

# BMJ Open Investigating the accuracy of parentally reported weights and lengths at 12 months of age as compared to measured weights and lengths in a longitudinal childhood genome study

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## ABSTRACT

**Background:** Childhood obesity studies rely on parentally reported anthropometrics. However, the accuracy of such data has not been evaluated for 12-month-old children. Moreover, methods to improve the accuracy of reported data have not been assessed in prior studies.

**Methods:** A total of 185 children enrolled in a northern Virginia childhood longitudinal cohort genomic study had parentally completed surveys at 12 months. Measured weights and lengths were recorded for the same children from their 12-month paediatrician visit. Weight for length percentiles were calculated using World Health Organization gender-specific growth charts. The agreement between reported and measured values was examined using Pearson's correlation, paired t-test and  $\kappa$  statistics. The interquartile outlier rule was used to detect and remove outliers.

**Results:** Parentally reported weight was strongly associated with measured weight at 12 months ( $r=0.90$ ). There was only a moderate correlation between parentally reported and measured lengths ( $r=0.52$ ) and calculated weight for length percentiles ( $r=0.65$ ). After removing outliers from parentally reported data, there was an increase in correlation between parentally reported and measured data for weight ( $r=0.93$ ), length ( $r=0.69$ ) and weight for length percentiles ( $r=0.76$ ). Outliers removed compared to all children included were more likely to have maternal education less than a bachelor's degree ( $p=0.007$ ).

**Conclusions:** After removal of outliers from reported data, there is a strong correlation between calculated reported and measured weight for length percentiles suggesting that this may be an effective method to increase accuracy when conducting large-scale obesity studies in young children where study costs benefit from using parentally reported data.

## INTRODUCTION

The prevalence of obesity in the USA remains high in adults and children, is

## Strengths and limitations of this study

- This is the first study to assess the accuracy of parentally reported anthropometrics at 12 months of age and offer a statistical method to improve accuracy.
- Parentally reported weight was strongly associated with measured weight at 12 months, but there was only a moderate correlation between parentally reported and measured lengths and calculated weight for length percentiles.
- After removal of outliers using the interquartile outlier rule from reported data, there is a strong correlation between calculated reported and measured weight for length percentiles suggesting that this may be an effective method to increase accuracy when conducting large-scale obesity studies in young children where study costs benefit from using parentally reported data.
- The main limitation of this study is that measured data were collected from paediatricians' health records rather than investigators actually weighing and measuring the children.
- Although Pearson's correlation coefficient is the most popular test in agreement studies, it is not the most appropriate approach. We used a combination of more than one statistical method in order to overcome the limitations of each method.

increasing worldwide and is considered a global epidemic.<sup>1–3</sup> Many studies examining obesity rely on self-reported weights and heights to derive a body mass index (BMI) and estimate the prevalence of obesity in populations.<sup>4–7</sup> There are concerns, however, regarding the accuracy of self-reported weights and heights, and there is a large body of evidence in adults and adolescents demonstrating inaccuracies in self-reported values with a tendency for study participants who are overweight to under-report their weight.<sup>8–11</sup>

Although much research is being conducted into childhood obesity, there are limited data regarding the accuracy of reported weights and heights in children, which are parentally reported rather than self-reported. A systematic review and meta-analysis available suggest a high proportion of mothers inadequately perceive the nutritional status of their child with underestimation for children who are overweight and obese.<sup>12–13</sup> Moreover, there is a lack of published data regarding the accuracy of parentally reported weights and lengths in very young children with no studies to date assessing the reliability of this data for children at 12 months of age. This may differ from older children for many reasons, including more frequent paediatrician visits with weight and length measurements at this age, rapidly changing weights and lengths in young children and differing parental perceptions of nutritional status in toddlers.<sup>14–16</sup>

Despite the unavoidable use of reported rather than measured anthropometrics in large-scale obesity studies, there have been minimal attempts to assess how the accuracy of this data can be improved. Therefore, the primary aim of this study was to determine the accuracy of parentally reported weights and lengths at 12 months of age compared with measured weights and lengths obtained from a paediatrician's visit and to examine factors associated with parentally reported inaccuracies. A secondary study aim was to explore factors related to these reported inaccuracies in order to develop methods to improve the accuracy of parentally reported data.

## METHODS

### Recruitment

The First Thousand Days of Life Study is a childhood longitudinal cohort study in Northern Virginia. Starting in April 2012, women were recruited during the second trimester of pregnancy from several area obstetrical practices, including a large safety net clinic with a racially and ethnically diverse population. Inclusion criteria included that the women had to be at least 18 years of age, in generally good health, willing to participate in longitudinal surveys every 6 months and be fluent and literate in English or Spanish. This study is identifying genomic, clinical and environmental risk factors that may enhance our understanding of adverse health outcomes such as obesity and developmental disorders. Each participant provided informed consent, and IRB approval was obtained for the study protocol (WIRB# 20120204).

This analysis of the study cohort compares parentally reported data to data from medical records collected by the healthcare team, specifically related to length and weight at the age of 12 months. Medical record-derived lengths and weights from the first 185 children in the study were analysed for the purposes of data verification and for direct comparison to parentally reported length and weight data.

The study was funded by Inova Translational Medicine Institute, Inova Fairfax Medical Center, in Northern Virginia and has recruited >3000 family trios consisting of mothers, fathers and newborns. This community is known for having great racial and ethnic diversity as well as diverse socioeconomic indicators such as maternal educational level, household income, country of origin and other family characteristics, as reflected in this cohort.

### Anthropometric measurements

Family study specific surveys used in this analysis were returned at newborn age 12 months which included parentally reported weight in pounds and ounces, and length in inches, weights and lengths were converted to metric units. In order for the survey data to be included in the study, the survey had to be returned within 2 months of when a child turned 12 months of age. A corrected age of 12 months was used for children who were born prematurely at <37 weeks gestation, for example, for a child born at 32 weeks gestation, a 12-month survey was sent at their actual age of 14 months.<sup>17</sup> Data recorded from the surveys also included demographics (including gender, race and ethnicity), socioeconomic factors (including parental education level, occupation and income level) and parental factors (including maternal age and maternal BMI).

Measured weights and lengths were obtained and recorded for the same child from a paediatrician visit that occurred during the same 2-month time window allowed for the survey. Once again, a corrected age of 12 months was used for those born prematurely. For reported and measured values, weight for length percentiles at 12 months was calculated using WHO gender-specific growth charts. Based on calculated weight for length percentiles for parentally reported and paediatrician-measured values, children were classified as severely obese ( $\geq 99$ th centile), obese (95–98th centile), overweight (85–94th centile) or underweight and normal weight (<85th centile).<sup>18</sup>

### Statistics

Characteristics of the study cohort are described. Pearson's correlation coefficient was calculated to assess the relationship between reported and measured weights and lengths as well as calculated weight for length percentiles. As the validity of reported values may differ after detecting outliers, the interquartile outlier range rule was used to detect potential outliers, and all the detected values as outliers were checked against WHO reference data to verify whether they are also outside 3 SDs of the WHO reference data. All the length values that were not detected as an outlier were defined as inliers.

After removing outliers, Pearson's correlation coefficient was calculated again to assess the relationship between reported and measured weights and lengths as well as calculated weight for length percentiles.<sup>19</sup>

Pearson's correlation coefficient  $>0.7$  was considered a strong correlation.<sup>20</sup> A paired t-test was used to detect existing differences between the means of measured and parentally reported weights, lengths and calculated weight for length percentiles and to compare means of values with and without removing outliers. Bland-Altman plots were used to examine the agreement between parentally reported and measured weights and lengths. In these plots, the differences between measured and parentally reported values were plotted against the mean of measured and parentally reported values without and with outliers removed.<sup>21</sup>

Reported and measured weight for length centile categories, including normal and underweight ( $<85$ th), overweight (85–94th), obese (95–98th) and severely obese ( $\geq 99$ th) at 12 months of age, were compared, without outliers removed and with outliers removed using a  $\chi^2$  test. The degree of agreement between reported and measured weight for length centile classification of normal weight and overweight without outliers removed and with outliers removed was assessed using weighted  $\kappa$  statistics.<sup>22</sup>

Demographic characteristics and lifestyle of parents whose children's length was detected as outlier were compared to those whose children's length was an inlier. The parental demographic and lifestyle were evaluated using the t-test (continuous variables) and the  $\chi^2$  test (categorical variables).

SAS V.9.3 and SPSS V.23 were used for statistical analyses. p Values of 0.05 or less were considered statistically significant.

## RESULTS

Characteristics of the study cohort, including maternal and child data, are listed in [table 1](#). Of the 185 participants, 51.4% were men, 11.35% were born preterm, 48.7% had a white mother, 7% had a Hispanic mother and 62.7% of mothers were born in the USA.

**Table 1** Characteristics of participants

Characteristic	n=185
Children	
Gender (male)	51.4%
Preterm	11.35%
Mothers	
Race (white)	48.7%
Ethnicity (Hispanic)	7.0%
Country of birth (USA)	62.7%
Education ( $\geq$ bachelor's degree)	85.1%
Income ( $\geq$ \$100 000 per year)	74%
Occupation (management)	40%
Age	33.9 $\pm$ 4.2
BMI	25.1 $\pm$ 5.1
Maternal confidence score	57.5 $\pm$ 3.3
Maternal depression score ( $\geq 10$ )	4.9%

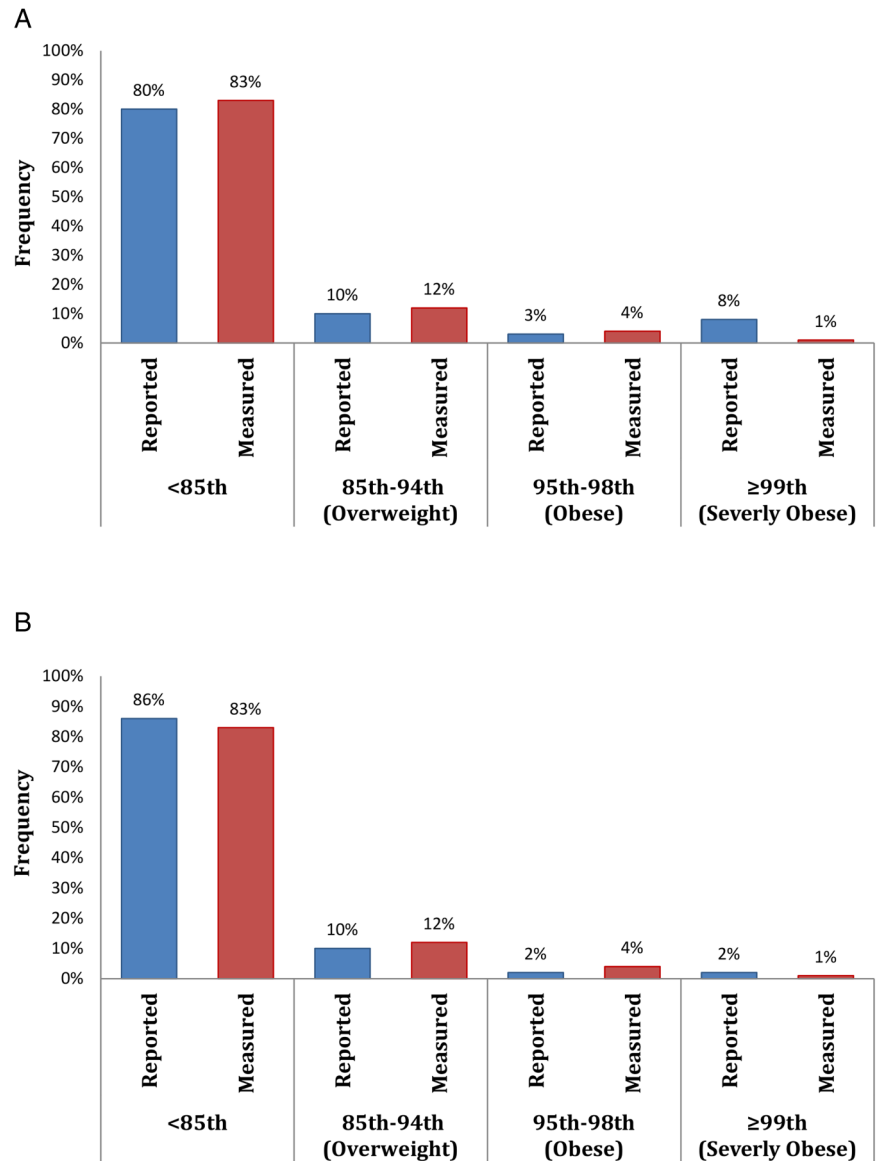
BMI, body mass index.

The differences in the prevalence of weight for length centile categories between measured and reported values were compared among total study cohort and after removing outliers. Differences between prevalence of measured and reported values of overweight, obese and severely obese were 2%, 1% and 7% for the total study cohort, respectively. Differences between the prevalence of overweight, obese and severely obese were 2%, 2% and 1%, respectively. After removing outliers, the prevalence of normal or underweight increased by 6%, the difference between prevalence of measured and reported overweight stayed the same, the difference between prevalence of obesity slightly increased and the difference between prevalence of severe obesity considerably decreased. The difference in prevalence after outliers was removed for overweight and obese was minimal or none, and so the magnitude change has little significance for clinicians. However, there was a significant decrease in the reported number of severely obese children when outliers removed; this is important for research and clinically and reiterates that for reported data, an attempt should be made to remove outliers, and so the prevalence of severe obesity is not overestimated ([figure 1](#)).

Parentally reported weight was strongly associated with measured weight at 12 months (Pearson's  $r=0.90$ ). However, there was only a moderate correlation between parentally reported and measured lengths ( $r=0.52$ ) and calculated weight for length percentiles ( $r=0.65$ ). When the interquartile outlier rule was used to remove outliers from parentally reported data, 15 outliers were detected for length. Importantly, all outliers had parentally reported lengths far outside the entire range of measured lengths and weights, with 100% outside 3 SDs of national reference data.<sup>18</sup> With outliers removed, there was an increase in correlation between parentally reported and measured data for weight ( $r=0.93$ ) and length ( $r=0.69$ ). This resulted in a strong correlation of weight for length percentiles ( $r=0.76$ ). All correlations were stronger and significant ( $p<0.001$ ; [table 2](#)).

Paired t-test was used to detect existing differences between the means of measured and parentally reported weights, lengths and calculated weight for length percentiles; mean differences for length were  $1.86\pm 4.14$  and  $0.92\pm 2.57$  without and with outliers removed, respectively ([table 2](#)). To assess and compare the agreement between measured and reported weights and lengths in the total study cohort and after removing outliers, Bland-Altman plots were generated. [Figure 2A, B](#) shows the differences between reported and measured weight values without outliers removed and with outliers removed. [Figure 3A, B](#) shows the differences between reported and measured length values without outliers removed and with outliers removed. There was an upward trend in Bland-Altman plot for lengths, indicating that there is a proportional bias and the difference of measured and reported lengths changes in proportion to the average of measured and reported lengths.<sup>23</sup>

**Figure 1** Comparison of reported and measured weight for length centile at 12 months: (A) without outliers removed and (B) with outliers removed.



**Table 2** Correlation between reported and measured weight, length and weight for length percentiles at 12 months, with and without outliers removed using the IQR rule

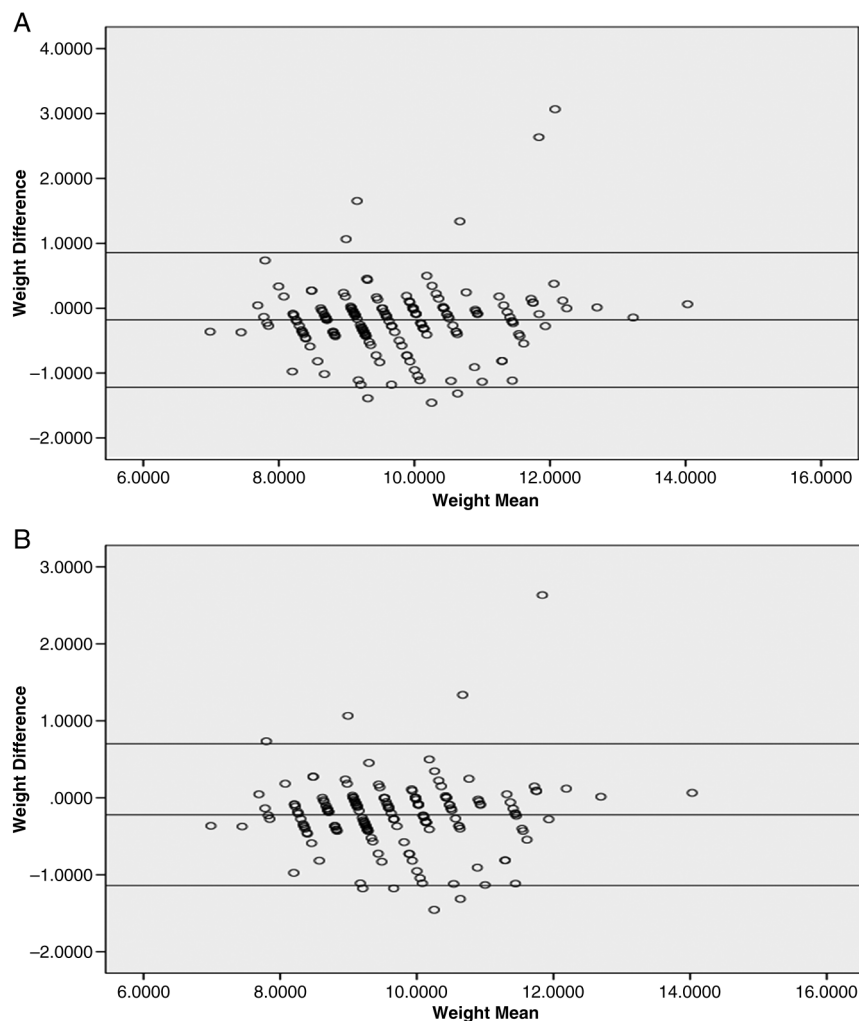
Variables	Collection method		Pearson's correlation coefficients	p Value
	Reported	Measured		
All (n=185)	Mean±SD	Mean±SD		
Weight (kg)	9.66±1.23	9.84±1.17	0.90*	<0.0001
Length (cm)	75.12±4.83	76.98±2.93	0.52	<0.0001
Weight for length percentile	46.3±34.7	52.5±28.7	0.65	<0.0001
Outliers removed (n=170)				
Weight (kg)	9.64±1.20	9.85±1.17	0.93*	<0.0001
Length (cm)	76.14±3.47	77.06±2.92	0.69	<0.0001
Weight for length percentile	41.8±32.6	52.5±28.7	0.76*	<0.0001

\*≥0.7 considered as strong correlation.

It is interesting for clinicians to know that there is a proportional bias and that parents can over-report and under-report lengths. Applying the outlier removal addresses this partially by removing some of the over-reported and under-reported lengths.

Weighted  $\kappa$  statistics were calculated to evaluate the degree of agreement between measured (MWforL) and reported (RWforL) weight for length centile classes, including overweight ( $\geq 85$ th) and normal weight ( $< 85$ th).  $\kappa$  Statistics for the total study cohort was 0.46

**Figure 2** Bland-Altman plots of differences between measured and reported weights: (A) without outliers removed and (B) with outliers removed.



(95% CI 0.29 to 0.62) and after removing outliers was 0.58 (95% CI 0.41 to 0.75).  $\kappa$  Statistics <0.40 are considered as minimal agreement.<sup>24</sup>

Outliers removed for length compared to children included were more likely to have maternal education less than a bachelor's degree ( $p=0.007$ ); there was no difference in other factors examined, including participant gender, maternal ethnicity and race, household income, prematurity and maternal BMI (table 3).

## DISCUSSION

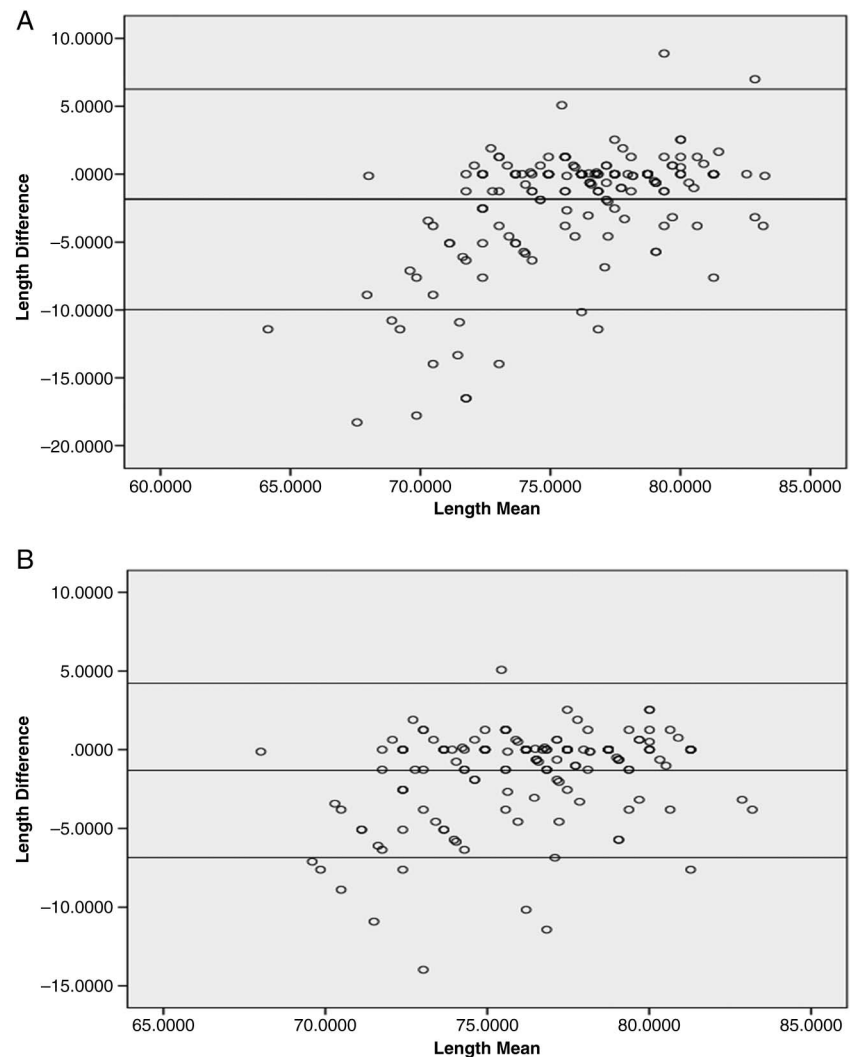
To the best of our knowledge, this is the first study to assess the accuracy of parentally reported weights and lengths in children at 12 months of corrected age and to offer a method to improve the accuracy of parentally reported anthropometrics. We found that parentally reported weights strongly correlated with measured weights; however, parentally reported lengths and hence calculated parentally reported weight for length percentiles were less accurate. By applying the interquartile outlier rule to remove recorded outliers, the accuracy of parentally reported values was significantly improved.

The strong correlation between parentally reported weights and measured weights in this study appears to

differ from other studies looking at older children, although directly comparable methods were not used.<sup>25 26</sup> Gordon *et al*<sup>25</sup> reported that parentally submitted weights were only accurate, defined as within 2 lbs of measured weight, in 58% of children aged 3–12 years, and O'Connor *et al*<sup>26</sup> found 64% of parentally reported weights to be either over or under actual weight by at least 0.45 kg in children aged 2–17 years. Interestingly, Gordon *et al*<sup>25</sup> found that weight was less likely to be reported accurately in older children aged 6–12 years compared with younger children aged 3–5 years. These previous studies support our finding of a strong correlation between parentally reported and measured weights at the young age of 12 months. A possible reason for this may be more frequent paediatrician visits at this age with weight measurements allowing a more accurate recall of a recent weight.<sup>14</sup> There may also be fewer stigmas and negative connotations associated with being overweight as an infant and toddler than in older children, and so parents may report weight more accurately at this age.<sup>27</sup>

In our study, the correlation between parentally reported and measured lengths was less strong. The inaccuracy of parentally reported heights has been demonstrated in studies of older children, with reports

**Figure 3** Bland-Altman plots of differences between measured and reported lengths: (A) without outliers removed and (B) with outliers removed.



**Table 3** Comparison of characteristics of inliers included and outliers removed for length using the IQR rule

Variables	Outliers removed, n=15 (8%)	Inliers included, n=170 (92%)	p Value
Children			
Gender (male)	46.7%	51.8%	0.70
Preterm	6.7%	11.8%	0.55
Mothers			
Race (white)	60%	47.6%	0.36
Ethnicity (Hispanic)	6.7%	7.1%	0.95
Country of birth (USA)	53.3%	63.5%	0.43
Education ( $\geq$ bachelor's degree)	61.5%	88.5%	<b>0.007*</b>
Household income ( $\geq$ \$100 000 per year)	57.1%	76.2%	0.26
Occupation (management)	40%	40%	1
Age	32.2 $\pm$ 4.5	34.1 $\pm$ 4.1	0.08
BMI	23.9 $\pm$ 4.7	25.2 $\pm$ 5.2	0.37
Maternal confidence score	57.6 $\pm$ 4.9	57.4 $\pm$ 3.1	0.84
Maternal depression score ( $\geq$ 10)	13.3%	4.1%	0.1

\*p<0.05.

BMI, body mass index.

of <50% of parents accurately reporting height within 2.5 cm, although in one study, parentally reported height was more accurately reported than weight in pre-school children.<sup>24 28 29</sup> The correlation between

calculated weight for length percentiles from parentally reported and physician-measured data was also less strong in our study. Previous studies have shown that parentally reported data are inaccurate for classifying

preschool-aged children into BMI categories with parentally reported data under-reporting a significant number of obese and overweight children.<sup>27–28</sup> These prior studies also found that parentally reported data overestimated the proportion of children who are overweight.<sup>27</sup> None of the studies have reported on the accuracy of calculated weight for length percentiles from parentally reported data at 12 months of age. In our study, calculated values from parentally reported data were similar to measured data in classifying children into the weight for length categories of less than the 85th centile, overweight (85–94th centile) and obese (95–98th centile). However, we found a large difference in calculated values from parentally reported data and measured data for children falling in the severely obese category ( $\geq 99$ th centile) with an overestimation of those who are severely obese from parentally reported data resulting from the outlying misreported underestimation of lengths in these children. When the interquartile outlier rule was used to remove outliers, the correlation between parentally reported and measured lengths improved and the correlation of weight for length is considered strong. Importantly, outliers had parentally reported lengths or weights far outside the entire range of measured lengths and weights and were also outside 3 SDs of the national reference data (WHO) with many reported lengths that were removed being physiologically implausible. Moreover, when looking for weight for length categories for obesity, after removing outliers, reported and measured values for children who are severely obese became more similar. Although in obesity studies, measured data are considered the gold standard, in large population-based studies, this may not be feasible. Therefore, this method of removing outliers may prove a valuable tool in obesity studies in young children using parentally reported data to increase accuracy.

Profiling the characteristics of the mothers of the outliers for length that were removed from analysis compared to the mothers of all children included found that outlier mothers were more likely to have a lower education, but no other behaviour or socioeconomic factors were identified. In other reported studies, lower socioeconomic status, Hispanic ethnicity and sex were associated with increased misreported parental data.<sup>2–25 26 29</sup>

The main limitation of this study is that measured data were collected from paediatricians' health records rather than investigators actually weighing and measuring the children. However, it has been shown that routinely collected child health records for height/length and weight in young children are comparable with investigator-measured data, supporting their use in research.<sup>30</sup> Additionally, there was an up to 2-month time window allowed between parentally reported and measured data, possibly allowing for some inaccuracies. However, the error this adds to the study is likely minimal given that there are no significant changes in weight and length within this time window.<sup>31</sup> This time window has been used in other studies, and much of the

parentally reported data were likely maternal recall from a recent paediatrician's visit.<sup>30</sup>

## CONCLUSIONS

At 12 months of age, parentally reported weights appear to be accurate, but parentally reported lengths and hence calculated weight for length percentiles are less accurate. However, after removal of clear outliers from parentally reported data using the interquartile outlier rule, there is a strong correlation between calculated parentally reported and measured weight for length percentiles suggesting that this may be an effective method to use to increase accuracy in large obesity studies in young children when using parentally reported data. This study is useful in studies on being overweight and obese in very young children which use parentally reported data as it shows the accuracy of parentally reported data in this age group and also gives a method to remove outliers to improve accuracy.

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**Contributors** SH designed the study, conducted statistical analysis, wrote first draft of the manuscript and reviewed and approved the final submitted manuscript. SKH designed the study, wrote first draft of the manuscript and reviewed and approved the final submitted manuscript. AW, YY and NC collected data and reviewed and approved the final submitted manuscript. KH and JN designed the study and reviewed and approved the final submitted manuscript.

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**Competing interests** None declared.

**Patient consent** Patient consent was obtained.

**Ethics approval** This study was approved by Western Institutional Review Board (WIRB# 20120204).

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