ORIGINAL ARTICLE

Associations between Stunting and high-ponderosity defined through Weight-for-Height or Body-Mass-Index-for-Age in Under-five Children

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Abstract

Background: Association between overweight and stunting has been inconsistently documented. In under-five children, high-ponderosity is defined as >1SD WHO standards for either weight-for-height or body-mass-index-for-age metrics. Unlike body-mass-index-for-age (BMI-for-age), weight-for-height ignores physiological changes in ponderosity with age, resulting in underestimation of overweight defined through weight-for-height in comparison to BMI-for-age in populations with high stunting prevalence. Consequently, associations between overweight and stunting may differ depending on the metric used. **Aim:** To test whether concurrent possible risk of overweight-stunting defined through weight-for-height and BMI-for-age (CSPO_WHZ and CSPO_BMIZ) associations are similar. **Methods:** Demographic Health Survey datasets after 2010 from South-and South-East Asia and Sub-Saharan Africa were evaluated. CSPO_WHZ and CSPO_BMIZ associations were estimated as odds ratio (OR) for individual datasets, which were pooled (random-effects meta-analysis). Stratified analyses were done for age and region. **Results:** Young-infants (0-6 months) comprised 8%-14% of under-five children, with almost equal representation of boys and girls. Participants, especially Asians, were mostly shorter with lower ponderosity than WHO standards. CSPO_WHZ prevalence was lower than CSPO_BMIZ in 6-59 months, but higher in young infants. Pooled CSPO_WHZ estimates were not significant. In contrast, pooled CSPO_BMIZ associations were significantly positive for, Africa and combined, but not for Asia. **Conclusion:** CSPO_WHZ and CSPO_BMIZ associations differ, likely because WHZ fails to capture age-related changes in ponderosity.

Keywords

Body-mass-index-for-age, Stunted, Under-five children, Overweight, Weight-for-height

Introduction

Reducing overweight among under-five children is a key Sustainable Development Goal and a global nutrition priority. The World Health Assembly targets includes: no increment in the prevalence of childhood overweight and a 40% reduction in the stunting by 2025 and to reduce the prevalence of childhood overweight to below 3%.(1) Children who were born stunted are believed to be at a risk of becoming overweight and obese in later life.(2) The occurrence of both stunting and overweight simultaneously is one type of double burden of malnutrition (DBM).

In Sub-Saharan Africa, a pooled analysis of 210,565 children estimated the prevalence of concurrent stunting and overweight at 1.82% (95% CI: 1.76-1.87), identifying it as an emerging public health concern.(3) However, limited attention has been given to the statistical dimensions of this relationship. Overweight in young children is assessed using either weight-for-height (WHZ) or BMI-for-age (BMIZ). Although highly correlated, these indicators yield different cut-offs and prevalence estimates, particularly among stunted children, where WHZ may underestimate high ponderosity.(4)

This methodological variation may partly explain inconsistencies in reported stunting-overweight associations. Therefore, this study compares CSO and stunting-possible overweight using both WHZ and BMIZ metrics.

Aim

To determine whether associations between stunting and high ponderosity differ when overweight is defined using WHZ versus BMIZ.

Material & Methods

Study Type and Design: This study was a cross-sectional analytical study based on the National Demographic Health Survey (DHS) datasets from South and South-East Asia and Sub-Saharan Africa.

Study Duration and population: The analysis was limited to anthropometric datasets that were obtained in 2010 or after up till October 4, 2024 (last searched date), for children aged 0-59 months.(5) With the same variables, names, kinds, lengths, coding schemes, unit of measurement, and file format, a single set-up was created for the DHS datasets. These comprised case ID, age, sex, length/height, and weight.

Sample Size: As this was a secondary analysis of existing DHS datasets, no separate sample size calculation was performed.

Working Definition: We used the WHO macro syntax of STATA for generating the z-scores of the four anthropometric indices from the length/height-for-age (HAZ), weight-for-age (WAZ), weight-for-height (WHZ), and body-mass-index-for-age (BMIZ) respectively.(6)

Inclusion and Exclusion criteria: The children with valid data on age, sex, length/height, and weight were included in the analyses. The WHO criteria were used to delete the missing or flagged values (z-scores): "HAZ <-6 or >6; WAZ <-6 or >5; WHZ <-5 or >5; and BMIZ <-5 or >5.(6,7) Stunting was defined as HAZ <-2SD of WHO standards".(6)

Ethical Statement: This study is based exclusively on secondary analyses of de-identified data obtained from previously conducted surveys for which all necessary ethical approvals had already been secured by the original investigators. As no new data were collected and no direct contact with human participants occurred, additional ethical approval was not required. The authors confirm that the analyses procedures adhered to the ethical standards and were conducted in accordance with the principles outlined in the Declaration of Helsinki.

Data Analysis and Software: CSPO and CSO associations for both metrics (WHZ and BMIZ) were estimated by calculating the Odds Ratio (OR) separately for each country's dataset. DerSimonian-Laird model in the random-effects meta-analysis was used to pool the ORs from each dataset,(8,9) as the clinical context of the surveys was heterogeneous. The five categories which were used to compare the WHZ (or BMIZ) and HAZ were, namely, possible risk of overweight only, overweight only, stunted only, CSPO, and CSO. Pearson correlation coefficients were calculated between WHZ and BMIZ. Additionally, coefficients for the log weight regressed on log height were calculated. We used the STATA 17.0/MP-Parallel Edition version (StataCorp LLC) for analyses.

Results

From the available online DHS datasets, twenty-one countries (7 from South and South-East Asia and 14 from Sub-Saharan Africa) fulfilled the inclusion criteria. **Table 1** summarizes the demographic and anthropometric characteristics of the analyzed datasets. The surveys had been conducted between 2011 and 2022. The sample size in the DHS ranged from 2,342 in Maldives to 17,280 in Kenya; except for India where the sample size was 197,651. In under-five children, approximately 8-14% of the children were young infants (0-6 months) and with almost equal representation of both the sexes (boys and girls). Most of the participants were shorter according to the WHO growth standards. The overall means of HAZ were ranging from -1.6 to -0.9 and their SDs were from 1.1 to 1.7, respectively. The range of means for WHZ and BMIZ in Sub-Saharan Africa were -0.5 to +0.4 and -0.5 to 0.5. For South and South-East Asia, the mean z-scores were lower ranging from -0.8 to -0.2 and -0.7 to -0.1 for WHZ and BMIZ, respectively. The SDs in both the regions for both variables were almost similar ranging from 1.0 to 1.5.

Table 1: Description of the datasets used in the analyses

Country (Year)	N (0-59)	N [0-6 (%)]	Sex (Male (%))	HAZ: Mean (SD)	WHZ: Mean (SD)	BMIZ: Mean (SD)
Demographic Health Survey Datasets: South and South-East Asia (a)						
Bangladesh (2022)	4,083	10.6	51.3	-1.2 (1.2)	-0.8 (1.1)	-0.7 (1.1)
Cambodia (2021-22)	3,747	8.9	51	-1.1 (1.4)	-0.5 (1.3)	-0.4 (1.3)
India (2019-21)	1,97,651	9.1	51.4	-1.4 (1.7)	-0.8 (1.5)	-0.7 (1.5)
Maldives (2016-17)	2,342	7.6	50.9	-0.9 (1.2)	-0.4 (1.3)	-0.4 (1.3)
Myanmar (2015-16)	4,146	10.4	51.6	-1.4 (1.3)	-0.5 (1.1)	-0.3 (1.1)
Nepal (2022)	2,586	9.6	52.3	-1.3 (1.1)	-0.5 (1.0)	-0.4 (1.0)
Pakistan (2017-18)	4,079	10.4	50.5	-1.6 (1.7)	-0.2 (1.3)	-0.1 (1.3)
Pooled	***2,18,634***			***-1.4 (1.7)***	***-0.8 (1.5)***	***-0.7 (1.5)***
Demographic Health Survey Datasets: Sub-Saharan Africa (b)						
Angola (2015-16)	6,268	12.2	49.9	-1.5 (1.5)	-0.1 (1.2)	0.0 (1.2)
Benin (2017-18)	11,626	11.6	50.6	-1.4 (1.3)	-0.3 (1.1)	-0.2 (1.1)
Cameroon (2018)	4,435	11.5	50.7	-1.1 (1.7)	0.4 (1.4)	0.5 (1.4)
Congo (2011-12)	4,464	11.9	51	-1.1 (1.5)	-0.2 (1.2)	-0.1 (1.2)
Ethiopia (2019)	5,055	11	51.2	-1.4 (1.5)	-0.5 (1.2)	-0.3 (1.2)
Gambia (2019-20)	3,805	13.8	52.4	-1.1 (1.1)	-0.4 (1.0)	-0.3 (1.0)
Ghana (2022)	4,394	11.2	51.1	-1.0 (1.2)	-0.4 (1.1)	-0.3 (1.1)
Kenya (2022)	17,280	10.7	50.8	-0.9 (1.3)	-0.3 (1.2)	-0.3 (1.2)
Liberia (2019-20)	2,439	11.2	49.1	-1.4 (1.3)	0.0 (1.1)	0.2 (1.1)
Malawi (2015-16)	5,110	9.4	49.1	-1.5 (1.4)	0.1 (1.1)	0.2 (1.1)
Mali (2018)	8,202	11.4	50.8	-1.1 (1.6)	-0.5 (1.2)	-0.5 (1.2)
Mozambique (2022-23)	3,720	12	49.8	-1.5 (1.4)	0.1 (1.1)	0.2 (1.1)
Nigeria (2018)	11,308	10.4	50.7	-1.5 (1.6)	-0.3 (1.1)	-0.2 (1.2)
Tanzania (2022)	4,791	11.4	50.5	-1.4 (1.3)	0.0 (1.1)	0.1 (1.1)
Pooled	***88,106***			***-1.3 (1.4)***	***-0.3 (1.2)***	***-0.1 (1.2)***

Table 2 summarizes the prevalence of the concurrent stunting and possible risk of overweight (CSPO) defined through weight-for-height and BMI-for-age among 6-59 months children from various DHS datasets. The overall prevalence (95% CI) of those stunted [34.6% (34.3%, 34.7%)], possible risk of overweight defined through weight-for-height [9.7% (9.6%, 9.8%)], possible risk of overweight defined through BMI-for-age [12.4% (12.3%, 12.5%)], CSPO_WHZ [4.1% (3.9%, 4.1%)], and CSPO_BMIZ [6.04% (5.9%, 6.4%)]. Overall deficits were higher in Sub-Saharan Africa, except for stunting, which showed a higher deficit in Asian regions, while the prevalence of CSPO_WHZ was nearly comparable between the two regions. Cameroon had the highest prevalence for all the anthropometric deficits and especially, for those with possible risk of overweight defined through weight-for-height (31.5%) and BMI-for-age (35.9%), CSPO_WHZ (9.7%), and CSPO_BMIZ (12.6%). In all the datasets, the prevalence of CSPO_BMIZ was significantly higher than that of CSPO_WHZ. Similar results were encountered in concurrent stunting and overweight in 6-59 months old children (**Supplementary Table S1**) while the reverse pattern was observed in children below 6 months of age (**Table 3 and Supplementary Table S2**).

Table 2: Prevalence (%) of Anthropometric Deficits in 6-59 months in the Demographic Health Survey datasets for Concurrent Stunting and Possible Risk of Overweight defined through weight for height and BMI for age from 21 countries

Datasets	Sample Size (N)	Stunting (95% CI)	Possible Risk of Overweight defined through weight for height (95% CI)	Possible Risk of Overweight defined through BMI for age (95% CI)	CSPO_WHZ (95% CI)	CSPO_BMIZ (95% CI)	*P-value#*
Demographic Health Survey Datasets: South and South-East Asia (a)							
Bangladesh	4,083	24.8 (23.5, 26.3)	5.4 (4.7, 6.2)	6.8 (6.0, 7.6)	1.15 (0.9, 1.6)	1.89 (1.5, 2.4)	*<0.0001*
Cambodia	3,747	34.8 (33.3, 36.3)	10.0 (9.0, 11.0)	12.1 (11.1, 13.2)	3.25 (2.7, 3.9)	4.54 (3.9, 5.3)	*<0.0001*
India	197,651	37.2 (37.1, 37.5)	8.94 (8.8, 9.1)	11.4 (11.2, 11.5)	4.49 (4.4, 4.6)	6.42 (6.3, 6.5)	*<0.0001*
Maldives	2,342	14.6 (13.2, 16.2)	13.4 (12.0, 14.9)	14.2 (12.8, 15.8)	1.85 (1.4, 2.5)	2.36 (1.8, 3.1)	*0.002*
Myanmar	4,146	33.5 (32.0, 35.0)	6.4 (5.6, 7.2)	9.5 (8.6, 10.5)	1.70 (1.3, 2.2)	3.79 (3.2, 4.5)	*<0.0001*
Nepal	2,586	28.6 (26.8, 30.5)	5.1 (4.3, 6.1)	6.7 (5.8, 7.8)	0.78 (0.5, 1.2)	1.80 (1.3, 2.4)	*<0.0001*
Pakistan	4,079	41.0 (39.4, 42.6)	13.8 (12.7, 14.9)	18.6 (17.3, 20.0)	5.86 (5.1, 6.7)	9.88 (9.0, 10.9)	*<0.0001*
Pooled	***218,634***	***36.4 (36.2, 36.7)***	***8.9 (8.8, 9.1)***	***11.4 (11.2, 11.5)***	***4.30 (4.2, 4.4)***	***6.21 (6.1, 6.3)***	**<0.0001**
Demographic Health Survey Datasets: Sub-Saharan Africa (b)							
Angola	6,268	40.4 (39.1, 41.2)	13.0 (12.1, 13.9)	17.1 (16.2, 18.2)	5.01 (4.5, 5.6)	8.03 (7.3, 8.8)	*<0.0001*
Benin	11,626	34.0 (33.1, 35.0)	9.0 (8.4, 9.5)	12.2 (11.5, 12.8)	2.96 (2.6, 3.3)	5.16 (4.7, 5.6)	*<0.0001*
Cameroon	4,435	29.6 (28.2, 31.1)	31.5 (30.1, 33.0)	35.9 (34.4, 37.4)	9.68 (8.8, 10.6)	12.6 (11.6, 13.7)	*<0.0001*
Congo	4,464	29.1 (27.7, 30.1)	12.2 (11.2, 13.2)	15.0 (13.9, 16.1)	3.84 (3.3, 4.5)	5.62 (4.9, 6.4)	*<0.0001*
Ethiopia	5,055	38.4 (37.0, 39.8)	8.1 (7.4, 9.0)	10.6 (9.8, 11.6)	2.80 (2.4, 3.3)	4.58 (4.0, 5.2)	*<0.0001*
Gambia	3,805	20.0 (18.6, 21.4)	6.3 (5.5, 7.2)	8.0 (7.1, 9.0)	0.88 (0.6, 1.3)	1.83 (1.4, 2.3)	*<0.0001*
Ghana	4,394	18.8 (17.6, 20.1)	7.0 (6.2, 7.8)	8.6 (7.7, 9.5)	0.97 (0.7, 1.3)	1.61 (1.3, 2.1)	*<0.0001*
Kenya	17,280	18.9 (18.3, 19.5)	10.2 (9.8, 10.7)	12.1 (11.6, 12.6)	1.29 (1.1, 1.5)	2.33 (2.1, 2.6)	*<0.0001*
Liberia	2,439	33.9 (31.9, 35.9)	14.7 (13.3, 16.3)	18.8 (17.3, 20.5)	5.22 (4.4, 6.2)	7.94 (6.9, 9.2)	*<0.0001*
Malawi	5,110	37.0 (35.6, 38.4)	16.5 (15.5, 17.6)	22.0 (20.8, 23.2)	6.05 (5.4, 6.8)	9.77 (8.9, 10.7)	*<0.0001*
Mali	8,202	28.6 (27.6, 29.6)	7.1 (6.5, 7.7)	9.4 (8.7, 10.1)	2.49 (2.2, 2.9)	4.10 (3.7, 4.6)	*<0.0001*
Mozambique	3,720	35.4 (33.8, 37.1)	16.1 (14.9, 17.4)	21.4 (20.1, 22.9)	5.81 (5.1, 6.7)	9.20 (8.3, 10.2)	*<0.0001*
Nigeria	11,308	38.4 (37.4, 39.3)	10.1 (9.5, 10.7)	14.4 (13.7, 15.1)	3.85 (3.5, 4.2)	7.26 (6.8, 7.8)	*<0.0001*
Tanzania	4,791	30.4 (29.0, 31.8)	14.3 (13.4, 15.5)	18.9 (17.8, 20.1)	4.66 (4.1, 5.3)	7.28 (6.5, 8.1)	*<0.0001*
Pooled	***88,106***	***30.0 (29.7, 30.4)***	***11.4 (11.1, 11.6)***	***14.6 (14.3, 14.8)***	***3.38 (3.3, 3.5)***	***5.52 (5.4, 5.7)***	**<0.0001**
Grand Pooled (a + b)	***311,531***	***34.6 (34.3, 34.7)***	***9.7 (9.6, 9.8)***	***12.4 (12.3, 12.5)***	***4.05 (3.9, 4.1)***	***6.04 (5.9, 6.1)***	**<0.0001**

#P-values calculated between the prevalence of CSPO_WHZ and CSPO_BMIZ using Mc-Nemar test

Table 3: Prevalence (%) of Anthropometric Deficits in 0-6 months in the Demographic Health Survey datasets for Concurrent Stunting and Possible Risk of Overweight defined through weight for height and BMI for age from 21 countries

Datasets	Sample Size (N)	Stunting (95% CI)	Possible Risk of Overweight defined through weight for height (95% CI)	Possible Risk of Overweight defined through BMI for age (95% CI)	CSPO_WHZ (95% CI)	CSPO_BMIZ (95% CI)	*P-value*[#]
Demographic Health Survey Datasets: South and South-East Asia (a)							
Bangladesh	4,083	11.5 (8.8, 14.9)	12.2 (9.4, 15.6)	8.5 (6.2, 11.6)	2.3 (1.2, 4.2)	1.2 (0.1, 2.7)	*0.06*
Cambodia	3,747	15.2 (11.8, 19.5)	23.3 (19.1, 28.1)	17.9 (14.2, 22.4)	11.3 (8.4, 15.2)	8.1 (5.6, 11.5)	*0.001*
India	197,651	23.5 (22.9, 24.1)	17.2 (16.7, 17.8)	10.6 (10.2, 11.1)	11.0 (10.5, 11.4)	5.7 (5.4, 6.0)	*<0.0001*
Maldives	2,342	20.9 (15.5, 27.6)	18.1 (13.1, 24.5)	10.2 (6.5, 15.6)	10.2 (6.5, 15.6)	3.4 (1.5, 7.4)	*<0.001*
Myanmar	4,146	7.2 (5.1, 10.1)	18.8 (15.4, 22.0)	15.3 (12.2, 19.1)	2.8 (1.6, 4.9)	1.4 (0.1, 3.1)	*0.03*
Nepal	2,586	17.4 (13.2, 22.7)	20.7 (16.0, 26.2)	13.0 (9.3, 17.8)	5.7 (3.4, 9.4)	1.6 (0.1, 4.3)	*0.002*
Pakistan	4,079	17.8 (14.5, 21.8)	19.0 (15.6, 23.0)	13.2 (10.2, 16.7)	5.6 (3.8, 8.3)	3.3 (2.0, 5.5)	*0.002*
Pooled	***218,634***	***22.5 (22.0, 23.1)***	***17.3 (16.8, 17.8)***	***10.8 (10.5, 11.3)***	***10.4 (10.0, 10.9)***	***5.4 (5.1, 5.7)***	**<0.0001**
Demographic Health Survey Datasets: Sub-Saharan Africa (b)							
Angola	6,268	17.7 (15.1, 20.5)	29.3 (26.2, 32.7)	20.2 (17.5, 23.2)	7.7 (6.0, 9.8)	3.0 (2.0, 4.5)	*<0.0001*
Benin	11,626	16.7 (14.8, 18.8)	18.4 (16.4, 20.6)	12.6 (10.9, 14.5)	5.0 (3.9, 6.3)	1.6 (1.0, 2.4)	*<0.0001*
Cameroon	4,435	16.5 (13.5, 20.0)	38.5 (34.3, 42.8)	32.6 (28.7, 36.8)	9.8 (7.5, 12.7)	5.1 (3.5, 7.4)	*<0.0001*
Congo	4,464	11.1 (8.7, 14.1)	21.3 (18.0, 25.0)	16.8 (13.8, 20.2)	5.5 (3.8, 7.8)	4.3 (2.9, 6.5)	*0.03*
Ethiopia	5,055	16.0 (13.2, 19.3)	21.4 (18.2, 25.0)	15.8 (13.0, 19.1)	5.8 (4.1, 8.0)	2.2 (1.2, 3.8)	*<0.0001*
Gambia	3,805	7.8 (5.8, 10.4)	23.2 (20.0, 27.0)	15.6 (12.7, 19.0)	2.9 (1.7, 4.7)	1.3 (0.4, 2.8)	*0.03*
Ghana	4,394	12.8 (10.1, 16.0)	23.9 (20.4, 27.9)	18 .1 (14.9 21.7)	5.3 (3.6, 7.6)	2.0 (1.1, 3.7)	*<0.0001*
Kenya	17,280	10.1 (8.8, 11.4)	30.6 (28.5, 32.7)	23.6 (21.7, 25.5)	5.0 (4.1, 6.0)	2.3 (1.7, 3.1)	*<0.0001*
Liberia	2,439	20.1 (15.7, 25.3)	42.3 (36.6, 48.3)	29.6 (24.4, 35.3)	14.2 (10.6, 18.9)	8.0 (5.3, 11.9)	*<0.0001*
Malawi	5,110	20.9 (17.5, 24.8)	38.8 (34.5, 43.2)	30.3 (26.3, 34.6)	12.7 (10.0, 15.9)	7.9 (5.8, 10.7)	*<0.0001*
Mali	8,202	12.6 (10.6, 14.8)	15.1 (13.0, 17.6)	11.8 (9.9, 14.0)	3.9 (2.8, 5.3)	1.6 (0.9, 2.7)	*<0.0001*
Mozambique	3,720	15.6 (12.5, 19.3)	29.0 (25.0, 33.4)	19.6 (16.2, 23.6)	8.5 (6.2, 11.5)	3.4 (2.0, 5.5)	*<0.0001*
Nigeria	11,308	18.0 (15.9, 20.3)	20.0 (17.8, 22.4)	14.7 (12.7, 16.8)	4.5 (3.5, 5.9)	12.8 (0.7, 2.1)	*<0.0001*
Tanzania	4,791	16.9 (14.0, 20.3)	39.5 (35.5, 43.7)	30.7 (27.0, 34.7)	9.4 (7.2, 12.1)	5.9 (4.2, 8.2)	*<0.0001*
Pooled	***88,106***	***14.5 (13.8, 15.2)***	***25.4 (24.5, 26.3)***	***18.9 (18.2, 19.7)***	***6.0 (5.6, 6.5)***	***2.7 (2.4, 3.1)***	**<0.0001**
Grand Pooled (a + b)	***311,531***	***19.8 (19.4, 20.3)***	***20.4 (19.9, 20.8)***	***13.9 (13.5, 14.2)***	***9.0 (8.7, 9.3)***	***4.5 (4.3, 4.8)***	**<0.0001**

[#]P-values calculated between the prevalence of CSPO_WHZ and CSPO_BMIZ using Mc-Nemar test; Association between stunted and overweight defined through weight for height or BMI for age

Figure 1 depicts the possible risk of CSPO_WHZ and CSPO_BMIZ associations in the children below 6-59 months of age in the DHS datasets. For possible risk of overweight defined through weight for height, significant positive associations were documented in two Asian and African countries while significant negative associations were encountered in three Asian countries and two African countries. In South and South-East Asia, there was no significance in the pooled estimates [OR (95% CI) 1.04 (0.55, 1.54); I^2=98.44%], Sub-Saharan Africa [0.95 (0.84, 1.07); I^2=84.07%], or the overall dataset [0.99 (0.77, 1.20); I^2=97.37%] with considerable heterogeneity for the possible risk of overweight defined through weight for height. While, for the possible risk of overweight defined through BMI for age, significant positive associations were seen in three Asian countries and twelve African countries. The pooled estimates were positively associated but not significant for Asia [1.57 (1.01, 2.13); I^2=96.59%]. A significant positive association was encountered in the pooled estimates for Africa [1.46 (1.30, 1.61); I^2=84.86%] and in combined datasets [1.50 (1.24, 1.75); I^2=96.51%]. The converse was documented in the 0-6 months age group (**Figure 2**) for CSPO_WHZ with significant positive associations [3.23 (2.17, 4.29); I^2=93.74%] and for CSPO_BMIZ with non-significant positive association [1.40 (0.90, 1.90)]. Almost similar results were encountered for concurrent stunting and overweight defined through both the indices, with overall positive significant associations in both the age groups (**Supplementary Figures 1 and 2**).

Almost perfect correlation was found between WHZ and BMIZ (r=0.98 to 0.99) in all the datasets (**Supplementary Table S3**). The beta coefficients of the log weight regressed on log height was almost 2 (1.66 to 1.87). Generally, both BMIZ and WHZ had analogous patterns of lower correlation with height than with weight.

Figure 1: Summary of stunting-possible risk of overweight with respect to Weight-for-Height and Body-Mass-Index-for-age (CSPO_WHZ and CSPO_BMIZ) associations in 6-59 months old children in the Demographic Health Survey datasets.

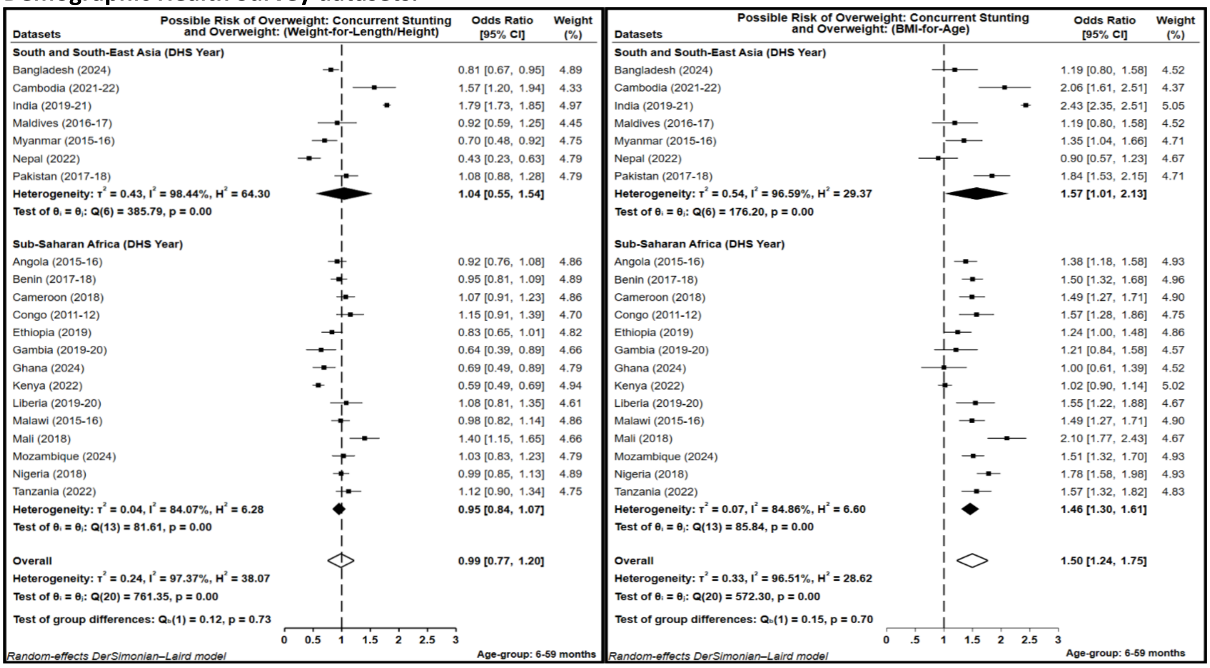
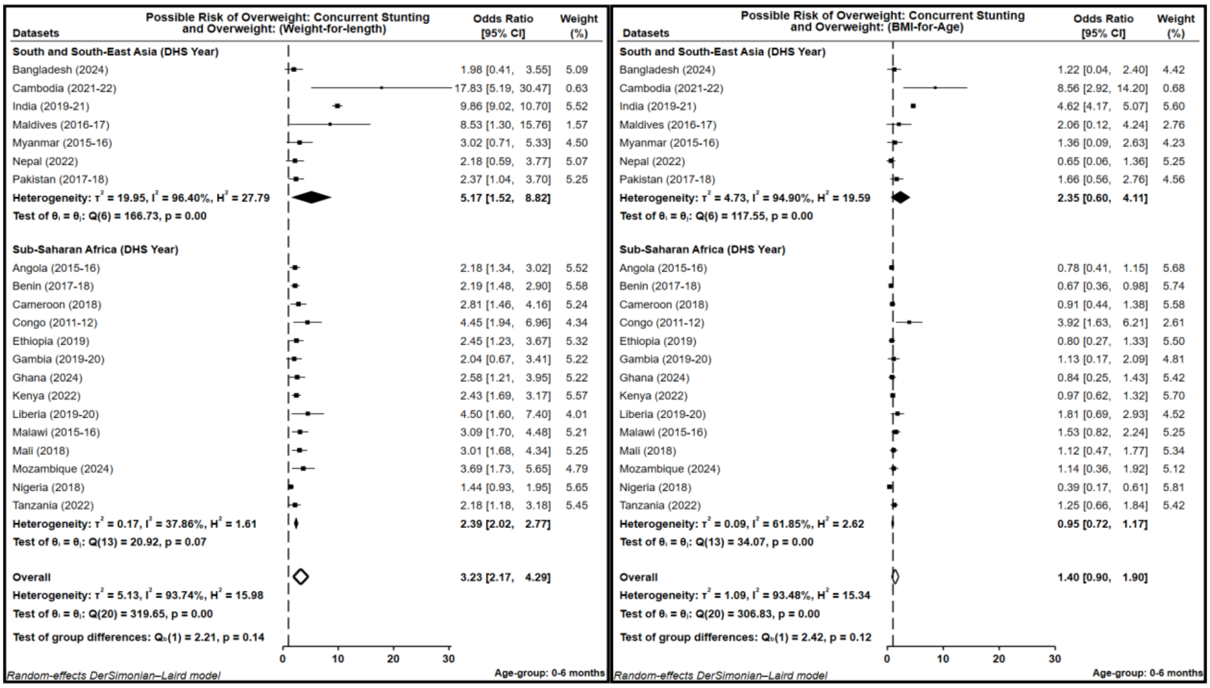


Figure 2: Summary of stunting-possible risk of overweight with respect to Weight-for-Height and Body-Mass-Index-for-age (CSPO_WHZ and CSPO_BMIZ) associations in 0-6 months old children in the Demographic Health Survey datasets.



Discussion

The associations between CSPO_BMIZ and CSPO_WHZ were different in the analyses and the directions varied with age. For the children in 6-59 months age group, the overall pooled estimates for CSPO_BMIZ were positively significant but were not significant for CSPO_WHZ. While the pooled estimates for Asia were not significant in both CSPO_BMIZ and CSPO_WHZ, but were positively significant in the pooled estimates for Africa in CSPO_BMIZ and not for CSPO_WHZ. In the age group of 0-6 months, the overall CSPO_BMIZ was not significant, but CSPO_WHZ association was positively significant. Similar pattern was documented in CSO_WHZ and CSO_BMIZ for both the age groups (0-6 and 6-59 months). The results are strengthened by the use of recent contemporary datasets among various countries and regions, and orientation with the earlier reports of higher CSO_BMIZ prevalence in boys,(4) and in comparison, to CSO_WHZ.(3) Further, the flipover in the CSPO_WHZ and CSPO_BMIZ, CSO_WHZ and CSO_BMIZ associations starts after the age 6 months, which is in consonance with the earlier findings on age differences.(4)

Stunting and the two measures of ponderosity defined through weight for height and BMI for age z-scores have different, largely contrasting associations which indicates a primary statistical explanation for the observed CSPO_WHZ and CSO_WHZ association which originates from ignoring physiological changes with age in the weight for height metric. Additionally, the following support this disagreement i) the flip over of these associations around 6 months of age, as predicted by curvature change in the WHO BMI for age charts,(6) ii) Almost perfect correlation between BMIZ and WHZ, iii) the beta coefficients of log weight regressed on log height (1.66 to 1.87)(10,11) which substantiates the use of BMI for age in children below the age of five years, and iv) comparable patterns among both metrics of lower correlations with height than with weight.

Zemene et al in their pooled datasets from 35 countries of SSA found that the prevalence of concurrent stunting and overweight among under-five children was 1.82% (1.76, 1.87).(3) Although our results are consistent with previous studies,(3,12,13) the separate analyses for the age-groups 0-6 months and 6-59 months calculations were excluded in other studies wherein in the current study the CSO_WHZ association was positive for 0-6 months, thereby raising queries regarding the estimates. Moreover, our 6-59 months pooled estimates were positively associated, but with a lower magnitude.

The statistical origin of CSO association requires greater consideration. Stunting individually is linked to low adult income, short height in adulthood, and lower educational attainment(14) and some other cardiometabolic risk factors.(15) Similarly, overweight or obesity is also considered as an important factor for the existence of numerous non-communicable ailments(16) and is one of the major reasons of mortality and disability in the world.(17) Reports from influential bodies like the World Bank and other reviews(18,19) tend to focus on stunting(18-22) and overweight(18,19,23) separately.

Zemene et al highlighted that the recommended programs to CSO children(3) deserve a careful consideration since this condition was largely a statistical phenomenon, primarily driven by the severity and high prevalence of stunting. The WHO guidelines on preventing overweight and obesity in the context of double burden of malnutrition state(24): *"Routinely providing supplementary foods to moderately wasted infants and children presenting to primary healthcare facilities is not recommended"* and *"The provision of supplementary foods for treating stunting among infants and children who present to primary health-care facilities is not recommended."* This conditional recommendation by the WHO along with recent findings from the Indian Comprehensive National Nutrition Survey states that at least half of children aged 5-19 years, even those who were skinny or stunted, had "metabolic obesity" (dysglycemia or dyslipidemia) highlights the need to revisit on addressing these issues of malnutrition.(25)

Conclusion

In conclusion, concurrent stunting and overweight associations defined through weight for height and BMI for age are dissimilar. This suggests a primary statistical explanation for the reported stunting-overweight association, which originates from ignoring physiological changes with age in weight for height metric.

Recommendation

BMI-for-age should be preferred over weight-for-height when assessing overweight in under-five children, as weight-for-height underestimates high ponderosity and obscure overweight-stunting co-existence. Use of age-sensitive metrics is recommended for surveillance and research.

Limitation of the Study

This analysis should be interpreted in the backdrop of some limitations. Although the DHS data from these nations were gathered over a ten-year period, they were collected in different years. In addition, we could have explored databases from refugee settings and all DHS datasets. Nevertheless, since the analysis includes areas with a high prevalence of stunting, their inclusion is unlikely to change the main finding. Because of fewer measurement errors, a pooled analysis from exclusive research settings might have produced results with higher confidence and precision.

Relevance of the Study

This study clarifies inconsistencies in overweight-stunting evidence by showing that associations depend on the anthropometric metrics used. It highlights the importance of appropriate indicator selection for accurately identifying the double burden of malnutrition in under-five children.

Authors Contribution

All authors have contributed equally.

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Nil

Conflict of Interest

The authors declare no conflict of interest

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None

Declaration of Generative AI and AI Assisted Technologies in the Writing Process

The authors have not used any AI tools in the writing process.

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