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ORIGINAL ARTICLES

Accuracy of weighing infants with the diaper on in primary health care

Acurácia da pesagem de lactentes com a fralda na atenção primária à saúde

Exactitud del pesaje del niño pequeño con el pañal en la atención primaria de salud

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Abstract

Objective: to estimate the bias introduced by weighing infants with the diaper on in primary health care. **Methods:** we enrolled infants who were about to be weighed at a primary care center and weighed each infant twice - once without the diaper and once with the diaper on - after the scale had been tared with a dry diaper. The bias was calculated, as the percentage difference in weight, by first subtracting the no-diaper weight from the diaper-on weight and then dividing the result by the no-diaper weight. **Results:** we enrolled 30 infants from July 23 to August 1, 2013. Most infants were present for a scheduled medical doctor's visit, and their diapers had been changed less than 45 minutes before. The mean percentage difference in weight was 0.3% (95% confidence interval, 0.2% to 0.5%). **Conclusion:** we found a substantial agreement between the two weighing techniques. The bias (that is, loss of accuracy) introduced by weighing infants with the diaper on compared favorably with the precision of the standard technique and the physiological variability of the infants' weights. Our findings suggest that weighing infants with the diaper on may be a valid technique for the cross-sectional assessment of the nutritional status in primary health care settings. However, further research is needed before it is used for the longitudinal assessment of the weight velocity.

Keywords:
Validity of Tests
Body Weight
Infant
Primary Health Care
Child Health Services

Resumo

Objetivo: estimar o viés introduzido pela pesagem de lactentes com fralda na atenção primária à saúde. **Métodos:** recrutamos lactentes que estavam para ser pesados numa unidade básica de saúde e pesamos cada lactente duas vezes: uma sem fralda, e outra com fralda, depois de a balança ter sido tarada com uma fralda seca. O viés foi calculado como a diferença percentual de peso, subtraindo o peso sem fralda do peso com fralda, e então dividindo o resultado pelo peso sem fralda. **Resultados:** recrutamos 30 lactentes entre os dias 23 de julho e 1º de agosto de 2013. A maioria estava lá para uma consulta médica agendada, e tinha tido sua fralda trocada havia menos de 45 minutos. A diferença percentual de peso média foi 0,3% (intervalo de confiança de 95%, 0,2% a 0,5%). **Conclusão:** houve concordância substancial entre as duas técnicas de pesagem. O viés (isto é, perda de acurácia) introduzido pela pesagem de lactentes com a fralda se compara favoravelmente à precisão da técnica padrão e à variabilidade fisiológica do peso dos lactentes. Pesar lactentes com a fralda parece ser uma técnica válida para a avaliação transversal do estado nutricional na atenção primária à saúde, apesar de mais pesquisa ser necessária antes de ela ser usada para a avaliação longitudinal da velocidade de ganho de peso.

Palavras-chave:
Validade dos Testes
Peso Corporal
Lactente
Atenção Primária à Saúde
Serviços de Saúde da Criança

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Resumen

Objetivo: estimar el sesgo introducido por el pesaje de niños pequeños con el pañal en la atención primaria de salud. **Métodos:** se incluyó a los niños pequeños que estaban a punto de ser pesados en un centro de salud, y se pesó cada niño dos veces: una vez sin pañal, y una vez con pañal, después de que la balanza había sido tarada con el pañal seco. El sesgo se calculó como la diferencia porcentual de peso, restando el peso sin pañal del peso con pañal y luego dividiendo el resultado por el peso sin pañal. **Resultados:** fueron seleccionados 30 niños pequeños entre el 23 de julio y el 1 de agosto del 2013. La mayoría estaba allí para una visita médica programada, y habían tenido el pañal cambiado a menos de 45 minutos antes. La diferencia porcentual de peso media fue del 0,3% (intervalo de confianza del 95%, 0,2% hasta 0,5%). **Conclusión:** existe un acuerdo sustancial entre las dos técnicas de pesaje. El sesgo (es decir, pérdida de exactitud) introducido por el pesaje de niños pequeños con el pañal se compara favorablemente con la precisión de la técnica estándar y la variación fisiológica del peso de los niños pequeños. Pesar niños pequeños con el pañal parece ser una técnica válida para la evaluación transversal del estado nutricional en la atención primaria de salud, aunque se necesite más investigación antes de que ella sea utilizada para la evaluación longitudinal de la velocidad de peso.

Palabras clave:
Validez de las Pruebas
Peso Corporal
Lactante
Atención Primaria de Salud
Servicios de Salud del Niño

Introduction

Because growth curves were constructed by weighing infants without any clothes,[1,2] it is usually recommended that the diaper is removed before weighing infants.[3-6] Nevertheless, in busy primary care centers infants are often weighted with their diaper on, and then the weight of the diaper is discounted. This is supported by a World Health Organization (WHO) manual from 1995, which recommends that the infant is weighed "with or without a diaper... If a diaper is worn, its weight is subtracted from the observed weight",[1] based on an anthropometric standardization manual.[7]

Even if the weight of a dry diaper is discounted, urine contained in the diaper should bias the weighing upward. However, no study ever measured that bias (that is, loss of accuracy) in the context of ambulatory child health care. Our objective in this study was to estimate the bias due to weighing infants with the diaper on in primary health care.

Methods

Participants

We estimated the bias due to weighing infants with the diaper on by means of the lack of agreement between two weighings: one with the diaper on (after taring the scale with a dry diaper identical to that used by the infant) and another, without a diaper. We included children aged under 24 months who were already going to be weighed in a primary care center. We included infants only if they had a dry diaper for taring the scale, and excluded those who urinated or passed stools between the two weighings.

The infants were enrolled in a primary care center that implements the Family Health Strategy (ESF - *Estratégia Saúde da Família*) in the city of Vitória (Espírito Santo state, Brazil). As in other ESF primary care centers, physicians and nurses from ESF perform scheduled and urgent (same-day) assistance to people of all ages, including infants. The chosen primary care center usually has a pediatrician, but she was in vacation when the data were collected. Other professionals also serve infants (dentists, a social worker, a psychologist, speech therapists), but their visits are not preceded by weighing. All families enrolled in the cited primary care center live within a thousand meters away, mostly without any geographical barriers on their way.

Measures

The infants were weighed on a digital scale that belongs to the primary care center, model 109-E (Welmy), with 5g accuracy, which calibration is monthly verified by the Municipal Health Secretariat. One of the authors (LFF), a family and community physician experienced in providing primary health care, had especially trained two other authors (MAR and RAL), medical students, for data collection.

One of the authors (MAR) addressed the infants' parents (or guardians) at the time they were going to be weighed. He then obtained written informed consent, and collected through interview data about the infants (gender, date of birth, gestational age at birth) and context (time elapsed since latest diaper change; if weighing was to be followed by an visit; if it was urgent; and which professional would be consulted). If the parent/guardian wasn't sure about an answer, data was checked in the child health record. (This booklet is distributed by the Ministry of Health to all newborns, and health professionals write down information about birth, growth, development and vaccination.) Afterward, another author (RAL) weighed the infants with standardized technique.[7]

Both weighings were performed immediately one after the other, with the same scale. To prevent that a possible systematic difference between the first and second weighings would bias the measure of interest, some infants were first weighed without a diaper and then with the diaper on (after the scale was tared to the weight of the dry diaper) and others were weighed inversely. The weighing order was determined by a random computer-generated sequence.

Considering that an agitated infant might have various "stable" weights, we adopted a technique to minimize the arbitrariness in the weight choice. During the weighing, one of the authors (RAL) was positioned so that he could not read the weight on the digital display, and when he thought the infant was quiet enough, he warned the colleague (MAR), who then had to write down the first value which was accompanied by the stability indicator light.

Temperature and humidity in the city were obtained by the hourly monitoring of a web page (http://www.redemet.aer.mil.br), maintained by the Brazilian Air Force Meteorology Network Command. Our protocol included the description of both variables for the period of data collection as a whole. However, considering the little time between changing the diaper and weighing, we chose to include among the variables for each infant the latest values of temperature and humidity.

Statistical analysis

We calculated the bias as the lack of agreement, that is, as the percentage difference between the weight with the diaper on (discounting the dry diaper) and the weight without a diaper:

$$\textit{difference} = \frac{(\textit{weight with diaper - weight without diaper})}{\textit{weight without diaper}} \quad (1)$$

Considering a urine output of 3.4ml/kg/h (standard deviation: 1.3ml/kg/h),[8] time since the last diaper change varying uniformly between 15 minutes and 3 hours, and a further imprecision in weighing expressed by a mean difference of 2.35g (standard deviation: 4.62g)[9] for infants who weighed 3,500g, we estimated that 9 infants would be enough to achieve 95% power to reject the null hypothesis of no difference in weight between infants with and without diaper, with alpa of 0.05. Even so, we chose a sample size of 30 infants, to ensure that the sampling error of the mean would have a normal distribution, as well as to provide greater statistical power for the association analysis.

We inspected the distribution of the percentage difference in weight around its mean through a scatter plot of the percentage difference in weight *versus* the mean of the two weighings. Since the distribution was asymmetrical, we used the 2.5 and 97.5 percentiles to estimate the 95% concordance interval between the weighings, namely, the range containing the percentage difference in weight for 95% of infants.[10]

We used the same scatter plot to assess the assumption that the percentage difference in weight does not depend on the weight of the infant.[10,11] We used the Pearson correlation test to assess the same assumption, and also the assumptions that the percentage difference in weight was not associated with the order of the infant within the sample, or to their weighing order (with or without a diaper).

We estimated the hourly increase in the percentage difference in weight by simple linear regression, fixing the intercept at zero to avoid dilution bias due to the imprecision in the parent's report of the time elapsed since the last diaper change. We also used simple linear regression to explore for associations between the percentage difference in weight and the infant's age (corrected for preterm birth, when appropriate) or gender; reason for weighing (which could be associated with different times elapsed since the last diaper change); and weather conditions (which could interfere with insensible water loss and thus with urine output).

We would handle missing data by using only complete cases, but there was no missing data point.

In order to analyze the data we used the standard components of the statistical computing environment R, version 3.0.1 (R Core Team, Vienna, Austria).

The research was approved by the EMESCAM Research Ethics Committee (Certificate of Presentation for Ethical Consideration nº 11608613.9.0000.5065), and authorized by the Municipal Secretariat of Health of Vitória. After the conclusion of the research, the authors presented preliminary research results for the infants' families.

Results

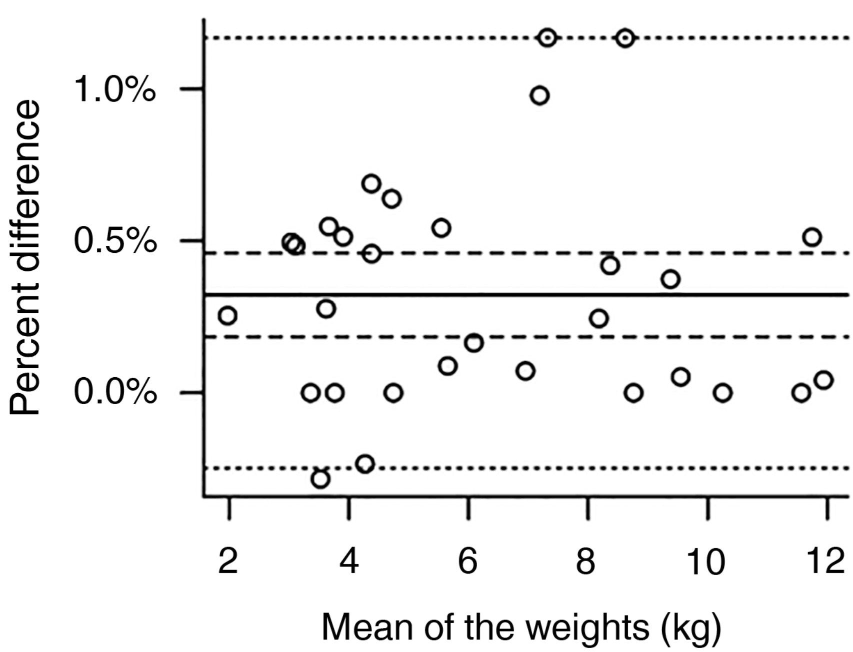
Enrollment took place on weekdays between July 23 and August 1st, 2013. Although we were not able to enroll strictly consecutive infants, we did invite most infants weighed in the primary care center during the period, from all the opening hours (7 am to 8 pm). From the 37 infants whose parents or guardians we approached, one refused to participate in the study; five did not carry a dry diaper; none urinated or passed a stool between weighings; and one was more agitated and had to be released without being weighed twice to avoid delaying the visit. At the end, the sample consisted of 30 infants (81% of those invited). There were no adverse events related to weighing with the diaper on.

The infants had a mean corrected age of 4.3 months, and little more than half were male (Table 1). Most infants were being weighed because of a subsequent scheduled medical doctor's visit at the primary care center. Mean time since last diaper change was 36 minutes (range 5min to 2h). Mean temperature was 26º C (range, 21º C to 29º C), and mean relative humidity was 67% (range, 33% to 83%).

The mean percentage difference in weight was 0.3% (95% confidence interval [CI], 0.2% to 0.5%, $p<0.01$) (Graph 1). The percentage difference had an asymmetric distribution, with a median of 0.3% and a 95% concordance interval from -0.2% to 1.2%.

Table 1. Sample description

Characteristic	N (%)
Gender	
Male	17 (57%)
Corrected age (months)	
0	9 (30%)
1 - 2	9 (30%)
3 - 5	3 (10%)
6 - 11	6 (20%)
12 - 23	3 (10%)
Weighing is for a subsequent visit	
Yes	28 (93%)
Whose visit?	
Doctor's	25 (89%)
Nurse's	3 (11%)
Visit is for an urgent problem	
Yes	2 (7%)
Time since last diaper change	
5 or 10m	9 (30%)
20min	7 (23%)
30min or 35min	7 (23%)
40min or 1h	2 (7%)
1½ h or 2h	5 (17%)



Graph 1. Bland & Altman scatter plot for the agreement between the diaper-on weight (discounting the weight of a dry diaper) and the weight without a diaper. Solid line indicates mean percentage difference, dashed lines indicate 95% confidence interval for this mean, and dotted lines indicate 95% concordance interval.

The percentage difference in weight was not associated either with the infant weight (Graph 1; p=0.95), or with his/her position in the sequence of the sample (p=0.26), or with which weighing had been done first (with or without diaper; p=0.06).

For every hour elapsed since the diaper had been changed, the infants' percentage difference in weight increased by 0.37 percentage points (95% CI, 0.20 to 0.54; p<0.001).

Percentage difference in weight was not associated with gender (p=0.68) or age (p=0.39); it was not associated with whether the infant was being weighed for a visit (p=0.27), whether the visit was for an urgent problem (p=0.78) or whether if the visit was a doctor's or a nurse's visit (p=0.71); and it was not associated with temperature (p=0.50) or humidity (p=0.48).

Discussion

In the context of primary health care, weighing infants with their diaper on introduces a bias of +0.3%, even after taring the scale with a dry diaper identical to the one used by the infant. This would mean, for instance, a difference of 10g in an infant weighing 3,000g.

This bias is zero when the diaper has just been changed, and increases 0.37 percentage points with every hour, which is compatible with a previously reported urine output of 3.4ml/kg/h.[8]

There are no consensual limits that we are aware of for how much bias is acceptable in weighing infants for clinical purposes. Understanding the bias as a loss of accuracy, we may assess its magnitude by comparing it with the degree of reliability of weighing infants without a diaper. The lack of reliability can be divided into two components: imprecision of the measurement technique and physiological variability of what is being measured.[12]

We can assume that measurement imprecision was an important component of the variability we found in the percentage difference in weight. Among 30 infants, 6 had a difference of zero (including one with 2 hours since latest diaper change) and 2 other infants had a negative difference between the weight with the diaper on and the weight without it. Unfortunately, we were not able to directly estimate the weighing precision because in that busy primary care center it was not feasible to weigh each infant four times (two with the diaper on, and two without it). On the other hand, the WHO Multicenter Growth Reference Study provides a more direct estimate of the measurement imprecision in the weighing of infants. In that study, 4.0% of the newborn weighings and 6.8% of the weighings in the longitudinal component of the study had to be repeated due to a difference between examiners that was greater than 100g.[2] In comparison, in our study only 1 (3%) infant had a difference of 100g between the weighing techniques, and none had any greater difference. This suggests that the loss of accuracy due to weighing the infant with the diaper on is not larger than the imprecision of the standard weighing technique.

We can also compare the loss of accuracy due to weighing the infant with the diaper on with the physiological variability of the infants weight. Although meals and bowel movements are sources of variability of weight, no anthropometry manual recommends weighing infants at a specific time in relation to them. In exclusively breastfed infants aged 4-26 weeks, each meal has a mean weight of 101g,[13] which is much more than the mean difference in weight of 30g we found in the same age group between the weighing techniques. Furthermore, infants from Myanmar aged 12-23 months have stools with a mean weight of

Table 2. Comparison between variability due to bowel movements and bias due to urine in the diaper, when weighing infants.

Age group	Mean weight (interval) of feces[15]	Mean weight (interval) of urine in the diaper[a]
1 week	4g (0 to 48)	5g[b]
2 to 4 weeks	11g (0 to 40)	9g (-10 to 20)
1 to 12 months	17g (2 to 98)	25g (-10 to 100)
13 to 24 months	35g (4 to 180)	22g (0 to 60)

[a] Difference between weighing the infant with the diaper on (after taring the scale with a dry diaper) and without the diaper; data from this study [b] Sample consisted of a single infant.

83g,[14] which again is much more than the mean difference in weight of 22g we found in the same age group between the weighing techniques. Finally, infants from the United Kingdom have stools with mean weights[15] similar to the mean differences in weight we found for each age group (Table 2). In summary, the loss of accuracy due to weighing infants with the diaper on is not larger than the physiological variability of the infants weight.

Our estimates should only be generalized to settings where infants arrive for weighing up to about 2 hours after their diaper had been changed. We believe this description fits most primary care centers, but not necessarily other infant health services. Furthermore, one should be careful when generalizing these results to places with significantly different weather conditions. The effect of weather conditions was a secondary measure in our study, and the apparent lack of association might be due to low statistical power.

We realize that, in clinical practice, it would be much easier to simply discount a previously estimated diaper weight, instead of taring the scale with a dry diaper as we did. In our study, we decided to tare the scale for every infant because we could not depend on knowing the manufacturer and exact model for each infant's diaper, and the scale was not meant for weighing single diapers by themselves. If the conclusions of this study are ever translated into clinical practice, the actual bias will depend on how accurately the diaper weight was estimated.

Finally, it is important to underline that this study relates to single episodes of weighing, not to the estimation of weight velocity, which is an integral component of the longitudinal assessment of the nutritional status.

Conclusion

This study has confirmed that weighing infants with the diaper on in primary health care leads to bias, that is, reduces the accuracy in weighing, even if the weight of the dry diaper is carefully subtracted. However, this loss of accuracy is small if we take into consideration the imprecision of the standard weighing technique and the physiological variability resultant from the infants' meals and bowel movements. Weighing infants with the diaper on seems to be a valid technique for the cross-sectional assessment of the nutritional status in primary health care, even though more research is needed before it is used for the longitudinal assessment of the weight velocity.

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