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Original article

Assessment of the nutritional status of school children in Galle Municipality area: A comparison between different body mass index classification systems

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ABSTRACT

Introduction: Asian populations are at an increased risk of cardiometabolic disorders due to higher fat mass at a relatively lower body mass index (BMI). Several discrepancies have been reported in the BMI classification systems currently in practice to assess the nutritional status among children. Aim of this study was to compare the different international BMI based classification systems to identify the nutritional status in a cohort of Sri Lankan children.

Methods: A cross sectional study was conducted on 833 (48.37% boys) school children aged 5-15 years in Galle Municipality area, Sri Lanka. The nutritional status of each child was defined according to five BMI classification systems: World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), and International Obesity Task Force (IOTF), Indian and Sri Lankan systems. The agreement between them was tested using Cohen's kappa coefficient.

Results: Prevalence of under-weight, overweight and obesity of children, as determined by the WHO, CDC, IOTF, Indian and the Sri Lankan classification systems showed significant differences. The WHO classification system had the best agreement (k=0.649) with the Indian classification system. A wide difference between the Sri Lankan classification system (24.37%) and the Indian (9.60%) and WHO (5.04%) classification systems in defining obesity were observed.

Conclusion & recommendations: A wide difference between different BMI classification systems when determining the nutritional status in children emphasise the importance of developing a country-specific classification system to identify the nutritional status among Sri Lankan children.

Keywords: *Body Mass Index, CDC, Classification, IOTF Sri Lanka, WHO.*

Introduction

According to the World Health Organization (WHO), 42 million children under the age of five were overweight or obese, 156 million were affected by stunting and 50 million children were affected by wasting in 2014 (1). Children who suffered from malnutrition early in life, even *in utero,* are at a higher risk of having childhood obesity, poor school performance and non-communicable diseases later in life (1) with long-term impacts on economic and social outcomes especially in South Asia (2).

Due to the simplicity of the measurement, body mass index (BMI) is the most widely used anthropometric index for the assessment of nutritional status. The BMI changes considerably with age and dynamics of growth (3). Therefore, growth curves representing BMI as a function of age and sex have been introduced to ensure its applicability in the paediatric population. When the BMI cut-offs for overweight and obesity were lowered for South Asians based on evidence (4, 5), very little information surfaced about the other end of the spectrum, underweight over the years. Use of one set of BMI cut-off values for all ethnic groups has limitations, because the Asian populations have higher percentage of body fat than other populations and are at an increased risk of cardiometabolic disorders at a lower BMI compared to other ethnic groups (6). In addition, varying underweight rates were reported between countries, especially due to differences in socioeconomic factors (7). South Asia has also reported the highest underweight rates in the world (4). Therefore, defining accurate BMI cut-off points for underweight, overweight and obesity are equally important and have many advantages in terms of diagnosis and management.

Based on the BMI, multiple organizations such as WHO, Centers for Disease Control and Prevention (CDC), and International Obesity Task Force (IOTF) have developed classifications to assess the individuals who are at the risk of being underweight, overweight, and obesity. The WHO Growth References 2007 (8) is a combination of two systems, resulting from collaboration between the WHO and the National Center for Health Statistics (NCHS): the NCHS/WHO International Growth Reference (9) and the WHO Child Growth Standards (10). IOTF cut-off values derived based on six international representative data sets obtained from 1968 to 1993 (11) have shown the lowest prevalence, while CDC showed the highest prevalence in the detection of obesity (12).

Although the IOTF and WHO classifications of overweight and obesity are recognised as international references, there are differences in the methods used to elaborate these tools and some discrepancies have been reported (13). According to the results reported by a Canadian study, 37% of boys aged 2-5 years were in the overweight/obese category according to the WHO definition, but it was only 19% when the IOTF system was applied (14). The WHO references often give higher prevalence figures than national references or other international references but IOTF and CDC references often gave rise to comparable results. These observations have already been made in studies conducted in India (15), Italy (16) and Great Britain (17). The WHO cut-off values are still well-received worldwide and they have been adopted by over 110 countries and many researchers. Even in Sri Lanka, they are still being used for the assessment of nutritional status during childhood at the community level (18).

In children, BMI is calculated as for adults and then compared with Z-scores or percentiles. During childhood and adolescence, the ratio between weight and height varies with sex and age, therefore the cut-off values that determine the nutritional status of those aged 0-19 years are gender- and age-specific (19). Because of the increasing burden of childhood obesity in Asia, in 2004, the WHO recommended lowering the BMI cut-offs for Asian adults, from 25 to 23 kg/m^2 for overweight and from 30 to 27.5 kg/m^2 for obesity (20) in anticipation of the increased cardiometabolic risks associated with obesity. But these newly derived cut-off values are still too high for the South Asian populations which have an increased risk of cardiovascular and metabolic disease risks at an even lower BMI compared to other populations (21).

Such diverse relationships of BMI classification systems emphasise the requirement of identifying the most applicable cutoff value system to assess underweight, overweight and obesity state for Sri Lankan children and adolescents.

Based on this background, the present study was designed to evaluate the potential differences among the existing classification systems for BMI; IOTF, CDC, an Indian classification and a Sri Lankan classification compared to the currently practiced WHO classification to assess the prevalence of underweight, overweight and obesity in a cohort of school children aged 5-15 years from the Galle Municipality area.

Methods

Study population

A cross sectional study was conducted among 833, 5-15 year-old school children who were selected randomly from 29 schools in the Galle Educational Zone, Galle, Sri Lanka after obtaining written informed consent/assent. Children were recruited after excluding children who were diagnosed with chronic illness, who were on any medication, who had an illness during the preceding two weeks. Their nutritional status was determined according to BMI classification systems.

Measurements

Standing height was measured using a stadiometer (*Seca 214,* Hamburg, Germany) which was calibrated in millimeters with a precision of 0.1 cm, with occiput, back of chest, buttock and heel touching the vertical plane and head kept in the horizontal Frankfurt plane. Weight was measured to the nearest 100 g, using an electronic weighing scale (*Seca,* France). BMI was calculated as weight (kg) divided by height^2 (m^2). All anthropometric measurements were performed by the same investigator.

BMI classification

All the children recruited to the study were categorised into four groups, underweight, normal weight, overweight and obese according to the recommendations of different BMI classification systems; CDC, IOTF, WHO and Indian classification defined by Agarwal *et al,* 2001 (21). Children were also classified as obese and non-obese according to the Sri Lankan cut-off values defined by Wickramasinghe *et al.,* in 2011 (4).

CDC classification system

Using data collected by National Centre for Health Statistics (NCHS), USA, in five cross sectional nationally representative health examination surveys and a modified international LMS (Lamda, Mu and Sigma) tables estimation procedure, multiple charts including BMI for age charts were generated using children and adolescents in the United States in 2000 (22). The nutritional status of each child was determined according to the cut-off values associated with the percentile curves (22) and underweight was defined as BMI less than 5th percentile; normal weight: 5th to less than 85th percentile, overweight: 85th to less than 95th percentile and obese: 95th percentile or greater.

IOTF classification system

In this system, scores were calculated using the formula associated with the international LMS parameters by age as defined by the population used in the study which consist of 97,876 males and 94,851 females from birth to 25 years of age from Brazil, Great Britain, Hong Kong, Singapore, United States and the Netherlands measured in the years 1968 to 1993 (11). Centile curves were drawn so that at age 18 years they passed through the widely used cut off points of 25 and 30 kg/cm^2 for adult overweight and obesity. The resulting curves were averaged to provide age and sex specific cut off points from 2-18 years. The nutritional status of each child was determined according to the cut-off values associated with the percentile curves. Underweight was defined as percentile curve passing through BMI less than 18.5 kg/cm^2 at the age 18, normal weight: percentile curve passing through BMI = 18.5 kg/cm^2 at the age 18, overweight: percentile curve passing through BMI = 25 kg/cm^2 at the age 18 and obese: percentile curve passing through BMI = 30 kg/cm^2 at the age 18 (13).

WHO classification system

The sample used for the reconstruction of the reference for school-aged children and adolescents (5-19 years) was the same as that used for the construction of the original NCHS charts in 1977, pooling three data sets from the Health Examination Survey (HES), and the Health and Nutrition Examination Survey. Given the similarity of the three data sets, the data were merged without adjustments. The total sample size was 22,917 (11,410 boys). State-of-the-art statistical methods such as the Box-Cox power exponential (BCPE) method with appropriate diagnostic tools were used for the selection of best models and subsequently they were applied to the combined sample (8).

The nutritional status of each child was also determined according to the cut-off values defined by the WHO in 2007 for children above 5 years of age (13) where underweight was defined as BMI Z-score < -2, normal, normal weight: -2 < BMI Z-score ≤ 1, overweight: BMI Z-score > +1 and obese: BMI Z-score > +2.

Indian classification system

Data were collected from healthy, affluent adolescents aged 4-18 years after visiting public schools in 12 cities in India (boys 11,863 and girls 7,694) from 1988 to 1991. The nutritional status of each child was determined according to the cut-off values associated with the percentile curves (5) in which underweight was defined as BMI less than 5th percentile, normal weight: 5th percentile to less than 85th percentile, overweight: 85th to less than 95th percentile and obese: 95th percentile or greater.

Sri Lankan classification system

Sri Lankan cut-off values were based on the biological endpoints associated with metabolic consequences and data were obtained from two hundred and eighty-five (160 boys and 125 girls) healthy Sri Lankan children aged 5-14 years old in the year 2005 (4). Obese and non- obese were defined as those with BMI cut-off values corresponding to 98thpercentile for percentage fat mass (FM) of British children; FM ≥ 25% and < 25% respectively in boys and BMI cut-off values corresponding to percentage FM ≥ 35% and < 35% respectively in girls.

Ethical approval for the study was obtained from the Ethics Review Committee of the Faculty of Medicine, University of Ruhuna, Sri Lanka and the study was conducted according to the Helsinki declaration. Written informed consent and assent were obtained from the parents and children respectively after explaining the procedure to be followed.

Statistical analysis

The basic characteristics of children are reported as mean ± SD or as a percentage. Using the classification systems listed above, frequencies of underweight, normal weight, overweight and obese were calculated for the study population. The prevalence of nutritional status was calculated as a percentage based on each anthropometric cut-off value provided by different classification systems. The degree of agreement between the BMI based nutritional status calculated based on different classification systems were calculated according to Cohen's Kappa coefficient. Depending on the kappa coefficient, different classification systems were considered to be in disagreement to a weak agreement (k = zero to 0.40), moderate to strong agreement (k=0.41 to 0.80), nearly perfect agreement (k=0.81 to 1.00) and perfect agreement (k=1.00) (23). The level of significance was considered as $p<0.05$ for all comparisons. *SPSS* statistical package version 25.0 was used for the analysis.

Results

Characteristics of the study sample

As shown in Table 1, the study sample consisted of 403 boys and 430 girls. There was no significant difference in weight, height and BMI between boys and girls in the majority of age groups studied.

Prevalence of different nutritional states by classification systems

The prevalence of underweight, normal weight, overweight and obesity in the study sample are presented in Table 2. Compared to other classification systems, percentages obtained for IOTF reference was the highest for underweight and the lowest for normal weight and obese. Prevalence for underweight, normal weight, overweight and obesity identified by CDC was compatible with that of IOTF. According to the CDC, IOTF, WHO and Indian references, for underweight, there is a wide difference in percentages from 13.56 to 42.02% (Table 2). However, for overweight children for the same age range, the percentages were ranged from 7.32% to 9.73%. The prevalence of children classified in to the "obesity" category was comparable between CDC (4.68%) and WHO (5.04%). The percentage of children classified as overweight (8.04%) and obese (9.6%) was highest and the percentage classified as underweight (13.56%) was lowest according to the Indian classification.

Sri Lankan cut-off values based on BMI corresponding to percentage FM of 25% for boys and 35% for girls and the BMI corresponding to 98th percentile for percentage FM of British children are also given in Table 2. Almost the same prevalence for non-obese (75.63% and 74.43%) and obese (24.37% and 25.57%) was obtained according to both cut-off values respectively (Table 2). However, the prevalence of obesity determined according to the Sri Lankan classification system was significantly different compared to the currently practiced WHO classification system.

When different assessment methods were compared, (Table 3), moderate to strong agreements were observed between CDC vs. IOTF (k=0.681), CDC vs. WHO (k=0.607) and WHO vs. Indian (k=0.649). Although other agreements were weaker, all were statistically significant ($p<0.001$).

Out of all four systems investigated, the Indian classification system had weaker agreements with IOTF and CDC (k=0.304, 0.341). However, agreement with the Sri Lankan classification system derived in 2011 (5) could not be tested as children were classified as only obese and non-obese and not for underweight.

Prevalence of underweight, overweight and obesity states were also investigated among children according to different classifications by age and sex (Table 4). In the majority of age groups, girls showed a higher prevalence of underweight state compared to boys. With increasing age, a comparatively lower prevalence of underweight state was noted among boys and girls. On the other hand, the prevalence of overweight state and obesity was higher in boys compared to girls in the majority of age groups. Compared to other age groups, children above 13 years in both sexes showed a higher prevalence of obesity with the highest prevalence identified by the Indian classification system.

Table 1: Weight (kg), height (cm) and BMI (kg/m^2) in boys and girls across different age groups.

Age	Boys (n=403)				Girls (n=430)			
Years	n	Weight	Height	BMI	n	Weight	Height	BMI
		Mean ± SD	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	Mean ± SD
5	44	19.7 ± 4.4	115.8 ± 5.80	14.6 ± 2.4	41	19.0 ± 4.6	114.4 ± 5.5	14.4 ± 2.8
6	40	19.9 ± 3.6	120.4 ± 5.4	13.7 ± 1.7	30	19.0 ± 3.2	119.8 ± 5.3	13.2 ± 1.7
7	46	24.1 ± 5.4	125.6 ± 4.7	15.2 ± 2.7	49	22.3 ± 4.9	124.2 ± 6.2	14.3 ± 2.1
8	42	24.8 ± 5.1	130.8 ± 5.8	14.4 ± 2.2	40	27.5 ± 5.6*	131.7 ± 6.	15.8 ± 2.5*
9	41	30.3 ± 8.0	134.8 ± 6.8	16.5 ± 3.0	48	27.3 ± 6.8*	134.9 ± 6.4	14.8 ± 2.8*
10	36	31.6 ± 7.0	141.5 ± 6.4	15.7 ± 2.8	36	32.9 ± 8.2	141.5 ± 6.1	16.3 ± 3.1
11	47	37.6 ± 8.9	146.8 ± 7.5	17.3 ± 3.1	46	35.7 ± 9.7	145.2 ± 7.2	16.8 ± 3.8
12	19	42.4 ± 11.1	154.3 ± 7.8	17.6 ± 3.4	34	42.7 ± 11.0	152.1 ± 6.6	18.3 ± 4.0
13	43	49.8 ± 13.1	160.6 ± 7.8	19.2 ± 4.3	39	43.9 ± 10.2*	154.1 ± 4.4*	18.4 ± 3.6
14	25	47.9 ± 9.0	163.4 ± 7.4	17.8 ± 2.6	27	44.7 ± 6.3	155.5 ± 5.2*	18.5 ± 2.1
15	20	59.3 ± 11.5	166.5 ± 4.7	21.5 ± 4.6	40	45.6 ± 7.9*	153.7 ± 5.3*	19.3 ± 3.2*

* $p<0.05$, statistically significant difference compared to boys.

Prevalence for non-obese and obese status was also determined among children according to the Sri Lankan classification systems corresponding to both percentage FM of 25% and 35% for boys and girls respectively and 98th percentile by age and sex. When the prevalence of obesity was considered, corresponding to percentage FM of 25% and 35% for boys and girls, a significant difference was observed between boys and girls only in the age groups 12, 13 and 15 years. However, highly significant differences were observed in almost all age groups between boys and girls when the obesity was determined according to the BMI corresponding to percentage FM of 98th percentile (Table 5).

Table 2: Prevalence of underweight, normal weight, overweight and obesity states among children according to different classifications

Determined based on cut-off values of	Underweight n (%)	Normal weight n (%)	Overweight n (%)	Obese n (%)
CDC	269 (32.3)	464 (55.7)	61 (7.3)	39 (4.7)
IOTF	350 (42.0)	387 (46.5)	75 (9.0)	21 (2.5)
WHO	176 (21.1)	534 (64.1)	81 (9.7)	42 (5.0)
Indian cut-off	113 (13.6)	573 (68.8)	67 (8.0)	80 (9.6)
Sri Lankan cut-off based on BMI corresponding to % FM of 25% (Boys) and 35% (Girls)		630 (75.6)		203 (24.4)
Sri Lankan cut-off based on BMI corresponding to % FM of 98th percentile		620 (74.4)		213 (25.6)

FM: CDC: Centers for Disease Control and Prevention, IOTF: International Obesity Task Force, WHO: World Health Organization and INDIAN: Indian classification according to Agarwal *et al.,* 2001.

Table 3: Agreement between CDC, IOTF, WHO and Indian references for the determination of nutritional status in children aged 5-15 years

Comparison	Kappa coefficient	Standard error of mean (SEM)
CDC Vs IOTF	0.681*	0.022
CDC Vs WHO	0.607*	0.025
CDC Vs Indian	0.341*	0.026
IOTF Vs WHO	0.558*	0.024
IOTF Vs Indian	0.304*	0.023
WHO Vs Indian	0.649*	0.024

CDC: Centers for Disease Control and Prevention, IOTF: International Obesity Task Force, WHO: World Health Organization and INDIAN: Indian classification according to Agarwal *et al,* 2001. *denotes kappa coefficient significant at $p<0.001$.

Table 4: Prevalence of underweight, overweight and obesity status among children according to different classifications by age and sex

Age	Boys (%)				Girls (%)			
	CDC	IOTF	WHO	Indian	CDC	IOTF	WHO	Indian
Underweight								
5	38.6	54.6	25.0	6.8	48.8	56.1	24.4	19.5
6	62.5	77.5	40.0	37.5	56.7	73.3	43.3	53.3
7	32.6	34.8	19.6	17.4	40.8	51.0	22.4	26.5
8	52.4	59.5	35.7	19.0	15.0	12.5	5.0	5.0
9	19.5	29.3	7.3	0.0	45.8	60.4	37.5	16.7
10	38.9	50.0	25.0	11.1	27.8	36.1	25.0	13.9
11	19.2	27.7	8.5	4.3	37.0	41.3	28.3	13.0
12	26.3	26.3	26.3	10.5	23.5	35.3	14.7	2.9
13	16.3	23.3	14.0	4.6	15.4	38.5	7.7	5.1
14	40.0	40.0	20.0	8.0	7.4	22.2	7.4	7.4
15	10.0	15.0	10.0	0.0	17.5	35.0	12.5	10.0
Overweight								
5	12	4.6	4.5	9.1	7.3	4.9	7.3	7.3
6	13	7.5	5.0	2.5	3.3	3.3	3.3	3.3
7	14	8.7	10.9	6.5	6.1	6.1	8.2	4.1
8	2.4	2.4	4.8	4.8	5.0	5.0	7.5	12.5
9	14.6	12.2	17.1	17.1	6.2	6.2	6.2	4.2
10	8.3	5.6	13.9	11.1	8.3	11.1	8.3	2.8
11	10.6	17.0	12.8	8.5	10.8	13.0	10.8	4.3
12	5.3	15.8	26.3	26.3	17.6	20.6	17.6	2.9
13	9.3	18.6	14.0	11.6	7.7	7.7	12.8	7.7
14	4.0	4.0	4.0	16.0	0.0	3.7	3.7	3.7
15	0.0	10.0	10.0	25.0	10.0	10.0	10.0	5.0
Obese								
5	9.1	4.5	9.1	9.1	7.3	7.3	7.3	14.6
6	NA	NA	2.50	NA	NA	NA	NA	NA
7	6.5	4.3	6.5	10.8	2.0	2.0	2.0	8.2
8	2.4	2.4	2.4	2.4	5.0	5.0	5.0	10.0
9	7.3	4.9	7.3	7.3	2.1	2.1	4.2	8.3
10	2.8	2.8	2.8	5.6	NA	NA	5.6	NA
11	NA	NA	8.5	NA	4.3	2.2	6.5	15.2
12	NA	NA	NA	NA	NA	NA	5.88	NA
13	14.0	4.6	14.0	18.6	2.6	2.6	2.6	10.3
14	NA	NA	NA	NA	NA	NA	NA	NA
15	15.0	10.0	15.0	15.0	NA	NA	NA	10.0

CDC: Centers for Disease Control and Prevention, IOTF: International Obesity Task Force, WHO: World Health Organization and INDIAN: Indian classification according to Agarwal et al, 2001. NA: Obese children were not identified for the respective classification system, sex and the age.

Table 5: Prevalence of non-obesity and obesity among children according to the Sri Lankan classification systems corresponding to % FM of 25% and 35% and 98th percentile by age and sex

Age	Boys (n=403)				Girls (n=430)			
	BMI corresponding to % FM of 25% Sri Lankan data		BMI corresponding to % FM of 98th percentile Sri Lankan data		BMI corresponding to % FM of 35% Sri Lankan data		BMI corresponding to % FM of 98th percentile Sri Lankan data	
	Obese	Non-Obese	Obese	Non-Obese	Obese	Non-Obese	Obese	Non-Obese
5	7	37	10	34	6	35	12	41*
6	3	37	3	37	2	28	28*	18*
7	8	38	5	41	5	44	26*	21*
8	4	38	1	41	5	35	39*	14*
9	11	30	3	38	5	43	29*	9*
10	7	29	1	35	7	29	34*	7*
11	14	33	3	44	13	33	22*	12*
12	8	11	1	18	12	22*	28*	12
13	20	23	9	34	13*	26	20*	11*
14	9	16	2	23	10	17	25*	7*
15	14	6	8	12	20*	20*	12	15
Total	**105**	298	**46**	**357**	**98**	**332**	**167**	**263**
(%)	**26.0**	**74.0**	**11.4**	**88.6**	**22.8**	**77.2**	**38.8**	**61.2**

* *p*<0.05 between boys and girls of the corresponding groups

Discussion

This cross-sectional study revealed a discrepancy between different BMI based, widely used international classification systems of nutritional status, among children in Galle municipality. The prevalence of under-weight, overweight and obesity status of children and adolescents in our study are significantly different as determined by CDC, IOTF, WHO, Indian and the Sri Lankan classification systems. Nevertheless, there was an agreement between certain classification systems such as CDC vs. IOTF, CDC vs. WHO and WHO vs. Indian classification as shown by the moderate kappa coefficients obtained. A significant deviation was observed between the Sri Lankan classification system and other classifications systems, especially the Indian classification system, in identifying obesity. However, it is interesting to note that the WHO classification which is currently practiced in Sri Lanka, has a moderate agreement with CDC, which was derived by the NCHS, USA using five cross-sectional, nationally representative health examination surveys using children and adolescents in the United States (22).

The highest agreement observed between IOTF CDC in the current study is consistent with a similar study carried out by Partap *et al,* in Malaysia who reported that the overall agreement was greater between IOTF and CDC references (24). However, another study conducted on Chinese, Vietnamese and Indonesian children reported a larger difference between the prevalence of underweight than that of overweight when measured according to IOTF and CDC references (25). In our study, we also report the same trend where a difference of 9.7% was observed between IOTF and CDC classification systems in the detection of under-weight whereas the difference between the same in the detection of overweight and obesity states were 1.68% and 2.14% respectively. Because of the higher degree of variability reported among different BMI classification systems in the current study, identifying the correct proportion of underweight state among children as well as the management at individual level has become problematic in Sri Lanka.

The difference observed between the percentages of obese identified by WHO and the Indian classification system compared to the CDC and IOTF and the opposite trend obtained for underweight is consistent with the previous studies (13). Consistently higher prevalence estimates for both overweight and obesity states when using the WHO reference, and lower when using the IOTF reference are consistent with the study reported in Malaysian children (24). Another study conducted on 877 Indian adolescents also reported a significant agreement between CDC vs IOTF and WHO vs CDC classifications but a moderate agreement between WHO vs IOTF classifications (26). These results are parallel to the relationships we reported in the current study.

Existing Sri Lankan classification system focuses solely on obesity and stems from a completely different approach, combining BMI and FM percentage to classify obesity. According to previous reports, BMI might rather reflect fat-free mass than FM in some individuals and the relationship between FM and BMI may not be linear throughout the BMI range (12). According to Wickramasinghe et al, Sri Lankan girls always had a higher percentage FM for a narrower range of BMI and the fat free mass index was comparatively lower and was not elevated significantly with advancing age (4). This was evident in the results obtained in this study where a higher number of girls from each age category reported to be either overweight or obese compared to boys of the same age. Compared to girls, Sri Lankan boys had similar percentage FM but the fat free mass index was lower without much increase in age, which leads to the conclusion that Sri Lankan children have much higher adiposity and less fat free mass from a younger age. BMI cutoff values previously derived in Sri Lankan children with a metabolic risk were comparatively low, 19.2 kg/m^2 and 19.7 kg/m^2 for males and females aged 18 years respectively (4). Considering the cardiovascular risk, another study conducted in Sri Lanka proposed a BMI of 21·5 kg/m^2 as the BMI cut-off level associated with two or more cardiovascular risk factors in Sri Lankan adults (27).

In addition, a meta-analysis on the prevalence of childhood and adolescent overweight and obesity in the Asian countries also revealed that compared to the CDC criteria, the IOTF and WHO definitions underestimated the prevalence of obesity and over--estimated the prevalence of overweight among Asian children and adolescents (28). One of the reasons would be that CDC classification was derived entirely based on the study population in USA but IOTF and WHO had representations from several regions in the world (8, 11). A similar trend was observed in the present study when prevalence of overweight and obesity was reported by the WHO classification system.

Indian cut-off values derived by Agarwal *et al*., in 2001 (21) were used in this study as they have defined cut-off values for all types of malnutrition; underweight, overweight as well as obesity in children from 5-18 years old. Indian classification had a better agreement with the WHO classification system, which is the currently practiced classification at the community level in Sri Lanka. Sri Lankan classification system derived in 2011 (4) could not be tested for the full spectrum of malnutrition against other international classification systems as children were classified only as obese and non-obese. Indians and Sri Lankans share many similarities in their socio-economic status, diversity of the cultures and genetics compared to the western populations where most of the international classifications were defined.

BMI cut-off points are important clinically to identify children at high-risk for screening purposes, to identify children for risk assessment, to determine the type, duration and intensity of treatment, to monitor children for effects of treatment over a period of time and also to determine institutional policies on nutritional status of children in Sri Lanka.

Conclusion & recommendations

The prevalence of underweight, overweight and obesity states of children under study were significantly different as determined by the CDC, IOTF, WHO, Indian and the Sri Lankan classification systems. The prevalence of obesity as determined by the Sri Lankan classification system was significantly different compared to the currently practiced WHO classification system. Therefore, it emphasises the urgent requirement of country specific growth references for the assessment of malnutrition in children and adolescents in Sri Lanka. Such growth references will enable accurate diagnosis of undernutrition, overweight and obesity and prompt early interventions for the prevention of complications of undernutrition and metabolic syndrome later in life.

Limitations

Cut-off values for the international anthropometric references in children were defined statistically based on the deviation from the mean. Furthermore, classifications such as CDC were defined based on the data collected from children in the USA and no other populations were represented. In all these international classifications, the health status of a child was not considered but the BMI distribution of children across a certain age range from the general population was considered (25). In light of such limitations, a universal BMI classification system has limitations when applying to children from different populations because their growth patterns are too distinct. The importance of defining country specific and relatively recent cut-off values can be further justified because of the fact that children are nowadays taller than earlier when data for almost all these classifications were collected (29). This study itself had some limitations. Waist circumference (WC), which is considered as a measure of central obesity was not available in this study. However, the study was conducted in a more suburban area outside the city of Colombo where a more representative study sample of Sri Lanka was collected. Therefore, to derive an internationally acceptable classification system to diagnose malnutrition, national cross-sectional growth charts for height, weight, WC and BMI, should be drawn in a large randomised sample of schoolchildren aged 6-19 years recruited from each province in Sri Lanka to represent a population-based sample of schoolchildren. This would also minimize the burden on the healthcare system created by the children with a potential to develop non-communicable diseases and would increase the productivity of the future generation.

Competing interests

The authors have no competing interests to declare.

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References

1. Neri C, Edlow AG. Effects of Maternal Obesity on Fetal Programming: Molecular Approaches. Cold Spring Harb. *Perspect. Med.* 2015; **6**(2): a026591.
2. Stewart CP, Iannotti L, Dewey KG, Michaelsen KF, Onyango AW. Contextualising complementary feeding in a broader framework for stunting prevention. *Matern Child Nutr.* 2013; **9**(S2):27-45.
3. Rolland-Cachera MF, Sempe M, Guilloud-Bataille M, Patois E, Pequignot-Guggenbuhl F, Fautrad V. Adiposity indices in children. *Am J Clin Nutr.* 1982; **36**(1): 178-84.
4. Wickramasinghe VP, Lamabadusuriya SP, Cleghorn GJ, Davies PSW. Defining anthropometric cut-off levels related to metabolic risk in a group of Sri Lankan children. *Ann Hum Biol.* 2011; **38**: 537-543.
5. Duncan JS, Duncan EK, Schofield G Ethnic-specific body mass index cut-off points for overweight and obesity in girls. *N Z Med J.* 2010; **123**: 22-29.
6. Neovius M, Linne´ Y, Barkeling B, Rossner S. Discrepancies between classification systems of childhood obesity. *Obes Rev.* 2004; **5**:105-14.
7. de Onis M, Blossner M, Borghi E, Frongillo EA, Morris R. Estimates of global prevalence of childhood underweight in 1990 and 2015. *JAMA*. 2004; **291**: 2600-2606.
8. de Onis M, Onyango AW, Borghi E, Siyan A, Nishida C, Siekmann J. Development of WHO growth reference for school-aged children and adolescents. *Bull World Health Organ.* 2007; **85**(9):660-7.

9. World Health Organization. Physical status: the use and interpretation of anthropometry. [Report of WHO Expert Committee] Geneva: World Health Organization; 1995. [Contract No: 854].

10. Multicentre Growth Reference Study WHO Group. WHO Child Growth Standards based on length/height, weight and age. *Acta Paediatr.* 2006; **450**: 76-85.

11. TJ. Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatr Obes.* 2012; **7**: 284-294.

12. Misra A. Revisions of cut-offs of body mass index to define overweight and obesity are needed for the Asian-ethnic groups. *Int J Obes.* 2003; **27**: 1294-1296.

13. Kêkê LM, Samouda H, Jacobs J, *et al.* Body mass index and childhood obesity classification systems: A comparison of the French, International Obesity Task Force (IOTF) and World Health Organization (WHO) references. *Rev Epidemiol Sante Publique.* 2015; **63**(3): 173-182.

14. Shields M, Tremblay MS. Canadian childhood obesity estimates based on WHO, IOTF and CDC cut-points. *Int J Pediatr Obes.* 2010; **5**: 265-73.

15. Khadilkar V, Khadilkar A. Growth charts: a diagnostic tool. *Indian J Endocrinol Metab.* 2011; **15**(3): S166-71.

16. Vidal E, Carlin E, Driul D, Tomat M, Tenore A. A comparison study of the prevalence of overweight and obese Italian preschool children using different reference standards. *Eur. J. Pediatr.* 2006; **165**(10): 696-700.

17. Johnson W, Wright J, Cameron N. The risk of obesity by assessing infant growth against the UK-WHO charts compared to theUK90 reference: findings from the Born in Bradford birth cohort study. *BMC Paediatr.* 2012; **12**(1): 104.

18. Wickramasinghe VP, Cleghorn GJ, Edmiston KA, Murphy AJ, Abbott RA, Davies PS. Validity of BMI as a measure of obesity in Australian white Caucasian and Australian Sri Lankan children. *Ann Hum Biol.* 2005; **32**: 60-72.

19. Gray LJ, Yates T, Davies MJ, Brady E, Webb DR, *et al.* Defining obesity cut-off points for migrant South Asians. *PLoS One.* 2011; **6**: e26464.

20. World Health Organization Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet.* 2004; **363**(9403): 157-163.

21. Agarwal KN, Saxena A, Bansal AK, Agarwal DK. Physical growth assessment in adolescence. *Indian Pediatr.* 2001; **38**(11): 1217-1235.

22. Centers for Disease Control web site. https://www.cdc.gov/nccdphp/dnpao/growthcharts/training/bmiage/index.html

23. Bertino E, Gilli G, Occhi L, *et al.* Postnatal growth of preterm infants: which reference charts? *Minerva Pediatr.* 2010; **62**(3 Suppl 1): 71-74.

24. Partap U, Young EH, Allotey P, Sandhu MS, Reidpath DD. The Use of Different International References to Assess Child Anthropometric Status in a Malaysian population. *The Journal of Pediatrics.* 2017; **190**: 63-68.

25. Deepika B, Kalyani S, Manisha S. Comparison of WHO, CDC and IOTF growth references in relation to overweight and obesity in school going adolescents of Delhi. *India. Indian J Public Health Res Dev.* 2016; **7**(3): 83.

f26. Tichá L, Regecová V, Šebeková K, *et al.* Prevalence of overweight/obesity among 7-year-old children - WHO Childhood Obesity Surveillance Initiative in Slovakia, trends and differences between selected European countries. *Eur. J. Pediatr.* 2018; **177**: 945-953.

27. Katulanda P, Jayawardena MA, Sheriff MH, Matthews DR. Derivation of anthropometric cut- off levels to define CVD risk in Sri Lankan adults. *Br. J. Nutr.* 2011; **105**(7): 1084-1090.

28. Mazidi M, Banach M, Kengne AP. Lipid and Blood Pressure Meta-analysis Collaboration Group. Prevalence of childhood and adolescent overweight and obesity in Asian countries: a systematic review and meta-analysis. *Arch Med Sci.* 2018; **14**(6): 1185-1203.

29. de Wilde JA, Van Dommelen P, Middelkoop BJ. Appropriate body mass index cut-offs to determine thinness, overweight and obesity in South Asian children in the Netherlands. *PLoS One.* 2013; **8**(12): e82822.