The double burden of malnutrition among adolescents: analysis of data from the Global School-Based Student Health and Health Behavior in School-Aged Children surveys in 57 low- and middle-income countries

Rishi Caleyachetty,[1,2] *GN Thomas,*[2] *Andre P Kengne,*[3,4] *Justin B Echouffo-Tcheugui,*[5] *Samantha Schilsky,*[6] *Juneida Khodabocus,*[7] *and Ricardo Uauy*[8-10]

[1]Warwick Medical School, University of Warwick, Coventry, United Kingdom; [2]Institute of Applied Health Research, College of Medical and Dental Sciences, University of Birmingham, Birmingham, United Kingdom; [3]South African Medical Research Council, Cape Town, South Africa; [4]The George Institute for Global Health, Sydney, Australia; [5]Brigham and Women's Hospital, Harvard Medical School, Boston, MA; [6]George Washington University School of Medicine and Health Sciences, Washington, DC; [7]University Hospital Southampton NHS Foundation Trust, Southampton General Hospital, Southampton, United Kingdom; [8]Institute of Nutrition and Food Technology, University of Chile, Santiago, Chile; [9]Division of Pediatrics, School of Medicine, Catholic University of Chile, Santiago, Chile; and [10]London School of Hygiene and Tropical Medicine, London, United Kingdom

ABSTRACT

Background: Adults and young children in countries experiencing the nutrition transition are known to be affected simultaneously by undernutrition and overnutrition. Adolescence is a critical period for growth and development. Yet, it is unknown to what extent this double burden of malnutrition affects adolescents in low- and middle-income countries (LMICs) and the macrolevel contextual factors associated with the double burden of malnutrition.

Objective: The aim was to quantify the magnitude of the double burden of malnutrition among adolescents and to examine the potential sources of heterogeneity in prevalence estimates across LMICs.

Design: We used individual-participant data from the Global School-Based Student Health and Health Behavior in School-Aged Children surveys conducted in 57 LMICs between 2003 and 2013, comprising 129,276 adolescents aged 12–15 y. Pooled estimates of stunting, thinness, or both; overweight or obesity; and concurrent stunting and overweight or obesity were calculated overall, by regions, and stratified by sex, with random-effects meta-analysis. Guided by UNICEF's conceptual framework for child malnutrition, we used ecological linear regression models to examine the association between macrolevel contextual factors (internal conflict, lack of democracy, gross domestic product, food insecurity, urbanization, and survey year) and stunting, thinness, and overweight and obesity prevalence, respectively.

Results: The prevalence of stunting was 10.2% (95% CI: 8.3%, 12.2%) and of thinness was 5.5% (95% CI: 4.3%, 6.9%). The prevalence of overweight or obesity was 21.4% (95% CI: 18.6%, 24.2%). Between 38.4% and 58.7% of the variance in adolescent malnutrition was explained by macrolevel contextual factors. The prevalence of concurrent stunting and overweight or obesity was 2.0% (95% CI: 1.7%, 2.5%).

Conclusions: The double burden of malnutrition among adolescents in LMICs is common. Context-sensitive implementation and scale-up of interventions and policies for the double burden of malnutrition are needed to achieve the Sustainable Development Goal to end malnutrition in all of its forms by 2030. This trial was registered at clinicaltrials.gov as NCT03346473. *Am J Clin Nutr* 2018;108:414–424.

Keywords: adolescent, malnutrition, stunting, thinness, obese, double burden

INTRODUCTION

Low- and middle-income countries (LMICs) formerly confronted with a high prevalence of undernutrition (stunting or thinness) (1) now must face overnutrition (overweight or obesity) as an additional burden. This is now referred as the "double burden of malnutrition." Originally described in adults, the double burden of malnutrition is now affecting children (1, 2), and its magnitude among adolescents across LMICs remains poorly defined.

Despite 90% of adolescents living in LMICs, the global health community has largely neglected the health needs of this population (3). Adolescence is a period of rapid growth, with higher nutritional demands placing adolescents at greater

The authors reported no funding received for this study.

Supplemental Tables 1–7 and Supplemental Figures 1–26 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/ajcn/.

Address correspondence to RC (e-mail: r.caleyachetty@warwick.ac.uk).

Abbreviations used: GDP, gross domestic product; GSHS, Global School-Based Student Health Survey; HSBC, Health Behavior in School-Aged Children, LMIC, low- and middle-income country.

Received April 28, 2017. Accepted for publication April 26, 2018.

First published online June 27, 2018; doi: https://doi.org/10.1093/ajcn/nqy105.

risk of malnutrition. The nutritional status of adolescent girls is particularly important because adolescent fertility still accounts for 11% of all births globally, with 95% of these births occurring in LMICs (4).

Stunting begins in utero and manifests itself across infancy and affects brain and muscle growth (1). Among adolescents, stunting is associated with impaired cognitive development and school achievement, reduced economic productivity (5), and poor reproductive health outcomes in females (6). Childhood stunting has also been reported to coexist with overweight or obesity (7, 8). The consequences of concurrent stunting and obesity in adolescents are likely to compound health issues in adolescence and later in adulthood, particularly for females because of the heightened obstetric risk. Thinness in adolescence is associated with delayed maturation, poor muscle strength leading to constraints in capacity for physical work, and reduced bone density later in life (9). Obesity in adolescence has been associated with an increased risk of early onset of adult chronic diseases (type 2 diabetes, hypertension) and mortality in adult life (10, 11).

Quantifying the double burden of malnutrition among adolescents and examining the macrolevel contextual factors shaping the distribution of the double burden across LMICs are important for policymakers to support actions to achieve the Sustainable Development Goal of ending malnutrition in all its forms by 2030. We estimated the burden of stunting, thinness, or both; overweight or obesity; and concurrent stunting and overweight or obesity in adolescents aged 12–15 y in LMICs with the use of data from 57 nationwide school-based surveys during the years 2003–2013. We also investigated potential sources of heterogeneity in the estimates across countries.

METHODS

Design

We used the most recent Global School-Based Student Health Survey (GSHS) and Health Behavior in School-Aged Children (HSBC) surveys with data available on height and weight. The GSHS is a WHO initiative, designed to assess health behaviors of adolescents through cross-sectional school-based surveys, across several countries with the use of similar standardized procedures (12). The HSBC study includes WHO-sponsored, cross-sectional, school-based surveys that use similar standardized procedures to the GSHS to examine the physical and mental health of adolescents in the WHO European Region and North America (13). This study was registered at clinicaltrials.gov as NCT03346473.

Anthropometric measurements

Trained survey staff weighed and measured the height of each student. BMI (weight in kilograms divided by height in meters squared) was calculated from height and weight. Stunting was defined as height-for-age <2 SDs below the WHO Child Growth Reference median. Thinness was defined as BMI-for-age <2 SDs below the WHO Growth Reference median. Overweight was defined as BMI-for-age >1 SD above the WHO Growth Reference median, and obesity was defined as >2 SDs above the WHO Growth Reference median.

Statistical analysis

In view of the complex design of the surveys, we used sampling weights and accounted for stratification and clustering in the sample design to estimate the proportion and 95% CIs for stunting, thinness, stunting or thinness, overweight or obesity, and concurrent stunting and overweight or obesity. Meta-analysis was performed to synthesize the prevalence estimates overall and for WHO regions. Variances of the raw proportions were stabilized with a double arcsine transformation and then pooled on the basis of a random-effects model. We calculated the pooled prevalence estimates and the 95% CIs. To evaluate the extent of heterogeneity of prevalence estimates between the LMICs, we used heterogeneity tests with the I^2 statistic.

Guided by the UNICEF's conceptual framework for child malnutrition (1), we examined macrolevel contextual factors that might explain heterogeneity in prevalence estimates for stunting, thinness, and overweight or obesity. We first examined Pearson correlations between macrolevel contextual factors [including recent internal conflict, lack of democracy, gross domestic product (GDP) per capita, food insecurity, percentage living in urban areas, and year of survey] and the overall prevalence of stunting, thinness, and overweight or obesity, respectively. Significant macrolevel contextual factors ($P < 0.05$) were then entered into ecological multiple linear regression models. **Supplemental Table 1** provides a description of the macrolevel contextual factors. For the outcomes of thinness and overweight or obesity, macrolevel contextual factors were extracted to correspond to the country's survey year and the 5 previous years (where available). The mean value was then calculated and used in correlation and regression analyses. Because the causes of adolescent stunting occur much earlier in the life course, we extracted macrolevel contextual factor data to correspond to the mean age of the population at birth to age 2 y. The mean value was then calculated and used in correlation and regression analyses.

All of the statistical analyses were performed with the use of STATA version 14 (StataCorp). We used Meta-XL (version 2.2) to stabilize the variances of the raw proportions and pool proportions with a random-effects model (http://www.epigear.com/index_files/metaxl.html).

RESULTS

Characteristics of surveys and participants

In all, 76 LMICs had GSHS and HBSC surveys between 2003 and 2013. Two surveys (Tajikistan and Zimbabwe) had no data on height and weight. **Table 1** shows the characteristics of the available 74 surveys. Due to poor availability of data on height and weight (i.e., <60%), 23% (17 of 74) of the countries were excluded from the analysis. By WHO region, per total number of LMICs ($n = 57$), 7 (15%) of 47 in Africa, 15 of (50%) 30 in the Americas, 12 (80%) of 15 in the Eastern Mediterranean, 6 (35%) of 17 in Europe, 6 (60%) of 10 in Southeast Asia, and 11 (52%) of 21 in the Western Pacific had GSHS or HBSC survey data. Adolescents ($n = 129,276$) had a mean age of 14.3 y (range: 13.3–14.9 y). The mean BMI (in kg/m^2) was 20.3 (range: 17.1 in Sri Lanka to 24.9 in Niue). The percentage of boys ranged from 39% in Swaziland to 66% in Benin. The mean overall response rate (total sample of students aged 12–15 y divided by the total

TABLE 1
Characteristics of adolescents aged 12–15 y in low- and middle-income countries[1]

Region	Year	Sample size, *n*	Coverage	Response rate,[2] %	Boys, %	Age, y	BMI, kg/m^2	Height, m
Africa								
Algeria	2011	3387	National	96.0	46.0	14.1 ± 1.1	19.3 ± 3.3	1.6 ± 0.1
Benin	2009	1137	National	96.4	66.0	14.7 ± 0.9	19.5 ± 2.5	1.6 ± 0.1
Ghana	2012	1064	National	94.8	48.6	14.3 ± 1.0	19.1 ± 2.8	1.6 ± 0.1
Mauritania	2010	856	National	64.8	52.8	14.7 ± 0.9	20.2 ± 3.7	1.6 ± 0.1
Republic of Mauritius	2011	2974	National	94.8	48.5	14.3 ± 1.0	19.6 ± 4.2	1.6 ± 0.1
Sudan	2012	1302	National	88.2	51.8	14.7 ± 0.8	19.1 ± 3.9	1.5 ± 0.1
Swaziland	2013	1258	National	91.9	39.1	14.6 ± 0.9	20.4 ± 3.6	1.6 ± 0.1
Uganda	2003	1801	National	91.7	47.3	14.8 ± 0.8	19.1 ± 2.8	1.6 ± 0.1
Americas								
Argentina	2007	1067	National	67.9	46.9	14.7 ± 0.8	21.0 ± 3.3	1.6 ± 0.1
Belize	2011	1487	National	91.7	48.3	14.1 ± 1.1	21.8 ± 4.8	1.6 ± 0.1
Bolivia	2012	2682	National	90.7	49.8	14.5 ± 0.9	20.9 ± 3.3	1.6 ± 0.1
British Virgin Islands	2009	1106	National	91.6	47.6	14.0 ± 1.1	22.5 ± 6.1	1.6 ± 0.1
Chile	2004	5158	National	67.4	48.1	14.1 ± 1.0	20.8 ± 3.0	1.6 ± 0.1
Costa Rica	2009	2198	National	96.5	49.9	14.5 ± 0.8	21.2 ± 3.9	1.6 ± 0.1
Dominica	2009	1049	National	79.7	53.1	14.2 ± 1.1	21.3 ± 4.9	1.6 ± 0.1
Guatemala	2009	4286	National	93.5	52.1	14.5 ± 0.9	21.3 ± 3.9	1.5 ± 0.1
Guyana	2012	1896	National	95.5	48.3	14.6 ± 0.8	19.7 ± 3.9	1.6 ± 0.1
Honduras	2012	1422	National	94.7	46.0	14.1 ± 1.0	20.1 ± 3.9	1.6 ± 0.1
Jamaica	2010	1177	National	95.9	49.4	14.8 ± 0.7	21.2 ± 4.3	1.6 ± 0.1
Peru	2010	2143	National	90.3	50.1	14.6 ± 0.8	21.0 ± 2.8	1.5 ± 0.1
St. Kitts and Nevis	2011	1264	National	85.3	50.1	14.6 ± 0.8	22.0 ± 5.4	1.6 ± 0.1
Suriname	2009	997	National	93.9	44.5	14.5 ± 1.0	20.1 ± 4.1	1.6 ± 0.1
Uruguay	2012	2590	National	89.2	46.0	14.6 ± 0.8	21.2 ± 3.9	1.6 ± 0.1
Eastern Mediterranean								
Djibouti	2007	887	National	86.3	59.3	14.8 ± 0.8	19.5 ± 4.1	1.6 ± 0.1
Egypt	2011	2038	National	84.1	48.2	14.0 ± 0.9	21.1 ± 4.0	1.5 ± 0.1
Iraq	2012	1459	National	93.9	54.4	14.4 ± 1.0	20.7 ± 4.2	1.6 ± 0.1
Jordan	2007	1043	National	63.1	51.1	14.9 ± 0.7	20.5 ± 4.0	1.6 ± 0.1
Lebanon	2011	1359	National	68.1	49.9	14.2 ± 1.0	20.5 ± 3.7	1.6 ± 0.1
Libya	2007	1693	National	87.9	48.7	14.1 ± 1.0	20.5 ± 4.3	1.6 ± 0.1
Morocco	2010	2270	National	92.6	52.6	14.2 ± 1.0	19.3 ± 3.3	1.6 ± 0.1
Pakistan	2009	4808	National	96.1	60.9	14.6 ± 0.8	18.6 ± 2.7	1.6 ± 0.1
Palestine	2010	3904	Subnational	89.0	50.0	14.3 ± 0.9	20.3 ± 4.0	1.6 ± 0.1
Syria	2010	2799	National	95.2	51.0	14.1 ± 1.0	20.3 ± 3.8	1.6 ± 0.1
Yemen	2008	665	National	69.3	61.5	14.4 ± 0.9	18.5 ± 4.6	1.5 ± 0.1
Europe								
Bulgaria	2006	1704	National	93.5	50.8	13.5 ± 0.6	19.1 ± 3.1	1.6 ± 0.1
Macedonia	2007	1282	National	81.9	52.5	14.4 ± 0.9	20.3 ± 3.0	1.6 ± 0.1
Romania	2006	1648	National	94.4	44.9	13.5 ± 0.7	19.1 ± 3.2	1.6 ± 0.1
Russia	2006	2493	National	82.8	44.4	13.5 ± 0.6	19.0 ± 2.9	1.6 ± 0.1
Turkey	2006	2503	National	87.7	52.4	13.3 ± 0.9	18.8 ± 3.1	1.5 ± 0.1
Ukraine	2006	2134	National	91.2	52.1	13.4 ± 0.7	18.5 ± 2.8	1.6 ± 0.1
Southeast Asia								
India	2007	6132	National	83.0	57.6	14.4 ± 0.9	18.6 ± 3.3	1.6 ± 0.1
Indonesia	2007	2285	National	75.5	47.1	14.3 ± 0.8	18.5 ± 3.2	1.5 ± 0.1
Malaysia	2012	15,709	National	96.5	48.9	14.5 ± 0.8	20.4 ± 4.7	1.6 ± 0.1
Myanmar	2007	2000	National	89.1	48.1	14.2 ± 1.0	17.9 ± 2.7	1.5 ± 0.1
Sri Lanka	2008	2167	National	86.2	46.1	14.2 ± 0.9	17.1 ± 2.7	1.5 ± 0.1
Thailand	2008	2599	National	97.0	47.8	14.1 ± 1.0	19.6 ± 3.9	1.6 ± 0.1
Western Pacific								
China	2003	7341	Subnational	85.5	50.1	14.2 ± 1.0	19.5 ± 4.0	1.6 ± 0.1
Cook Islands	2011	794	National	93.2	48.4	14.2 ± 1.0	24.4 ± 5.2	1.7 ± 0.1
Fiji	2010	1388	National	92.3	47.8	14.5 ± 0.8	19.7 ± 4.0	1.6 ± 0.1
Kiribati	2011	1223	National	90.1	45.7	14.6 ± 0.9	22.4 ± 3.5	1.6 ± 0.1
Nauru	2011	336	National	87.3	50.4	14.2 ± 1.0	23.1 ± 4.4	1.5 ± 0.1
Niue	2010	80	National	97.6	55.4	13.9 ± 1.2	24.9 ± 5.2	1.7 ± 0.1
Philippines	2011	3488	National	89.8	47.0	14.4 ± 1.0	18.9 ± 3.5	1.5 ± 0.1
Samoa	2011	1490	National	67.3	47.3	14.5 ± 0.8	24.0 ± 5.3	1.6 ± 0.1
Solomon Islands	2011	782	National	79.9	51.3	14.6 ± 0.9	20.6 ± 3.4	1.6 ± 0.1
Tonga	2010	1874	National	95.7	50.4	14.6 ± 0.9	24.4 ± 4.8	1.6 ± 0.1
Vanuatu	2011	598	National	69.1	50.6	14.0 ± 1.1	18.8 ± 2.9	1.6 ± 0.1

[1] Values are means ± SDs unless otherwise indicated; $n = 57$.
[2] Response rate = total sample of students aged 12–15 y divided by the total sample of students with complete sex, age, and anthropometric data.

sample of students with complete sex, age, and anthropometric data) was 87.3% (range: 63.1–97.6%).

Prevalence of stunting

The overall prevalence of adolescent stunting was 10.2% (95% CI: 8.3%, 12.2%; I^2: 99.3%) and ranged from 0% (Niue) to 38.0% (Myanmar) (**Figure 1**). Per region, the overall estimate was lowest for Europe at 5.5% and highest for Southeast Asia at 19.8% (**Supplemental Table 2**). In boys, stunting prevalence ranged from 1.8% (British Virgin Islands) to 45.2% (Yemen), with the regional estimate being lowest in the Western Pacific (7.9%) and highest in Africa (21.7%) (**Supplemental Table 3**). In girls, the prevalence of stunting ranged from 0% (Niue) to 36.5% (Myanmar). The regional estimate of stunting in girls was lowest for the Western Pacific (5.0%) and highest for Southeast Asia (18.2%) (**Supplemental Table 4**).

Prevalence of thinness

The overall prevalence of adolescent thinness was 5.5% (95% CI: 4.3%, 6.9%; I^2: 99.0) and ranged from 0.0% (Nauru and Niue) to 31.5% (Sri Lanka) (**Figure 2**). The regional estimate was lowest for the Americas (2.5%) and highest for Southeast Asia (15.0%) (**Supplemental Table 2**). Among boys, the prevalence of thinness ranged from 0.0% (Nauru and Niue) to 39.0% (Sri Lanka), with the regional estimate being lowest for the Americas (2.9%) and highest for Southeast Asia (17.9%) (**Supplemental Table 3**). In girls, the prevalence of thinness ranged from 0% (Nauru, Tonga, and Niue) to 25.1% (Sri Lanka). The regional estimate of thinness in girls was lowest for the Western Pacific (1.8%) and highest for Southeast Asia (12.4%) (**Supplemental Table 4**).

Prevalence of overweight or obesity

The overall prevalence of overweight or obesity in adolescents was 21.4% (95% CI: 18.6%, 24.2%; I^2: 99.4%) and ranged from 4.8% (Sri Lanka) to 59.7% (Niue) (**Figure 3**). The regional estimate was lowest for Southeast Asia (11.1%) and highest for the Western Pacific (33.7%) (**Supplemental Table 2**). In boys, the prevalence of overweight or obesity ranged from 2.1% (Uganda) to 61.1% (Tonga), with the regional estimate being lowest for Africa (10.1%) and highest for the Western Pacific (31.8%) (**Supplemental Table 3**). In girls, the prevalence of overweight or obesity ranged from 4.8% (Sri Lanka) to 63.5% (Niue). The regional estimate for overweight or obesity in girls was lowest for Southeast Asia (9.8%) and highest for the Western Pacific (34.9%) (**Supplemental Table 4**).

Prevalence of stunting or thinness

Supplemental Table 5 shows the prevalence of stunting or thinness among adolescents. The overall prevalence of stunting or thinness in adolescents was 15.6% (95% CI: 13.2%, 18.2%; I^2: 99.4%) and ranged from 0% (Niue) to 50.6% (Yemen), with the regional estimate being lowest for the Western Pacific region (9.3%) and highest for Southeast Asia (32.1%). In boys, the prevalence of stunting or thinness ranged from 0% (Niue) to 59.3% (Yemen), with the regional estimate being lowest for Europe (9.3%) and highest for Southeast Asia (35.9%). In girls, the prevalence of stunting or thinness ranged from 0% (Niue) to 45.2% (Myanmar), with the regional estimate being lowest for the Western Pacific (7.5%) and highest for Southeast Asia (28.9%).

Prevalence of overweight or obesity by prevalence of stunting or thinness

Figure 4 shows the prevalence of adolescent overweight or obesity by stunting or thinness prevalence. Sixteen percent of LMICs (9 of 57) had prevalences of overweight or obesity and stunting or thinness greater than the overall pooled prevalence estimates for overweight or obesity and stunting or thinness, respectively. By WHO region, per total number of LMICs, 14% (1 of 7) in Africa, 7% (1 of 15) in the Americas, 17% (2 of 12) in the Eastern Mediterranean region, 33% (2 of 6) in Europe, 0% in Southeast Asia, and 9% (1 of 11) in the Western Pacific had overweight or obesity and stunting or thinness prevalences greater than their regional prevalence estimates for overweight or obesity and stunting or thinness (**Supplemental Figures 1–6**).

Prevalence of concurrent stunting and overweight or obesity

The overall prevalence of concurrent stunting and overweight or obesity in adolescents was 2.0% (95% CI 1.7%, 2.5%; I^2: 96.0%) and ranged from 0% (Niue) to 10.1% (Egypt) (**Figure 5**), with the regional estimate being lowest for Africa (1.2%) and highest for the Eastern Mediterranean region (3.4%) (**Supplemental Table 6**). In boys, the prevalence of concurrent stunting and overweight or obesity ranged from 0% (Niue) to 12.7% (Egypt), with the regional estimate being lowest for Africa (1.3%) and highest for the Eastern Mediterranean region (4.1%) (**Supplemental Table 6**). In girls, the prevalence of concurrent stunting and overweight or obesity ranged from 0.0% (Niue) to 7.7% (Egypt), with the pooled regional estimate lowest for Africa (1.1%) and highest for the Eastern Mediterranean region (2.8%) (**Supplemental Table 6**).

Sources of heterogeneity

LMICs were heterogeneous ($I^2 > 99\%$) in overall pooled estimates for adolescent stunting, thinness, and overweight or obesity, which suggested marked variation. **Supplemental Figures 7–26** show the correlations between adolescent nutritional status and macrolevel contextual factors. Recent internal conflict ($r = 0.46$, $P = 0.002$), lack of democracy ($r = 0.45$, $P = 0.002$), and food insecurity ($r = 0.43$, $P = 0.004$) were positively correlated with stunting prevalence (Supplemental Figures 7, 9, and 11). GDP per capita was negatively correlated with stunting prevalence ($r = -0.35$, $P = 0.015$) (Supplemental Figure 10). Similarly, recent internal conflict ($r = 0.34$, $P = 0.025$), lack of democracy ($r = 0.26$, $P = 0.017$), and food insecurity ($r = 0.32$, $P = 0.032$) were positively correlated with the prevalence of thinness (Supplemental Figures 13, 15, and 17). Year of survey ($r = -0.26$, $P = 0.049$) was negatively correlated with thinness prevalence (Supplemental Figure 19). Recent internal conflict ($r = -0.48$, $P < 0.001$) and food insecurity ($r = -0.47$, $P = 0.001$) were negatively correlated with

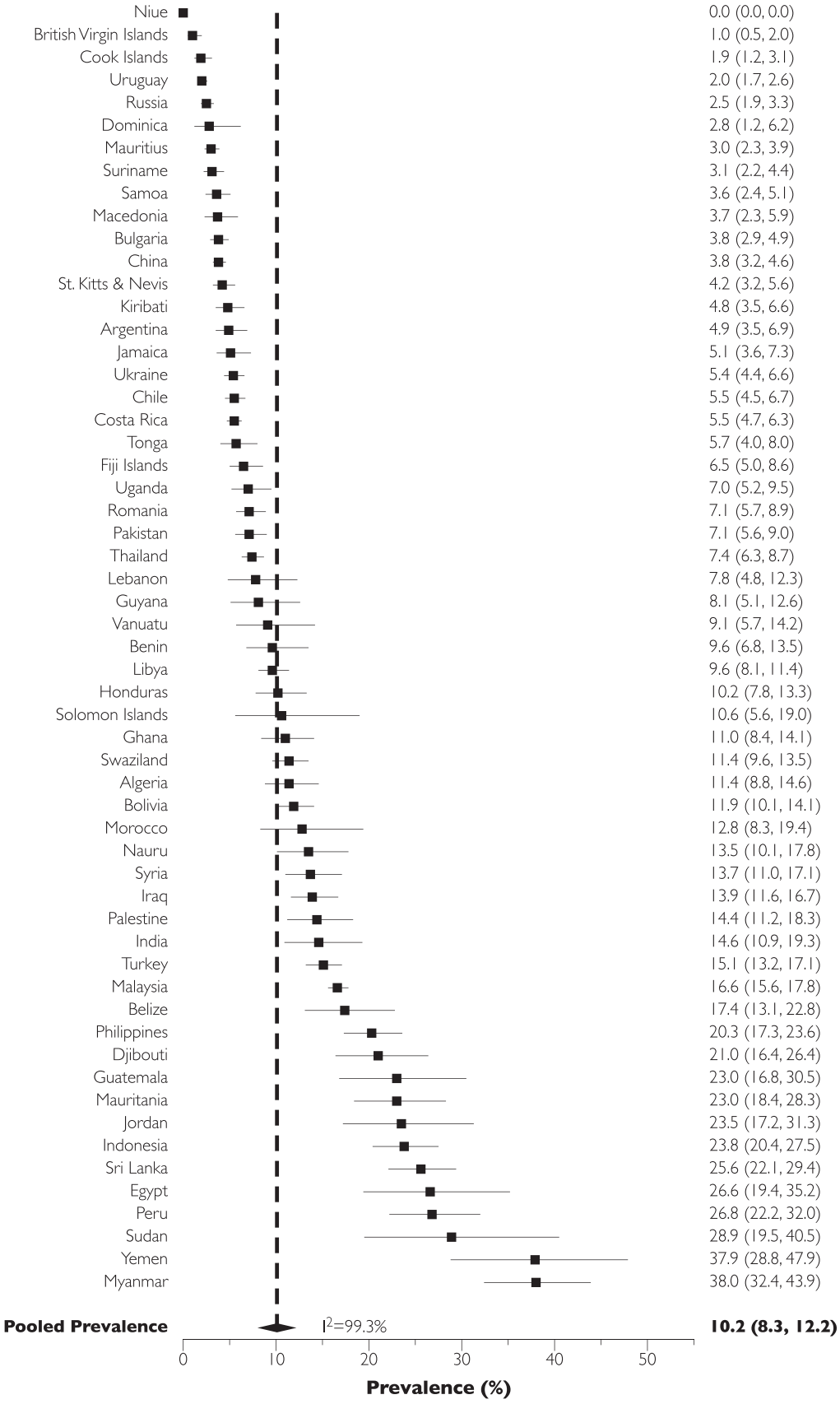

FIGURE 1 Forest plot of stunting prevalence among adolescents aged 12–15 y in low- and middle-income countries. Values are proportions (95% Confidence Intervals).

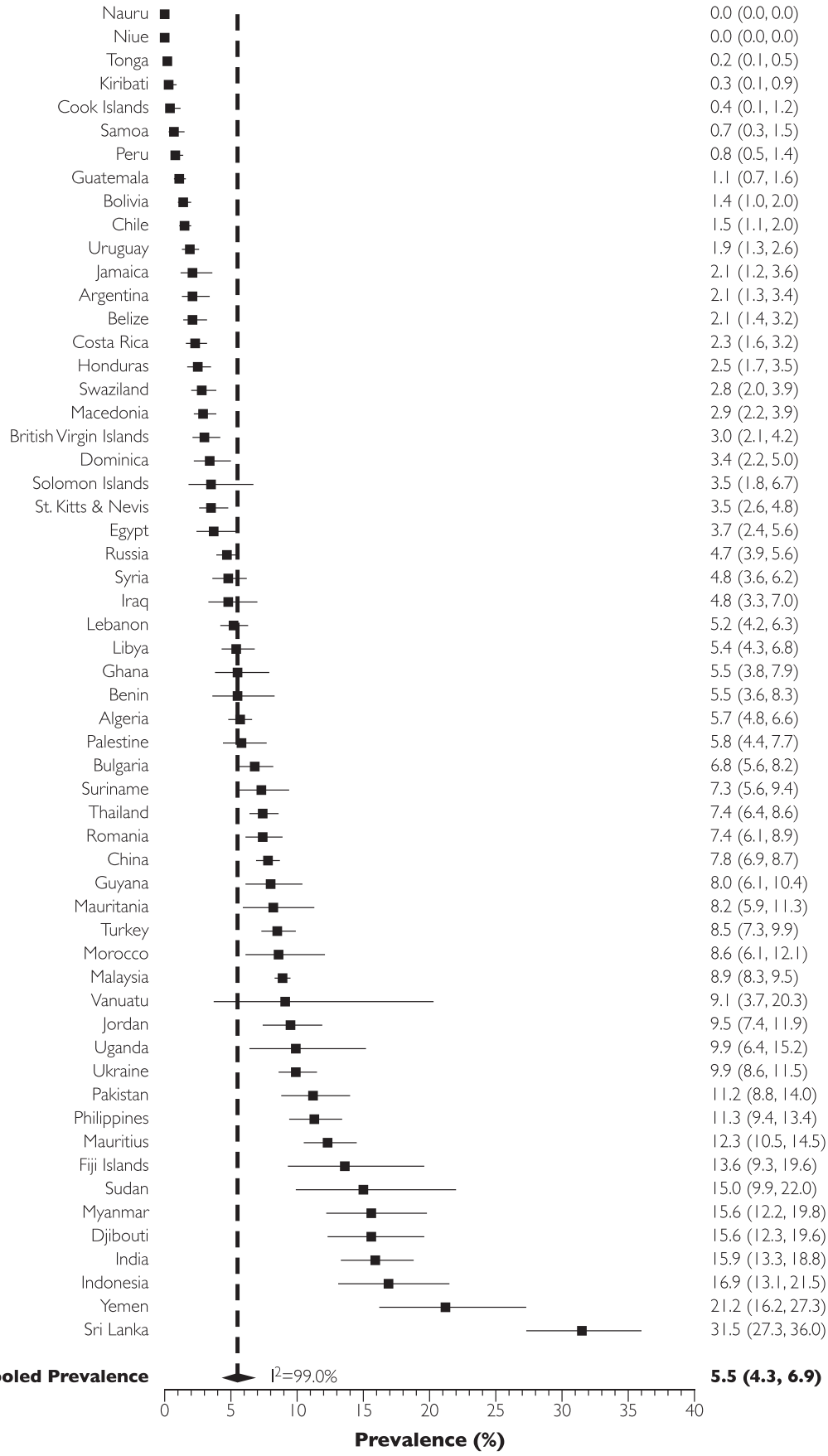

FIGURE 2 Forest plot of thinness prevalence among adolescents aged 12–15 y in low- and middle-income countries. Values are proportions (95% Confidence Intervals).

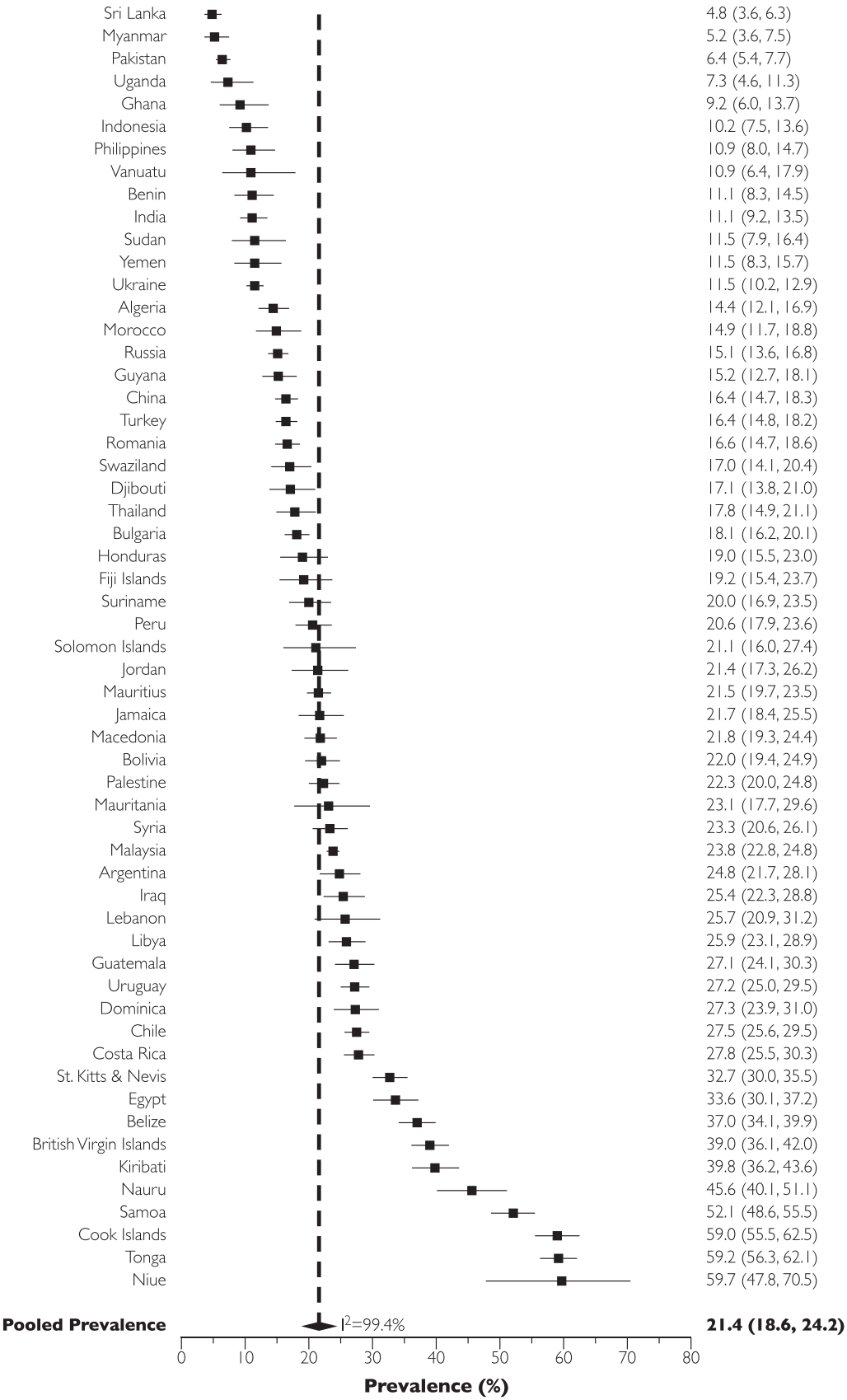

FIGURE 3 Forest plot of overweight or obese prevalence among adolescents aged 12–15 y in low- and middle-income countries. Values are proportions (95% Confidence Intervals).

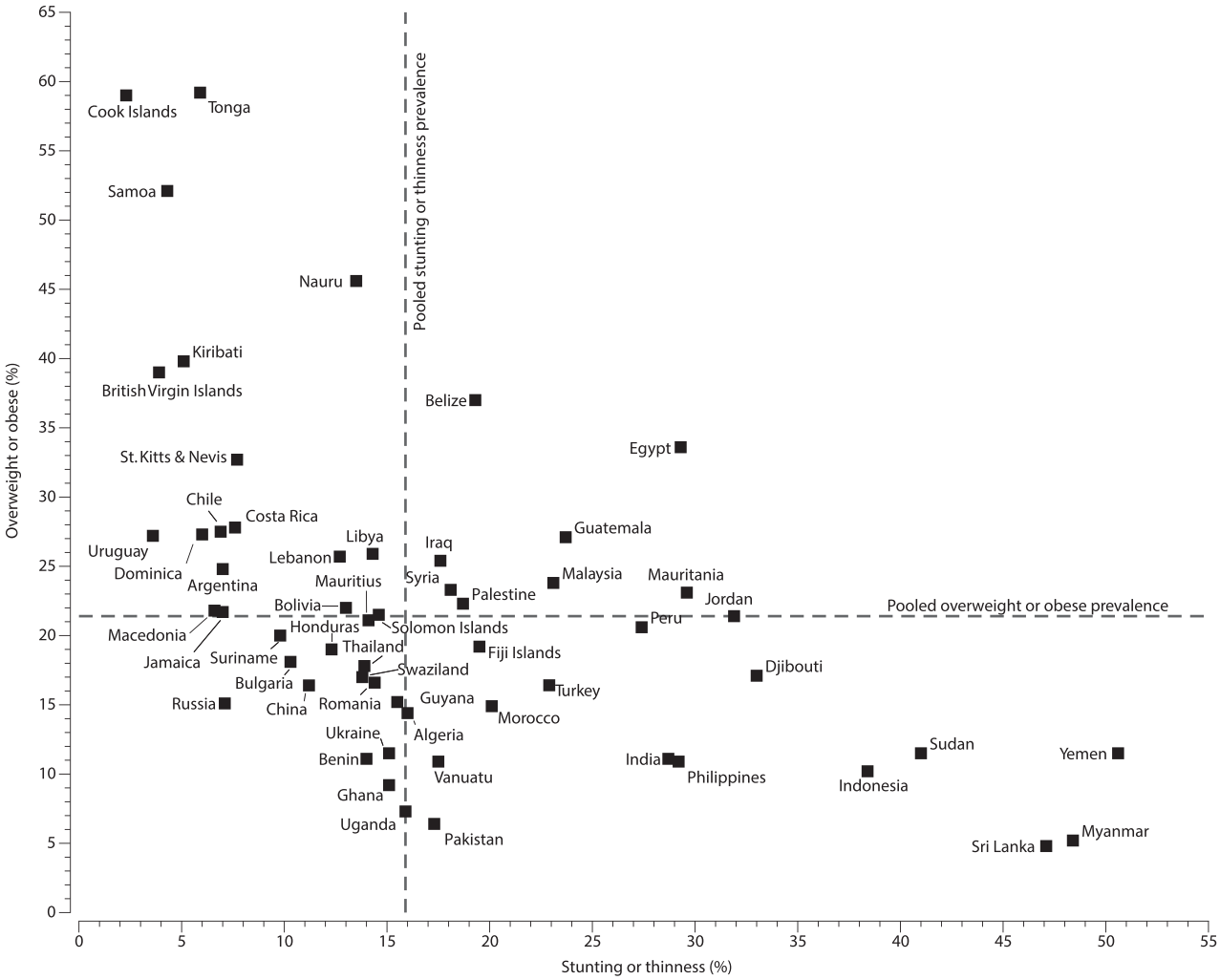

FIGURE 4 Scatterplot of overweight or obesity prevalence by stunting or thinness prevalence among adolescents aged 12–15 y in low- and middle-income countries. Values are proportions.

the prevalence of overweight or obesity (Supplemental Figures 20 and 24). GDP per capita ($r = 0.42$, $P = 0.002$) and level of urbanization ($r = 0.33$, $P = 0.014$) were positively correlated with the prevalence of overweight or obesity (Supplemental Figures 23 and 25).

Up to 43.4% of the variance in stunting prevalence was accounted for by internal conflict, lack of democracy, GDP per capita, and food insecurity; 38.4% of the variance in thinness prevalence was accounted for by recent internal conflict, lack of democracy, food insecurity, and survey year; and 58.7% of the variance in overweight or obesity prevalence was accounted for by recent internal conflict, GDP per capita, food insecurity, urbanization, and survey year.

DISCUSSION

We estimated the prevalence and distribution of the double burden of malnutrition among adolescents at both the population and individual levels from 57 LMICs between 2003 and 2013. The prevalence of stunting, thinness, or both among adolescents was 15.6% or 3 in 20 adolescents, whereas 21.6% or ~1 in 4 adolescents was overweight or obese. A smaller proportion of adolescents also had concurrent stunting and overweight or obesity. There was significant heterogeneity in adolescent malnutrition prevalence estimates across LMICs; 38%–59% of the variance at the population level could be explained by macrolevel contextual factors, including internal conflict, lack of democracy, GDP, food insecurity, urbanization, and the year of survey.

To our knowledge, no previous analyses have comprehensively examined the prevalence of the double burden of malnutrition among adolescents in LMICs at both the population and individual levels and attempted to explain the heterogeneity of adolescent malnutrition prevalence estimates. For thinness and overweight or obesity, our results are not directly comparable with those of the NCD Risk Factor Collaboration (NCD-RisC) (14), because the 2 studies covered different age ranges [5–19 y in the NCD Risk Factor Collaboration (NCD-RisC) (14) study compared with 12–15 y in our study]. However, both studies found thinness prevalence to be highest in the Southeast Asia region and overweight or obesity prevalence was highest in the Western Pacific region. We additionally observed that concurrent stunting and overweight or obesity among adolescents in LMICs was highest in the Eastern Mediterranean region.

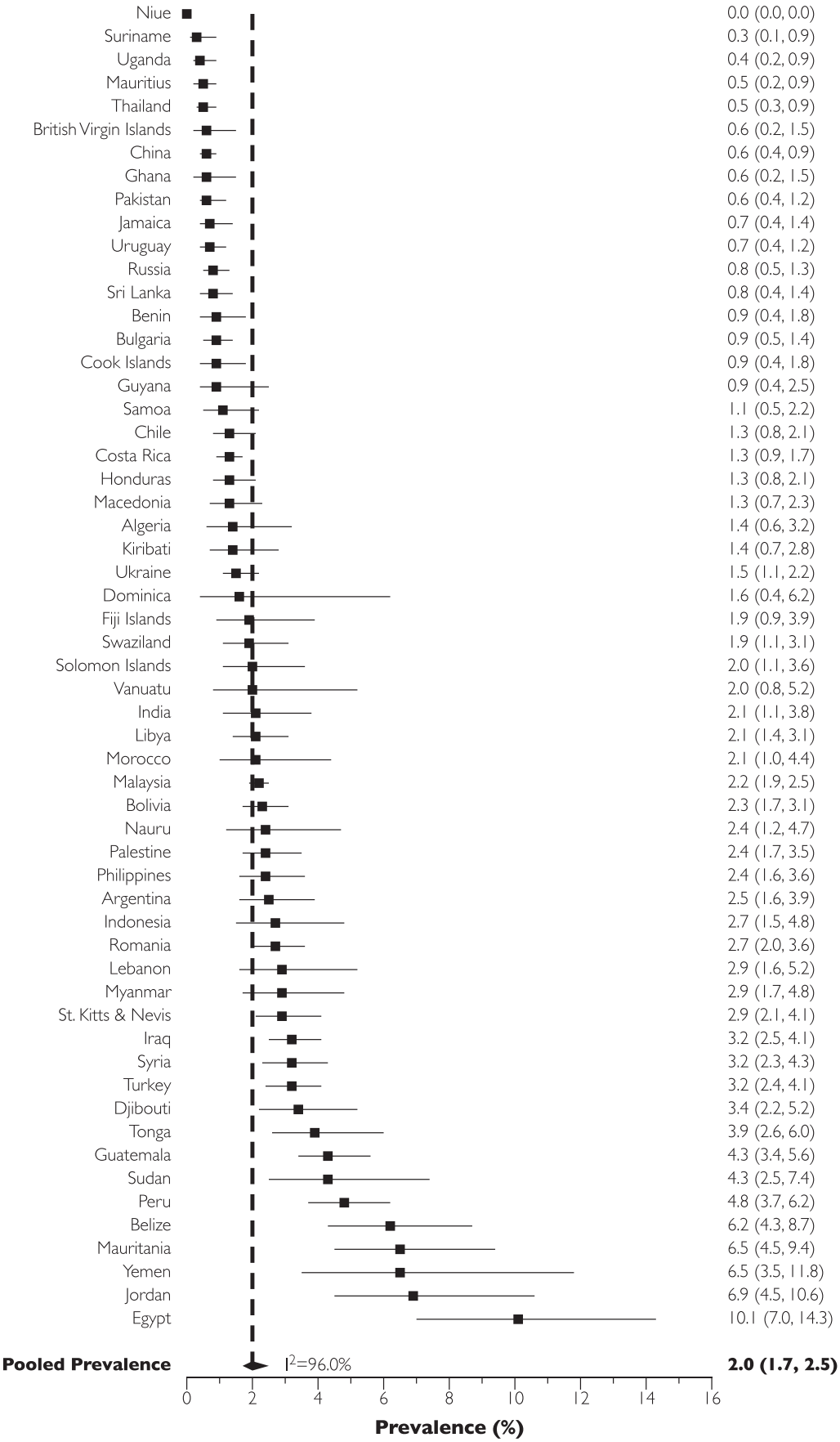

FIGURE 5 Forest plot of concurrent stunting and overweight or obesity among adolescents aged 12–15 y in low- and middle-income countries.

Inadequate nutrition in the period between conception and age 2 y can lead to reduced linear growth (1). Given that resolution of these height deficits may take several generations (15), stunted children also exposed to obesogenic environments may be at greater risk of becoming overweight or obese. Stunting has been reported to alter body composition and fat distribution (e.g., via greater insulin sensitivity or lower fat oxidation), predisposing adolescents to excess adiposity (16).

The double burden of malnutrition poses an important challenge for governments in LMICs with regard to how limited resources are allocated. Double-duty actions (17) (which include interventions, programs, and policies) have the potential to simultaneously reduce the risk or burden of stunting, thinness, and obesity. A key principle is to ensure that current actions designed to address one form of malnutrition do not unintentionally increase the risk of another. For example, in LMICs, school food programs emphasize children having enough food or encouraging school attendance (18). However, these programs typically have limited guidance on nutritional quality. In the Americas, processed foods are widely served and many programs lack adequate fresh foods and diet diversity (19). Although evidence-based double-duty actions can offer an integrated approach to addressing malnutrition, they warrant adaptation to different contexts. We showed that a large proportion of the variance in adolescent malnutrition at the population level was explained by macrolevel contextual factors. The macrolevel context is rarely and inconsistently examined when examining the double burden of malnutrition (14), creating challenges for policymakers and program planners who may play a key role in contextualizing double-duty actions.

Our study is not without limitations. Our only measure of adiposity was BMI, which may be affected by variation in lean mass. However, BMI is the most commonly used measure for monitoring the prevalence of overweight and obesity at the population level and is well correlated with more precise adiposity measures (20). Moreover, precise measures of adiposity are costly, time consuming, and not feasible for use in large population–based studies across continents (21). Although we attempted to use all available GSHS or HSBC survey data, 23% of countries were excluded because of incomplete availability of anthropometric data. Thus, certain WHO regions are underrepresented (particularly Africa), limiting the generalizability of our findings. Nonincluded countries had a higher prevalence of stunting (19.6%) and overweight or obesity (30.4%). Our estimates of the prevalence of the double burden of malnutrition apply only to adolescents who attend school. Although the GSHS and HBSC surveys are limited to adolescents attending school, only one-third of countries had a median net secondary school enrollment rate of <50% (**Supplemental Table 7**) (22). Thus, our results are most probably representative of most of the students in this age bracket in LMICs. Finally, although we were able to investigate the macrolevel contextual factors as sources of heterogeneity for prevalence estimates across LMICs, the GSHS and HBSC surveys do not collect individual socioeconomic, ethnic, or urban/rural data and thus we could not examine inequalities in prevalence across these subgroups. Despite these limitations, our study is the first, to our knowledge, to make comparable estimates of a complete set of anthropometric categories with clinical and public health relevance among adolescents in LMICs, in addition to examining the potential sources of heterogeneity in prevalence estimates. Our study also made use of a large amount of nationally representative adolescent anthropometric data based on standardized data-collection methods across 57 LMICs.

In conclusion, the double burden of malnutrition among adolescents, particularly at the population level, is common in LMICs. A large proportion of the variance in adolescent malnutrition was explained by macrolevel contextual factors. Without consideration of context, interventions and programs for adolescent malnutrition in LMICs may fail or underperform.

The authors' responsibilities were as follows—RC, APK, and JBE-T: designed the study; RC and SS: were responsible for data management and analyzed data; RC: wrote the manuscript and had primary responsibility for final content; APK, JBE-T, RU, GNT, SS, and JK: provided intellectual content to revise the manuscript and critically reviewed the manuscript; and all authors: read and approved the final manuscript. None of the authors reported a conflict of interest related to the study.

REFERENCES

1. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, Ezzati M, Grantham-McGregor S, Katz J, Martorell R, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet 2013;382:427–51.
2. Tzioumis E, Adair LS. Childhood dual burden of under- and overnutrition in low- and middle-income countries: a critical review. Food Nutr Bull 2014;35:230–43.
3. Mokdad AH, Forouzanfar MH, Daoud F, Mokdad AA, El Bcheraoui C, Moradi-Lakeh M, Kyu HH, Barber RM, Wagner J, Cercy K, et al. Global burden of diseases, injuries, and risk factors for young people's health during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 2016;387:2383–401.
4. WHO. Adolescent pregnancy. Version current 1 November 2017. Available from: http://www.who.int/maternal_child_adolescent/topics/maternal/adolescent_pregnancy/en/ (accessed 1 November 2017).
5. Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, Richter L, Strupp B. Developmental potential in the first 5 years for children in developing countries. Lancet 2007;369:60–70.
6. Dewey KG, Begum K. Long-term consequences of stunting in early life. Matern Child Nutr 2011;7(Suppl 3):5–18.
7. Fernald LC, Neufeld LM. Overweight with concurrent stunting in very young children from rural Mexico: prevalence and associated factors. Eur J Clin Nutr 2007;61:623–32.
8. Popkin BM, Richards MK, Montiero CA. Stunting is associated with overweight in children of four nations that are undergoing the nutrition transition. J Nutr 1998;126:3009–16.
9. Best C, Neufingerl N, van Geel L, van den Briel T, Osendarp S. The nutritional status of school-aged children: why should we care. Food Nutr Bull 2010;31:400–17.
10. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. Int J Obes (Lond) 2011;35:891–8.
11. Twig G, Yaniv G, Levine H, Leiba A, Goldberger N, Derazne E, Ben-Ami Shor D, Tzur D, Afek A, Shamiss A, et al. Body-mass index in 2.3 million adolescents and cardiovascular death in adulthood. N Engl J Med 2016;374:2430–40.
12. CDC. Global School-based Student Health Survey (GSHS). Version current 1 November 2017. Available from: https://www.cdc.gov/gshs/ (accessed 1 November 2017).
13. Currie C, Nic Gabhainn S, Godeau E; International HBSC Network Coordinating Committee. The Health Behaviour in School-aged Children: WHO Collaborative Cross-National (HBSC) study: origins, concept, history and development 1982–2008. Int J Public Health 2009;54(Suppl 2):131–9.
14. NCD Risk Factor Collaboration. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. Lancet 2017;390(10113):2627–42.
15. Onis M, Branca F. Childhood stunting: a global perspective. Matern Child Nutr 2016;12(Suppl 1):12–26

16. Sawaya AL, Roberts S. Stunting and future risk of obesity: principal physiological mechanisms. Cad Saude Publica. 2003;19(Suppl 1):S21–8
17. Hawkes C, Demaio AR, Branca F. Double-duty actions for ending malnutrition within a decade. Lancet Glob Health 2017;5:e745–6.
18. Jomaa LH, McDonnell E. School feeding programs in developing countries: impacts on children's health and educational outcomes. Nutr Rev 2011;69:83–98.
19. Food and Agriculture Organization (FAO). School feeding and possibilities for direct purchases from family farming—case studies in eight countries. Rome (Italy): FAO; 2013.
20. Prentice AM, Jebb SA. Beyond body mass index. Obes Rev 2001;2:141–7.
21. Must A, Anderson SE. Body mass index in children and adolescents: considerations for population-based applications. Int J Obes (Lond) 2006;30(4):590–4.
22. World Bank. Net enrolment rate, secondary, both sexes (%). Version current 1 November 2017. Available from: https://data.worldbank.org/indicator/SE.SEC.NENR (accessed 1 November 2017).