised by a nurse. .	Direct, visual measurement of milk intake from a bottle, measured on the bottle scale to the nearest 1ml. Again it is unclear if this reading was performed by the infant's mother or a nurse, though the process was supervised by a nurse.	Correlation of milk intake as determined by test weighing compared to direct measurement from bottle.
	This was a two part study. The first part was a preliminary validation study to validate test weighing. This is the section of relevance to our question. The second part used test weighing to compare the fluid intake and weight gain of breast-fed versus formula-fed infants. This section is not critically appraised in this review.						
Woolridge et al, 1980	Diagnostic cohort study	18 infants	John Radcliffe Hospital, UK.	Newborn infants. Gestation unclear but no suggestion that babies were premature or unwell. Actual age of the infants used for the preliminary validation study is unclear however, subjects used for the second part of study were	Test weighing of infant by a nurse in a hospital setting. Weighings were performed on an electronic balance, the Sartorius 3806 MP, used in conjunction with an animal weighing keyboard. The balance was programmed to weigh 10 times with an integration time of 0.5sec and average the results. This was then repeated and if readings were not	Formula intake as determined by weighing the bottle on the same balance both before and after feeding. It is unclear if the same weighing procedure was used as for the babies (i.e. two times with ±0.5g difference acceptable).	Correlation between milk intake as determined by test weighing compared to measurement of milk through weighing the feeding bottle.

				observed from the 5th to 8th day after birth.	within ±0.5grams it was repeated a third time.		
	This was a two part study. The first part was a preliminary validation study to validate test weighing. This is the section of relevance to our question. The second part used test weighing to compare the fluid intake and weight gain of breast-fed whose mothers were using nipple shields. This section is not critically appraised in this review.						
Hendrick-son, 1985	Diagnostic cohort study	188 pairs of measure ments. Number of infants unclear.	St Vincent's Hospital, Montana, US.	Healthy, full-term, formula-fed infants admitted to the well baby nursery. No clear information on age but it seems likely that the well baby nursery is for newborns.	Test weighing of formula-fed newborns by nurses in a hospital setting before and after each feed. No information available on brand or model of scale.	Formula intake as determined by a nurse subtracting the amount of formula remaining in the bottle after feeding from the original amount of formula available. Different nurses performed measurement of fluid intake and weighing of baby.	Mean of weight gain in infants and mean volume of formula consumed. Correlation between weight gain and formula consumption.
Borschel et al, 1986	Diagnostic cohort study	20 infants	Home setting, Indiana, USA.	Healthy, full-term infants. Test weighing performed at 1, 2, 4 and 6 months of age. Only one month results were considered pertinent to this review about the use of test weighing in newborns.	Test weighing by the mother in the home. Mothers used a paediatric scale (Detecto, Model 2501, Brooklyn, New York) accurate to ±10grams and calibrated against standard weights. Weighing was performed immediately before and after each feed without a change of clothes.	Direct measurement of formula volume by mothers using a standard measuring cup.	Comparison of volume of milk intake as measured by test weighing compared to direct measurement was compared using Pearson's correlation.

Quality of included studies									
Study:	**Specified inclusion/ exclusion criteria**	**Explicit description of study subjects**	**Appropriate selection method**	**Use of 'gold standard' reference test**	**All participants tested with both study test and reference test**	**Assessment of test outcomes are independent**	**Assessors are blind to result of other test**	**Appropriate statistical analysis**	**Comments**
Culley et al, 1979	No	No	Unclear	Yes	Yes	No	No	No	No description of study subjects or method of selection, other than that infants were randomly selected. Babies were all weighed on the same scale but formula was measured by eye from the bottle, to the nearest 1ml. It appears the same nurse did, or at least supervised, both the weighing and the formula reading thus there is potential for bias. Though the description of the study says infants were studied for a single feed the graphic representation of results says that some infants were test weighed on more than one occasion.
Woolridge et al, 1980	No	No	Unclear	Yes	Yes	Yes	Unclear	No	Description of inclusion criteria and study subjects limited to number of formula-fed babies. No description of subject selection. Unknown if the same person weighed the baby and the bottle. The repeatability of the weighing is not discussed and we do not know how often a third measurement had to be taken. It is possible that such a procedure may artificially increase the reported correlation of the method.

Hendrickson, 1985	Some	No	Yes Sequen-tial	Yes	Yes	Yes	Yes	No	Inclusion criteria were healthy, full-term, formula-fed infants admitted to the well-baby nursery, however there was no explicit description of gestation or weight. Babies were test-weighed every time they were fed. 188 pairs of weights were included; however the number of infants contributing to this data is unclear. 22 pairs of weights were excluded as the baby had regurgitated or had a nappy change. This was a post-hoc exclusion after weights were actually recorded thus introducing a potential source of bias. Different nurses were responsible for the weighing of baby and the recording of volume of formula taken from bottle, eliminating a potential source of bias.
Borschel et al, 1986	Some	No	No	Yes	Yes	No	No	No	Women volunteered to take part in this study. It was not a sequential or random sample. Thirteen infants were exclusively formula-fed from birth. Seven were initially breast-fed but changed to formula prior to six months of age. It is unclear how many of these contributed to the test-weighing at 1 month. Mothers performed both the test weighing and the measurement of formula volume thus introducing a potential bias.

Results of included studies	
Culley et al, 1979.	This was a preliminary study performed to validate test weighing prior to using the method in breast-fed babies. The correlation coefficient was considered by the authors to be sufficient for the method to be used in the following study. Comparison of test weighing of formula-fed infants with the amount ingested, as measured directly from the scale on the bottle to the nearest 1 ml, gave a correlation coefficient of 0.83 (See results section for discussion around correlation coefficients). Results are presented graphically and show that there is a large spread of readings. For example infants fed 60ml from the bottle showed an intake of between 20ml and 90ml by test weighing. There is no discussion of the range of measurements.
Woolridge et al, 1980.	This was a preliminary study performed to validate the test weighing procedure prior to using it in a study on the evaluation of nipple shields for breast feeding. Comparison of test weighing of formula-fed babies with the amount ingested, as measured by weighing the bottle before and after feeding, gave a correlation coefficient of 0.99. Eighteen subjects were said to be involved however the graph displays twenty values. The number of times each baby was test weighed is unknown. There is no discussion of, or data presented on, the spread of measurements. The authors commend the use of the electronic balance in conjunction with an animal weighing keyboard for weighing babies and suggest it is more accurate than spring balances.
Hendrickson, 1985.	Comparison of test weighing of formula-fed infants with the amount of milk ingested gave a correlation coefficient of 0.8198. There was no significant difference between the mean of weight change and the mean of the actual volumes consumed however it is unclear if this study had the power to detect such a difference. There is no discussion of, or data presented on, the spread of measurements. The authors concluded that test weighing can give a valuable estimate of fluid intake but cautioned that their experiment was conducted under controlled conditions. Weighing was in a hospital setting by nurses and infants were monitored for regurgitation and diaper and clothing changes. Different nurses weighed the baby and the bottle, unaware of the outcome of the other weighing.
Borschel et al, 1986.	This study was a part of a larger study that then went on to assess the volume of milk intake by breast-fed babies compared to formula-fed babies. This study test weighed babies for a 24 hour period at 1, 2, 4 and 6 months of age. Only the one month results are relevant to our definition of newborn as from birth to one month of age. References in text to figures do not appear to correspond to correct figures however it seems the correlation coefficient was 0.66 for one month old babies' intake of milk as determined by test weighing compared to volume of formula measured by a standard measuring cup. The volume determined by test weighing was 90% of that determined by direct measurement. Correlation coefficients were increased in older infants though this data has not been considered in this review of the use of test weighing in newborns. Direct measurement resulted in higher intakes than test weighing at each time point.