DANISH MEDICAL JOURNAL

Original Article

Dan Med J 2023;70(9):A11220712

Validity of parent-reported weight and length of infants

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Dan Med J 2023;70(9):A11220712

ABSTRACT

INTRODUCTION. Anthropometric data are key to evaluating infant health. This study assessed the validity of parent-reported infant weight and length, and their reliability to categorise children by BMI z-score, as compared to clinical measurements.

METHODS. From a cohort of 4,262 infants, parent-reported and clinically measured anthropometric data were obtained and compared at three months and one year of age.

RESULTS. Parent-reported and clinically measured data generally correlated well. Mean differences at three months and at one year, respectively, were 0.08 kg (95% confidence interval (CI): 0.07-0.09 kg) and 0.10 kg (95% CI: 0.08-0.12 kg) for weight, 0.8 cm (95% CI: 0.8-0.9 cm) and 1.0 cm (95% CI: 0.9-1.1 cm) for length and –0.16 kg/m^2 (95% CI: –0.20–-0.12 kg/m^2) and –0.22 kg/m^2 (95% CI: –0.27–-0.18 kg/m^2) for BMI. Effect sizes were negligible to small. Bland-Altman plots showed clinically insignificant bias, but 95% limits of agreement were wide enough to be significant. Comparing categorisation of BMI z-score showed only fair agreement.

CONCLUSION. Parents' reports of measured infant weight and length are reliable at a population level in a setting with routine preventive care. Parent-reported data should not be used for assessment of individual infants, particularly not if a health condition is suspected. BMI calculated from parent-reported anthropometrics is not reliable.

FUNDING. None.

TRIAL REGISTRATION. This study was registered with www.clinicaltrials.gov, registration number NCT01694108.

Monitoring growth is essential in assessing infant and child health. On a global scale, both under- and overweight are key challenges. The prevalence of underweight remains high in the world's least developed regions [1]. Childhood obesity and overweight are increasingly global concerns and are associated with a wide range of adverse outcomes [2, 3]. Overweight in infancy is associated with an increased risk of childhood obesity [4]. Reliably surveying the growth of infants and identifying those at risk of complications later in life is key to improving prevention strategies. Clinically weighing and measuring children using standardised methods yields the most accurate data but is not always feasible due to logistics or cost. Instead, some large-scale surveys use parent-reported weight and length [5, 6]. The validity of parent-reported anthropometric data has been assessed in children from two to 17 years with varying results [7-13]. Some studies showed agreement between parent-reported and measured data; other studies found that parents overestimated weight, length and/or BMI; and some studies found that weight, length and/or BMI were underestimated. Several studies have reported low

predictive values of parent-reported data for classifying children into BMI categories [8, 11]. Reliability increased when specifically asking parents to measure – as opposed to estimating - the child's weight and length [12]. Growth in infancy is commonly monitored more closely than in older children, likely increasing the reliability of parent-reported data.

The aims of this study were:

i) to assess the validity of parent-reported infant weight and length compared with clinical measurements.

ii) to assess the validity of using parent-reported anthropometrics for classification into BMI categories as defined by the World Health Organization (WHO).

Ethics: This was a pre-planned secondary analysis of data from a study of neonatal BCG immunisation [14, 15], which was approved by the Danish Data Protection Agency (R. no. 2009-41-4141), the Committees on Biomedical Research Ethics (R. no. H-3-2010-087) and the Danish Medicines Agency (R. no. 2612-4356. EudraCT 2010-021979-85. Protocol 2009-323). The parent(s) with custody gave written informed consent.

METHODS

Population

This study was based on data from a cohort of 4,262 infants followed since birth. Detailed background characteristics were described in previous publications [16].

Data collection

Follow-up consisted of telephone interviews and clinical examinations at three months and one year of age. In telephone interviews, parents were asked to report the latest measured weight and length along with the date of measurement. At clinical examinations, weight was measured to the nearest 0.01 kg using a digital baby scale (*seca 384*) and length to the nearest 0.1 cm using an infantometer (*seca 416*).

Data handling

Telephone interviews and clinical follow-up did not occur on the same date. To enable comparison, parent-reported data were extrapolated to generate a projected weight and length at the date of clinical examination (by assuming that the infant's growth would follow the trajectory of a standardised WHO growth chart in the intermediate timespan, i.e. z-scores for weight-for-age and length-for-age would remain the same) [17]. Parents did not specifically report BMI, but projected BMI was calculated from parent-reported data. BMI was converted into z-scores with reference to WHO data using the lambda, mu and sigma (LMS) method [18, 19]. WHO definitions of overweight (BMI ≥ 2 standard deviations (SD) and BMI < 3 SD) and obesity (BMI ≥ 3 SD) were used [20].

Statistical analyses

We compared projected parent-reported data to clinical data using the Pearson correlation coefficient, paired t-test with Cohen's d and Bland-Altman plots. Analyses were stratified by sex, mother's education level and exclusive breastfeeding at three months of age. Agreement in BMI categorisation was calculated using weighted kappa statistics. Finally, we calculated sensitivity and specificity of using parent-reported projected BMI to predict clinically measured overweight and obesity.

Trial registration: This study was registered with www.clinicaltrials.gov, registration number NCT01694108.

RESULTS

Three-month follow-up

Main results are presented in **Table 1**.

TABLE 1 Comparing projected parent-reported and clinical anthropometrics at the three-month follow-up.

	n[a]	Projected parent-reported	Clinical	Difference (95% CI)***	Cohen's d	Effect size
Mean weight	3,873	6.28 kg	6.20 kg	0.08 (0.07-0.09) kg	0.11	Negligible
Mean length	3,786	62.6 cm	61.8 cm	0.8 (0.8-0.9) cm	0.33	Small
Mean BMI[b]	3,508	16.05 kg/m^2	16.21 kg/m^2	0.16 (0.12-0.20) kg/m^2	0.11	Negligible
Overweight[c]	3,508	28	34	6		-
Obese[c]	3,508	5	3	2		-

CI = confidence interval.
***) $p < 0.0001$.
a) Only includes participants for whom both parent-reported and clinical data were available.
b) BMI was calculated if both weight and length data were available.
c) Number of participants meeting the WHO criteria for overweight or obesity based on BMI z-score.

Median age at parent-reported measurements was 63 days (interquartile range (IQR): 11 days). Median age at clinical follow-up was 89 days (IQR: 7 days).

A strong correlation was shown between projected parent-reported and clinical weight ($r = 0.92$, $p < 0.0001$), length ($r = 0.77$, $p < 0.0001$) and BMI ($r = 0.71$, $p < 0.0001$).

Mean difference between parent-reported and clinical weight was smaller in infants who were not exclusively breastfed (mean difference = 0.03 kg, 95% confidence interval (CI): 0.01-0.05 kg) compared with those who were exclusively breastfed (mean difference = 0.12 kg, 95% CI: 0.11-0.13 kg), with a small effect size (Cohen's d = 0.28). No such difference was observed for length. Neither the sex of the child nor the mother's education level affected the differences between parent-reported and clinical data.

Figure 1 shows Bland-Altman plots for weight, length and BMI at the three-month follow-up.

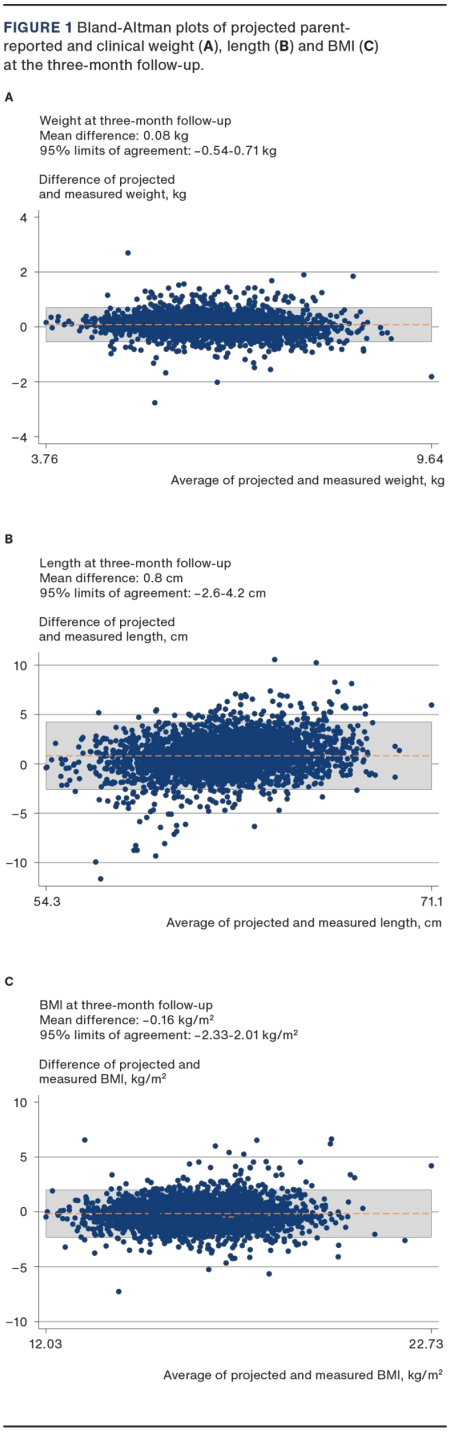

FIGURE 1 Bland-Altman plots of projected parent-reported and clinical weight (**A**), length (**B**) and BMI (**C**) at the three-month follow-up.

For weight, the bias (0.08 kg) was interpreted as smaller than clinically significant, but the 95% limits of agreement (–0.54-0.71 kg) wide enough to be clinically significant. The plot showed consistent variability and no clear trend.

For length, the bias (0.8 cm) was interpreted as smaller than clinically significant but the 95% limits of agreement (–2.6-4.2 cm) wide enough to be clinically significant. Variability was consistent. Parent-reported values increasingly overestimated length as average values increased.

For BMI, the bias (–0.16 kg/m^2) was interpreted as smaller than clinically significant, but the 95% limits of agreement (–2.33-2.01 kg/m^2) wide enough to be clinically significant. The plot showed a slightly increasing,

evenly distributed variability with increasing average values.

One-year follow-up

Main results are presented in **Table 2**.

TABLE 2 Comparing projected parent-reported and clinical anthropometrics at the one-year follow-up.

	n[a]	Projected parent-reported	Clinical	Difference (95% CI)***	Cohen's d	Effect size
Mean weight	2,889	10.40 kg	10.30 kg	0.10 (0.08-0.12) kg	0.08	Negligible
Mean length	2,703	78.6 cm	77.6 cm	1.0 (0.9-1.1) cm	0.35	Small
Mean BMI[b]	2,623	16.85 kg/m²	17.07 kg/m²	0.22 (0.18-0.27) kg/m²	0.15	Negligible
Overweight[c]	2,623	129	97	32		-
Obese[c]	2,623	19	8	11		-

CI = confidence interval.
***) p < 0.0001.
a) Only includes participants for whom both parent-reported and clinical data were available.
b) BMI was calculated if both weight and length data were available.
c) Number of participants meeting the WHO criteria for overweight or obesity based on BMI z-score.

Median age at parent-reported measurements was 367 days (IQR: 17 days). Median age at clinical follow-up was 392 days (IQR: 22 days).

A strong positive correlation was shown between projected parent-reported and clinical weight ($r = 0.93$, $p < 0.0001$), length ($r = 0.73$, $p < 0.0001$) and BMI ($r = 0.72$, $p < 0.0001$). Stratification by child sex, mother's educational level and exclusive breastfeeding at three months of age did not affect differences between parent-reported and clinical data.

Figure 2 shows Bland-Altman plots for weight, length and BMI at the one-year follow-up.

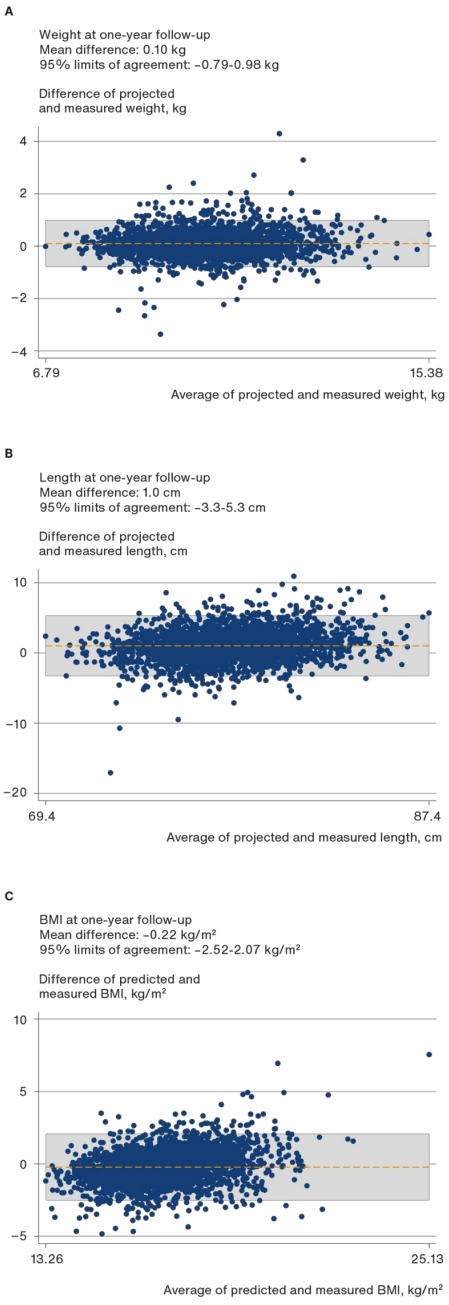

FIGURE 2 Bland-Altman plots of projected parent-reported and clinical weight (**A**), length (**B**) and BMI (**C**) at the one-year follow-up.

For weight, the bias (0.10 kg) was interpreted as smaller than clinically significant but the 95% limits of agreement (–0.79-0.98 kg) wide enough to be clinically significant. The plot showed consistent variability and no clear trend.

For length, the bias (1.0 cm) was interpreted as smaller than clinically significant but the 95% limits of agreement (–3.3-5.3 cm) wide enough to be clinically significant. Parent-reported values increasingly overestimated length as average values increased.

For BMI, the bias (–0.22 kg/m^2) was interpreted as smaller than clinically significant but the 95% limits of agreement (–2.52-2.07 kg/m^2) wide enough to be clinically significant. Parent-reported values increasingly

overestimated BMI as average values increased.

Agreement in BMI classification

Only fair agreement was found at both the three-month follow-up (K = 0.33, 95% CI: 0.30-0.35, p < 0,0001) and the one-year follow-up (K = 0.27, 95% CI: 0.24-0.29, p < 0,0001).

A classification of overweight based on parent-reported data had a sensitivity of 17.6% (95% CI: 6.8-34.5%) and a specificity of 99.4% (95% CI: 99.0-99.6%) at the three-month follow-up, and a sensitivity of 41.2% (95% CI: 31.3-51.7%) and a specificity of 96.5% (95% CI: 95.7-97.2%) at the one-year follow-up.

A classification of obesity based on parent-reported data had a sensitivity of 0.0% (95% CI: 0.0-70.8%) and a specificity of 99.9% (95% CI: 99.7-100%) at the three-month follow-up, and a sensitivity of 25.0% (95% CI: 3.2-65.1%) and a specificity of 99.3% (95% CI: 99.0-99.6%) at the one-year follow-up.

DISCUSSION

Key results

Projected parent-reported anthropometric data correlated well with clinical data at three months and one year. Although there were statistically significant mean differences, they were of negligible to small effect sizes, and likely of little or no clinical consequence. Correlations were unaffected by child sex or by mother's education level. For children who were not exclusively breast-fed at three months, the parent-reported weight was significantly closer to the clinical weight. Parents using alternatives to breastfeeding may be more attentive to factors related to infant thriving and thus be able to report more accurate data. It is also possible that breastfed Danish infants are, on average, larger than the WHO reference population used to calculate projected values, as suggested by the baseline growth data of the Danish Calmette Study [16].

Bland-Altman plots generally supported the use of parent-reported data at the population level as biases were interpreted as clinically insignificant. However, the 95% limits of agreements were wide enough to be of clinical significance in all plots, discouraging the use of parent-reported data for individual assessment of infants.

Our findings suggest that parent-reported anthropometrics may be useful when collecting data on a population of infants, e.g. for survey purposes, in regions where parents are likely to have accurate measurement data, e.g. if contacts with a healthcare-worker follow regular schedules. Surveyors should aim to contact parents shortly after the child has been measured by a health professional. Our findings do not support the use of parent-reported data to monitor individual infants.

Using projected parent-reported weight and length to categorise children into WHO categories of BMI z-score showed only fair agreement with clinical categorisation. For both overweight and obesity, sensitivity was very low. Other studies found a higher sensitivity of parent-reported overweight in older children [11]. This may be partly explained by how BMI is calculated (weight in kg divided by length in meteres squared) – originally intended for adults and later adapted with reference material for children [20]. As values for weight and length are much smaller in infants, variations in either will have a relatively large impact on the calculated BMI. For this reason, and because infant body composition and growth patterns are different from those of older children and adults, BMI is less useful in assessing infant growth.

Strengths and limitations

This was the first study to assess the validity of parent-reported anthropometrics in infants specifically. Previous studies have assessed their validity in children aged from six months to 17 years with mixed results [7-13].

The study had a large sample size, with high rates of participation at both first and second clinical follow-up (94% and 92%, respectively) and at the first telephone interview (95%), but lower for the second telephone interview (70%). Comparing the subjects who did not participate in the second telephone interview to those who did, using available data from the corresponding clinical visit, showed no clinically significant differences in mean weight or length, suggesting that no systematic bias was introduced.

Measurements at clinical visits were systematic and standardised between study sites. Parents were asked to report the latest *measured* data (as opposed to guessing or estimating), but were not asked how the reported measurements had been obtained. This is an important limitation as the data may be of a lower quality if the measurements were not made using proper equipment and technique. This limitation is likely somewhat mitigated as most infants in Denmark are measured regularly within the first year of life by healthcare professionals as part of routine preventive care. A previous study found an improved reliability when asking parents to measure their children at home instead of estimating weight and length [12], but no study has compared the accuracy of measurements by parents to measurements made by a healthcare worker.

We used child-growth reference data from the WHO to calculate projections of parent-reported data as recommended by the Danish Health Authority. These factors should lead to good internal study validity. However, our findings may not be directly applicable in regions where infants are not routinely measured by healthcare professionals.

Our study design cannot detect the cause of any differences between projected parent-reported and clinical data. Such differences may potentially arise due to reporting errors (faulty memory or biased reporting) or correct reporting of inaccurate measurements. Using parent-reported data to make projections may also introduce inaccuracies as growth patterns in individual infants may vary from standardised population-based models. The mean time elapsed between parent-reported and clinical measurements was 28 and 25 days at the first and second follow-up, respectively. Thus, some projections span a substantial proportion of the infants' life, reducing the accuracy of projections in any individuals with naturally occurring deviations from standardised growth charts. Under the present study conditions, individual variation is large enough to discourage the use of parent-reported measurements to monitor an individual infant. However, such individual deviations are unlikely to have a substantial population-level impact for two reasons: Firstly, large deviations are uncommon (which is the premise of standardised charts). And, secondly, naturally occurring deviations likely follow a normal distribution, with values both below and above the normal range.

On average, the parents participating in the Danish Calmette Study had a higher level of education and higher socio-economic class than the background population [16], which may affect external validity, although we found no effect of education level on reporting accuracy within the study.

CONCLUSION

Parents' reports of measured infant weight and length are reliable at a population level in a setting with routine preventive care. However, parent-reported measurements should not be used for assessment of individual infants, particularly not if a growth- or weight-related condition is suspected. BMI calculated from parent-reported anthropometrics should not be used to identify infants as overweight or obese.

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Accepted 27 July 2023

Conflicts of interest none. Disclosure forms provided by the authors are available with the article at ugeskriftet.dk/dmj

Cite this as Dan Med J 2023;70(9):A11220712

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