BMI status relative to international and national growth references among Pakistani school-age girls

Asima Karim (✉ akarim@sharjah.ac.ae)

University of Sharjah <https://orcid.org/0000-0002-6288-0686>

Rizwan Qaisar

University of Sharjah

Research article

Keywords: Underweight, overweight, obesity, schoolgirls, Punjab

Posted Date: May 21st, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-29793/v1>

License: This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background

A sizable proportion of school going children from developing countries has abnormal growth parameters, which are often not standardized with international reference values. We intended to evaluate the prevalence of BMI status in schoolgirls of the Punjab by using international and national references.

Methods

In this population based cross-sectional study, 10,050 school-going girls aged 8–16 years from 12 districts of northern, central and southern Punjab were recruited. Estimates of normal weight, underweight, overweight and obesity were calculated in the girls according to three international BMI references including centres for disease control (CDC) 2000, international obesity task force (IOTF) 2012 and world health organisation (WHO) 2007 in addition to national reference for population under study. We used Cohen's kappa statistics to analyse agreement of our data with reference values.

Results

There was marked overestimation of underweight (23.9%, 14.5%, 15.2% and 4.37%), slight underestimation of overweight (5.3%, 7.3%, 7.9% and 8.97%) and moderate underestimation of obesity (1.9%, 1.5%, 2.2% and 5.67%) according to CDC, IOTF, WHO and local reference, respectively. When the weight status of the study cohort was compared with the local data, we found comparable results in all the four weight categories.

Conclusion

We recommend selection of appropriate reference to estimate prevalence of weight status in school-age girls for devising strategies for public health policy and management.

Background

There is an increasing prevalence of abnormal growth including weight gain and underweight (1). Pakistan faces dual burden of co-existence of overweight/obesity and underweight due to abnormalities in nutritional status both in childhood and adolescent period. Overweight and obesity may be attributed to life style transitions, whereby a switch to sedentary lifestyle leads to a weight gain in populations which previously had a trend of underweight or normal weight (2, 3). On the other hand, childhood malnutrition/underweight also imposes negative impact on the health status and a predisposing factor for ill health in adults. Both the abnormalities in weight status i.e. overweight and underweight during childhood and adolescent periods of life contribute to development of several cardiac and metabolic

diseases in the adulthood (4–6). Estimates and intervention of underweight and overweight/obese in school aged population is an important prerequisite for applying preventive medicine in paediatrics and general health of population (7).

Several studies suggest that childhood obesity is associated with a number of nutrition related chronic diseases such as diabetes, cardiovascular diseases, and cancer in adulthood (4, 8). Additionally, adolescence is considered a high-risk period for the weight gain due to changes in body composition, insulin sensitivity, eating habits, and physical activity (9, 10). In teen age girls during adolescent period the chances of being underweight are also high due to change in eating habits or improper diet intake because of being conscious about self-image. Weight gains and undernutrition are two common problems in school-going girls in Pakistan, with major repercussions in later life. Unfortunately among school children, girls are more prone to obesity than boys owing to inherent difference in the pattern of female hormones (11). Excess weight gains during this transitional phase in girls places them at an increased risk of accumulating increased body fat stores during the childbearing age. An effective way to combat obesity during adolescence is by adopting healthy lifestyle and eating habits which have far reaching outcomes on the health of female conception periods (9, 12, 13). On the other hand, poor nutrition especially in teen age girls during the adolescent period has harmful effects on the health of the adult females. Nutritional status of the girls influences the health outcomes of current and future generations (14), because being underweight for girls has a strong association with infertility (15). Malnutrition in school aged girls also has negative impact on their cognitive abilities and their educational performance (16). Malnutrition is widespread in the developing countries in pre-school girls and the condition worsens in the school years. Underweight is mostly related to under nutrition and an imbalance in calorie intake and expenditure, but several other factors also influence the intake and expenditure of calories (17). Due to ill impacts of this dual burden of abnormal nutrition on population health it is extremely important to understand its prevalence in the school aged girls.

In order to devise proper interventions, the first important task is to identify the high-risk paediatric population facing two extremes of nutrition and the ideal tool to estimate the weight extremes is using BMI (18). For the children aged 0 to 5 years the growth status is assessed by the universally accepted world health organisation (WHO) references (19). However, for the school aged children and adolescents there is no globally consensual single reference. Multiple studies on assessment of weight status in older children have no consensus on the utilisation of a single reference. Mostly one out of three accepted references are typically recommended in research or in the clinical practice. The criteria for estimating underweight, overweight and obese is almost similar according to centres for disease control (CDC), international obesity task force (IOTF) and WHO references, they differ in terms of categorizing the percentages of children falling in each category of weight status. Therefore, prevalence of several categories of nutritional status would vary by applying different references. Few studies conducted to estimate the growth status of Pakistani school children have utilised either WHO and/or CDC references to measure prevalence of two extremes i.e. under- and over- nutrition in older children and have found conflicting results (20–27). This indicates dire need to come to a consensus for using one reference and to generate indigenous population BMI cut-offs. In most of these national studies WHO reference has

been used as standard to estimate weight status of school aged students in Pakistan. However, the application of WHO references of weight status in South Asian school children has been criticized because of high metabolic rate of Asian children in comparison to the children in rest of the world (28). For example, an underestimation for prevalence of overweight and obese and overestimation for underweight have been reported in Pakistani school children according to WHO references (22). This discrepancy is partly explained by regional differences among populations, the methodology of constructing the BMI-for-age reference graphs and the criteria used to define BMI cut-offs (7, 29–31). Therefore, to correctly characterize the underweight and overweight/obese in Pakistani school aged children, the population specific BMI cut-offs need to be generated and validated as the interpretation of child's growth status depends upon the growth reference used (32). Additionally, the recommended three references have not been comprehensively applied to Pakistani population to explore the similarities and differences among them in estimating both extremes of nutrition. Moreover, the local BMI cut-offs, when compared with these references will help identify the discrepancy or consistency in classifying nutritional abnormalities in schoolgirls of Punjab, Pakistan.

Differences in the prevalence of underweight, overweight and obesity have been observed among different districts of Punjab (33). These differences in weight status can partly be explained by regional differences in geography and nutritional status of schoolgirls. Prevalence of obesity and underweight display variability which can be attributed to differences in the risk factors either at the individual level or area level (34). Regional variabilities can possibly be due to the characteristics/living style of individuals in that area, landscapes of the area itself and the execution of policies to combat abnormal nutrition in the region. It was found that the region influences childhood weight abnormalities more as compared to the individual characteristics (34). Regions having low levels of overweight/obesity might have cultural, environmental or policy related features to promote physical activity and provision of healthy diets among the school children thereby reducing the incidence of being overweight. On the other hand, high prevalence of underweight in certain regions might be attributed to undernutrition and due to high prevalence of chronic diseases leading to malnutrition. Several studies conducted in Pakistan to determine prevalence of abnormal weight status in children and adolescents have reported discrepancies in their results (20–26), indicating regional differences as one of the contributing factors leading to these variable results. Local data describing the regional differences as contributing factors for obtaining variable results in prevalence of weight status is scarce. Regional differences are important to be considered while tackling with the overweight/obesity and underweight for considering resource allocation and to conclude the success of area-based policies to deal with these weight abnormalities. Punjab being the most populous province of Punjab, a more thorough profiling of school children in this province is required in a region-specific manner before appropriate interventions can be implied. We recently compared the percentile values of selected schoolgirl population to international references (35), however the relative contribution of abnormalities of weight status to local percentile values are not known. Additionally, these changes are not performed in region specific manner. In this study we aimed to fill these gaps by exploring the comparability of local BMI references obtained from our study population with CDC, WHO and IOTF in assessing the weight status of 8–16 years old schoolgirls of the Punjab

overall and to northern Punjab (NP), central Punjab (CP) and southern Punjab (SP). We hypothesised that our study populations have weight status which only partially correlate with other international and national references and vary between the different regions of the province of Punjab.

Methods

Study group

The study was conducted at the Department of Physiology & Cell Biology, University of Health Sciences, Lahore starting in January 2015 after obtaining ethical approval from The Institutional Ethical Review Committee (vide letter no UHS/ERB/22546/2014).

In this cross-sectional study, stratified multi-stage cluster sampling technique was employed to obtain data of 10,050 schoolgirls aged 8–16 years from 12 districts of NP, CP and SP. The study participants were recruited from 35 different public and private sector schools located in rural, semi-urban and urban areas of the Punjab. The province of Punjab was considered the stratum and was divided into central, northern, and southern Punjab (sub-stratum) keeping in view their geographical location, topography, climatic condition, and population for objective sampling. According to the population density, data was collected from 1355 (13.5%) girls from NP, 6580 (65.47%) from CP and 2115 (21%) from SP. 12 out of 36 districts (geographically subdivided by the government) of Punjab and considered as clusters were selected from each identified sub-stratum for data collection. Districts were stratified using probability proportional to size technique taking into consideration the percentage of adolescent population in each district after obtaining information from Pakistan census bureau (36). Lists of schools were obtained and school names were stratified considering their urban, semi-urban and rural status. From the selected schools, the grades were selected based upon the age criterion of our study. The students were selected randomly from each selected grade. Due consideration and weightage were given to ethics and privacy rights from the beginning. Parents of the girls were informed about the procedure of data collection and prior consents were obtained. Normal and healthy girls were recruited for this study and those having any past medical history or suffering from metabolic syndrome (like Prader-willi syndrome) or not willing to participate were excluded. To ensure the exact age, the date of birth of each participant was obtained from the school register. The age of the subjects was then calculated from the date of sampling in exact day/month/year. The study population was divided into 12 monthly 9 groups. However, for the analysis and documentation purposes the ages were truncated to full years: thus: for example, 10 years refers to participants aged between 9.5–10.49 years. In this study we have not stratified our study population based on the socio-economic status, however, our data includes representatives from all the classes. Therefore, we are confident that socio-economic class will have little/no effect on our pooled data. The demographic data about the girls was obtained by filling in the questionnaires one to two days prior to our visit to the school for data collection.

Anthropometric measurements:

Anthropometric measurements were recorded for everyone by trained personnel following CDC's recommendations given in anthropometry procedures manual 2007 by National Health and Nutrition Examination Survey (NHANES) (37). The assistants in data collection belonged to the medical field and were given extensive training previously to ensure the data quality. The anthropometric measurements comprised recording of the weight, height, done in all the subjects.

The same equipment was used to obtain anthropometric data from all the participating subjects for quality assurance. All the measurements were done from eight to eleven in the morning during the school timings with due permission from the principal/dean of the participating school.

Weight in Kilograms of the participants was measured with light clothing without shoes using a digital scale (City scale, Fzc, UAE) to the nearest 0.2 Kg. Weighing scale was calibrated with a set of 20 kg weight to ensure accuracy following a standard protocol.

Standing Height is the measurement of maximum vertical size of the body and was measured with a portable stadiometer (SECA 217, SECA, USA), consisted of a vertical stand and an adjustable headpiece. Height was measured to the nearest of 0.1 cm. stadiometer was calibrated with a set of predefined lengths to ensure accuracy. While recording the standing height, correct body posture was attained.

Statistical analysis:

All data entry and analysis were performed using SPSS Version 15.0 (SPSS Inc. Chicago IL, United States, 2009). BMI calculated by the formula $BMI = \text{weight (kgs)} / \text{height (m}^2\text{)}$. Data were presented as Mean $\pm$ SD for 'n' where n representing the number of study participants. The outliers, *i.e.*, values above and below 4SD were considered outliers and not included in the analysis. The outliers were identified from the z-score plot of the parameter under consideration and excluded from the dataset. The four levels of weight status [normal weight, underweight, overweight, or obese] were expressed according to the cut offs obtained from three international BMI references and the cut offs obtained from the study participants. The three international BMI references used in this study were CDC, IOTF and WHO.

The CDC 2000 reference contains data from 32,653 children aged 2 to 20 years of age. This reference encompasses United States surveys and additional data from some national surveys conducted until the year 1994. According to this international reference the BMI-for-age $\geq$ 5th percentile is considered UW, $\geq$ 85th percentile is considered OW and $\geq$ 95th percentile as Ob (30).

The IOTF 2012 reference contains data from 1,92,727 children aged 2 to 18 years of age. This reference encompasses data from six countries namely Hong Kong, Great Britain, Singapore, Netherlands, Brazil, and the United States of America through the national health surveys conducted between 1963 to 1993. According to this international reference, BMI at the age of 18 with a value of 18.5, 25 and 30 kg/m² respectively is considered as underweight, overweight and obese. Therefore, in girls BMI-for-age $\geq$ 16.5th percentile, $\geq$ 89.3rd percentile and $\geq$ 98.6th percentiles is considered underweight, overweight and obese, respectively (31).

The WHO 2007 reference contains data obtained from 22,917 children aged 5–19 years of age. This reference encompasses data from the three surveys conducted on the US national population between 1963–1974. In addition to this the WHO 2007 reference also contains data retrieved from the Multicenter Growth Reference Study from 1997–2003. According to this international reference BMI-for-age $\pm$ 2SD below the mean, $\pm$ 1SD above the mean and $\pm$ 2SD above the mean is considered underweight, overweight and Obese, respectively (38).

We also obtained BMI cut offs from our study group data by using BMI-for-age $\pm$ 2SD below the mean, $\pm$ 1SD above the mean and $\pm$ 2SD above the mean considering as underweight, overweight, and obese, respectively. In order to have a good comparable data across the references we compared the data of our study group of girls 8–16 years with age and sex matched values obtained from three international references and then applied cut-offs obtained from our data and estimated all the four weight categories in the study group. The incidences of normal weight, underweight, overweight, and obese were calculated for the pooled data to estimate the overall incidence in the province and then in all the three substrata i.e. NP, CP, and SP individually. Prevalence of normal weight, underweight, overweight, and obesity in different regions of the Punjab was compared by the chi-squared tests. Cohen kappa statistic was applied to estimate the overall agreement between the 3 international references and the study population cut-offs with all the three international references while classifying normal weight, underweight, overweight, and obese. Kappa $\geq$ 0.6 was defined as the poor agreement, 0.6 to $\geq$ 0.8 as moderate agreement and $\geq$ 0.9 as excellent agreement (39). The incidence of various weight status categories was compared by using chi square test and $p \leq 0.05$ was considered statistically significant.

Results

The mean age of 10,050 schoolgirls included in this study was of 12.7 ± 2.29 years (Mean $\pm$ SD). The overall prevalence of normal weight, underweight, overweight and obesity was measured in the study population ($n = 10,050$) using three references and the study population cut-offs (Fig. 1). Overall, according to all the three references the percentage of normal weight girls of all age groups under study was comparable (68.9%, 76.8%, 74.6% according to CDC, IOTF and WHO respectively). However there was notable prevalence of overweight (5.3%, 7.3%, 7.9% of our cohort were overweight according to CDC, IOTF and WHO respectively) and obesity (1.9%, 1.5%, 2.2% of our cohort were obese according to CDC, IOTF and WHO respectively) and a high prevalence of underweight (23.9%, 14.5%, 15.2% children were underweight according to CDC, IOTF and WHO respectively) especially in younger age groups (8, 9 years) in our paediatric population (Table 1). When we applied the local BMI cut-offs obtained from our study population then prevalence of normal weight population was significantly higher (81%; $p \leq 0.05$; Fig. 1a), prevalence of overweight and obesity was higher (8.97% and 5.67% respectively; $p \leq 0.05$; Figs. 1c & d) and a particularly lower prevalence of underweight (4.37%; $p \leq 0.05$; Fig. 1b) was found in comparison with the three international references. The estimates of prevalence of growth status categories varied broadly between the three references. However, notably when the study group cut-offs were applied the estimates for the prevalence of all weight categories displayed comparable results (Table 1). We compared BMI values from our cumulative study cohort with CDC, WHO and IOTF references by applying kappa

correlation. There was poor agreement of the study population with WHO and IOTF respectively ($\kappa = 0.44$; 0.44), while the correlation between study population and CDC had least agreement ($\kappa = 0.27$).

Table 1

Incidence of four weight status categories (underweight, normal weight, overweight and obesity) using age- and gender- specific BMI cut-offs from the Centres for Disease Control and prevention (CDC), International Obesity task Force (IOTF), World Health Organization (WHO) and the study group in the girls of Punjab; (n = 10,050).

CDC reference									
BMI Status Categories	8 y	9 y	10 y	11 y	12 y	13 y	14 y	15 y	16 y
Underweight n (%)	35.7	34.8	23.7	24	19.6	18.7	22.4	21.9	29.4
Normal weight n (%)	56.1	60.1	66.4	69.5	74.7	74.8	71.2	69.3	62.9
Overweight n (%)	4.3	3.6	7.7	5.2	3.5	5.7	4.6	6.2	6.1
Obese n (%)	3.9	1.5	2.2	1.3	2.2	0.9	1.8	2.5	1.7
IOTF reference									
Underweight n (%)	19.3	22.8	18.3	18.5	15.2	13.9	7	12.9	13.9
Normal weight n (%)	72.4	70.6	72.4	72.4	77.1	77.4	83.6	78.7	76.3
Overweight n (%)	4.8	5.1	7.8	7.8	6.5	7.7	8	6.9	8.2
Obese n (%)	3.5	1.5	1.5	1.3	1.2	1.1	1.5	1.4	1.7
WHO reference									
Underweight n (%)	17	22.8	20	19.8	16.8	14.5	13.3	10.7	11.3
Normal weight n (%)	73	69.3	68.2	68.4	73.9	75.1	76.4	80	78.4
Overweight n (%)	6.3	5.6	9.5	9.2	7.2	8.2	8.1	7.5	8.3
Obese n (%)	3.7	2.3	2.2	2.7	2.2	2.2	2.2	1.8	2
Study group reference									
Underweight n (%)	5	4.29	4.59	4.08	4.44	4.35	5.09	4	3.77
Normal weight n (%)	80.87	81.68	79.03	80.82	80.9	80.97	80.32	82.95	80.91
Overweight n (%)	7.39	9.9	11.19	9.08	9.43	8.96	8.59	7.79	8.83
Obese n (%)	6.74	4.13	5.18	6.02	5.22	5.72	6.01	5.26	6.49

To dissect region-specific differences, we sub-categorized our study population into three regions of Punjab (NP, CP and SP). We observed differences in the distribution of girls' weight status categories

across the study population subgroups when using three international references and local population cut-offs. Among the schoolgirls of NP (n = 1335) the estimates of percentages of normal weight children of all age groups accumulative were variable between all the references applied (63.7%, 67.4%, 70.9%, $p \leq 0.05$; according to CDC, IOTF and WHO respectively) with the highest percentage found when local cut-offs were applied (73.65%; $p \leq 0.05$; Table 2, Fig. 2a). Estimates of underweight prevalence varied hugely when values were compared after applying the three references and in between the several age groups analysed. Estimates for underweight prevalence were quite similar when using IOTF and WHO references (11.1% and 11% respectively), but estimates using CDC reference were noticeably higher (18.2%; $p \leq 0.05$; Fig. 2b). The prevalence of underweight was strikingly lower in all the age groups when the study population cut-offs were applied (2.58%; $p \leq 0.05$; Fig. 2b). Estimates of overweight were largely in agreement when the three international references, when the local cut offs were applied (10.3%, 13.1%, 13.7%, 12.92%; according to CDC, IOTF, WHO and local cut-offs respectively, Fig. 2c). However, the incidence of obesity was significantly higher with the local cut-offs (10.85%, $p \leq 0.05$) in comparison to all three references (3.8%, 3%, 4% according to CDC, IOTF and WHO respectively; Fig. 2d), with highest prevalence among the 16 year old girls (15.65%).

Table 2

Incidence of four weight status categories (underweight, normal weight, overweight and obesity) using age- and gender- specific BMI cut-offs from the Centres for Disease Control and prevention (CDC), International Obesity task Force (IOTF), World Health Organization (WHO) and the study group in the girls of Northern Punjab; (n = 1355).

CDC reference									
BMI Status Categories	8 y	9 y	10 y	11 y	12 y	13 y	14 y	15 y	16 y
Underweight n (%)	25.5	27.9	17.4	12.6	15.2	15	18.7	14.2	20
Normal weight n (%)	60.6	60.7	71.3	72	75.6	70.5	68.7	63.9	60.9
Overweight n (%)	8	7.1	9	10.5	6.1	12.1	9.3	15.5	16.5
Obese n (%)	5.8	4.3	2.2	4.9	3	2.3	3.3	6.5	2.6
IOTF reference									
Underweight n (%)	14.6	17.1	14	9.8	11	12.1	6.7	5.8	8.7
Normal weight n (%)	71.5	69.3	74.7	72	76.2	71.1	76	72.3	69.6
Overweight n (%)	8.8	9.3	9.6	13.3	11.6	13.9	15.3	18.7	19.1
Obese n (%)	5.1	4.3	1.7	4.9	1.2	2.9	2	3.2	2.6
WHO reference									
Underweight n (%)	11.7	17.1	14	11.2	12.2	12.7	8	3.9	7
Normal weight n (%)	73	67.9	71.9	68.5	72	68.2	72.7	72.9	71.3
Overweight n (%)	10.2	7.9	11.8	13.3	12.8	14.5	16	19.4	18.3
Obese n (%)	5.1	7.1	2.2	7	3	4.6	3.3	3.9	3.5
Study group reference									
Underweight n (%)	2.19	2.14	2.81	1.4	1.22	2.31	5.33	1.94	4.35
Normal weight n (%)	75.91	73.57	78.09	75.52	77.44	71.1	72.67	70.32	66.09
Overweight n (%)	9.49	15	12.92	9.79	12.8	16.18	10.67	14.84	13.91
Obese n (%)	12.41	9.29	6.18	13.29	8.54	10.4	11.33	12.9	15.65

Estimates of normal weight varied markedly in the girls of CP (n = 6580) across all four references applied (67.4%, 76.3%, 74.2% according to CDC, IOTF and WHO respectively) and the highest incidence of

normal weight girls was found with local cut-offs (82.49%, $p \leq 0.05$, Table 3, Fig. 3a). Estimates of underweight prevalence was very high across the three references, with the highest estimates obtained with CDC reference (26.9%, 16.7%, 17.6%, according to CDC, IOTF and WHO respectively, Fig. 3b). Strikingly low estimates of underweight prevalence in all the age groups were observed with the application of local cut-offs (5.27%, $p \leq 0.05$). Estimates for overweight and obesity prevalence were comparable (4.3%, 6%, 6.4% and 1.5%, 1.1%, 1.8% for overweight and obesity respectively, Figs. 3c & d) when using CDC, IOTF and WHO respectively, while prevalence estimates of overweight and obesity were found to be noticeably higher using local cut-offs (7.69%, 4.54% respectively).

Table 3

Incidence of four weight status categories (underweight, normal weight, overweight and obese) using age- and gender- specific BMI cut-offs from the Centres for Disease Control and prevention (CDC), International Obesity task Force (IOTF), World Health Organization (WHO) and the study population in the girls of Central Punjab; (n = n = 6580)

CDC reference									
BMI Status Categories	8 y	9 y	10 y	11 y	12 y	13 y	14 y	15 y	16 y
Underweight n (%)	42	42	29.4	27.9	23.3	20.6	25	23.3	31.9
Normal weight n (%)	53.2	55.9	62.6	66.7	72.1	74.2	69.8	69.3	61.1
Overweight n (%)	2.2	2.1	6.7	3.8	2.9	4.3	3.6	5.3	5.3
Obese n (%)	2.6	2.1	1.3	0.6	1.7	0.9	1.7	2.1	1.6
IOTF reference									
Underweight n (%)	22.5	29.1	23.3	21.9	18.8	15.2	7.7	14.7	15.8
Normal weight n (%)	72.7	67.9	69.1	71.9	75.2	77.3	84.5	78.4	75.4
Overweight n (%)	2.6	3	6.7	5.5	5.3	6.5	6.4	5.9	7.2
Obese n (%)	2.2	0	0.9	0.6	0.7	1	1.4	1	1.6
WHO reference									
Underweight n (%)	20.8	29.1	25.7	22.9	20.6	15.8	15.3	12.6	12.8
Normal weight n (%)	72.3	66.1	64.4	69.1	72.1	75.5	76.2	79.6	78.1
Overweight n (%)	4.3	4.5	8.6	6.2	5.6	6.6	6.4	6.4	7.2
Obese n (%)	2.6	0.3	1.3	1.9	1.7	2.1	2	1.4	1.9
Study group reference									
Underweight n (%)	6.93	6.61	7.13	4.89	6.01	5.14	5.76	4.62	3.48
Normal weight n (%)	83.12	84.38	79.48	83.75	81.85	82.28	81.27	84.44	82.4
Overweight n (%)	6.93	7.21	10.15	7.1	7.81	7.81	7.9	6.33	8.19
Obese n (%)	3.03	1.8	3.24	4.26	4.33	4.78	5.07	4.62	5.94

Among the girls of SP (n = 2115) estimates of normal weight were comparable according to all the four references used (74.4%, 80.9%, 78.2%, 81.04% according to CDC, IOTF, WHO and local references respectively, Table 4, Fig. 4a). We observed marked variation in the distribution of underweight estimates across the study groups. Underweight prevalence was found to be comparable when WHO and IOTF references were used (10.6%, 9.8% respectively, Fig. 4b), it was significantly higher with CDC reference

(18.3%, $p \leq 0.05$). The estimates of underweight were strikingly lower (2.7%, $p \leq 0.05$) and consistency was observed among all the age groups of girls analysed when local cut-offs were applied (Fig. 4b). The overall prevalence of overweight (10.4%) and obesity (5.86%) was higher when local cut-offs applied as compared to CDC, IOTF and WHO references ($p \leq 0.05$; Figs. 4c & d).

Table 4

Incidence of four weight status categories (underweight, normal weight, overweight and obese) using age- and gender- specific BMI cut-offs from the Centres for Disease Control and prevention (CDC), International Obesity task Force (IOTF), World Health Organization (WHO) and the study population in the girls of Southern Punjab; (n = 2115).

CDC reference									
BMI Status Categories	8 y	9 y	10 y	11 y	12 y	13 y	14 y	15 y	16 y
Underweight n (%)	34.8	24.1	16.3	19.7	11.1	14.5	16.2	21.2	23.2
Normal weight n (%)	56.5	69.9	70.7	73.4	81.9	78.6	76.7	72.6	71.2
Overweight n (%)	4.3	3.8	8.7	5.9	3.8	6.6	5.3	4.4	4.3
Obese n (%)	4.3	2.3	4.3	1	3.1	0.3	1.8	1.8	1.3
IOTF reference									
Underweight n (%)	18.5	12.8	10.6	13.8	7.3	10.7	5	10.6	8.6
Normal weight n (%)	72.8	78.9	77.9	74.4	82.9	80.6	84.1	83.6	93.3
Overweight n (%)	4.3	6	8.7	10.8	7.3	8.4	9.4	4	6.9
Obese n (%)	4.3	2.3	2.9	1	2.4	0.3	1.5	1.8	1.3
WHO reference									
Underweight n (%)	15.2	12.8	12.5	16.3	8	11.3	9.4	8	7.3
Normal weight n (%)	75	78.9	73.6	66	80.1	77.5	78.8	85.4	83.3
Overweight n (%)	5.4	6	9.6	15.8	8.4	10.1	9.7	4.7	8.2
Obese n (%)	4.3	2.3	4.3	2	3.1	1.2	2.1	1.8	1.3
Study group reference									
Underweight n (%)	4.35	0.75	0.48	3.45	1.74	2.89	2.95	2.92	4.72
Normal weight n (%)	82.61	83.46	78.85	75.37	80.14	81.79	80.83	84.67	81.97
Overweight n (%)	5.43	11.28	12.02	14.78	12.2	8.96	9.73	9.12	9.01
Obese n (%)	7.61	4.51	8.65	6.4	5.92	6.36	6.49	3.28	4.29

When the three regions of Punjab i.e. NP, CP and SP were compared for prevalence of weight status by applying local BMI cut-offs, the school girls of CP had the highest prevalence of being underweight as

compared to NP and SP (Fig. 5a). The girls belonging to NP had the highest prevalence of overweight and obese population as compared to central and southern Punjab (Figs. 5b & c).

Prevalence of normal weight, underweight, overweight and obesity according to CDC, IOTF, WHO and local population cut-offs were compared by the chi-squared tests and found significantly different among the girls of northern, central, and southern Punjab ($P < 0.001$). In summary, when CDC, IOTF and WHO references were employed the prevalence of underweight was strikingly higher, estimates of overweight were moderately lower and obesity was remarkably lower in comparison to the local reference.

Discussion

In this study of school going girls aged 8–16 years from the Punjab, we observed a very high prevalence of underweight and a notable burden of overweight and obesity among girls with the application of CDC, WHO and IOTF references. The incidence of underweight was highest with CDC as compared to WHO and IOTF and the incidence of overweight and obesity was generally comparable with all three references. Overall, the three references showed good agreement among themselves when they were applied to underweight and overweight status in our paediatric population (Fig. 1). Notably we found that there was a poor agreement when we compared the three international references (CDC, IOTF and WHO) and the study population own BMI cut-offs. Our data suggests that the choice of BMI reference may significantly influence the estimates for prevalence of underweight, overweight and obesity, which can in turn influence strategies adopted by the health resources to address these abnormalities. Additionally, these estimates may substantially affect the decisions by the paediatricians to recommend clinical advice and management.

Our results reinforce the existing problem of dual burden of abnormal nutrition in Pakistani population (1, 26, 27), where obesity is on an increase on one side of the spectrum and underweight is also rising on the other hand. In the recent years in Pakistan there is little emphasis on estimating prevalence of overweight in a region-specific manner, despite the fact that occurrences of overweight and obesity are increasing among school going children (20, 23–27, 40, 41). Few studies conducted to evaluate the weight problems used inconsistent references to define overweight and obesity which undermine their usefulness in assessing and characterizing local populations. We addressed this problem by simultaneously applying all three major international and one national reference values to regional populations of Punjab to allow for a streamlined clinical action and meaningful comparison of incidence of abnormal weight status between the studies.

When WHO percentiles were applied to the Pakistani school aged children there was an underestimation for prevalence of overweight and obesity and overestimation for underweight (22). Our study supports this trend and showed an underestimation of overweight/obesity and overestimation of underweight when CDC, IOTF and WHO references were applied. Our results also indicate that the references applied to assess growth status are inconsistent even when utilized between demographic smaller groups.

Our study results are in good agreement with a latest study conducted on 1244 Pakistani children aged 7–18 years (20), where the researchers applied the study population BMI cut-offs to estimate weight status in these children. We found majority of the study population (81%) had the normal weight according to the study population cut-offs, this agrees with the previous study where they found 79.2% children were normal weight. The prevalence of underweight in our study was 4.37% which is comparable with the incidence of 5.2% reported in the above mentioned study (20), but contrasts with findings from previous studies with underweight prevalence of 29.7% and 27.3% according to National Health Survey of Pakistan (NHSP) and Karachi surveys respectively (27). In these national health surveys, the study population (5–14 years) was slightly younger than the present study (8–16 years) with a smaller sample size ($n = 2074$) than ours ($n = 10,050$). Further, they only applied WHO reference to estimate underweight incidence, while ignoring CDC and IOTF references. Moreover, we also noticed that when we applied WHO reference on our data the overall incidence of underweight was found to be 15.2%, which suggests that WHO reference overestimates underweight prevalence in our population.

The overall overweight prevalence of 8.97% was similar to that in the latest study on Pakistani children of 9.2% where the researchers applied indigenous BMI cut-offs (20). This however differed from the NHSP and Karachi survey which reported incidences of overweight and obesity as 3% and 5.7% respectively (27), lower than the incidence in our study group. Similarly incidence of overweight in our paediatric population as reported in previous national studies is quite inconsistent and reported to be 17% (5–12 years) with WHO reference, 33% with IOTF reference (40); 19.1% (11–15 years) with CDC reference (24); 16% (10–14 years) with WHO reference (23); 8% (10–14 years) with modified BMI cut-offs for Asian population (26); 19% (6–17 years) with CDC reference (25). The overall prevalence of obesity in our 8–16 years old schoolgirls was 5.67%. This was comparable with the obesity incidence of 6.4% in a latest study conducted on Pakistani children 7–18 years of age where study population BMI cut-offs were applied (20). This was in agreement with the incidence of obesity reported by the Karachi survey of 5.7% (27). This incidence of obesity as reported by previous researchers in several studies conducted on Pakistani children showed inconsistent results (23, 24, 40) and also differed from our study estimates. Additionally, we observed significant differences in the estimates of weight status when school going girls from NP, CP and SP were compared (Figs. 2, 3, 4 & 5 respectively). The incidence of overweight and obesity was found to be highest in NP, and incidence of underweight was highest in the CP. We are not sure about the underlying factors contributing to these differences. However, these three regions of Punjab differ enormously in terms of climate, culture, geography, dietary patterns and living styles and these factors can possibly affect the growth of children and may lead to differences in estimates of abnormal nutrition incidences reported here.

This study highlights the importance of understanding the comparability of globally used references of anthropometric measurements when applied to our paediatric population and their degree of agreement with the study population own cut-offs. Several countries have emphasized the importance of generating local anthropometric references based upon the data collected from their own population (22, 42, 43). Data from such populations shows that it is not justifiable to utilise one reference as a universal one to all populations because growth pattern of children differs significantly between populations. It is difficult

to evaluate population-specific references in comparison with the international references as there is no established criteria for comparison. The population-specific references need to be validated robustly to be considered suitable for application especially in terms of predicting adverse health consequences in adulthood. Very scarce data available on health assessment of adults while applying local references (44). Although there is a consensus on the utilisation of international references in the younger age group, reference values are not well defined for the older children especially school aged population.

There are certain limitations of our study. First, the study was conducted on the girls and boys had not been included in the study. Second, this study was conducted in the Punjab which is one of the four provinces of Pakistan, so other provinces also need to be taken into consideration in future. Third, it was a cross sectional study, thereby depicting the estimates of malnutrition i.e. underweight, overweight and obesity at one time point. Longitudinal studies are recommended to generate population specific reference, to trace the trend of abnormal weight status and to assess the future risk of cardiometabolic and other adverse outcomes in adulthood.

Conclusions

In conclusion, we observed noticeable differences in estimating the incidence of abnormal nutrition for classification of underweight, normal weight, overweight and obesity among the school girls of Punjab aged 8–16 years of age when CDC, IOTF, WHO and local references were applied to the study population. There was a notable incidence of overestimation for underweight and underestimation of overweight and obesity among the study population when the international references were applied in comparison to study population own references. Our results indicate the importance of conducting longitudinal studies to generate population specific references. Estimation of weight status should be uniform throughout the population to initiate nationwide policies to combat with the dual burden of abnormal nutrition existing in our school age girls.

Abbreviations

BMI

Body mass index

CDC

Centres for disease control and prevention

WHO

World health organization

IOTF

International obesity task force

IREC

Institutional ethical review committee

NHANES

National health and nutrition examination survey

Declarations

Ethics approval and consent to participate:

The study was approved by the institutional ethical review committee of University of Health sciences, Lahore. An informed written consent was obtained from the parents or legal guardians of schoolgirls participated in this study.

Consent for publication:

Not applicable.

Availability of data and materials:

Data is included in the form of supplementary tables in the manuscript. The datasets analysed in this study are available from corresponding author upon reasonable request.

Competing interests:

The authors have no competing interests to declare in relation to the work presented here.

Funding information:

No funding was obtained from any source for conducting this study.

Author's contributions:

Conception and design: AK & RQ

Analysis, statistical evaluation and interpretation of data: AK & RQ

Drafting of the manuscript: AK & RQ

Critical revision of the article for important intellectual content: AK & RQ

Final approval of the manuscript: AK & RQ

Acknowledgements:

The authors would like to acknowledge University of Health Sciences, Lahore, Pakistan for providing the support. The data has been archived in the Department of Physiology & Cell Biology at the University of Health Sciences, Lahore. The authors would like to acknowledge the assistance rendered by the trained health workers in obtaining the data and getting the questionnaires filled in from the students. We would also like to acknowledge the support of school administration, children and their parents for permission to collect data.

References

1. Pappas G, Akhtar T, Gergen PJ, Hadden WC, Khan AQ. Health status of the Pakistani population: a health profile and comparison with the United States. *Am J Public Health*. 2001;91(1):93–8.
2. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev*. 2012;70(1):3–21.
3. WHO. Action plan to reduce the double burden of malnutrition in the western pacific region (2015–2020). Geneva: World Health Organization; 2015.
4. Sahoo K, Sahoo B, Choudhury AK, Sofi NY, Kumar R, Bhadoria AS. Childhood obesity: causes and consequences. *J Family Med Prim Care*. 2015;4(2):187–92.
5. Bhargava SK, Sachdev HS, Fall CH, Osmond C, Lakshmy R, Barker DJ, et al. Relation of serial changes in childhood body-mass index to impaired glucose tolerance in young adulthood. *N Engl J Med*. 2004;350(9):865–75.
6. Lobstein T, Baur L, Uauy R, TaskForce IIO. Obesity in children and young people: a crisis in public health. *Obes Rev*. 2004;5(1):4–104.
7. de Onis M, Garza C, Onyango AW, Borghi E. Comparison of the WHO child growth standards and the CDC 2000 growth charts. *J Nutr*. 2007;137(1):144–8.
8. Choudhary AK, Donnelly LF, Racadio JM, Strife JL. Diseases associated with childhood obesity. *AJR Am J Roentgenol*. 2007;188(4):1118–30.
9. Alberga AS, Sigal RJ, Goldfield G, Prud'homme D, Kenny GP. Overweight and obese teenagers: why is adolescence a critical period? *Pediatr Obes*. 2012;7(4):261–73.
10. Neumark-Sztainer D, Story M, Perry C, Casey MA. Factors influencing food choices of adolescents: findings from focus-group discussions with adolescents. *J Am Diet Assoc*. 1999;99(8):929–37.
11. Power ML, Schulkin J. Sex differences in fat storage, fat metabolism, and the health risks from obesity: possible evolutionary origins. *Br J Nutr*. 2008;99(5):931–40.
12. Todd AS, Street SJ, Ziviani J, Byrne NM, Hills AP. Overweight and obese adolescent girls: the importance of promoting sensible eating and activity behaviors from the start of the adolescent period. *Int J Environ Res Public Health*. 2015;12(2):2306–29.
13. Kubo A, Deardorff J, Laurent CA, Ferrara A, Greenspan LC, Quesenberry CP, et al. Associations Between Maternal Obesity and Pregnancy Hyperglycemia and Timing of Puberty Onset in Adolescent Girls: A Population-Based Study. *Am J Epidemiol*. 2018;187(7):1362–9.

14. Christian P, Smith ER. Adolescent Undernutrition: Global Burden, Physiology, and Nutritional Risks. *Ann Nutr Metab.* 2018;72(4):316–28.
15. Boutari C, Pappas PD, Mintziori G, Nigdelis MP, Athanasiadis L, Goulis DG, et al. The effect of underweight on female and male reproduction. *Metabolism.* 2020;107:15422.
16. Jukes M. The long-term impact of preschool health and nutrition on education. *Food Nutr Bull.* 2005;26(2 Suppl 2):193–201.
17. Uzogara SG. Underweight, the Less Discussed Type of Unhealthy Weight and Its Implications: A Review. *American Journal of Food Science Nutrition Research.* 2016;3(5):126–42.
18. Chumlea WC, Schubert CM, Roche AF, Kulin HE, Lee PA, Himes JH, et al. Age at Menarche and Racial Comparisons in US Girls. *Pediatrics.* 2003;111.
19. de Onis M, Onyango A, Borghi E, Siyam A, Blossner M, Lutter C, et al. Worldwide implementation of the WHO Child Growth Standards. *Public Health Nutr.* 2012;15(9):1603–10.
20. Sadiq S, Qureshi MFH, Farooq L, Mohammad D, Lakhani M, Lodhi M. Reference percentile for height, weight and BMI among children/adolescents of Karachi Pakistan Research. *Journal of Food Science Nutrition Volume.* 2019;4(5):90–6.
21. Ahmed J, Laghari A, Naseer M, Mehraj V. Prevalence of and factors associated with obesity among Pakistani schoolchildren: a school-based, cross-sectional study. *East Mediterr Health J.* 2013;19(3):242–7.
22. Mushtaq MU, Gull S, Mushtaq K, Abdullah HM, Khurshid U, Shahid U, et al. Height, weight and BMI percentiles and nutritional status relative to the international growth references among Pakistani school-aged children. *BMC Pediatr.* 2012;12:31.
23. Hashmi A, Soomro JA, Saleem K. Prevalence of Obesity and Factors Leading to Obesity among High School Students of Pakistan. *J Medicine.* 2013;14:33–9.
24. Mansoori N, Nisar N, Shahid N, Mubeen SM, Ahsan S. Prevalence of obesity and its risk factors among school children in Karachi, Pakistan. *Trop Doct.* 2018;48(4):266–9.
25. Aziz S, Noorulain W, Zaidi UR, Hossain K, Siddiqui IA. Prevalence of overweight and obesity among children and adolescents of affluent schools in Karachi. *J of Pakistan Medical Association.* 2009;59(1).
26. Warraich HJ, Javed F, Faraz-Ul-Haq M, Khawaja FB, Saleem S. Prevalence of obesity in school-going children of Karachi. *PLoS One.* 2009;4(3):e4816.
27. Jafar TH, Qadri Z, Islam M, Hatcher J, Bhutta ZA, Chaturvedi N. Rise in childhood obesity with persistently high rates of undernutrition among urban school-aged Indo-Asian children. *Arch Dis Child.* 2008;93(5):373–8.
28. de Wilde JA, Dekker M, Middelkoop BJC. BMI-for-age in South Asian children of 0–20 years in the Netherlands: secular changes and misclassification by WHO growth references. *Ann Hum Biol.* 2018;45(2):116–22.

29. Borghi E, de Onis M, Garza C, Van den Broeck J, Frongillo EA, Grummer-Strawn L, et al. Construction of the World Health Organization child growth standards: selection of methods for attained growth curves. *Stat Med*. 2006;25(2):247–65.
30. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, et al. 2000 CDC Growth Charts for the United States: methods and development. *Vital Health Stat*. 2002;11(246):1–190.
31. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatr Obes*. 2012;7(4):284–94.
32. de Onis M, Onyango AW. The Centers for Disease Control and Prevention 2000 growth charts and the growth of breastfed infants. *Acta Paediatr*. 2003;92(4):413–9.
33. Di Cesare M, Bhatti Z, Soofi SB, Fortunato L, Ezzati M, Bhutta ZA. Geographical and socioeconomic inequalities in women and children's nutritional status in Pakistan in 2011: an analysis of data from a nationally representative survey. *Lancet Glob Health*. 2015;3(4):e229-39.
34. Hawkins SS, Griffiths LJ, Cole TJ, Dezateux C, Law C. Millennium Cohort Study Child Health G. Regional differences in overweight: an effect of people or place? *Arch Dis Child*. 2008;93(5):407–13.
35. Karim A, Qaisar R. Anthropometric measurements of schoolgoing-girls of the Punjab, Pakistan. *BMC Pediatrics*. 2020;20(223):1–13.
36. GOP. Census of Pakistan. Pakistan Census Bureau. Population census organization, statistics division, Islamabad, Government of Pakistan. Retrieved 2017 from <http://pap.org.pk/statistics/population.htm>. 2017.
37. CDC. Centers for Disease Control and Prevention. Anthropometry Procedures Manual (NHANES). http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf. [Accessed on Oct 2016].
38. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ*. 2007;85(9):660–7.
39. McHugh ML. Interrater reliability: the kappa statistic. *Biochem Med (Zagreb)*. 2012;22(3):276–82.
40. Mushtaq MU, Gull S, Abdullah HM, Shahid U, Shad MA, Akram J. Prevalence and socioeconomic correlates of overweight and obesity among Pakistani primary school children. *BMC Public Health*. 2011;11:724.
41. Tanzil S, Jamali T. Obesity. An Emerging Epidemic In Pakistan-A Review Of Evidence. *J Ayub Med Coll Abbottabad*. 2016;28(3):597–600.
42. Ma J, Wang Z, Song Y, Hu P, Zhang B. BMI percentile curves for Chinese children aged 7–18 years, in comparison with the WHO and the US Centers for Disease Control and Prevention references. *Public Health Nutr*. 2010;13(12):1990–6.
43. Khadilkar VV, Khadilkar AV. Revised Indian Academy of Pediatrics 2015 growth charts for height, weight and body mass index for 5-18-year-old Indian children. *Indian J Endocrinol Metab*. 2015;19(4):470–6.

44. Petkeviciene J, Klumbiene J, Kriaucioniene V, Raskiliene A, Sakyte E, Ceponiene I. Anthropometric measurements in childhood and prediction of cardiovascular risk factors in adulthood: Kaunas cardiovascular risk cohort study. BMC Public Health. 2015;15:218.

Figures

Figure 1

Age related prevalence of (a) normal weight, (b) underweight (c) overweight and (d) obesity in girls 8-16 years using the CDC 2000 (interrupted line), IOTF 2012 (dotted line), WHO 2007 (dashed line) and study group (solid line) BMI references in the Punjab (n=10050).

Figure 2

Age related prevalence of (a) normal weight, (b) underweight (c) overweight and (d) obesity in girls 8-16 years using the CDC 2000 (interrupted line), IOTF 2012 (dotted line), WHO 2007 (dashed line) and study group (solid line) BMI references in the northern Punjab (n=1355).

Figure 3

Age related prevalence of (a) normal weight, (b) underweight (c) overweight and (d) obesity in girls 8-16 years using the CDC 2000 (interrupted line), IOTF 2012 (dotted line), WHO 2007 (dashed line) and study group (solid line) BMI references in the central Punjab (n=6580).

Figure 4

Age related prevalence of (a) normal weight, (b) underweight (c) overweight and (d) obesity in girls 8-16 years using the CDC 2000 (interrupted line), IOTF 2012 (dotted line), WHO 2007 (dashed line) and study group (solid line) BMI references in the southern Punjab (n=2115).

Figure 5

Prevalence of (a) underweight, (b) overweight and (c) obesity in girls 8-16 years according to BMI cut-off values of international and national references in three regions of Punjab.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [STROBEchecklistcrosssectionalAK.doc](#)