Research Paper

Comparison of Weight-for-height and BMI-for-Age for Estimating Overnutrition Burden in Under-five Populations With High Stunting Prevalence

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ABSTRACT

Background: Overnourished under-five children are anthropometrically classified as either being at possible risk of overweight, overweight or obese and defined so, when either weight-for-height or Body-Mass-Index-for-age (BMI-for-age) are >1SD to 2SD, >2SD to 3SD and >3SD, respectively of the analogous World Health Organization standards.

Aim: To compare weight-for-height and BMI-for-age definitions for quantifying overnutrition burden.

Methods: Theoretical consequences of ignoring age were evaluated by comparing, at varying height-for-age z-scores, the age- and sex-specific cut-offs of BMI that would define overnutrition with these two metrics. Overnutrition prevalence was then compared in simulated populations (short, intermediate and tall) and real-life datasets from India.

Results: In short (-2SD) children, the BMI cut-offs with weight-for-height criteria were lower in comparison to BMI-for-age till 7-8 months, but higher at later ages. In National Family Health Survey-4, India dataset (short population), overnutrition (>1SD) prevalence with weight-for-height was higher from 0-0.5 years (exclusive breastfeeding age), but lower at subsequent ages. The prevalence difference (weight-for-height - BMI-for-age) in 0.5-5 years was -2.26% (6.57% vs 8.83%); this attenuated in 0-5 years (-1.55%; 7.23% vs 8.78%). The discrepancy was maximal for stunted children and was lower in girls. A similar pattern, of lower magnitude, was observed for overweight (>2SD) comparison. In intermediate and tall populations, there were no meaningful differences.

Conclusion: The two definitions produce cut-offs, and hence estimates of overnutrition, that differ with the age, sex, and height of under-five children. The relative invariance, with age and height, of BMI-for-age, favours its use.

Keywords: *Body-mass-index-for-age, Overnutrition, Overweight, Under-five children, Weight-for-height.*

Globally, an estimated 5.7% or 38.9 million under-five children, almost half in Asia and a quarter in Africa, were affected by overweight in 2020 [1]. Since overweight and obesity in childhood and adolescence are associated with adverse health consequences later in life, their prevention and control are important. Focusing on under-five children is an important component of this strategy [2]. Indeed, prevalence of overweight in under-five children is one of the Sustainable Development Goals (SDGs). The global nutrition targets endorsed by the World Health Assembly include: (i) no increase in childhood overweight prevalence as target for 2025; and (ii) reduce and maintain childhood overweight to below 3% as target for 2030 [1]. An accurate and bias free quantification of overnutrition burden is, therefore, crucial both at the individual and population level.

Overnutrition in under-five children can be identified by either of the two anthropometric indices: (a) Weight-for-height, and (b) Body-Mass-Index-for-age (BMI-for-age). Overnourished individuals are categorized as either obese, overweight or at possible risk of overweight, if these indices are >3SD, between >2SD and 3SD, and between >1SD and 2SD, respectively of the World Health Organization (WHO) growth references [3,4]. Currently, there is no unanimity regarding the preferred index among these two, to diagnose overnutrition in public health settings. Weight-for-height ignores the physiological changes in ponderosity with age, whereas by construct BMI-for-age accounts for such alterations [4,5]. Further, for a given weight and height at a particular age, the WHO SD (or Z) scores of the two indices could also differ. We recently demonstrated that these incongruencies resulted in appreciable and systematic differences in thinness estimates of populations [5]. A similar phenomenon is likely for overnutrition. Following the introduction of the WHO Growth charts, only few studies from HICs have partially explored this possibility [6-9]. However, there is no detailed and systematic evaluation from Low-and-Middle-Income-Country (LMIC) settings, in which the children are generally shorter and thinner, but the double burden of malnutrition is now assuming alarming proportions [2]. We therefore compared these two indices for diagnosing overnutrition in under-five children, in populations with different heights, through theoretical considerations, simulation, and real-life data sets from research and survey settings in India.

METHODS

An ethical clearance for the study was not required as it deals with hypothetical considerations, simulations [4,10-13], and the real-life analyses of secondary datasets for which the consent was taken from the parents of the participants and the ethical clearance was obtained from the respective institutional boards [10,14-15].

The two metrics (weight-for-height and BMI-for-age) were compared independently for both the sexes (boys and girls) at monthly intervals from 0 to 60 months. We considered the values ht(t,z), bmi(t,z), and wt(t,z), respectively at age t where ht, bmi, and wt are height, BMI, weight (at height ht(t,z)) and z is the WHO standard score of height, BMI, and weight-for-height [4]. The plots were made for bmi(t,+2) and $wt(t,+2)/ht^2(t,z)$ against age t (0 to 60 months), where z = -2, 0, +2 (short, intermediate, and tall), respectively. Further, at fixed weight-for-age with fixed height-for-age (both at 0SD, +1SD, and +2SD), we compared the SD scores of weight-for-height and BMI-for-age in both sexes, from 0 to 60 months, respectively.

The artificial datasets were constructed independently for boys and girls to study the effects of choice of metric on overnutrition estimates in short: National Family Health Survey-4 (NFHS-4) [10], intermediate: WHO [4], and tall: National Health and Nutrition Examination Survey, USA (NHANES), Greenland and Poland populations [11-13]. In six-monthly age-group intervals from 0-5 years, 100,000 subjects were generated homogeneously and independently for both the sexes. The WHO z-scores of heights and weights were generated through bivariate distribution with respect to their mean, SD, and correlations (Table 1). The height and weight were back calculated by using the LMS parameters of the WHO reference [4].

Three real-life datasets were used for the analyses: (a) the Meerut study, which was designed to assess the prevalence of severe acute malnutrition and to propose mid-arm circumference substitutes for the weight-for-height cut-offs [14]. This cross-sectional, community-based study was conducted between September 2012 and October 2013 in the district of Meerut, Uttar Pradesh, India. Two adjoining rural blocks were identified, and their 70 contiguous villages were selected. The inclusion criteria were children between 6-59 months old residing permanently in the study area, who had no severe ailments or physical deformities (n=18,463). The research team members were trained in recording anthropometry by standard techniques, assessment of age and examination for severe visible thinness and bipedal oedema. Length for the children below 24 months of age was measured using SECA 417 infantometer and for 24-59 months of age, SECA 213 stadiometer was used to measure the height with a minimal count of 0.1cm. Weight was recorded using SECA 383 digital weighing scale closest to 10g. Inter-observer and intra-observer technical errors of measurements were <2% [14]. (b) NFHS-4is the cross-sectional Demographic Health Survey conducted between 2015-2016. Data was collected on 241,531 children throughout India between 0-5 years age [10]. A two-stage stratified sampling was done in which the primary sampling units (PSUs) were villages in rural areas and census enumeration blocks (CEBs) in urban areas. The final sample PSUs were selected with the probability proportional to the size (PPS) sampling. In every selected rural and urban PSU, households and individuals were selected using a well-defined process. Weights were measured using the SECA 874 digital weighing scale. Length was measured using SECA 417 infantometer for infants below 24 months of age and SECA 213 stadiometer was used to measure the height of children between 24-59 months of age. The least count and technical errors of measurements are not mentioned in the report. However, in this demographic survey, we expect more measurement errors. (c) The Comprehensive National Nutrition Survey (CNNS) was a cross-sectional nutritional survey conducted between 2016-2018. The data was collected on 38,060 children in India between 0-5 years of age by following the standard procedures [15]. Multi-stage stratified sampling was used in the survey with PSUs for villages in the rural areas and CEBs in the urban areas. The final selection of the PSUs was done by using the PPS sampling. Families and individuals were selected by a well-defined procedure from each of the chosen rural and urban PSUs. The weight of the children and adults was measured using SECA digital weighing scale and the length/height was measured using the three-piece wooden board. Children younger than two years of age, were measured lying down while older subjects were measured standing. In this survey, we expect less errors as the measurements, except weight, were conducted in duplicate with quality control procedures in place.

We noted discrepancies between the z-scores of various indices available in the NFHS-4 dataset and the z-scores calculated from the raw weights and lengths/heights. Thus, we used the calculated WHO z-scores using the macro syntax for STATA [4]. WHO criteria were followed to set the missing values (z-scores): length/height-for-age <-6 or >6, weight-for-age <-6 or >5, weight-for-height <-5 or >5, and BMI-for-age <-5 or >5. Using these filters, 207,364 subjects were available for the analysis (**Web Fig. 1 and 2**). In the CNNS dataset, 3,162 subjects were excluded using the same filters and thus 34,898 subjects were available for the analysis. In Meerut study, we considered missing values below -7z for height-for-age, weight-for-age, and weight-for-height, as seemingly aberrant measurements had been reverified in the field. Using this filter, 11 subjects were excluded, and 18,452 subjects were available for the analysis. Age categories were divided into ten six-monthly intervals between 0-5 years age.

The proportions that were classified as overnourished with weight-for-height (>1 SD or >2 SD) metric but not with BMI-for-age for the corresponding cut-off, and vice versa, were estimated from 2 x 2 tables. The prevalence of overnutrition with both metrics, including for stratified ages, sex and height-for-age categories, was compared using the McNemar's test. Correlation between the two metrics was computed using Pearson correlation coefficient. Agreement between weight-for-height and BMI-for-age was examined by using Bland–Altman analyses with 95% limits of agreement.

The statistical analyses were done using STATA 16.0 version and the graphs were made using R software 4.0.2 version ((R Core Team, 2020, Vienna, Austria; www.R-project.org/) and STATA 16.0 version (StataCorp LLC, College Station, Texas, USA).

RESULTS

Web Fig. 3 compares the absolute Body-Mass-Index cut-offs for defining overweight (>2SD) according to weight-for-height and BMI-for-age criteria. In short children (-2 SD), the cut-offs with weight-for-height were lower till 7-8 months and after 48 and 54 months in girls and boys, respectively, but were higher in between these ages. The two cut-offs were broadly similar at median height (0SD). In tall children (+2 SD), the cut-offs with weight-for-height were higher till 5-6 months and after 36 and 39 months in boys and girls, respectively, but were lower in between these ages.

For a given weight-for-age (0, +1 and +2SD), the z-scores for weight-for-height and BMI-for-age were similar in children with median height-for-age (**Web Fig. 4**). However, in children with height-for-age at -2 SD, the weight-for-height z-scores were higher than BMI-for-age z-scores till 6 months of age and lower subsequently till 42-60 months of age. A reverse pattern was observed in tall children (height-for-age +2SD).

Fig. 1 compare the prevalence of possible risk of overweight (>1 SD) using the two metrics in simulated short, intermediate, and tall populations. The overall (0-5 years) prevalence with weight-for-height was lower in comparison to BMI-for-age in short populations. However, the prevalence was higher with weight-for-height criterion in 0 to 0.5 years (19.8% vs 8.1%) and lower in 0.5 to 5 years (8.3% vs 11.1%). A reverse pattern was observed in tall populations, except for the USA dataset where the overall prevalence with weight-for-height was marginally lower (35.7% vs 36.4%). In intermediate population, the 0-5 years and 0.5-5 years prevalence estimates were similar with both metrics, whereas the 0-0.5 years prevalence was slightly higher with weight-for-height criterion (17.2% vs 15.9%). A similar pattern, but with lower magnitude, was evident for overweight (>2SD) comparison in short population (**Web Fig. 5**). No differences were observed for the intermediate population. In the tall populations from Poland and Greenland databases, the weight-for-height estimates were slightly lower from 0-0.5 years, but comparable thereafter and for overall prevalence. In the USA dataset, the overall and 0.5-5 years prevalence was marginally lower with weight-for-height.

The mean (SD) age (months), height-for-age, weight-for-height, and BMI-for-age (z-scores) of the Meerut study were 32.6 (15.5), -1.87 (1.22), -1.11 (0.94), and -0.91 (0.94), respectively. Boys constituted 53% of the sample. Risk of overweight (>1SD) was lower with weight-for-height from 2-3 years and for overall (1.35% vs 2.15%) prevalence (**Fig. 2**). The difference was higher in stunted children and decreased with increasing stature. The discrepancy was more in boys. No significant differences were apparent for overweight (>2SD), but the overall prevalence was only 0.17%-0.22% (**Web Fig. 6**).

The mean (SD) age (months), height-for-age, weight-for-height, and BMI-for-age (z-scores) in the NFHS-4 survey were 28.3 (16.2), -1.46 (1.7), -0.93 (1.4), and -0.81 (1.4), respectively. Boys constituted 52% of the sample. The prevalence of possible risk of overweight with weight-for-height metric was higher in 0-0.5 years, but lower in 0.5-5 and 0-5 years (**Fig. 2**). The absolute differences in 0.5-5 years and overall sample were 2.26% (6.57% vs 8.83%) and 1.56% (7.23% vs 8.78%). In severely and moderately stunted children, the difference was much higher in 0-0.5 years (53.9% vs 11.6% and 39.1% vs 19.8%, respectively) in comparison to 0.5-5 years (11.9% vs 18.2% and 8.1% vs 12.5%, respectively). The differences decreased with increasing stature. The discrepancy was higher in boys. Similar patterns were evident for overweight (>2SD), but with a smaller magnitude of overall prevalence and absolute differences (**Web Fig. 6**). Kernel Density plots confirmed a shift in the entire distribution, which was in opposite direction in 0-6 months and 6-59 months and of a greater magnitude in the stunted subjects (**Web Fig.7**).

The mean (SD) age (months), height-for-age, weight-for-height, and BMI-for-age (z-scores) of the CNNS dataset were 30.53 (16.8), -1.15 (1.5), -0.72 (1.3), and -0.60 (1.3), respectively. Boys comprised 52% of the sample. Patterns similar to NFHS were documented for both the possible risk of overweight (>1SD) and overweight (>2SD) and the kernel density plots; however, the magnitude of overall prevalence and differences was lower and not statistically significant at more time intervals (**Fig. 3**, and **Web Fig. 8**).

Misclassification occurred in both directions, being more evident in short populations (**Web Tables I** and **II**). In 0-0.5 years, children classified as overnourished by weight-for-height and not by BMI-for-age was more frequent than opposite misclassification. The reverse pattern was observed in 0.5-5 years, except for the Poland and Greenland simulated datasets.

The Bland–Altman analyses varied with age for the simulated short population. In the 0–6 months age group, thinner infants had lower weight-for-height z-scores whereas obese infants had lower BMI-for-age z-scores (positive association between the difference and average of weight-for-height and BMI-for-age z-scores). An opposite but milder association was evident for 6–59 months. A similar but relatively milder pattern was seen in other data sets (**Web Table III**).

There was an excellent correlation between the two metrics in all data sets (r= 0.97–0.99; r^2 0.94–0.98) (**Table II**). In general, in thin and overweight subjects, the correlation coefficients were significantly lower (nonoverlapping 95% confidence intervals) than in those classified as normal with either the weight-for-height or BMI-for-age criteria. In the NFHS-4 and CNNS population, the correlation was weaker for obese subjects in comparison to thin subjects, whereas the converse was true for the tall populations. Further, the correlations were significantly, but slightly, weaker in stunted participants.

DISCUSSION

In under-five children, overnutrition definitions based on WHO's weight-for-height and BMI-for-age standards produced cut-offs, and hence prevalence estimates, that differed with the age, sex and height of subjects. Also, for a given height and weight, these characteristics were associated with subtle variations in the computed *Z*-scores for these two metrics. Consequently, in Indian real-life datasets, representative of a short population, prevalence with weight-for-height was higher from 0-0.5 years (exclusive breastfeeding age), but lower for 0.5-5 years. The discrepancy was lower in girls and maximal for stunted children. In simulated datasets from intermediate and tall populations, there were no meaningful or marginal differences. This study focuses on the systematic comparison of these two metrics, using the WHO standards, for defining various grades of overnutrition in a LMIC setting. Consonance between theoretical considerations, simulations and real-life data sets enhances confidence in the findings.

There is a paucity of published data from LMIC settings for comparison. Theoretically, Cole first demonstrated with the National Centre for Health Statistics (NCHS), USA standards, that short children above 6 months of age appear thinner based on weight-for-height [16]. He suggested that weight/height^2 should be the preferred index to prevent misleading assessments in tall or short under-five children. With NCHS standards, in 4348 children from USA, aged 2–5 years, overweight (≥85th percentile) prevalence by weight-for-height was lower (0.9%-6%) than by BMI-for-age with greater differences in shorter children and at 4 years age [17].

Using WHO standards, in 547 diseased, 0-2 years old Canadian children, the prevalence of stunting was 23%. Their BMI-for-age and weight-for-length percentiles differed by >25 percentile points in ~9%, and ~16% in those below 6 months. Overweight (≥85th percentile) prevalence was higher with weight-for-length (21% vs 18.3%), with differences (18.2% vs 12.5%) in 0-6 months age, but comparable estimates (23.7% in both) for 6-24 months. Similar findings were evident for obesity (≥95th percentile; 12.2% vs 9.9%) [6]. In 0-2 years and under-five healthy children, from Canada [7] and USA [18], respectively, the prevalence of stunting was low. Weight-for-length and BMI-for-age demonstrated high agreement with comparable overweight prevalence. These findings are similar to our analyses, factoring for stunting prevalence and age strata. In an analysis on global prevalence and trends of overweight and obesity among preschool children, 450 nationally representative cross-sectional surveys from 144 countries were evaluated [19]. Both metrics yielded comparable prevalence estimates in aggregated data from High Income Countries (HICs) (only graphical depiction), with similar results for other regions (text statement). In the absence of estimates related to stunting prevalence, age strata and sex, these findings cannot be compared with our analyses.

We depicted prevalence differences in under-five children with both 1SD and 2SD cut-offs. The former showed greater disagreement and are more relevant for LMICs, particularly India. First, this aligns the BMI-for-age cut-offs for defining overweight in under-five (currently 2SD) and 5-19 years (currently 1SD) [20] old children, which allows pertinent comparisons across age ranges. Second, metabolic perturbations associated with increased ponderosity start manifesting at lower cut-offs in older children, adolescents and adults in India [21]. However, prevalence estimates based on arbitrary cut-offs (1SD or 2SD) may be of restricted utility, if the underlying process is continuous. Z-scores distribution could therefore be more meaningful for population monitoring [22]. We documented a distributional shift too, compatible with the prevalence discrepancy. In the NFHS-4 survey, the mean Z-scores differences ranged from 0.16 to 0.21, which are roughly comparable to effective interventions at population level [23]. The excellent correlations (r=0.97 to 0.99), observed by us and others [5-7, 17] summarize only the degree of linear relation between these two metrics and do not establish the interchangeability of the two standards. The weaker correlations at the margins (>2SD or <-2SD), Bland Altman analyses and 2x2 tabular depictions provide a deeper insight into the disagreement patterns.

Among limitations, real-life datasets from diverse settings of linear growth failure, and intermediate and tall populations were not evaluated; however, simulations partly address this gap. Also, biological outcomes were not studied for determining the comparative utility of these two metrics. Data from USA indicate that BMIZ and its change are better indicators of adiposity at 1 month age [8] and fat accrual during the first 5 postnatal months [24], respectively. However, analyses of USA and Belarus cohorts concluded that "choice of weight-for-length vs body mass index to define overweight during the first 2 years of life may not greatly affect the association with cardiometabolic outcomes during early adolescence" [9]. There is a paucity of similar studies from LMIC settings.

There are potential policy implications of these findings. In contrast to intermediate or tall populations, in nations with substantial stunting, weight-for-height compared with BMI-for-age, inflates the undernutrition burden [5] and simultaneously deflates the overnutrition estimates, especially in 6-59 months old children. This magnifies the gap between the High-Income-Countries and LMICs for "malnutrition" (combined under- and over-nutrition) burden, and distorts the ranking and progress of nations in achieving the related SDGs. In routine Demographic National Surveys conducted in LMICs, the discrepancies in absolute prevalence may appear small. Nevertheless, with relatively lower overnutrition prevalence currently, these differences assume importance for urgently influencing investments and policy. The disagreements are likely to be larger and more relevant for granular planning, with over one-third of Districts in India having stunting prevalence above 40% [25]. The misclassification will assume prominence for identifying eligible individuals in public health programmes. BMI-for-age offers an additional advantage of using a uniform metric from birth till adulthood for identifying both thinness and obesity. Unlike weight-for-height, BMI-for-age like height- or weight-for-age, requires an accurate evaluation of age, which could rarely become a limitation. Global stakeholders' decision to replace or complement the weight-for-height indicator with BMI-for-age, for national, sub-national and individual use, should therefore be based on evidence-based consideration of potential benefits, harms and costs (financial and logistic) involved, including for potential biological outcomes like adiposity and cardiometabolic risk factors in later life.

In conclusion, weight-for-height and BMI-for-age definitions produce estimates of overnutrition, which vary with the age, sex and height of children. In populations with substantial stunting, in under-five children and especially those aged 6-59 months, overnutrition estimates are lower with weight-for-height criterion, but there are no meaningful differences in intermediate or tall populations. The relative invariance of BMI-for-age with age and stature, and establishment of a uniform metric definition from birth to adulthood, justifies its preference for classifying overnutrition in under-five children.

Ethics clearance: Authors confirm that such approval is not needed for these theoretical simulations and secondary analyses of data from other studies for which the requisite ethical permissions had been obtained. Authors declare that the study procedures conform to the principles laid down in the Declaration of Helsinki.

Contributors: HSS: conceptualized the study; LNR: primary analyses and interpretation under the supervision of MS, CO and HSS; LNR,HSS: drafted the initial manuscript. All authors provided critical inputs into revision of the article and are willing to be accountable for all aspects of the study.

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Note: Additional material related to this study is available with the online version at www.indianpediatrics.net.

WHAT IS ALREADY KNOWN?

- Overnourished under-five children are anthropometrically classified as either being at possible risk of overweight, overweight or obese and defined so, when either weight-for-height or Body-Mass-Index-for-age (BMI-for-age) are >1SD to 2SD, >2SD to 3SD and >3SD, respectively of the analogous World Health Organization standards.

WHAT THIS STUDY ADDS?

- The two definitions produce cut-offs, and hence estimates of overnutrition, that differ with the age, sex, and height of under-five children. The relative invariance, with age and height, of BMI-for-age, favours its use.

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Table I Details of Anthropometric Parameters Used for Creating the Simulated Populations

Simulated Population	*Height-for-age Z-score*		*Weight-for-age Z-score*		*Correlation*
	Mean	*SD*	*Mean*	*SD*	
Short (National Family Health Survey-4), India[15]	-1.89 to -0.44	1.28 to 1.92	-1.69 to 1.11	1.07 to 1.39	0.55 to 0.69
Intermediate[7]	0	1	0	1	0.72
Tall					
National Health and Nutrition Examination Survey, USA[16]	-0.18 to 0.29	0.96 to 1.32	0.21 to 0.58	0.94 to 1.26	0.63 to 0.75
Greenland[17]	0.80 to 0.83	1.17 to 1.18	0.80 to 0.83	0.98 to 1.07	0.72
Poland[18]	0.28 to 0.40	0.98 to 1.00	0.36 to 0.45	1.03 to 1.12	0.72

The values under various columns depict either a single value (if applicable) or a range for the stratified six-monthly age groups from birth to five years of age.

The superscript Roman numerals under the column simulated population depict the reference numbers from where these anthropometric details were collected for creating the synthetic populations.

Table II Bivariate Pearson Correlation Coefficients Between Weight-for-height and Body-Mass-Index-for-age (BMI-for-age)

Datasets	*N*	*Correlation coefficients (P-values)*	*Weight-for-height; [95% CI]*			*BMI-for-age; [95% CI]*			*Whether Stunted; [95% CI]*	
			<-2 SD (N)	*≥ -2 SD to ≤+2 SD (N)*	*> +2 SD (N)*	*<-2 SD (N)*	*≥ -2 SD to ≤ +2 SD (N)*	*>+2 SD (N)*	*Yes (N)*	*No (N)*
Simulated populations										
Short (NFHS-4)	200000	0.968 (<0.0001)	0.93 (44437); [0.92, 0.93]	0.93 (150236); [0.92, 0.93]	0.37 (4627); [0.34, 0.39]	0.91 (42417); [0.90, 0.91]	0.93 (151539); [0.92, 0.93]	0.71 (5344); [0.69, 0.72]	0.93 (74083); [0.92, 0.93]	0.99 (125217); [0.98, 0.99]
Intermediate	200000	0.988 (<0.0001)	0.87 (5764); [0.86, 0.87]	0.99 (189105); [0.98, 0.99]	0.92 (4991); [0.91, 0.92]	0.90 (5907); [0.89, 0.90]	0.99 (188874); [0.98, 0.99]	0.91 (5079); [0.90, 0.91]	0.93 (4611); [0.92, 0.93]	0.99 (195249); [0.98, 0.99]
Tall										
Poland	200000	0.990 (<0.0001)	0.87 (4461); [0.86, 0.87]	0.99 (182644); [0.98, 0.99]	0.94 (12598); [0.93, 0.94]	0.92 (4770); [0.91, 0.92]	0.99 (182392); [0.98, 0.99]	0.91 (12541); [0.90, 0.91]	0.94 (1788); [0.93, 0.95]	0.99 (197915); [0.98, 0.99]
Greenland	200000	0.982 (<0.0001)	0.58 (1923); [0.55, 0.61]	0.98 (181618); [0.97, 0.98]	0.92 (14905); [0.91, 0.92]	0.87 (2131); [0.85, 0.88]	0.98 (181554); [0.97, 0.98]	0.89 (14761); [0.88, 0.89]	0.93 (1576); [0.92, 0.93]	0.98 (196870); [0.97, 0.98]
NHANES	200000	0.987 (<0.0001)	0.78 (2453); [0.76, 0.80]	0.98 (177011); [0.97, 0.98]	0.94 (20379); [0.93, 0.94]	0.89 (2344); [0.88, 0.90]	0.98 (176385); [0.97, 0.98]	0.94 (8741); [0.93, 0.94]	0.93 (6236); [0.92, 0.93]	0.99 (193607); [0.98, 0.99]
Meerut Study	18452	0.974 (<0.0001)	0.89 (2930); [0.88, 0.89]	0.96 (15490); [0.95, 0.96]	0.91 (32); [0.82, 0.95]	0.89 (2087); [0.88, 0.89]	0.96 (16323); [0.95, 0.96]	0.90 (40); [0.82, 0.95]	0.97 (8379); [0.96, 0.97]	0.99 (10073); [0.98, 0.99]
NFHS-4	207364	0.971 (<0.0001)	0.90 (41761); [0.89, 0.90]	0.94 (160553); [0.93, 0.94]	0.58 (5050); [0.56, 0.60]	0.88 (37871); [0.87, 0.88]	0.94 (163858); [0.93, 0.94]	0.77 (5635); [0.76, 0.78]	0.95 (79053); [0.94, 0.95]	0.99 (128311); [0.98, 0.99]
CNNS	34898	0.979 (<0.0001)	0.90 (4850); [0.89, 0.91]	0.96 (29066); [0.96, 0.97]	0.76 (982); [0.73, 0.78]	0.89 (4251); [0.88, 0.90]	0.96 (29529); [0.96, 0.96]	0.82 (1122); [0.80, 0.84]	0.93 (1024); [0.92, 0.94]	0.98 (33874); [0.98, 0.98]

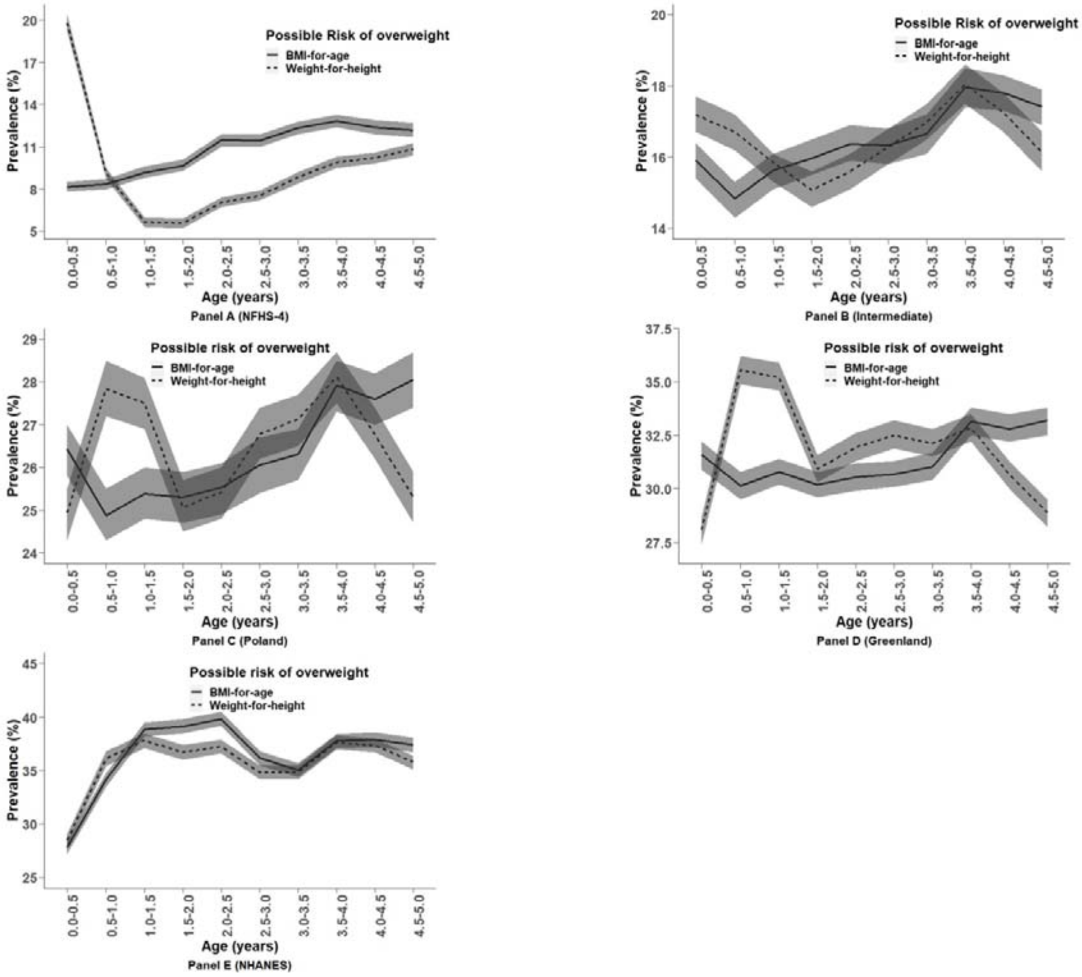


Fig. 1 Comparison of estimated prevalence and 95% confidence intervals of possible risk of overweight (>1SD) using weight-for-height and Body-Mass-Index-for-age criteria on simulated populations: Panel A - short based on the National Family Health Survey-4, India data; Panel B - intermediate; Panels C, D and E - tall based on Poland, Greenland and the National Health and Nutrition Examination Survey, USA data, respectively.

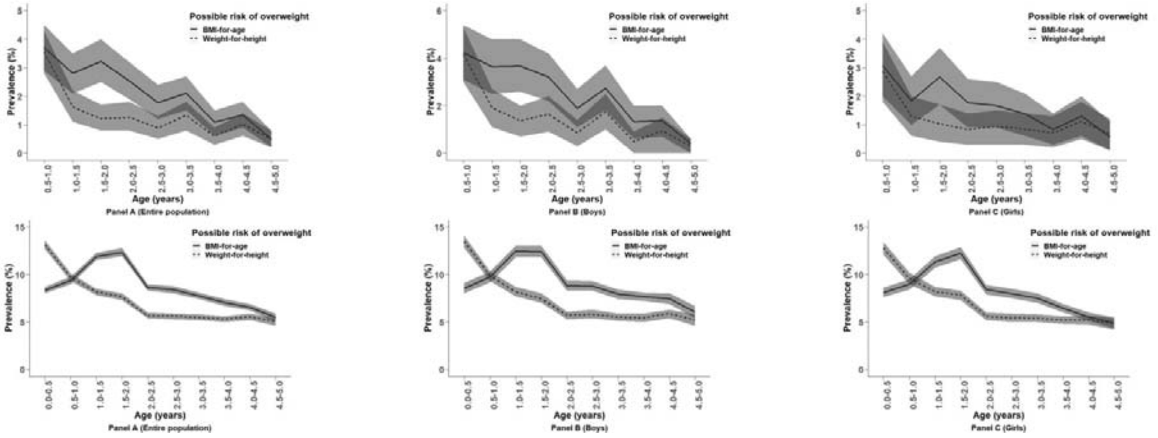


Fig. 2 Comparison of estimated prevalence and 95% confidence intervals of possible risk of overweight (>1SD) using weight-for-height and Body-Mass-Index-for-age criteria in Meerut (above) and National Family Health Survey-4 (below), India datasets: Panel A – Entire population, Panel B – Boys, and Panel C – Girls.

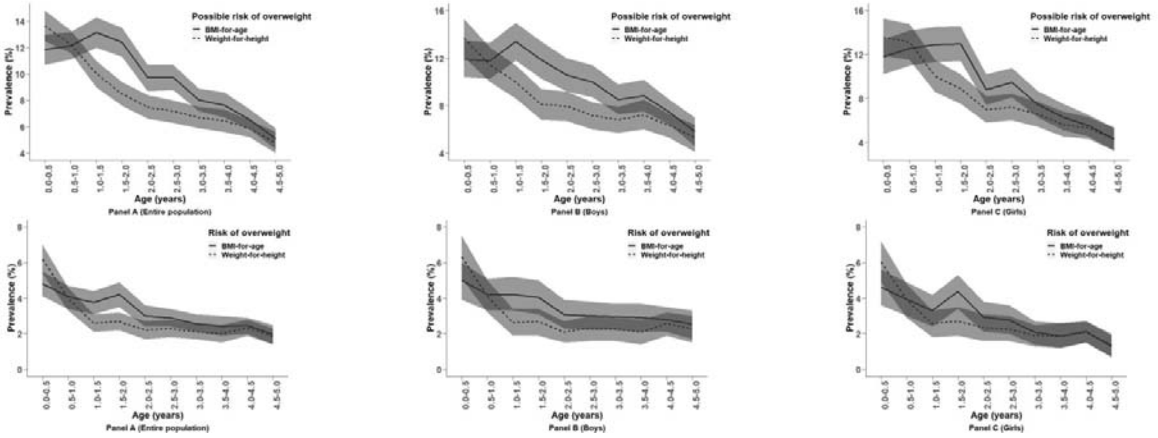


Fig. 3 Comparison of estimated prevalence and 95% confidence intervals of possible risk of overweight (above) and overweight (below) using weight-for-height and Body-Mass-Index-for-age criteria in Comprehensive National Nutrition Survey, India datasets: Panel A – Entire population, Panel B – Boys, and Panel C – Girls.

Web Table I Summary of Disagreement in Possible Risk of Overweight (>1 SD) Classification

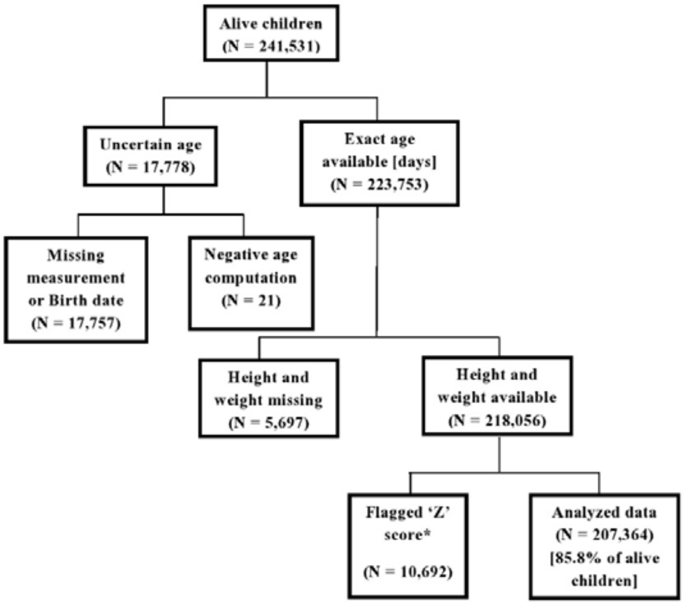
Datasets	*Age-groups (years)*							
	0.0-0.5				*0.5 - 5.0*			
	Overweight by weight-for-height but not by BMI-for-age (%) (a)	*Not overweight by weight-for-height but by BMI-for-age (%) (b)*	*Total (a+b)*	*Ratio (a/b)*	*Overweight by weight-for-height but not by BMI-for-age (%) (c)*	*Not overweight by weight-for-height but by BMI-for-age (%) (d)*	*Total (c+d)*	*Ratio (c/d)*
Short simulated from NFHS-4	11.9	0.2	12.1	54.0	0.3	3.1	3.3	0.1
Intermediate Population	3.4	2.1	5.4	1.6	1.0	1.1	2.1	0.9
Tall population simulated from								
Poland	2.3	3.8	6.2	0.6	1.5	1.1	2.6	1.3
Greenland	2.3	5.8	8.2	0.4	2.5	1.4	3.9	1.8
NHANES	4.3	3.6	7.9	1.2	1.2	2.1	3.3	0.6
Real-life datasets								
Meerut study	Not sampled	Not sampled	Not sampled	Not sampled	0.0	0.8	0.9	0.0
NFHS-4	5.2	0.4	5.6	14.0	0.2	2.4	2.6	0.1
CNNS	2.8	1.1	4.0	2.6	0.2	1.9	2.1	0.1

Web Table II Summary of Disagreement in Overweight (>2SD) Classification

Datasets	*Age-groups (years)*							
	0.0-0.5				*0.5 - 5.0*			
	Overweight by weight-for-height but not by BMI-for-age (%) (a)	*Not overweight by weight-for-height but by BMI-for-age (%) (b)*	*Total (a+b)*	*Ratio (a/b)*	*Overweight by weight-for-height but not by BMI-for-age (%) (c)*	*Not overweight by weight-for-height but by BMI-for-age (%) (d)*	*Total (c+d)*	*Ratio (c/d)*
Short simulated from NFHS-4	5.30	0.03	5.33	176.67	0.13	1.06	1.19	0.12
Intermediate Population	0.53	0.63	1.16	0.84	0.21	0.25	0.46	0.84
Tall population simulated from								
Poland	0.54	1.82	2.36	0.30	0.58	0.46	1.04	1.26
Greenland	0.78	2.41	3.19	0.32	0.82	0.64	1.46	1.28
NHANES	1.53	1.65	3.18	0.93	0.57	1.00	1.57	0.57
Real-life datasets								
Meerut study	Not sampled	Not sampled	Not sampled	Not sampled	0.05	0.17	0.22	0.29
NFHS-4	3.57	0.13	3.70	27.46	0.08	0.77	0.85	0.10
CNNS	1.67	0.30	1.97	5.57	0.06	0.64	0.70	0.09

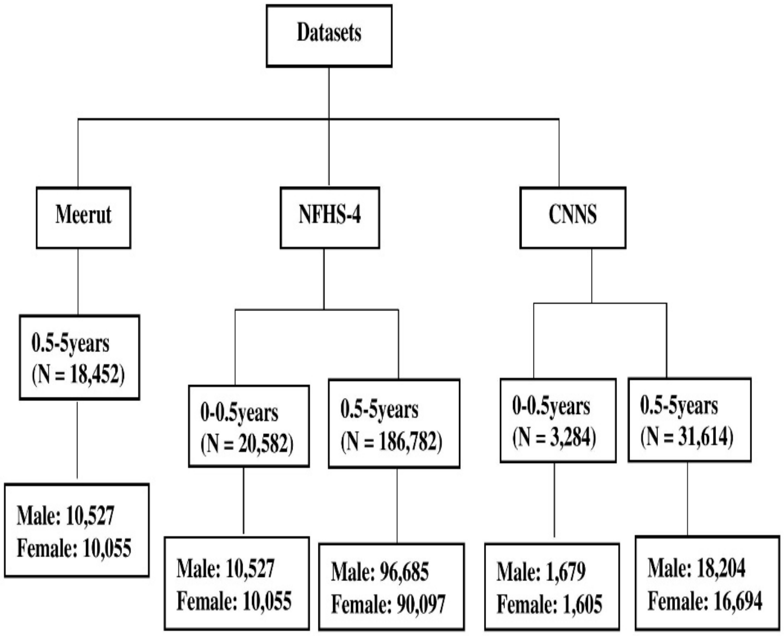
Web Table III Regression Coefficients Between the Difference and Average of Weight-for-height and Body-Mass-Index-for-Age *Z*-scores in Various Datasets

Datasets	*β coefficient (SE); P value*			
	Male		*Female*	
	0-6 months	*6-59 months*	*0-6 months*	*6-59 months*
Simulated Populations				
Short (NFHS-4)	0.2 (0.0); *<0.0001*	-0.1 (0.0); *<0.0001*	0.2 (0.0); *<0.0001*	-0.1 (0.0); *<0.0001*
Intermediate Population	0.0 (0.0); *<0.0001*	0.0 (0.0); *<0.0001*	0.0 (0.0); *<0.0001*	0.0 (0.0);*<0.0001*
Tall				
Greenland	0.1 (0.0); *<0.0001*	0.0 (0.0); *<0.0001*	0.0 (0.0); *<0.0001*	0.0 (0.0); *<0.0001*
NHANES	0.1 (0.0); *<0.0001*	0.0 (0.0); *<0.0001*	0.0 (0.0); *<0.0001*	0.0 (0.0); <0.0001
Real-life datasets				
Meerut Study	Not sampled	0.0 (0.0); *0.314*	Not sampled	-0.1 (0.0); *<0.0001*
NFHS-4	0.2 (0.0); *<0.0001*	0.1 (0.0); *<0.0001*	0.2 (0.0); *<0.0001*	-0.1 (0.0); *<0.0001*
CNNS	0.1 (0.0); *<0.0001*	0.0 (0.0); *<0.0001*	0.1 (0.0); *<0.0001*	-0.2 (0.0); *<0.0001*

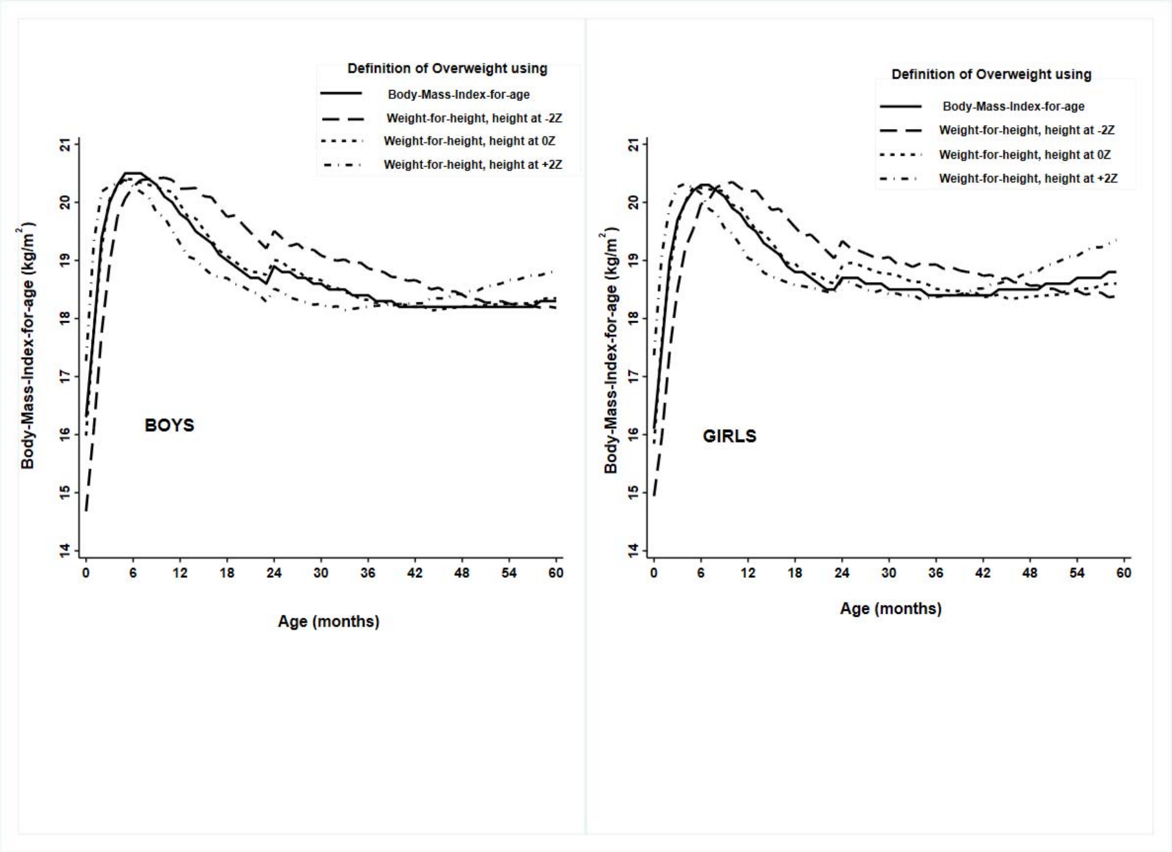


* *Weight-for-age z-score <-6 or >5; Length/Height-for-age z-score <-6 or >6; BMI-for-age z-score <-5 or >5; Weight-for-length/height z-score <-5 or >5*

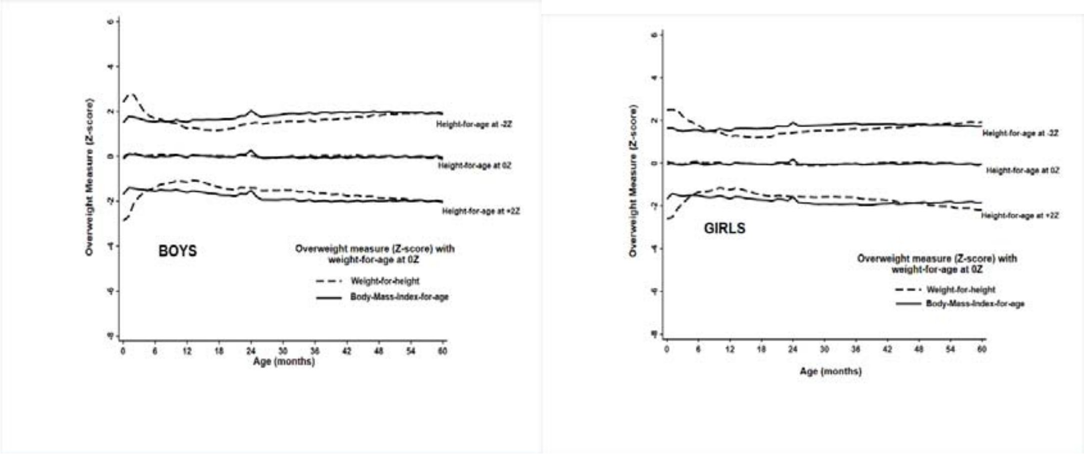
Web Fig. 1 Flowchart for arriving at the analytic sample in NFHS-4 dataset.



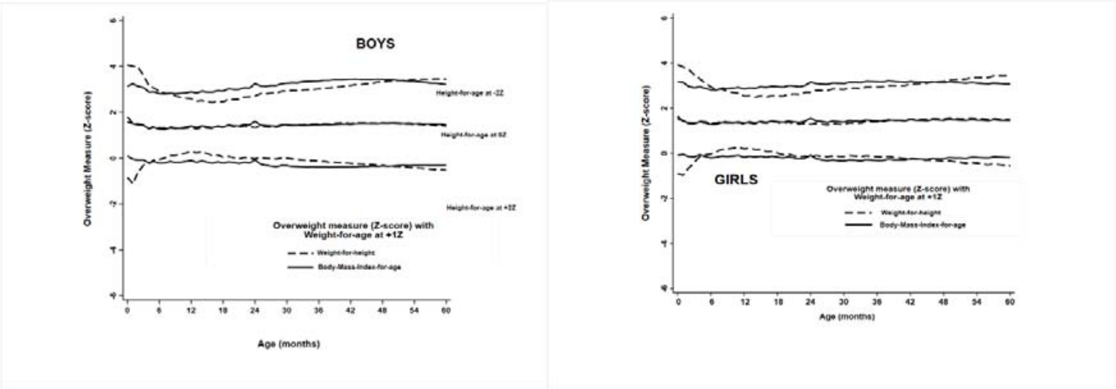
Web Fig. 2 Flowchart for Showing the Details of Children (age-wise and gender-wise) in Each of the Datasets



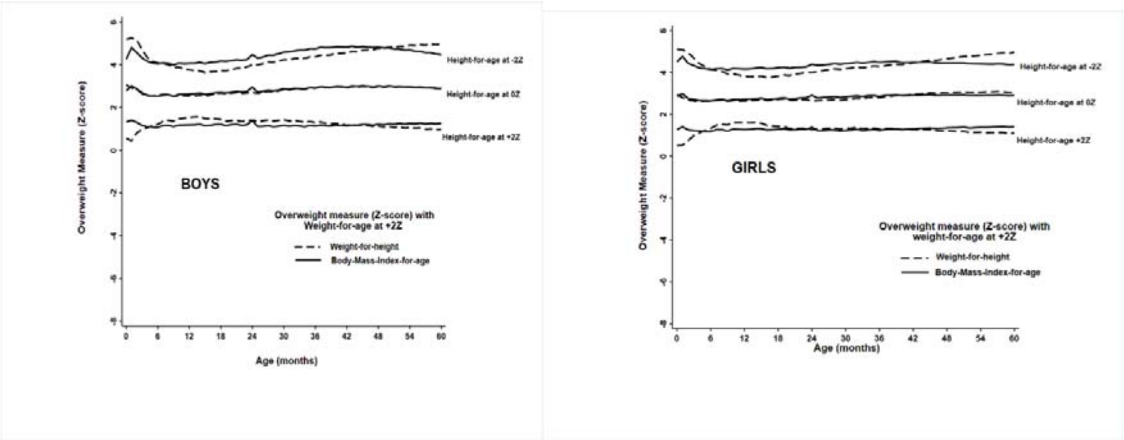
Web Fig. 3 Comparison of absolute Body-Mass-Index cut-offs for defining overweight (>2SD) according to weight-for-height and Body-Mass-Index-for-age criteria in boys (left side) and girls (right side) whose height is at -2SD, 0SD and +2SD of World Health Organization growth standards.



Panel A

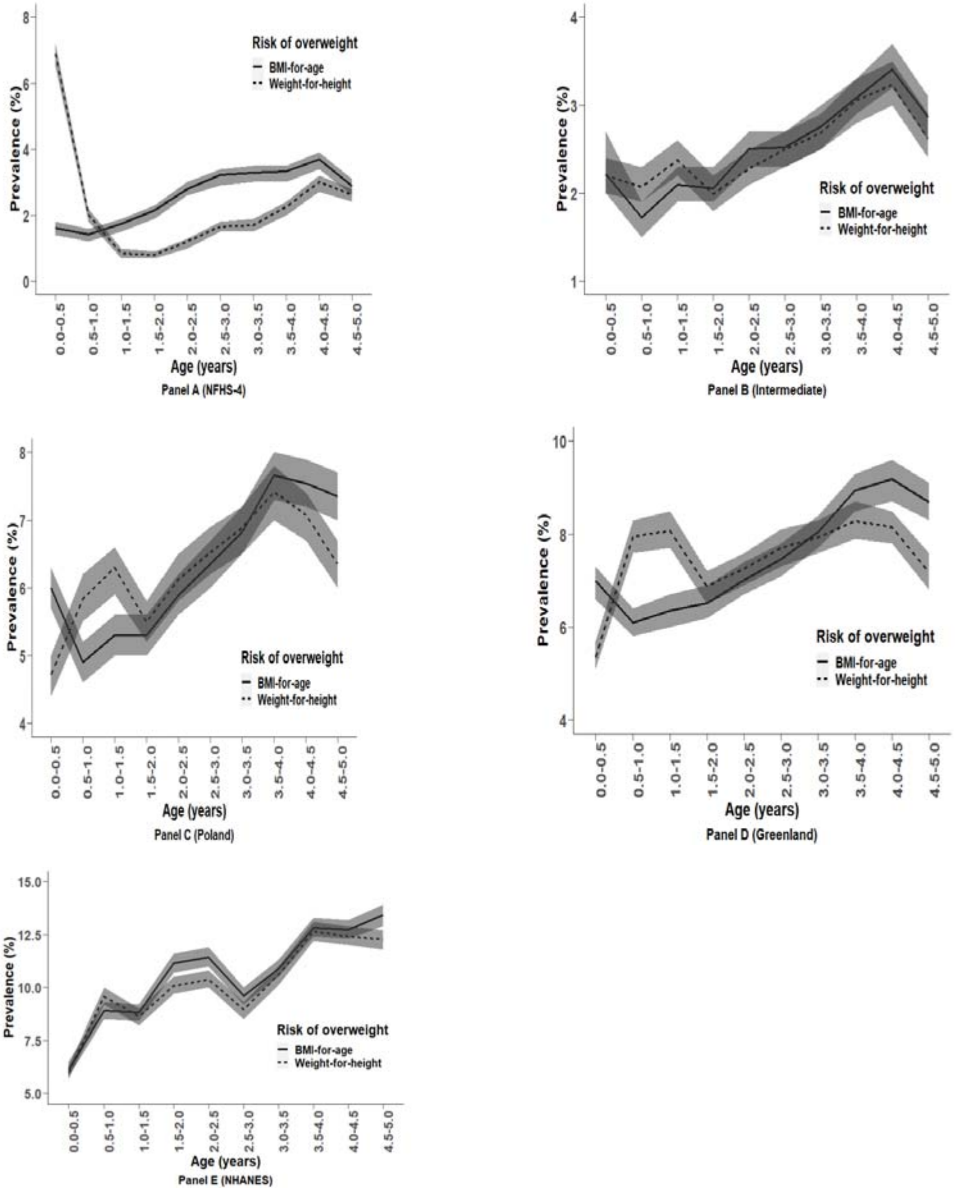


Panel B



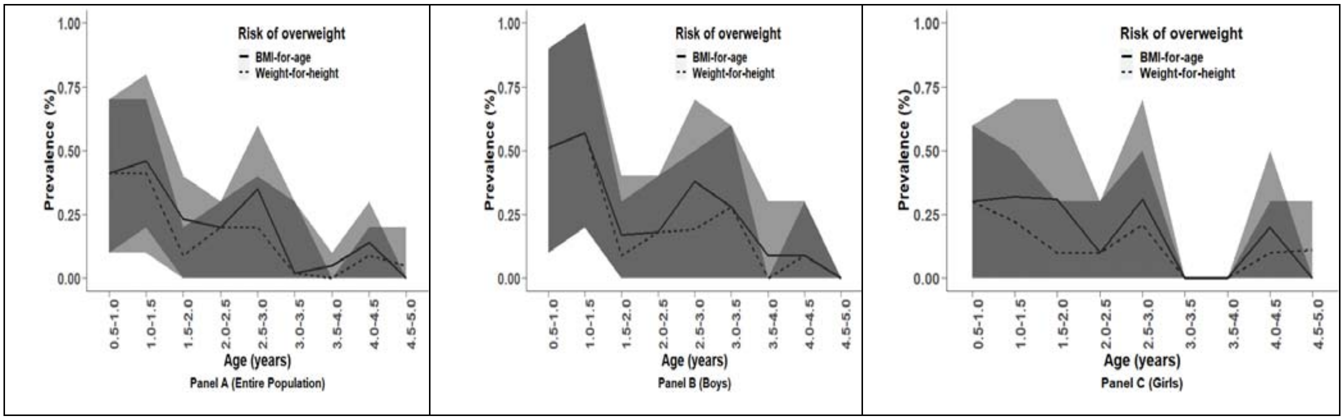
Panel C

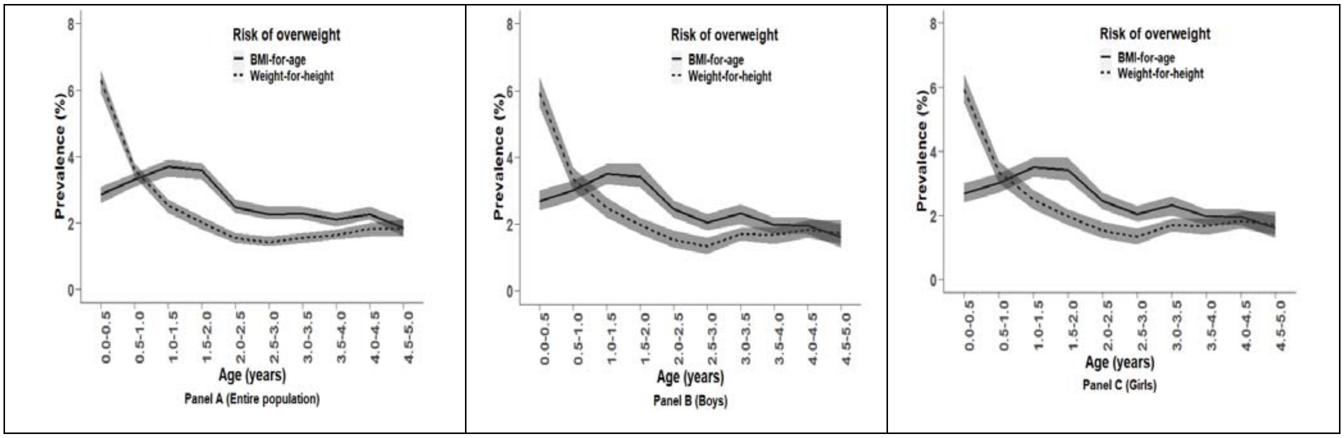
Web Fig. 4 Comparison of z-scores of weight-for-height and Body-Mass-Index-for-age for a fixed height-for-age (-2SD, 0SD, and +2SD) in boys (left side) and girls (right side) whose weight-for-age is at 0SD (Panel A), +1SD (Panel B) and +2SD (Panel C) of WHO growth reference.



Web Fig. 5 Comparison of estimated prevalence and 95% confidence intervals of risk of overweight (>2SD) using weight-for-height and Body-Mass-Index-for-age criteria on simulated populations: Panel A - short based on the National Family Health Survey-4, India data; Panel B - intermediate; Panels C, D and E - tall based on Poland, Greenland and the National Health and Nutrition Examination Survey, USA data, respectively.

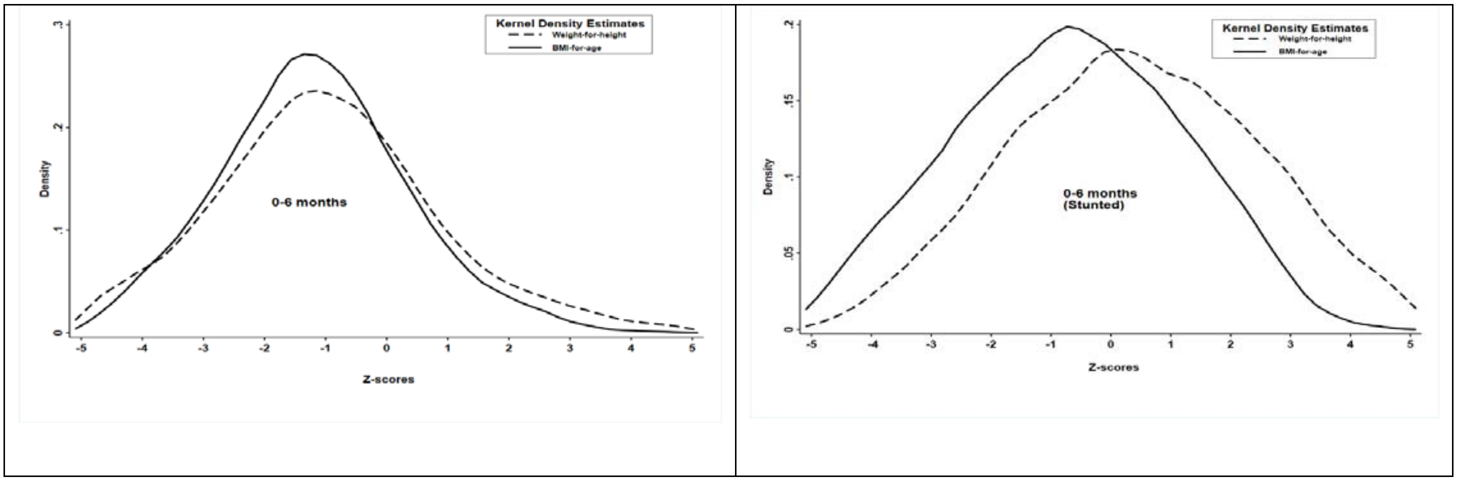
Meerut Study



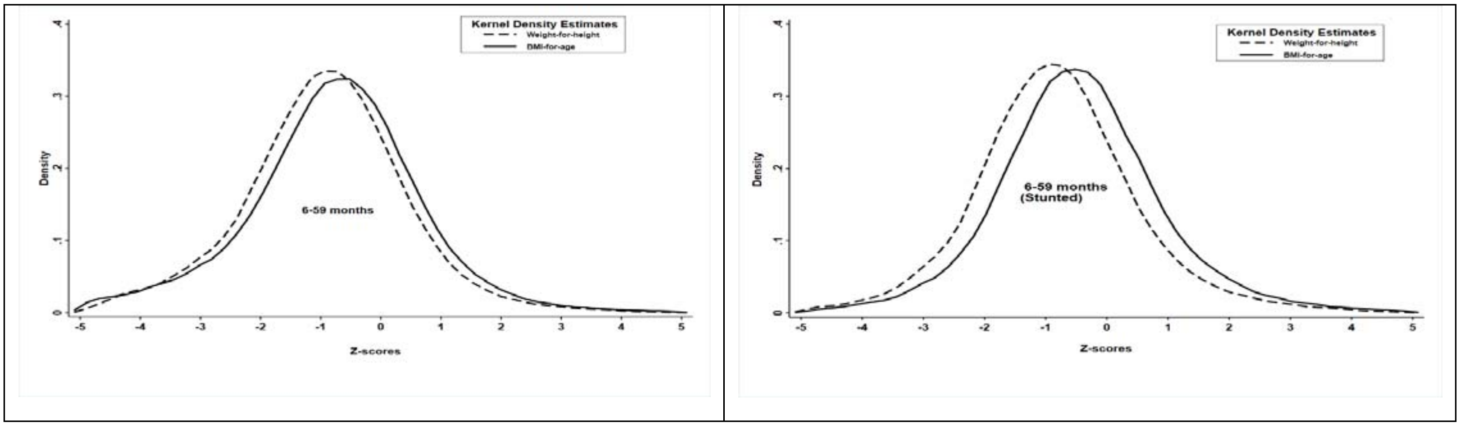


NFHS-4

Web Fig. 6 Comparison of estimated prevalence and 95% confidence intervals of overweight (>2SD) using weight-for-height and Body-Mass-Index-for-age criteria in Meerut (above) and National Family Health Survey-4 (below), India datasets: Panel A – Entire population, Panel B – Boys, and Panel C – Girls.



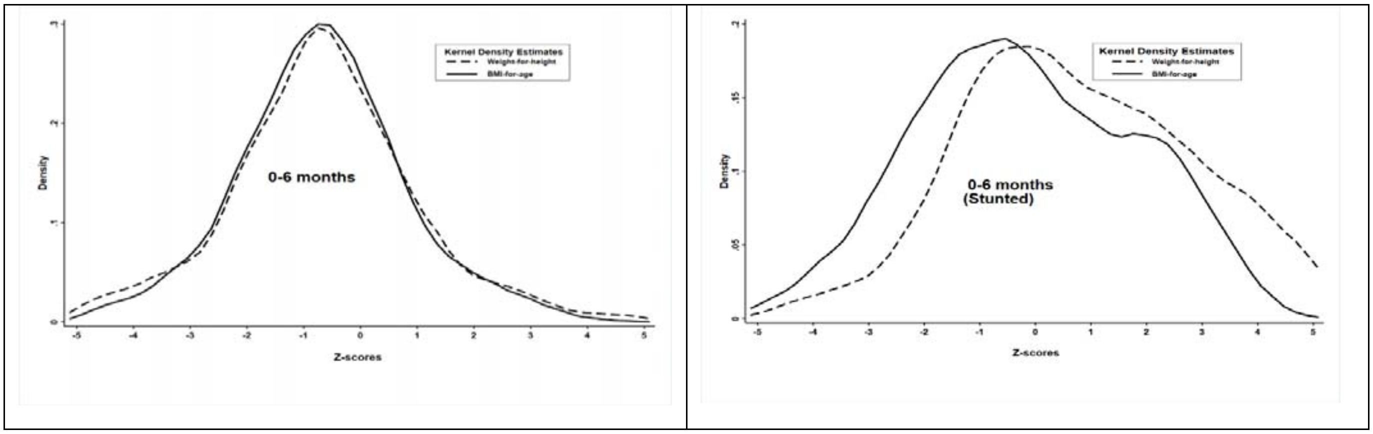
(0-6 months)



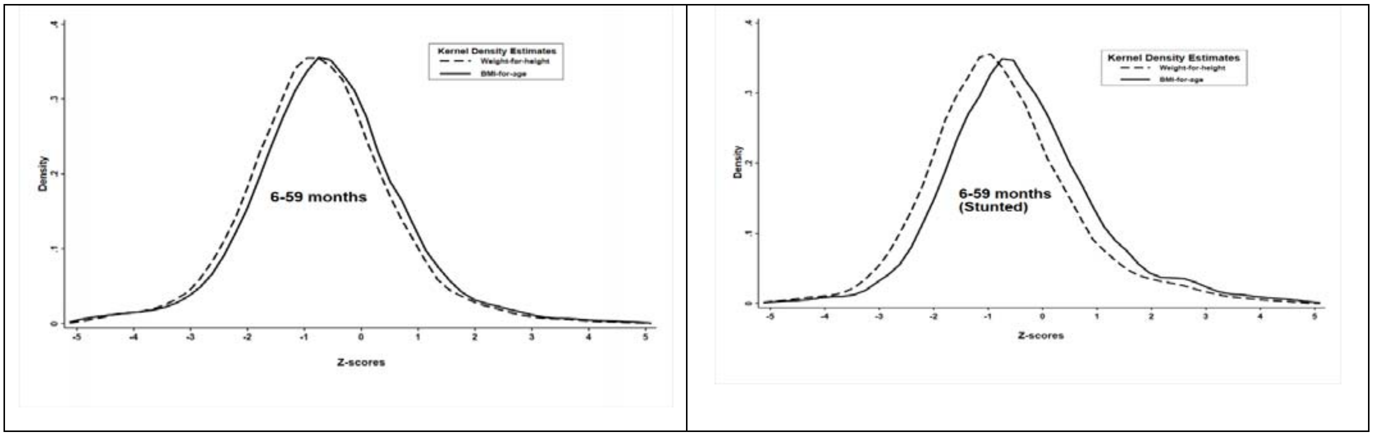
(6-59 months)

Panel A **Panel B**

Web Fig 7 Kernel density estimates for z-scores of Weight-for-height and Body-Mass-Index-for-age in NFHS 4 dataset: Panel A: Overall and Panel B: Stunted.



(0-6 months)



(6-59 months)

Panel A **Panel B**

Web Fig. 8 Kernel density estimates for z-scores of weight-for-height and Body-Mass-Index-for-age in Comprehensive National Nutrition Survey dataset: Panel A: Overall and Panel B: Stunted.