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Reported versus measured body weight and height of 4-year-old children and the prevalence of overweight

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Background: In adults, body weight tends to be underestimated when based on self-reported data. Whether this discrepancy between measured and reported data exists in healthy young children is unclear. We studied whether parental reported body weight and height of 4-year-old children corresponded with measured body weight and height. In addition, we studied the determinants and the consequences of differences between reported and measured data. **Methods:** Data on body weight and height of 864 4-year-old Dutch children born in 1996/1997 enrolled in the Prevention and Incidence of Asthma and Mite Allergy (PIAMA) birth cohort study were collected via a questionnaire and a medical examination. Overweight was defined according to standard international age and gender specific definitions. **Results:** Mean differences between measured and reported body weight, height, and body mass index (BMI) were small. Parents of children with a low BMI tended to over report body weight while parents of children with a high BMI tended to underreport body weight. Whereas 9.5% of the children were overweight according to reported BMI, the prevalence of overweight was 13.4% based on measured BMI. Over 45% of the overweight children according to measured BMI were missed when reported BMI was used. **Conclusion:** These findings suggest that overweight prevalence rates in children are underestimated when based on reported weight and height.

Keywords: BMI, body weight, child, overweight, validation study

Literature shows that, in adults and adolescents, self-reported body weight and height may not always be accurate.[1–20] Whether this is true for young children, when body weight and height are reported by the parents is not clear. Since worldwide prevalence rates of overweight and obesity in children are rising[21] it is important to know if reported data are a valid alternative for measured data. In case a discrepancy exists between measured and reported body weight and height in children, reported data could cause bias in etiologic studies and result in inaccurate overweight and obesity prevalence rates. In adults, body weight tends to be underestimated[1–8,10–19] and height tends to be overestimated[1–3,5–7,9,12–15,17] when self-reported data are used. In particular overweight and obese subjects tend to underreport their body weight[2,4,6–8,10–17,19] and over report height.[6,12,15] Women are more likely to underreport body weight than men.[12,14] If weight and height of children is underreported like it is in adults, overweight and obesity prevalence rates among children could be underestimated.

The aim of this study was to investigate whether body weight and height of 4-year-old children reported by their parents in a questionnaire corresponds with body weight and height measured during a medical examination. In addition, we studied the determinants associated with the differences between measured and reported body weight, height, and body mass index (BMI) as well as the impact of these differences on the overweight prevalence rates.

Methods

Study design and variables

The children in this validation study were born in the Netherlands in 1996/1997 and participated in the PIAMA (Prevention and Incidence of Asthma and Mite Allergy) birth cohort study. Mothers were recruited from the general population during pregnancy. A detailed description of the study design has previously been published.[22] When the children were 4 years of age, the parents were asked to report in a questionnaire their child's body weight (in kg) and height (in cm) the last time he or she was measured by a medical doctor or a nurse, for example during a visit at an under-five clinic. If these body weight and height measurements were not available, or were taken more than 3 months ago, we asked the parents to measure the child themselves. We asked them to weigh and measure the child without shoes and heavy clothes. The parents reported the date of the measurements and the person who performed the measurements (a medical professional, the parents or someone else).

Besides body weight and height of the child, the child's age, age of the mother, educational level of the mother, body weight (in kg), and height (in cm) of the mother were reported in the questionnaire. Educational level of the mother was measured as the highest education and then divided into three categories

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(low, intermediate, and high education). To assess rounding off of body weight, subjects were classified according to the decimal of their reported body weight. When parents reported body weight of their child as a multiple of 0.5 kg we categorized the observation as 'digit preference'.

From October 2000 till November 2001, when the children were ~4 years of age, a sub sample of the study population was invited for a medical examination. During the medical examination, body weight (in kg) was measured at the nearest 100 g on a calibrated scale and height (in cm) was measured at one decimal. The children were measured without shoes and heavy clothing. The parents of the children were not given written records of the weight and height of the child measured during the medical examination.

BMI was calculated as body weight in kilogram divided by height squared in meters (kg/m^2). Overweight and obesity were defined according to standard international age and gender specific definitions, which are based on adult overweight (>25 kg/m^2) and obesity (>30 kg/m^2) definitions.[23] The term 'overweight' was used to indicate a BMI equivalent to an adult BMI of over 25 kg/m^2. The term 'moderate overweight' means a BMI equivalent to an adult BMI between 25 and 30 kg/m^2 and 'obesity' means a BMI equivalent to an adult BMI of over 30 kg/m^2. The study protocol was approved by the medical ethics committees of the participating institutes. All parents gave written informed consent.

Study population

At baseline, the PIAMA study population consisted of 4146 children. A subsample was invited for a medical examination (n = 1808). During the medical examination, 1255 children were weighed and measured. Of 979 of these children, parents reported body weight, height, and date of measurement in the questionnaire when the child was 4 years of age. To ensure comparability between measured and reported data, children were excluded when the date of the medical examination and the date of the body weight and height measurements reported in the questionnaire were more than 6 months apart (n = 91). In addition, nine children were excluded, because the dates of the body weight and height measurement reported in the questionnaire were more than 8 weeks apart. This exclusion criterion was introduced because for calculating BMI in children and proper interpretation of it, body weight and height need to be measured around the same time. Another 15 observations were excluded, because of extreme unlikely values for body weight, height, or age of the child at measurement. The final study population available for analysis consisted of 864 children.

Statistical analysis

Data analysis was conducted using SAS software version 9.1 (SAS Institute, Inc., Cary, NC). The date of the medical examination and the date of the reported measurements differed up to 6 months. To take into account average growth between the date of the medical examination and the date of the reported measurements, measured body weight and height were standardized to the age of the child at the reported measurements, using the average increase in measured weight and height per week. To adjust for weight of clothing that was worn during the medical examination, 0.5 kg was subtracted from measured body weight. We did not subtract 0.5 from the parental reported body weight, because when a child is weighed by a medical doctor or a nurse, for example in a under-five clinics, the child is mostly weighed wearing only their underwear.

Pearson's correlation coefficients were calculated to assess correlation between measured and reported body weight, height, and BMI. The difference between measured and reported values was calculated by subtracting reported data from measured data within an individual. Therefore, positive values reflect underreporting. Simple and multiple linear regression analyses were used to study factors associated with the difference between measured and reported body weight, height, and BMI. Regression analysis was repeated for smaller time intervals between the medical examination and the reported measurement, for children in whom the medical examination preceded the questionnaire and for positive and negative differences in BMI separately. P-values below 0.05 were considered to be statistically significant.

Results

The study population consisted for 49.8% (n = 430) of girls. In 57.4% (n = 496) of the children the body weight and height measurements reported in the questionnaire were carried out by a medical professional (e.g. medical doctor, school doctor, or nurse), in 30.6% (n = 264) the parents performed the measurements and in 12.0% (n = 104) somebody else. The majority of the questionnaires were filled out by the mother of the child (88.2%, n = 759) and 46.9% (n = 405) of the parents reported body weight of their child as a multiple of 0.5 kg (digit preference). Mean age of the children during the medical examination was 4.1 years (SD = 0.19) and ranged from 3.4 to 4.6 years. The average time difference between the medical examination and the body weight and height measurements reported by the parents in the questionnaire was 7.2 weeks (SD = 10.3). In 81.7% (n = 706) of the children, the medical examination took place after the reported measurement.

Children who were included in the validation study (n = 864) were similar to those of whom only reported body weight and height were available (n = 2018). No differences were observed in the child's body weight, height, BMI, gender, BMI of the mother, age of the mother, digit preference, and the person who carried out the measurement reported in the questionnaire. Age of the child and educational level of the mother were somewhat higher among the children included in the validation study (data not shown).

In general, reported and measured data corresponded well. Pearson's correlation coefficients between measured and reported data were 0.91, 0.92, and 0.79 for body weight, height, and BMI, respectively. Over 92% of the parents reported body weight of their child within 10% of measured body weight and 72% within 5% of measured body weight. Almost 99% of the parents reported height of their child within 5% of measured height.

Table 1 shows mean values and standard deviations of measured and reported body weight, height, and BMI separately for boys and girls. Also, mean differences between measured and reported body weight, height, and BMI are shown. In both genders, the mean difference between measured and reported body weight was smaller than 0.1 kg. Reported height was, on average, 0.5 cm higher than measured height in girls and 0.4 cm higher in boys. Mean reported BMI was 0.1 kg/m^2 lower than measured BMI, both in girls and boys. When subjects were categorized in 'normal weight' and 'overweight' according to measured BMI, 15.1% (n = 65) of the girls and 11.8% (n = 51) of the boys were overweight. When reported data was used, 11.9% (n = 51) of the girls and 7.1% (n = 31) of the boys were overweight (Table 1).

Although the average differences between measured and reported body weight, height, and BMI were relatively small, size and direction of the difference between measured and reported data differed between measured BMI quartiles (Table 2). Whereas parents of children in the lowest BMI quartiles tended to report a higher body weight than was measured during the medical examination, parents of heavier children tended to underreport body weight. The extent of overestimation of height increased with increasing BMI. The

Table 1 Comparison of measured[a] and reported body weight, height, BMI, and percentages of overweight[b] children, by gender, of 864 4-year-old Dutch children

	Measured[a] mean (SD)	Reported mean (SD)	Difference[c] mean (SD)
Girls ($n = 430$)			
Body weight (kg)	17.3 (2.4)	17.3 (2.2)	−0.02 (1.0)
Height (cm)	104.5 (4.0)	105.0 (4.2)	−0.5 (1.7)
BMI (kg/m^2)	15.8 (1.6)	15.7 (1.5)	0.1 (1.0)
Overweight *n* (%)	65 (15.1%)	51 (11.9%)	
Moderate overweight *n* (%)	52 (12.1%)	43 (10.0%)	
Obesity *n* (%)	13 (3.0%)	8 (1.9%)	
Boys ($n = 434$)			
Body weight (kg)	17.7 (2.4)	17.7 (2.3)	0.02 (1.0)
Height (cm)	105.4 (4.3)	105.8 (4.5)	−0.4 (1.7)
BMI (kg/m^2)	15.9 (1.5)	15.7 (1.4)	0.1 (1.0)
Overweight *n* (%)	51 (11.8%)	31 (7.1%)	
Moderate overweight *n* (%)	41 (9.5%)	24 (5.5%)	
Obesity *n* (%)	10 (2.3%)	7 (1.6%)	

a: Measured body weight, height and BMI are standardized to the age at reported measurement
b: Definition moderate overweight and obesity are gender and age specific; cut off points moderate overweight: 17.19–17.89 kg/m^2; cut off points obesity: 19.12–19.57 kg/m^2.[23]
c: The difference was calculated by subtracting the reported value from the measured value per subject. Note that negative values reflect over reporting

Table 2 Mean (SD) measured body weight, height, and BMI and mean (SD) difference[a] between measured and reported body weight, height, and BMI by measured BMI quartile, of 864 4-year-old Dutch children

	BMI quartiles			
	1 Mean (SD)	2 Mean (SD)	3 Mean (SD)	4 Mean (SD)
BMI range (kg/m^2)	≤14.8	14.8–15.7	15.7–16.6	>16.6
n	216	216	216	216
Body weight (kg)	15.3 (1.4)	16.8 (1.4)	17.8 (1.5)	20.1 (2.2)
Height (cm)	104.3 (4.0)	104.7 (4.2)	104.9 (4.2)	105.9 (4.1)
BMI (kg/m^2)	14.0 (0.7)	15.3 (0.3)	16.1 (0.3)	17.9 (1.2)
Difference body weight[a]	−0.5 (0.9)	−0.2 (0.8)	0.2 (0.8)	0.5 (1.0)
Difference height[a]	−0.2 (1.7)	−0.4 (1.5)	−0.5 (1.7)	−0.6 (1.9)
Difference BMI[a]	−0.4 (0.9)	−0.1 (0.8)	0.3 (0.8)	0.7 (1.1)

a: The difference was calculated by subtracting the reported value from the measured value per subject. Note that negative values reflect over reporting

turning point in over and underreporting BMI appeared to be ~15.4 kg/m^2.

In total, 84 children (9.7%) were misclassified on the basis of reported BMI (Table 3). Of these misclassifications, 62 children (73.8%) were classified in a lower BMI category when reported data were used instead of measured data. Fifty-three of the 116 children (45.7%) who were classified as 'overweight' (moderate overweight or obesity) according to measured data were not classified as 'overweight' when reported data were used.

BMI

In Figure 1, the difference between measured and reported BMI is plotted against measured BMI. This figure demonstrates that the difference between measured and reported BMI increased with increasing measured BMI of the child. In simple linear regression analysis, the association of the difference between measured and reported BMI with measured BMI was statistically significant in both genders ($P < 0.001$). The difference between measured and reported BMI increased by 0.26 (95% CI 0.21–0.32) kg/m^2 per unit increase in measured BMI in girls and by 0.26 (95% CI 0.20–0.31) kg/m^2 in boys.

In addition, a multiple linear regression was performed. In this analysis, the child's age, age of the mother, BMI of the mother, educational level of the mother and 'digit preference' were included as independent variables besides measured BMI of the child. Including these variables did not affect the association between the difference between measured and

Table 3 Classification of 864 4-year-old Dutch children in normal weight, moderate overweight, and obesity[a] according to measured and reported BMI (kg/m^2)

Measured BMI	Reported BMI			
	Normal weight	Moderate overweight	Obesity	Total (%)
Normal weight	729	19	0	748 (86.6%)
Moderate overweight	51	39	3	93 (10.8%)
Obesity	2	9	12	23 (2.7%)
Total (%)	782 (90.5%)	67 (7.8%)	15 (1.7%)	864

a: Definitions moderate overweight and obesity are gender and age specific; cut off points moderate overweight: 17.19–17.89 kg/m^2; cut off points obesity: 19.12–19.57 kg/m^2.[23]

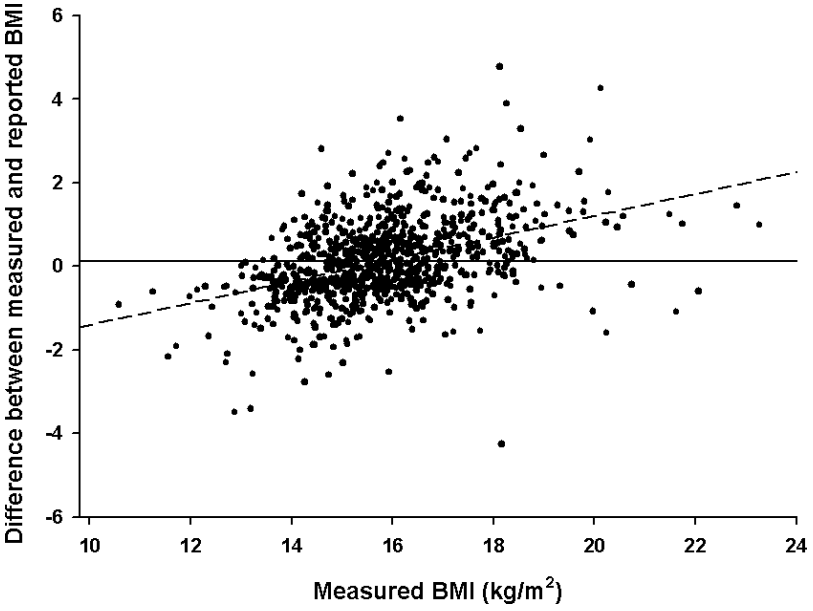

Figure 1 Difference between measured and reported BMI (measured minus reported) by measured BMI of 864 4-year-old Dutch children with regression line (dashed line) and line indicating mean difference (solid line).

reported BMI and measured BMI. In girls, 'digit preference' and BMI of the mother were both independently statistically significantly associated with the difference between measured and reported BMI. Parents who reported body weight as a multiple of 0.5 kg (digit preference) were more likely to underreport BMI compared to parents who did not ($\beta = 0.21$, 95% CI 0.03–0.39; $P = 0.03$). BMI of the mother was negatively associated with the difference between reported and measured BMI ($\beta = -0.03$, 95% CI −0.06 to −0.01; $P = 0.01$). In boys, besides measured BMI of the child none of the other variables included in the regression model were significantly associated with the difference between measured and reported BMI.

The results did not change when the analyses were restricted to children with a smaller time interval between the medical examination and the reported measurement or when only positive or only negative differences in BMI was taken into account. Also, no differences were observed between the children in whom the medical examination preceded the questionnaire and the children in whom the medical examination was performed after they returned the questionnaire. When we stratified the analysis to the person who carried out the measurement reported in the questionnaire, the results were similar for children weighed and measured by a medical professional as for children weighed and measured by their parents.

Body weight

With regard to the difference between measured and reported body weight, a significant association was observed with measured BMI of the child in both genders ($\beta = 0.25$, 95% CI 0.20–0.30 in girls and $\beta = 0.26$, 95% CI 0.21–0.32 in boys; both $P < 0.001$). In girls, also 'digit preference' ($\beta = 0.19$, 95% CI 0.01–0.37; $P = 0.04$), BMI of the mother ($\beta = -0.03$, 95% CI −0.05 to −0.00; $P = 0.02$) and educational level of the mother were statistically significantly associated with the difference between measured and reported body weight. In comparison to mothers with a high or intermediate education, mothers with a low educational level were more likely to underreport body weight of their daughter ($\beta = 0.39$, 95% CI 0.16–0.62; $P < 0.001$). In boys, besides measured BMI of the child, none of the explanatory variables was associated with the difference between measured and reported body weight.

Height

In girls, the difference between measured and reported height was significantly associated with measured BMI ($\beta = -0.11$, 95% CI −0.21 to −0.02; $P = 0.02$). In multiple linear regression, a significant association between the difference between measured and reported height and educational level of the mother was observed in girls. If the mother had a low educational level parents were less likely to over report height ($\beta = 0.53$, 95% CI 0.11–0.95; $P = 0.01$) than mothers with an intermediate or high education. In boys, no statistically significant association between the difference between measured and reported height and measured BMI ($\beta = -0.07$, 95% CI −0.17 to 0.04; $P = 0.21$) or any of the explanatory variables in the regression model was observed.

Discussion

The prevalence of overweight and obesity among 4-year-old children was underestimated when BMI was calculated from parental reported body weight and height. This underestimation was due to underreporting of body weight and over reporting of height by parents of children with a high BMI. On the other hand, parents of children with a low BMI tended to over report body weight. Mean body weight, height, and BMI reported by the parents corresponded well with measured values in this study. Measured BMI of the child appeared to be the main determinant of the difference between measured and reported body weight, height, and BMI in both genders and in all regression models.

Studies in adults and adolescents, in which participants were asked to report their body weight and height, reported similar findings. However, in adults and adolescents, women tend to underreport their body weight and BMI more then men.[12,14] No differences were found between boys and girls in the difference between measured and parental reported body weight, height, and BMI. In girls, but not in boys, some characteristics of the parents like, 'digit preference', BMI of the mother and educational level of the mother were also associated with the difference between measured and reported data. Parents who reported their daughters' body weight as a multiple of 0.5 kg reported, on average, a lower body weight than was measured during the medical examination, indicating a preference for rounding down. This preference is also observed in adults.[6,12]

A limitation of the study was that the time between the medical examination and the date of the reported measurement was not equal for all children and differed up to a couple of months for some children. To take this time difference into account, children in which the time interval between the medical examination and the date of the reported measurement was larger than 6 months were excluded from the analyses. The results of the analyses did not alter when a smaller time interval between the medical examination and the reported measurements was chosen. Furthermore, measured body weight and height of the child were standardized to the age of the child at the reported measurements to take into account average growth between date of the medical examination and the date of the reported measurements. Repeated analyses without standardization showed that this did not affect the outcomes of this study. Another limitation was that some of the parents reported weight and height after the medical examination was carried out. Although the parents of the children were not given written records of the weight and height of the child measured during the medical examination, they may have watched during the measurements. This could have affected our results. However, if the analyses were repeated for children in whom the measurement reported in the questionnaire was carried out before or after the medical examination separately, no differences were observed in the outcomes.

The medical examinations were not carried out at the same moment of the day for all children. Also, no information was available on the time of the day the reported measurements were carried out. Although difference in time of the day could have caused some noise, it is not likely that it has affected the results of this validation study to an important extent. Since the children were weighed wearing clothing, we decided to subtract 0.5 kg from the measured body weight for clothing. This adjustment did not affect the association between the difference between measured and reported BMI and measured BMI. We did not subtract 0.5 kg for clothes from the reported weight of the children, because at under-five clinics children are usually weighed wearing only their underwear and we did not know whether the children were weighed with their clothes on or only wearing their underwear when they were weighed by their parents. If some children were weighed wearing their clothes, the difference between measures and reported body weight of the child might even be more pronounced.

In the questionnaire, we asked who carried out the reported measurements. A total of 57% parents reported that the measurement was carried out by a medical professional. In the Netherlands, the majority of the children of 4-year-old are seen by a doctor in an under-five-clinic who weighs and measures them according to a standard procedure. Remarkably, also a positive association was observed between the difference between measured and reported BMI and measured BMI when only children measured by a medical professional were included. This observation might indicate that even when the child was measured by a person who has experience with measuring children and uses appropriate equipment, parents still tend to underreport body weight. The reason why parents tended to over report or underreport body weight of their child remains unclear, since we did not have data on that.

Due to underreporting body weight and over reporting height among children with a high BMI, the prevalence of overweight (moderate overweight or obesity) in this study differed markedly between reported and measured data. Whereas 9.5% of the children were overweight according to reported BMI, the prevalence of overweight was 13.4% based on measured BMI. Of the children with overweight according to measured data 45.7% was missed when reported data were used. Apparently, a large proportion of the parents of overweight children did not to report body weight and height accurately. Earlier studies in which parents were asked to describe whether their child was 'underweight', 'normal weight', or 'overweight', showed that, in general, parents of overweight or obese children failed to classify their children correctly. In these studies, the majority of the parents of overweight or obese children of different ages classified their child in a lower weight category.[24–30]

With regard to self-reported body weight and height in adults, it has been argued that data should be viewed with caution, due to underreporting body weight and over reporting height, especially since overweight individuals are more likely to under estimate their body weight.[6,9,10,13–15] Considering the results of the present study, the situation seems to be similar in young children when body weight and height are reported by the parents. In epidemiological research studying determinants of body weight, height, and BMI in children, reported data seems to be a valid alternative for measured data as long as authors bear in mind that associations with determinants could be attenuated due to over and under reporting. However, prevalence rates of overweight in children could be considerably underestimated when based on reported data. The usefulness of reported body weight and height for this purpose should therefore be questioned.

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Key points

- Overweight prevalence of young children is underestimated when based on parental reported body weight and height.
- The underestimation of the overweight prevalence is due to underreporting of body weight and over reporting of height by parents of children with a high BMI.
- Parents of children with a low BMI tended to over report body weight of their child.

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