Childhood Obesity in Developing Countries: Epidemiology, Determinants, and Prevention

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Rapidly changing dietary practices and a sedentary lifestyle have led to increasing prevalence of childhood obesity (5–19 yr) in developing countries recently: 41.8% in Mexico, 22.1% in Brazil, 22.0% in India, and 19.3% in Argentina. Moreover, secular trends indicate increasing prevalence rates in these countries: 4.1 to 13.9% in Brazil during 1974–1997, 12.2 to 15.6% in Thailand during 1991–1993, and 9.8 to 11.7% in India during 2006–2009. Important determinants of childhood obesity include high socioeconomic status, residence in metropolitan cities, female gender, unawareness and false beliefs about nutrition, marketing by transnational food companies, increasing academic stress, and poor facilities for physical activity. Childhood obesity has been associated with type 2 diabetes mellitus, the early-onset metabolic syndrome, subclinical inflammation, dyslipidemia, coronary artery diseases, and adulthood obesity. Therapeutic lifestyle changes and maintenance of regular physical activity through parental initiative and social support interventions are the most important strategies in managing childhood obesity. Also, high-risk screening and effective health educational programs are urgently needed in developing countries. **(*Endocrine Reviews* 33: 48–70, 2012)**

I. Introduction

Rapidly changing dietary practices and an increasingly sedentary lifestyle predispose to obesity-related noncommunicable diseases, including insulin resistance, the metabolic syndrome, type 2 diabetes mellitus (T2DM), coronary artery diseases (CAD), polycystic ovarian syndrome (PCOS), nonalcoholic fatty liver disease (NAFLD), and site-specific neoplasms, both in children and in adults (1–4). Recent data show that obesity-related noncommu-

Abbreviations: BMI, Body mass index; CAD, coronary artery diseases; CDC, Centers for Disease Control and Prevention; CI, confidence interval; hs-CRP, high-sensitivity C-reactive protein; IGT, impaired glucose tolerance; IOTF, International Obesity Task Force; MARG, Medical education for children/Adolescents for Realistic prevention of obesity and diabetes and for healthy aGeing; NAFLD, nonalcoholic fatty liver disease; NCEP ATP III, National Cholesterol Education Program Adult Treatment Panel III; NCHS, National Center for Health Statistics; ODM, offspring of diabetic mothers; PCOS, polycystic ovarian syndrome; SCAT, sc adipose tissue; SES, socioeconomic status; T2DM, type 2 diabetes mellitus; WC, waist circumference; WHO, World Health Organization.

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nicable diseases are increasing in many developing countries (2). Furthermore, cross-sectional and secular trends indicate an increase in childhood obesity globally, particularly in developing countries (5–10). The focus of this article is to review the diagnostic criteria for childhood obesity, cross-sectional prevalence and secular trends, and determinants and consequences of childhood obesity. We have also reviewed management of childhood obesity and ongoing large-scale community-based intervention studies and campaigns in this context in developing countries.

II. Search Strategy and Selection Criteria

A comprehensive literature search was carried out using the terms childhood obesity, abdominal obesity in children, developing countries, prevalence, and nutritional education as well as the names of several developing countries in PubMed (National Library of Medicine, Bethesda, MD) from 1966 to February 2011 and Google Scholar search engine until February 2011. A manual search for other important references and medical databases was also pursued. Data from countries considered emerging and developing economies according to the International Monetary Fund's World Economic Outlook Report, April 2010, were included (11). Originally, 701 articles were extracted from PubMed and Google Scholar search engines. Studies on prevalence and trends of childhood obesity in developing countries were critically read by two authors (A.M. and N.G.). The studies were selected based on the following criteria: adequate sample size, robust trial design (case-control or prospective studies), citations, published in good impact factor journal, and done by established research groups. Finally, 163 articles and papers were given preference for citation. Although we have attempted to provide data from developing countries, some portions of this review are more focused on South Asians and Asian Indians due to our research interest.

A. Diagnostic criteria for childhood obesity

The criteria for assessing childhood obesity have been the subject of debate and research. The following criteria for age- and gender-specific body mass index (BMI) cutoffs have been applied by different groups to diagnose childhood obesity.

1. Centers for Disease Control and Prevention (CDC) BMI percentiles (12)

The 1977 National Center for Health Statistics (NCHS) growth charts were revised for infants (birth to 36 months) and older children (2–20 yr). New BMI-for-age percentile curves were developed in a nationally representative population of North American boys and girls, aged 2–20 yr (overweight, 85–94th percentile; obese, >95th percentile) (www.cdc.gov/growthcharts). Use of national data ensured a smooth transition from the charts for infants to those for older children. These data better represent the racial/ethnic diversity and the size and growth patterns of combined breast- and formula-fed infants in the United States.

2. International Obesity Task Force (IOTF) cutoffs (13)

Percentile curves that correspond to the BMI cutoff points of 25 and 30 kg/m^2 at the age of 18 yr are used to define overweight and obesity, respectively, for children aged 2–18 yr. IOTF cutoffs were derived from an international survey of six large nationally representative cross-sectional growth studies in Brazil, United Kingdom, Hong Kong, The Netherlands, Singapore, and United States, including 97,876 males and 94,851 females from birth to 25 yr of age. These cutoffs are meant to provide more internationally comparable prevalence rates of overweight and obesity in children.

3. World Health Organization (WHO) growth standards (1995) (14, 15)

These standards are based on data collected in the United States as recommended by a 1995 WHO Expert Committee. Weight-for-height Z score higher than 1 and higher than 2 were used to define overweight and obesity, respectively, in preschool children (<5 yr).

4. New WHO growth standards in preschool children (2006) (16)

These standards were developed using data collected in the WHO Multicenter Growth Reference Study between 1997 and 2003 from approximately 8500 children from widely different ethnic backgrounds and cultural settings (Brazil, Ghana, India, Norway, Oman, and the United States). The new growth curves are expected to provide a single international standard for best physiological growth for all children from birth to 5 yr of age and to establish the breastfed infant as the normative model for growth and development. Overweight is defined as BMI-for-age Z score of 1 or higher and obesity as BMI-for-age Z score of 2 or higher.

5. WHO growth reference curves (17)

These curves were developed in 2007 for children and adolescents aged 5–19 yr to align with the recommended adult cutoffs for overweight and obesity at 19 yr (overweight, >+1 SD; obese, >+2 SD). The core sample used for the reconstruction of these reference curves was the same as that used for the construction of the original 1977

Figure 1.

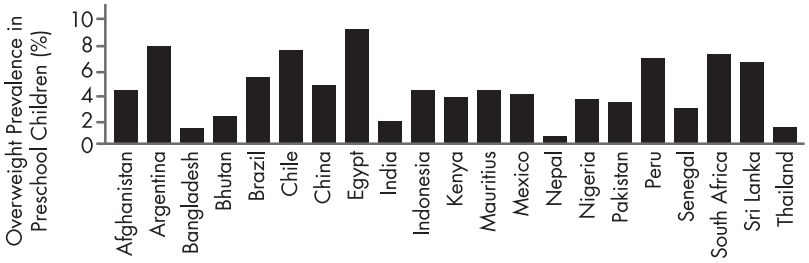


Figure 1. Prevalence (%) of overweight in preschool children (<5 yr) in developing countries (18, 29).

NCHS growth charts. A smooth transition from the WHO Child Growth Standards (0–5 yr) to the reference curves beyond 5 yr was provided by merging data from the growth standards' cross-sectional sample (18–71 months) with the NCHS final sample before fitting the new growth curves. The growth curves for ages 5–19 yr were thus constructed using data from 18 months to 24 yr. The final sample used for fitting the growth curves included 30,018 observations (15,103 boys and 14,915 girls) for the BMI-for-age curves.

With no definite consensus on the tool for assessment of age- and gender-specific childhood obesity, mostly the 85th and 95th percentiles of BMI data set are taken as cutoffs for assessment of childhood overweight and obesity, respectively.

III. Cross-Sectional Prevalence

A. Preschool children (<5 yr old)

Data from nationally representative cross-sectional surveys from developing countries have shown a high prevalence of overweight in preschool children (Fig. 1), including Uzbekistan at 14.4% (1996), Algeria at 9.2% (1995), Egypt at 8.6% (1995–96), Argentina at 7.3% (1994), and Chile at 7.0% (1996), whereas Bhutan at 2% (1986–88), Thailand at 1.2% (1987), Bangladesh at 1.1% (1996–97), Oman at 0.9% (1994–95), the Philippines at 0.8% (1993), and Nepal at 0.5% (1996) have relatively lower prevalence (18). On the basis of data from 88% of the total population aged under 5 yr, it was estimated that 3.3% (or 17.5 million) of preschool children were overweight in developing countries in 1995 (18). The percentage of overweight children was highest in Latin America and the Caribbean (4.4%), followed by Africa (3.9%) and Asia (2.9%). However, in absolute numbers, Asia had the highest numbers of overweight children; 60% (or 10.6 million) of the overweight children from developing countries lived in this region (18). In India, two nationally representative surveys in preschool children showed relatively low prevalence of obesity (1.5–1.6%) (19–23) (Table 1). These data assert that, in preschool children, even though undernutrition remains a major public health burden in most developing countries, some countries are starting to experience the dual epidemic of overnutrition and undernutrition. Therefore, during early years of life, focus should remain on sustaining adequate growth and development and avoiding overfeeding.

B. Schoolchildren and adolescents (5–19 yr old)

The calculated global prevalence of overweight (including obesity) in children aged 5–19 yr is 10%, the prevalence varying from 5.7% in Pakistan (24) to over 40% in Mexico (5) (Table 2). Prevalence rates of obesity are high (>15%) in many developing countries including Brazil, India, Argentina, and Mexico (5–7). Specifically, in 2004, Moraes *et al.* (5) reported 41.8% obesity prevalence in 5-

TABLE 1. Prevalence (percent) of overweight/obesity in preschool children (<5 yr) in India

Region/survey	Year	Age (yr)	Sample (n)	Overweight (%)	Obesity (%)	Standard criteria
National/NFHS-1 (19, 22)	1992–1993	<4	25,584	NA	1.6	1995 WHO (14, 15)
National (19, 22)	1992–1993	1–5	9,849	3.5	1.1	1995 WHO (14, 15)
National/NFHS-2 (19, 22)	1998–1999	1–5	NA	NA	1.6	1995 WHO (14, 15)
National/NFHS-3 (19, 22)	2005–2006	<5	46,655	NA	1.5	2006 WHO (16)
NNMB 2002/nine states, rural (20, 22)	2000–2001	1–5				
Males			11,074	5.7	0.4	Overweight ≥25 kg/m^2
Females			17,318	8.2	1.2	Obesity ≥30 kg/m^2
NNMB 2007/nine states, rural (20, 22)	2005–2006	1–5				
Males			14,039	7.8	0.8	Overweight ≥25 kg/m^2
Females			18,603	10.9	1.8	Obesity ≥30 kg/m^2
South India/one city (23)	2008	2–5	425	4.5	1.4	Overweight ≥85th percentile Obesity ≥95th percentile

NA, Not available; NFHS, National Family Health Surveys; NNMB, National Nutrition Monitoring Bureau.

TABLE 2. Prevalence of obesity in schoolchildren and adolescents (5–19 yr old) in developing countries*

Country	Author (Ref.)	Year	Age (yr)	Sample (n)	Criteria for measuring overweight/obesity	Prevalence (%)
Algeria	Oulamara *et al.* (148)	2001	6–10	19,263	IOTF standard cutoffs (13)	Overweight (obesity included), 6.8
		2006				Overweight (obesity included), 9.5
Argentina	Pituelli *et al.* (7)	2007	5–18	1,043	Overweight, BMI 85–95th percentile	Overweight, 13.9
					Obesity, BMI ≥95th percentile	Obesity, 5.4
	Kovalskys *et al.* (149)	2010	10–11	1588	CDC standard cutoffs (12)	Overweight (obesity included), 35.5
					IOTF standard cutoffs	Overweight (obesity included), 27.9
					WHO standard cutoffs (17)	Overweight (obesity included), 27.9
Brazil	de Vasconcelos *et al.* (150)	1980	17–19	316,925[a]	Overweight, BMI 25–29.9 kg/m^2	Overweight, 3.81; obesity, 0.27
		2000			Obesity, BMI ≥30 kg/m^2	Overweight, 9.40; obesity, 1.19
	Wang *et al.* (8)	1974	6–18	56,259	IOTF standard cutoffs	Overweight (obesity included), 4.1
		1997		4,875		Overweight (obesity included), 13.9
	Neutzling *et al.* (72)	1989	10–19	13,715	Overweight, BMI ≥85th percentile of NCHS reference population	Males, 4.8; females, 10.6
						Overall, 7.7
	de Assis *et al.* (6)	2005	7–10	2,936	IOTF standard cutoffs	Overweight, 16.6; obesity, 5.5
						Overweight (obesity included), 22.1
China	Wang *et al.* (8)	1991	6–18	3,014	IOTF standard cutoffs	Overweight (obesity included), 6.4
		1997		2,688		Overweight (obesity included), 7.7
	Li *et al.* (25)	2002	7–12	8,861	Overweight, BMI 85–95th percentile	Overweight, 4.1; obesity, 2.5
			12–18		Obesity, BMI ≥95th percentile	Overweight, 5.6; obesity, 1.6
	Ji CY *et al.* (30)	1985	7–18	409,946	WGOC reference	Overweight (obesity included)
		2005		226,602	Overweight, BMI >24 kg/m^2	Boys, 0.93; girls, 1.62
					Obesity, BMI >28 kg/m^2	Boys, 14.9; girls, 8.9
Costa Rica	Nunez *et al.* (151)	2003	7–12	1,718	Overweight, BMI ≥85th percentile Obesity[b]	Overweight, 34.5
						Obesity, 26.2
Egypt	Salazar *et al.* (152)	1997	11–19	1,502	CDC standards cutoffs	Overweight, 12.1; obesity, 6.2
Indonesia	Julia *et al.* (67)	1999	6–13	1,524	CDC standards cutoffs	Overweight, 2.7; obesity, 5.3
		2004		510		Overweight, 3.7; obesity, 8.6
Iran	Ayatollahi *et al.* (153)	2002–2003	6.5–11.5	2,397	CDC standards cutoffs	Boys, Overweight, 6.8; obesity, 3.3
						Girls, Overweight, 3.3; obesity, 6.1
	Moayeri *et al.* (154)	2004	11–17	2,900	CDC standards cutoffs	Overweight, 7.1; obesity, 17.9
Iraq	Lafta *et al.* (155)	2002	7–13	8,300	IOTF standard cutoffs	Overweight (obesity included), 6
Lebanon	Jabre *et al.* (73)	2005	6–8	234	IOTF standard cutoffs	Boys: overweight, 26; obesity, 7
						Girls: overweight, 25; obesity, 6
Malaysia	Tee *et al.* (74)	2002	7–10	5,995	Overweight, BMI ≥95th percentile of NCHS reference population	Overweight: boys, 9.7; girls, 7.1
						Overall, 8.4
	Sumarni *et al.* (156)	2006	11	699[a]	IOTF standard cutoffs	Overweight (obesity included), 7.2
Mexico	Salazar *et al.* (152)	1998–1999	11–19	10,537	CDC standards cutoffs	Overweight, 19.8; obesity, 7.9
	Moraes *et al.* (5)	2004	5–14	700	IOTF standard cutoffs	Overweight, 28.1; obesity, 13.7
Pakistan	Jafar *et al.* (24)	1990–94	5–14	2,074	CDC standards cutoffs	Overweight (obesity included), 3.0
		2004–2005		1,675		Overweight (obesity included), 5.7
Russia	Wang *et al.* (8)	1992	6–18	6,883	IOTF standard cutoffs	Overweight (obesity included), 15.6
		1998		2,152		Overweight (obesity included), 9.0
Saudi Arabia	El-Hazmi *et al.* (69)	2002	1–18	12,071	CDC standards cutoffs	Boys: overweight, 10.7; obesity, 6.0
						Girls: overweight, 12.7; obesity, 6.7
Seychelles	Chiolero *et al.* (157)	1998–2000	4–18	25,586	CDC standards cutoffs	Obesity: boys, 5.1; girls, 6.0
		2004–2006				Obesity: boys, 8.0; girls, 8.7
South Africa	Armstrong *et al.* (26)	2006	6–13	10,195	IOTF standard cutoffs	Boys: overweight, 10.9; obesity, 2.4
						Girls: overweight, 17.5; obesity, 4.8
Sri Lanka	Jayatissa *et al.* (158)	2006	10–15	1,257	IOTF standard cutoffs	Overweight (obesity included), 7.8
Thailand	Mo-suwan *et al.* (9)	1991	6–12	1,156	Weight-for-height >120% of Bangkok reference	12.2
		1992				13.5
		1993				15.6
	Rerksuppaphol *et al.* (159)	2007	6–15	1140	IOTF standard cutoffs	Overweight (obesity included), 12.8; obesity: 9.4
Turkey	Discigil *et al.* (160)	2005	6–16	1348	CDC standards cutoffs	Overweight, 12.2; obesity, 3.7

* Excluding India. WGOC, Working Group on Obesity in China.

[a] Boys only.

[b] Criteria for obesity were triceps skinfold at or above the 85th percentile for age and sex (for 7- to 9-yr-olds) (using the percentiles by age for children in the United States) and BMI at or above 85th percentile and both triceps and subscapular skinfold thickness at or above 90th percentile (for 10- to 12-yr-olds).

to 14-yr-old Mexican schoolchildren (n = 700), based on IOTF cutoffs. Analyses of data from the National Nutrition and Health Survey (2002) in China showed 6.6 and 7.2% obesity prevalence rates in age groups 7–12 and 12–18 yr, respectively (overweight, BMI in 85–95th percentile; obesity, BMI ≥95th percentile) (25). Armstrong *et al.* (26) looked at a sample of 10,195 South African primary schoolchildren, aged 6–13 yr, from diverse socioeconomic backgrounds, selected from five of the South African provinces, during the Health of the Nation Survey from 2001–2004. Based on IOTF standard cutoffs, and adjusting the contribution of each ethnic group to the demographics of South Africa, the prevalence of obesity and overweight among boys was 2.4 and 10.9%, respectively, whereas obese and overweight girls comprised 4.8 and 17.5%, respectively. Few nationally representative reports are available on the prevalence of obesity among Asian Indian children and adolescents (5–19 yr) living in India (Table 3). Most of these studies were conducted in urban areas and were confined to a selected region of the country. A recent multicentric cross-sectional study in 38,296 children from five urban cities located in different geographical regions of India showed that the prevalence of overweight and obesity in 8- to 18-yr-old children was 14.4 and 2.8% by IOTF cutoffs, 14.5 and 4.8% by CDC cutoffs, and 18.5 and 5.3% by WHO cutoffs, respectively (27). Also, the overall prevalence of abdominal obesity (defined according to the International Diabetes Federation consensus statement for at-risk children and adolescents) (28) in these children was 4.5%. This is the largest sample of urban schoolchildren to date from India, and on extrapolating these data to the urban Indian population, currently, more than 15 million children are overweight and 4 million abdominally obese.

IV. Secular Trends

A. Preschool children (<5 yr old)

De Onis *et al.* (29) analyzed a total of 450 nationally representative cross-sectional surveys from 144 developing countries. Based on 2006 WHO growth standards in preschool children (16), they reported that the worldwide prevalence of overweight and obesity in preschool children increased from 4.2% [95% confidence interval (CI) = 3.2–5.2%] in 1990 to 6.7% (95% CI = 5.6–7.7%)

TABLE 3. Prevalence of obesity in schoolchildren and adolescents (4–19 yr old) in India

Author, year (Ref.)	Age (yr)	Sample (n)	Criteria for measuring overweight/obesity	Region	Overweight (%)	Obesity (%)
Ramachandran *et al.*, 2002 (49)	13–18	4,700	IOTF standard cutoffs (13)	Chennai/SI	Boys, 17.8; girls, 15.8	Boys, 3.6; girls, 2.7
Kapil *et al.*, 2002 (33)	10–16	870	IOTF standard cutoffs	Delhi/NI	24.7	7.4
Mohan el al., 2004 (51)	11–17	2,467	Overweight, BMI = 25–30 kg/m^2 ; obese, BMI >30 kg/m^2	Ludhiana/NI	Urban, 11.63; rural, 4.70	Urban, 2.35; rural, 3.63
Khadilkar *et al.*, 2004 (161)	10–15	1,228	Overweight, BMI = 25–29.9 kg/m^2; obese, BMI ≥30 kg/m^2	Pune/WI	19.9	5.7
Rao *et al.*, 2006 (162)	9–16	2,223	IOTF standard cutoffs	Pune/WI	Boys, 24.7; girls, 21.1	
Raj *et al.*, 2007 (163)	5–16		CDC standard cutoffs (12)	Kerala/SI		
2003–2004		24,842			4.94	
2005–2006		20,263			6.57	
Sharma *et al.*, 2007 (50)	4–17	4,000	IOTF standard cutoffs	Delhi/NI	22	6
Laxmaiah *et al.*, 2007 (44)	12–17	1,208	IOTF standard cutoffs	Hyderabad/SI	Males, 6.1; females, 8.2	Males, 1.6; females, 1.0
Kaur *et al.*, 2008 (34)	5–18	16,595	IOTF standard cutoffs	Delhi/NI	LIG, 2.7; MIG, 6.5; HIG, 15.3	LIG, 0.1; MIG, 0.6; HIG, 6.8
Bhardwaj *et al.*, 2008 (10)	14–17	3,493	Overweight/obesity[a]	New Delhi/NI		PS, 29.0; GS, 11.3; total, 24.3
Gupta *et al.*, 2009 (38)	13–25	1,236	Overweight/obesity[a]	New Delhi/NI		Males, 16; females, 15
Premnath *et al.*, 2009 (68)	5–16	43,152	Overweight, BMI =85–95th percentile; obese, BMI ≥95th percentile	Mysore/SI	8.5	3.4
Misra *et al.*, 2010 (27)	8–18	38,296	IOTF, CDC, and WHO standard cutoffs (17)	NI and WI[b]	IOTF, 14.4; CDC,14.5; WHO, 18.5	IOTF, 2.8; CDC, 4.8; WHO, 5.3
Gupta *et al.*, 2011 (31)	14–17		Asian-Indian specific cutoffs (32)	New Delhi/NI		
2006		3493			24.2	9.8
2009		4908			25.2	11.7

NI, North India; WI, West India; SI, South India; LIG, low income group; MIG, middle income group; HIG, high income group; PS, private schools; GS, government-funded schools.

[a] BMI ≥85th percentile of reference population.

[b] NI includes Agra, Delhi, Mumbai, and Allahabad; WI includes Mumbai.

Figure 2.

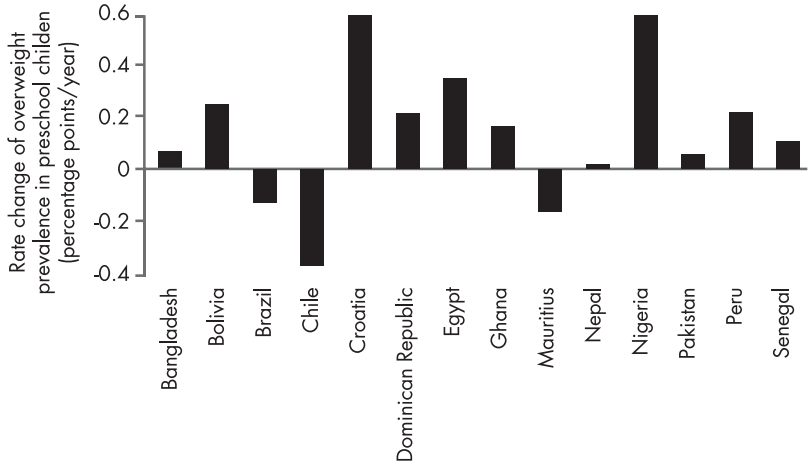


Figure 2. Rate change of overweight prevalence in preschool children (<5 yr) in developing countries (18). The rate change is the difference between the earliest and latest available national survey data points divided by the number of years between the two survey points (percentage points per year).

in 2010 and that this trend is expected to reach 9.1% (95% CI = 7.3–10.9%), or approximately 60 million in 2020. They also reported that the estimated prevalence of childhood overweight and obesity in Africa in 2010 was 8.5% (95% CI = 7.4–9.5%) and is expected to reach 12.7% (95% CI = 10.6–14.8%) in 2020. Although the prevalence is lower in Asia than in Africa (4.9% in 2010), the number of affected children (18 million) is higher in Asia. Trends in overweight prevalence in preschool children in some developing countries are shown (Fig. 2). The trend is presented as the change (in percentage points) per year and interpreted as rising, static, or falling. Most developing countries, including Bolivia, Croatia, Dominican Republic, Egypt, Ghana, Nigeria, Peru, and Senegal, demonstrated a rising trend in overweight prevalence in preschool children. Although the prevalence of overweight and obesity in developed countries is about double that in developing countries (11.7 and 6.1%, respectively), the vast majority of affected children (35 million) live in developing countries (29). In addition, the relative increase in the past two decades has been higher in developing countries (+65%) than in developed countries (+48%) (29).

B. Schoolchildren and adolescents (5–19 yr old)

Among older children and adolescents (5–19 yr old), the prevalence rates of obesity have also risen alarmingly in many developing countries (Table 2). For example, in Brazil, two random nationally representative surveys undertaken by the Brazilian agency in charge of national statistics in 1974–1975 and 1996–1997 showed that, based on IOTF standards, obesity prevalence (overweight included) in 6- to 18-yr-old children increased from 4.1% (n = 56,259) to 13.9% (n = 4,875) over a period of two decades (8). Furthermore, data sets of boys and girls aged 7–18 yr collected from the series of Chinese national surveillance on students' constitution and health between 1985 (n = 409,946) and 2000 (n = 226,602) showed that, in 2000, the prevalence of childhood obesity/overweight in coastal big cities, followed by that in coastal middle/small cities, had reached the average level of developed countries (30). In this dataset, based on the Working Group on Obesity in China BMI reference (overweight, BMI >24 kg/m^2; obesity, BMI >28 kg/m^2), between 1985 and 2000, the prevalence of overweight (obesity included) increased from 0.93 to 14.9% in boys and from 1.62 to 8.9% in girls. The prevalence of obesity in 5- to 12-yr-old children (n = 1156) in Thailand increased from 12.2 to 15.6% between 1991 and 1993 (9). Our group examined the secular trends in prevalence of overweight and obesity among urban Asian Indian adolescents aged 14–17 yr in New Delhi, North India (31). Analyzing data from cross-sectional sampling of children, 3493 in 2006 and 4908 in 2009, we reported that based on age, gender, and Asian Indian-specific cutoffs of BMI (32), the prevalence of obesity (BMI >95th percentile of reference population) increased significantly from 9.8% in 2006 to 11.7% in 2009 ($P < 0.01$), whereas underweight (BMI <5th percentile of reference population) decreased from 11.3 to 3.9% ($P < 0.001$). Also, males and privately funded schools' children had significantly higher increase in prevalence and risk of being overweight and obese over these 3 yr. However, two other studies conducted in urban schoolchildren in North India showed that the prevalence of overweight and obesity, based on IOTF standards, was constant over the past 5 yr, 24.7 and 7.4%, respectively, in 2002 and 24.5 and 7.5% in 2008 (33, 34).

V. Determinants of Overweight/Obesity

The key determinants of childhood obesity in developing countries are shown in Table 4.

A. Unhealthy nutrition

Five patterns of nutrition transition, derived from historical references of human development, are present and

TABLE 4. Key determinants of childhood obesity in developing countries

Determinant	Details
Reduced physical activity	Indoor leisure activities and entertainment (television viewing, internet, and computer games) Unsafe neighborhoods for walking and other outdoor activities Lack of open spaces and playgrounds in schools and communities Increasing pressure on children to perform in academics and reduced emphasis on sports
Increased caloric intake	Unrestricted access to energy-dense fast foods in school cafeteria, school vending machines, and school neighborhood Overfeeding of low-birth-weight babies Low knowledge about dietary components in schoolchildren
High SES	Daily allowance (pocket money) to purchase lunch Easy availability of domestic help to take care of household chores Commuting to school by bus or car instead of walking or bicycling Aggressive advertising by transnational fast-food and cola companies
Urbanization and residence in metropolitan cities	Limited availability of open spaces and parks due to population expansion and illegal settlements Increased exposure to Westernized lifestyle and dietary habits Abundance of fast-food outlets and eating joints in housing colonies
Sociocultural factors	Overprotection and forced feeding by parents False traditional beliefs about health and nutrition Low knowledge about nutrition in parents and caregivers
Age and female gender	More obesity in prepubertal phase compared with postpubertal phase Self-consciousness among postpubertal children about weight gain and physical appearance Females are mostly engaged in household chores and less involved in playground activities Sociocultural beliefs against sports and outdoor physical activity by girls
School meal programs	May actually lead to increase in obesity among those with marginal undernutrition Requires careful selection of beneficiaries of food assistance programs

evolve from one category to another in many ethnic groups and disparate geographical locations in developing countries (Fig. 3) (2). Pattern 1 nutrition transition is characteristic of hunter-gatherer populations and comprises diets rich in carbohydrates and fiber and low in fat, especially saturated fat, with a high-activity profile and lean body phenotype. In pattern 2, individuals exist in a famine-like situation (low-calorie, low-protein, and low-fat diets) and have growth retardation and low body fat and fat-free mass. In pattern 3, famine wanes, and nutrition improves, with increase in the consumption of fruits, vegetables, and animal proteins, and this pattern is associated with increasing inactivity. Pattern 4 is now most prevalent in developing countries, conducive to development of obesity, the metabolic syndrome, T2DM, and CAD. Driven by aggressive advertising practices, relatively low cost of energy-dense foods and improved purchasing power, children and adolescents are increasingly consuming foods high in saturated fat and refined carbohydrates, sweetened carbonated beverages, and diets low in polyunsaturated fatty acids and fiber. In the last (pattern 5), as people suffering from T2DM and CAD increase in the population, awareness of benefits of balanced diets and regular physical activity increases. Consequently, people attempt to change dietary and physical activity profiles to prevent or delay diseases. This pattern, unlike previous patterns, is driven by an individual's desire to seek healthy behavior, hence may not be evident in large segments of populations, and is likely to be adapted initially by affluent people. A rather rapid shift from pattern 3 to 4 in the developing countries is clearly responsible for a steep increase in obesity and the metabolic syndrome.

In developing countries, students often have ready access to high-calorie, nutritionally depleted foods in cafeteria and fast-food shops located around schools (35). Some researchers in developed countries have linked childhood obesity to these food choices available in the school cafeteria (36). Recent studies have reported inadequate knowledge about health and nutrition in urban Asian Indian schoolchildren before educational intervention (37) (Fig. 4). Lack of knowledge about adverse effects of unhealthy nutrition in urban schoolchildren in India may explain the high intake of dietary fat (38), resulting in a high prevalence of obesity in them (27). A study conducted in 13- to 25-yr-old Asian Indian adolescents and young adults reported an average total fat intake of 84 ± 29 g/d in males and 72 ± 21 g/d in females (38), nearly four times the recommended dietary allowance for Asian Indians (20–22 g/d) (39) and nearly at par with the intake in adolescents in North America (40). Furthermore, approximately 1.8 cans of cola per week (540 ml/wk) per person consumption was noticed [one can (300 ml) contains 132 kcal and 33–40 g sugar] in Asian Indian adolescents in this study. These data indicate a rapid shift in dietary patterns, from traditional high-carbohydrate meals to heterogeneous calorie-dense westernized foods (1, 2).

B. Physical inactivity

Rapid increase in childhood obesity has also been attributed to a shift in the activity patterns from outdoor play to indoor entertainment: television viewing, internet, and computer games (41). A study in 598 urban Indian

Figure 3.

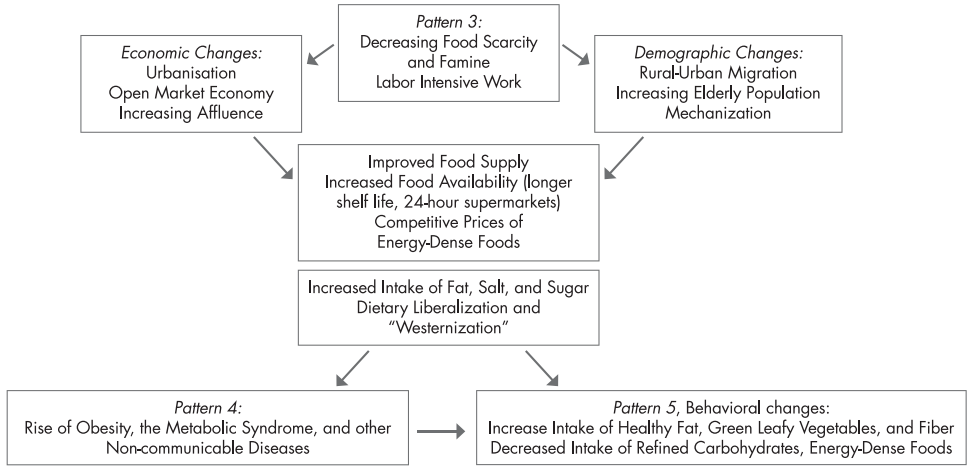


Figure 3. Relationship between nutrition transition, urbanization, and the rise in obesity and the metabolic syndrome in developing countries. *, Pattern 3 may be seen at different rates of progression in different developing countries; ¶, pattern 4 is likely to affect all SES; §, pattern 5 is most likely to occur in upper SES. [Reproduced from A. Misra and L. Khurana: Obesity and the metabolic syndrome in developing countries. *J Clin Endocrinol Metab* 93:S9, 2008 (2), with permission. © The Endocrine Society.]

children aged 6–16 yr in Bangalore (South India) suggested that the adjusted odds of being overweight for children who viewed television for at least 90 min/d was 19.6 (CI = 5.5–69.4; $P < 0.001$), when compared with children who viewed television for no more than 45 min/d (42). Furthermore, a considerable proportion of a child's daily energy intake is consumed while watching television, especially on weekends (43).

An important factor in many developing countries including India is the lack of open spaces and playgrounds in schools and communities. Neighborhoods are often considered unsafe for walking and other outdoor activities in these countries. Urban Asian Indian adolescents who participated regularly in outdoor games had lower prevalence of overweight, with the risk being three times higher in those not participating in outdoor games (44). Only

Figure 4.

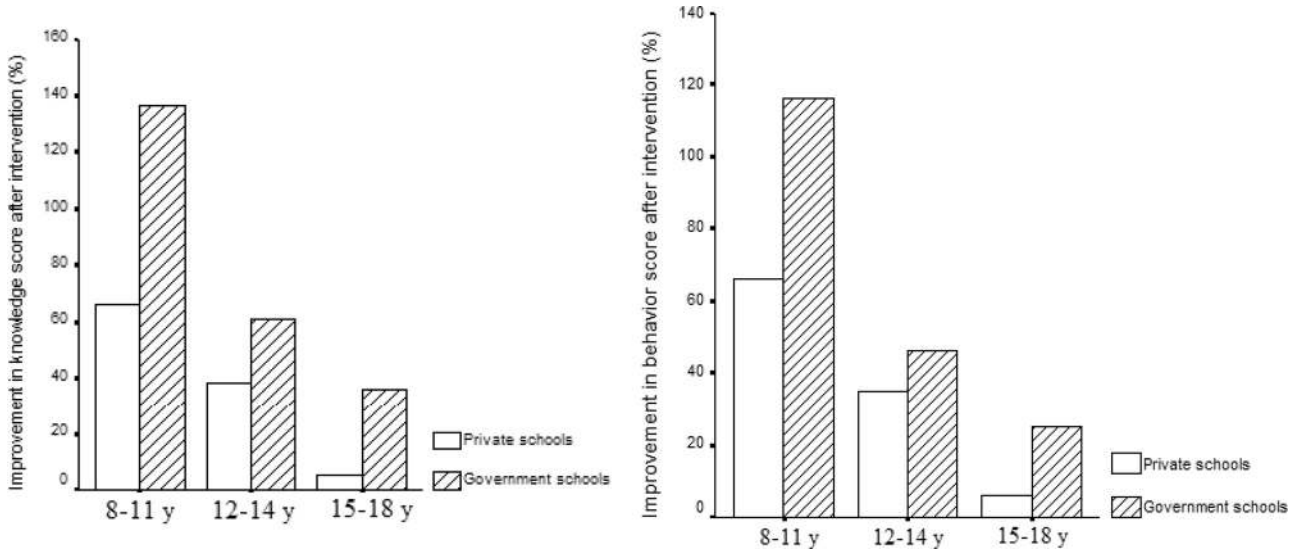


Figure 4. Percent improvement in knowledge and behavior assessment scores of urban Asian Indian children after intensive educational intervention (n = 3128). [Reproduced from P. Shah, *et al.*: Improvement in nutrition-related knowledge and behaviour of urban Asian Indian school children: findings from the 'Medical education for children/Adolescents for Realistic prevention of obesity and diabetes and for healthy aGeing' (MARG) intervention study. *Br J Nutr* 104:427–436, 2010 (140), with permission. © British Medical Association.]

22.4% of Saudi preschool children walked 10,000 steps or more per day (45) and nearly two thirds of Iranian adolescents aged 11–18 yr were physically inactive (46). Furthermore, nonobese Iranian children were reported to be more active in sports and went to school by foot compared with obese children, who did not participate much in sports and used mechanized transport (47). Finally, an increasing pressure on children to perform in academics and reduced emphasis on physical activity in schools has led to a further decline in physical activity in children.

C. Socioeconomic status (SES)

The relationship between SES and weight shows interesting asymmetry. In developed countries, SES is inversely related to childhood obesity (48), whereas in developing countries, affluent children studying in private schools have significantly higher prevalence of overweight and obesity than those belonging to lower SES (34, 49–53). Although urban poor in developed countries appear vulnerable to childhood obesity due to poor diet and decreasing physical activity, the urban rich in developing countries remain at risk probably due to an increased affinity toward a Western type of lifestyle (54–58). According to our recent data, prevalence of overweight among 14- to 17-yr-old urban children was 29% in private schools (high SES) and 11.3% in government-funded schools (low and middle SES) in 2006–2007 in New Delhi, North India (10). The reasons for these observations are manifold. Children from high SES receive daily allowance (pocket money) to buy lunch and snacks. Because of the brand-building efforts by transnational companies that heavily target this age group, fast foods, easily available in the school cafeteria, become their preferred choice. In addition, due to easy availability of domestic help in developing countries, affluent children may resort to a relatively inactive lifestyle. Although most children in private schools go to school by bus or car, active commuting either by walking or bicycling is seen more commonly among children in government schools.

D. Area of residence and urbanization

Lifestyle, occupational composition, dietary patterns, and outlooks differ greatly in metropolitan cities compared with nonmetropolitan cities in India and other developing countries. Fascination of urban youth with Western-style food outlets and their willingness to pay for these services make metropolitan cities lucrative targets for most transnational fast-food companies. Notably, a representative nutrition and health survey in metropolitan primary schoolchildren of Budapest showed an excess intake of fat and cholesterol, low intake of vegetables and fresh fruits, and a deficient intake of milk and dairy products. Furthermore, a higher frequency of consumption of sugar-sweetened beverages, potato chips, and energy-dense fast foods was observed (59). As stated previously, limited availability of open spaces and parks, increased rural-to urban migration, and illegal settlements also reduce the scope for physical activity for children in metropolitan cities. Previous studies from metropolitan cities (population over 4 million) in India reported a prevalence of overweight ranging from 11–28% and obesity ranging from 2–8% in children (34, 49–51). Finally, in most urban families, working parents have less free time to plan proper nutrition and cook healthy meals for their children; as a result, healthy home-cooked dinners have been widely substituted by T.V. dinners or restaurant dinners, which frequently take place in fast-food restaurants. Working mothers have been particularly known to indulge their children with a fairly constant flow of sweet treats and high-fat snacks (60).

Comparative data on overweight and obesity prevalence in urban *vs.* rural areas of developing countries are scarce (51, 61–63). A study in 2467 apparently healthy adolescent schoolchildren aged 11–17 yr from an urban area in North India and 859 students from the surrounding rural area showed that the prevalence of overweight (BMI = 25–30 kg/m^2) was significantly higher in the urban area (11.6% in urban area *vs.* 4.7% in rural area) (51). Raj *et al.* (61) looked at prevalence of underweight, normal-weight, overweight, and obesity, based on CDC 2000 cut-offs in paired data of 12,129 children aged 5–16 yr from Kerala (south India). Between 2003–2004 and 2005–2006, conversion of underweight to normal weight predominated in urban areas and girls; conversion of normal-weight to overweight status predominated in urban areas, private schools, and boys; conversion of normal-weight to underweight status predominated in rural areas, government schools, and boys. The persistence of underweight appears to be significantly more with rural children and boys. These data are further supported by a study in 1799 students aged 10–19 yr in southwestern Nigeria; using 2007 WHO reference values, rural adolescents had significantly lower BMI compared with those in urban areas (62). As discussed earlier, a valid justification to explain the spread of obesity epidemic in urban areas would be the imbalance of caloric consumption and expenditure resulting from energy-dense fast food and caffeinated beverages consumption. Large portion or serving size in restaurants is another contributing factor. However, contrasting results emerged from national basic health research in 2007 in Indonesia, with similar magnitude of overweight prevalence (WHO 2000 reference values) in urban and rural areas (in preschool children, 12% in both urban and rural areas; in 6- to 14-yr-old children, 9% in urban and 7% in

rural) (63). This disparity cannot be explained by an influx of Western culture in rural areas of developing countries but may correlate with the associated economic growth. This aspect warrants further research.

E. Sociocultural factors and traditional beliefs

There are a number of nutrition-related sociocultural and traditional beliefs, mostly passed down over centuries, firmly ingrained in mothers and grandmothers of children residing in developing countries. Overweight children are often said to have baby fat that parents believe will disappear as they get older, but it is known that a majority of them will remain obese during later life (64). Another common myth is that a fat child is a healthy child. Mothers in developing countries believe that feeding oils, ghee (clarified butter), and butter to children would be beneficial for their growth and impart strength. A study in Greek children aged 8–12 yr showed a positive relationship between prevalence of obesity and children living in homes where the grandmother cooked (65). Several similar observations emerged in a series of focus group discussions conducted in 1800 Asian Indian school children (9–18 yr) and their mothers to evaluate their perceptions on health and nutrition (Table 5) (Gulati, S., N. Gupta, K. Goel, A. Misra, unpublished work). Finally, Monasta *et al.* (66) also identified prenatal exposure to maternal smoking, no or short breastfeeding in infancy, and short sleep duration at 3–4 yr of age as some of the early-life determinants of overweight and obesity.

F. Age and gender

A longitudinal study in 308 Indonesian children reported a higher prevalence of overweight/obesity in the same cohort of children when they were 11–13 yr old (8.8%) compared with when they were 6–8 yr old (4.2%) (67). Although the prevalence of both overweight and obesity decreased as age advanced from 5–16 yr in a cross-sectional survey of 43,152 Asian Indian children in South India (68), contrasting findings were observed in 1- to 18-yr-old children in Saudi Arabia (69). In the latter study, a decrease in prevalence was found in both males and females up to the age group of 8–13 yr, and then the prevalence increased again up to the age of 18 yr. In a large-scale multicentric study conducted in 38,296 schoolchildren aged 8–18 yr in India by our group, an inverted U-shaped curve for prevalence of overweight was seen with increasing age (27). The prevalence increased from 8 to 12–13 yr and decreased thereafter. These observations suggest that children were more obese in the prepubertal phase compared with postpubertal phase. A possible reason could be the increased self-consciousness among postpubertal children about weight gain and physical appearance.

On account of sociocultural barriers, adolescent girls have very low levels of physical activity in most developing countries (70). Girls are mostly engaged in minor household chores and are less involved in outdoor activities compared with males (71). Several groups, including ours (27), have reported a higher prevalence of obesity in females compared with males in India, Saudi Arabia, South Africa, and Brazil (1, 26, 34, 49, 69, 72). In contrast, a higher prevalence of obesity was reported in males than females residing in Beirut, Malaysia, and Sri Lanka (73–75). However, sex-wise distribution of overweight and obesity prevalence did not show any significant difference in 3326 apparently healthy schoolchildren, aged 11–17 yr from an urban and rural area of North India (urban overweight male 11.57%, urban overweight female 11.69%, *P* value not significant; rural overweight male 5.44%, rural overweight female 4.03%, *P* value not significant; urban male obese 2.81%, urban female obese 1.91%, *P* value not significant; and rural male obese 4.08%, rural female obese 3.23%, *P* value not significant) (51).

TABLE 5. Key statements of Asian Indian mothers, reflecting their mindset about health and nutrition (n = 1800)

Statements:
A child with chubby cheeks is healthy, not fat.
Girls should have a glow on their face, to be considered healthy.
Most of the obesity in children is baby fat, which would eventually go away.
Children should not play outside if the weather is even a bit severe.
Girls should not play in field with boys; they should stay at home and help in household chores.
Studies come first; sports and exercise come later.
Prepackaged foods contain excessive amount of harmful chemicals and preservatives.
Do not eat raw carrot and cabbage because these foods contain bacteria that can affect the brain.
Eating ghee[a] and butter is essential for strong bones.
Do not leave any leftovers on plate after each meal.
Parantha[b] is the best food item to be given in lunchbox to school.

The source of this information is A. Misra et al. (unpublished work).

[a] Ghee is clarified butter.

[b] Parantha is flatbread, made by pan-frying whole-wheat flour.

G. Obesity secondary to endocrine or genetic causes

Far less common than lifestyle factors are genetic diseases (single-gene mutations) and hormonal disorders (hypothyroidism, Prader-Willi syndrome, Cushing's syndrome, *etc.*) that can predispose a child to obesity. In a systematic review, Parsons *et al.* (76) concluded that "parent obesity is an important factor in predicting adult obesity of offspring, and that offspring of obese parents who themselves were obese in childhood may be at particular risk." Maternal birth weight has also been shown to be significantly associated with offspring birth weight (77). A

detailed discussion on these disorders is beyond the scope of this review.

VI. Medical Consequences of Childhood Obesity

The key health consequences of childhood obesity are shown in Table 6.

A. Insulin resistance and the metabolic syndrome

Association of multiple factors like central obesity, dyslipidemia (hypertriglyceridemia and low levels of high-density lipoprotein-cholesterol), hypertension, and impaired glucose tolerance (IGT) characterizes the metabolic syndrome. Data pertaining to the metabolic syndrome in children and adolescents are limited due to lack of a well-established definition for the metabolic syndrome in children. A recent International Diabetes Federation definition of the metabolic syndrome in children included waist circumference (WC) as a mandatory criterion and two or more other risk variables (28). This definition is age specific and takes into account developmental challenges in growing children and adolescents.

Limited data in children show that the prevalence of the metabolic syndrome is increasing in most developing countries. A nationally representative cross-sectional survey in China in 2002 showed that, using the criteria for the metabolic syndrome proposed by de Ferranti *et al.* (78), the overall prevalence of the metabolic syndrome in Chinese adolescents (15–19 yr) was 3.7%; however, the prevalence rates were 35.2, 23.4, and 2.3% among adolescents who were obese (BMI ≥95th percentile), overweight (BMI 85–95th percentile), and normal weight (BMI <85th percentile), respectively (79). In Taiwan, the prevalence was 5.6% in boys and 6.4% in girls aged 6–12 yr in 2001–2002 using modified National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria (80, 81). Applying adult criteria for diagnosis of the metabolic syndrome to apparently healthy Turkish students aged 10–17 yr, 2.2% had the metabolic syndrome (82). In this study, the metabolic syndrome was nearly 10 times more common among overweight and obese students (21%) than among lean students. While prevalence of the metabolic syndrome was shown to be 5.6% among a sample of overweight and obese prepubertal children (8–10 yr) in Costa Rica (83), an elevated risk of developing the metabolic syndrome was also reported among obese adolescents (11–20 yr) in Argentina (odds ratio = 119.73; 95% CI = 27.6–519.4) (84). High prevalence of the metabolic syndrome has been reported in 10- to 19-yr-old Iranian adolescents (10.1%) (85) and 5- to 18-yr-old obese Bolivian children (36%) (86) according to the modified NCEP ATP III criteria, adapted for children. Kim *et al.* (87) showed a significant increase in the overall prevalence of the metabolic syndrome (defined using modified NCEP ATP III criteria) from 6.8% in 1998 to 9.2% in 2001, among South Korean adolescents aged 12–19 yr (87).

Importantly, the pattern of weight gain, particularly rapid weight gain after the age of 2 yr has been shown to be significantly associated with a higher prevalence of the metabolic syndrome in young (26–32 yr) Asian Indians (88). Recently, in a factorial analysis, obesity/insulin factor (BMI, WC, triceps skinfolds, subscapular skinfolds, and fasting insulin) was shown to be independently associated with a high cumulative risk of the metabolic syndrome in urban Asian Indian adolescents (89). Insulin resistance has been reported to be present as early as 8 yr of age in Asian Indian children (90), with an overall prevalence of fasting hyperinsulinemia in 29.0 and 63.9% normal-weight and overweight adolescents (BMI >23 kg/m^2), respectively (91). In this context, it is important to note that some ethnic groups in developing and developed countries (*e.g.* South Asians) have a higher tendency to develop hyperinsulinemia at an early age compared with white Caucasians (2).

TABLE 6. Key health consequences of childhood obesity

Medical consequences	Psychosocial consequences
The metabolic syndrome	Discrimination
T2DM	Social stigmatization
Insulin resistance	Subject to bullying
Subclinical inflammation	Poor body image
PCOS	Low self-esteem
Adulthood obesity	Low self-confidence
NAFLD	Stress
Hypertension	Depression
High cholesterol	Anxiety
Gallstones	Emotional fallout
Dyslipidemia	Poor learning
Obstructive sleep apnea syndrome	
Early puberty or menarche	
Eating disorders	
Skin infections	
Pseudotumor cerebri	
Orthopedic disorders	
Asthma and other respiratory diseases	

B. Type 2 diabetes mellitus

Globally, T2DM is being reported at an early age, primarily contributed by obesity and the metabolic syndrome in early childhood. Increasing prevalence of T2DM among children and young adults has been reported from the Middle East (92) and several Asian countries including Thailand (93). A hospital-based

study in North India suggests an increasing trend of T2DM in persons under 40 yr of age (94); however, in a population-based study of 3515 schoolchildren from South India, no child had T2DM (95).

Early weight gain (0–5 yr) is thought to be an important contributor to childhood obesity and consequently metabolic risk (96–98). A long-term prospective population-based cohort study was conducted in more than 1400 adults aged 26–32 yr, who had grown up in the city of New Delhi, North India, at a time of rapid nutrition transition. These young adults were measured sequentially from birth until 21 yr of age and were subsequently followed up. Their mean birth weight was 2851 g. As children, many subjects were underweight for age (>2 SD below the National Center for Health Statistics mean; 53% at 2 yr), but as adults, 47% were overweight, 11% were obese, and 51% were centrally obese (according to WHO criteria). In this cohort, birth weight and BMI gain during infancy and early childhood were correlated more strongly ($P < 0.001$) with adult lean mass than with adiposity or central adiposity. However, higher BMI and greater BMI gain in late childhood and adolescence were associated with increased adult adiposity and central adiposity (96). The study also showed that at the age of 30 yr, 15.2% of subjects had IGT or diabetes, and 4.4% had diabetes (98). The young adults who had IGT or diabetes were, as a group, overweight. They were not, however, overweight as young children but, instead, became overweight as a result of an accelerated gain in BMI starting in early childhood, having been thin in infancy (98). In a prospective study of 2639 individuals in Brisbane, Australia, Al Mamun *et al.* (97) reported that young adults who were overweight at 5 yr of age had an increased odds ratio (2.60; 95% CI = 1.29–5.22, in age- and sex-adjusted model) of experiencing diabetes by age 21 yr.

Data on follow-up of the offspring of diabetic mothers (ODM) is scarce in developing countries. Studies in developed countries, predominantly among the Pima Indian communities of North America, have shown that individuals whose mothers were diabetic when they were *in utero* have an increased risk of early obesity and IGT and T2DM in adult life (99). In a prospective study on 630 children in South India, of which 41 were ODM, Krishnaveni *et al.* (100) showed that the increased body size observed at birth in ODM diminished in the first postnatal year, reappeared in female children by 2 yr of age, and persisted until at least 5 yr of age and that female ODM had an increased risk of IGT at 5 yr and increased 30- and 120-min insulin concentrations ($P < 0.05$) compared with offspring of nondiabetic mothers. These differences were independent of maternal adiposity.

Body fat patterning is an important correlate of metabolic derangements in certain ethnicities. We have previously reported that the presence of central obesity (high waist-to-hip circumference ratio) along with hypertriglyceridemia and family history of T2DM increases the odds of T2DM by 112.1 in young Asian Indians (< 40 yr) (101). Several investigators have shown that Asian Indians have a higher amount of body fat for a similar level of BMI, compared with white Caucasians (2, 91, 101–103). This excess fat tends to be localized to the truncal region in Asian Indians (104, 105). Evidence in this regard has been reported in Asian Indian neonates who have a thicker truncal sc adipose tissue (SCAT; measured by subscapular skin folds) compared with British neonates (102). Similar results have been reported in adult Asian Indians who were shown to have significantly thicker abdominal SCAT (measured by magnetic resonance imaging) and significantly larger sc adipocytes compared with white Caucasians (103). This is important because we have shown previously that truncal SCAT was associated with a higher prevalence of insulin resistance in urban Asian Indian children and adolescents (104). Recently, we also substantiated this association in healthy Asian Indian adults, in whom SCAT was independently associated with obesity-related complications, particularly the metabolic syndrome (4).

C. Raised markers of inflammation

Subclinical inflammation, typified by markers such as high-sensitivity C-reactive protein (hs-CRP), is associated with atherosclerosis and has been shown to predict T2DM and CAD (106). Generalized and abdominal adiposity has been shown to be independently associated with increased levels of hs-CRP in Asian Indian adolescents and young adults (aged 14–25 yr) (107). In this study, high hs-CRP levels were seen in 13% of Asian Indian adolescents overall, in approximately 22% of overweight (BMI >85th percentile) and in approximately 25% of those with excess body fat (percent body fat >85th percentile) (107). The relationship between obesity, inflammation, and risk for atherosclerosis was supported by another study in 4.5- to 15-yr-old obese Turkish children and adolescents, wherein a positive correlation of hs-CRP with BMI, relative weight, blood pressure, and serum leptin levels was reported (108). Interestingly, excess dietary intake of saturated fat is also a strong correlate of high hs-CRP levels (109).

D. Other conditions

Obese adolescent girls are more likely to suffer PCOS (110). Insulin resistance, believed to be a key pathogenic factor in both PCOS and the metabolic syndrome, may be

a link between the two conditions (111). Higher prevalence of PCOS has been reported in South Asian women residing in the United Kingdom than in white Caucasians (112). The prevalence and course of PCOS in developing countries has not been adequately investigated. With the rapid rise in childhood obesity, there has also been an increase in the prevalence, recognition, and severity of pediatric NAFLD (113). Although prevalence of NAFLD is high in some developing countries (114), relevant data in children from developing countries are not available, and this issue needs to be researched further.

VII. Psychosocial Consequences of Childhood Obesity

Overweight and obese adolescents tend to have poor body image and low self-esteem. Social isolation and stress could interfere with their learning and lead to depression, anxiety, and emotional fallout. These negative factors work against the child with a weight problem and thus hamper his/her overall growth and development (115–117). However, qualitative in-depth interviews conducted with 10 overweight Black women who were resident in the metropolitan area of Khayelitsha in Cape Town showed that although women expressed the desire to lose some excess weight for practical reasons, there was no negative social pressure to motivate this (118). In this context, no other data are available from developing countries.

VIII. Management of Childhood Obesity

Recommendations for reducing childhood obesity in developing countries are shown in Table 7.

In a Cochrane systemic review, Oude Luttikhuis *et al.* (119) selected 64 randomized controlled trials (5230 participants) of lifestyle (*i.e.* dietary, physical activity, and/or behavioral therapy) and drug (metformin, orlistat, and sibutramine) interventions for treating obesity in children (mean age under 18 yr) with or without the support of family members, with a minimum of 6 months follow-up (3 months for actual drug therapy). Most of these randomized controlled trials were conducted in developed countries including the United States, United Kingdom, Belgium, Australia, Sweden, Israel, Germany, Finland, Switzerland, Italy, Austria, The Netherlands, Japan, and Canada, and four were conducted in developing countries including China, Turkey, and Brazil. Although there were limited quality data to recommend one treatment program to be favored over another, this review showed that combined behavioral lifestyle interventions compared with standard care or self-help can produce a significant and clinically meaningful reduction in overweight in children and adolescents.

TABLE 7. Recommendations for reducing childhood obesity in developing countries

	Recommendation
Monitoring and surveillance	Periodic monitoring of nutritional and obesity status of children and adults
	Maintain a nationwide database on secular trends in obesity and diabetes
Education	Nutrition and physical advice through audiovisual media and culturally conducive methods
	Endorsement of healthy lifestyle by prominent people and local champions
Community	Organization and participation in health walks and healthy food festivals
	Information about nutrition to parents (particularly mothers)
	Children-specific nutrition information workshops for newly married women
	Safe walk/bicycle routes to school
Perinatal and neonatal period	Balanced nutrition to pregnant mothers
	Encourage breastfeeding
	Avoidance of catch-up obesity in children
	Maintenance of correct growth velocity under guidance of physicians
	Avoid excess nutrition to stunted children
School-based programs	High importance of physical activity
	Healthy foods in cafeteria, ban on sweetened beverages and energy-dense junk food
	Training of teachers regarding health education
	Incorporation of more knowledge about nutrition and physical activity and nutrition-related diseases in school curriculum
Home	TV/computer time to be restricted to <2 h/d
	Mandatory 60 min of physical activity daily to be supervised by parents
	Restriction on eating out and junk foods
National Health Authority	Creation of national task force for obesity
	Decrease in taxes and prices of fruits and vegetables
	More playgrounds, parks, and walking and bicycle tracks
	Restriction on advertisement of commercial foods on television at prime time and during children's programs
	Encourage transnational food companies to manufacture healthy snacks
	Ban on unfair nutrition claims for commercial products
	Prohibition of promotional gifts with junk foods
	Restrictions on monetary sponsorship of youth festivals by cola companies
Legislative	Food labeling and quality monitoring
	Food policy to include country-specific guidelines for healthy nutrition for adults and children

A. Increasing physical activity

Children and adolescents should be encouraged to participate in at least 45–60 min of moderate intensity physical activity (either sports or bicycling) most days of the

week, preferably daily. This has been emphasized in a recent consensus statement on physical activity for Asian Indians (120).

1. Enhanced school-based physical education

Evidence in developed countries exists that physical education may enhance academic performance, self-confidence, and mental health in schoolchildren (121). Activities could be individualized according to the interests of children, culture, and local practices in developing countries. For instance, aerobic dance with popular music may appeal more to girls, whereas boys may enjoy more vigorous outdoor sports and martial arts. High success rates of such age-, gender-, preference/liking-specific school programs have been reported in Mexico and Chile (122, 123). In Chile, during 2003–2004, Kain *et al.* (123) developed and implemented a school-based obesity prevention intervention that included nutrition education and promotion of physical activity. The sample included 1760 children (first to seventh grade) from three elementary public schools in Casablanca (experimental group) and 671 from a similar school located in Quillota, a neighboring city (control). After the intervention, there was a significant decline in BMI Z scores in experimental schools for both genders, but greater in boys ($P < 0.001$ *vs.* $P = 0.0034$ in girls), whereas in controls, BMI Z scores increased. Obesity prevalence declined significantly in experimental schools; from 17 to 12.3% and from 14.1 to 10.3% in boys and girls, respectively, whereas in the control group, it remained unchanged.

2. Social support interventions in community settings

Promotion of group initiatives at the community level has been shown in developed countries to encourage participation in physical activity and thus prevent obesity among children as well as adults (124). Appropriate sports (cricket, soccer, and swimming) and activity (walking and yoga) clubs may be established. Fitness centers, courts for basketball and badminton, playgrounds for hockey and skating, and parks for jogging and walking should be made more accessible (125). However, studies show a limitation in such initiatives due to increased costs (125–127).

3. Encouraging parental involvement

Parental initiative is necessary to ensure a reasonable level of physical activity in children (128, 129). Schools can help encourage activity in parents by sending home activity homework that parents and children do together; recruiting parent volunteers for physical education classes and sponsoring parent-child activity programs at school. Parent-teacher meetings could be used for regular parent sensitization and involvement. Parents should try to set examples by exercising regularly themselves. Parents could accompany children to nearby parks and play with them. This would not only add to their health benefits but also let them supervise their children.

4. Safe routes to school for walking/bicycling

Creation of safe pedestrian pathways and enhancing neighborhood safety are long-term goals in this respect (125). Walking and bicycling to school are likely to enhance physical activity in children and adolescents greatly (47, 130). However, as mentioned previously, these initiatives have limitations due to huge financial investments required (126, 127).

5. Resistance training

Resistance training may be an attractive approach for children and adolescents in the contemporary scenario. A recent study showed that 14 obese children who underwent resistance training for 10 wk (three times/wk) had a significant improvement in muscle strength and a favorable change in body composition compared with 14 control obese subjects who had a significant increase in fat mass (approximately 2.5 pounds) during the same period (131). Previous studies have also shown that resistance training programs significantly increase insulin sensitivity in adolescents (132) and adults (133). However, care should be taken in designing these programs to prevent physical injuries (134).

B. Encouraging healthy eating

1. Healthy eating at home

It is important to have regular meals including breakfast at home, because children who take part in family meals are also more likely to eat fruits, vegetables, and grains and less likely to snack on unhealthy foods and smoke or drink alcohol (135). A variety of healthy and tasty foods and snacks should be served at home. Healthy cooking methods such as roasting, boiling, steaming, and baking should be advocated. Furthermore, previous studies indicate that vegetarian diets are associated with a lower BMI and a lower prevalence of obesity in adults and children (136). Compared with nonvegetarians, vegetarian children are leaner, and their BMI difference becomes greater during adolescence (137). Plant-based diets are low in energy density and high in complex carbohydrate, fiber, and water, which may increase satiety and resting energy expenditure. Therefore, plant-based dietary patterns should be encouraged for optimal health and environmental benefits.

2. Healthy eating at school

For children skipping breakfast at home, fast food is easily available in school (35). It is our experience during nutritional intervention programs (Gulati, S., N. Gupta, K. Goel, A. Mishra, *et al.*, unpublished work) that although younger children often carry a homemade lunch box (tiffin) to school, older ones do not because they consider it childish. The most commonly bought food from school cafeteria in developing countries includes colas, potato chips, chocolates, burgers, patties (fried triangular pastry with vegetable fillings), ice creams, and candies (35, 38, 138). It is important not only to limit the availability of fried and fatty foods and carbonated beverages in school cafeteria but also to provide healthier options for children. In the United Kingdom and many European countries, all commercial activities in primary schools are restricted as per the directive of Union of European Beverages Association. According to these, secondary school students may be offered a full range of beverages including water, 100% juice, sports drinks, and low-calorie drinks in appropriate portion sizes, only with the agreement and active participation of educators and parents (139). However, there is a lack of stringent laws and regulation pertaining to fast-food sale in schools in developing countries.

3. Nutritional education/behavioral intervention

Nutritional education in schools has been shown to improve nutrition-related knowledge, attitude, and practices among children (140). In our Medical education for children/Adolescents for Realistic prevention of obesity and diabetes and for healthy aGeing (MARG) educational intervention program, among 8- to 11-yr-olds, more than 15% improvement was noted in knowledge regarding obesity, *trans*-fatty acids, physical activity, diabetes, and blood pressure. After the intervention, more than 10% additional students considered steaming of food a healthy cooking practice and preferred outdoor games over indoor games (140). Parents should also talk to children about making the right food choices and planning a balanced meal. When shopping for groceries, children can be taught to check food labels to begin understanding what they are looking for. They can be involved in age-appropriate tasks in the kitchen.

4. Setting examples

The best way for parents to encourage healthy eating in children is to eat a balanced diet themselves. They should share at least one meal with children. Parents should themselves have smaller portions, green vegetables, and fruits and discourage overeating in children. Finally, foods are not recommended for behavior modification in children. It is important to foster a positive approach toward food and not bribe or reward children with food.

C. Regular health check-ups

Regular health check-ups should be done for each child at least once a year. During this visit, the doctor should calculate the child's BMI and the trajectory of weight and BMI and counsel parents appropriately if it is above the normal range. Many schoolchildren in developing countries do not get regular medical care. In this situation, schools can play a central role in addressing obesity-related issues among students by providing screening (by measuring BMI) at no cost, health information, and referrals to students. Standardized health report cards should be made available for all children to facilitate adequate growth monitoring over time. Although schools in developed countries offer many such opportunities (141), it has yet to become a norm in developing countries.

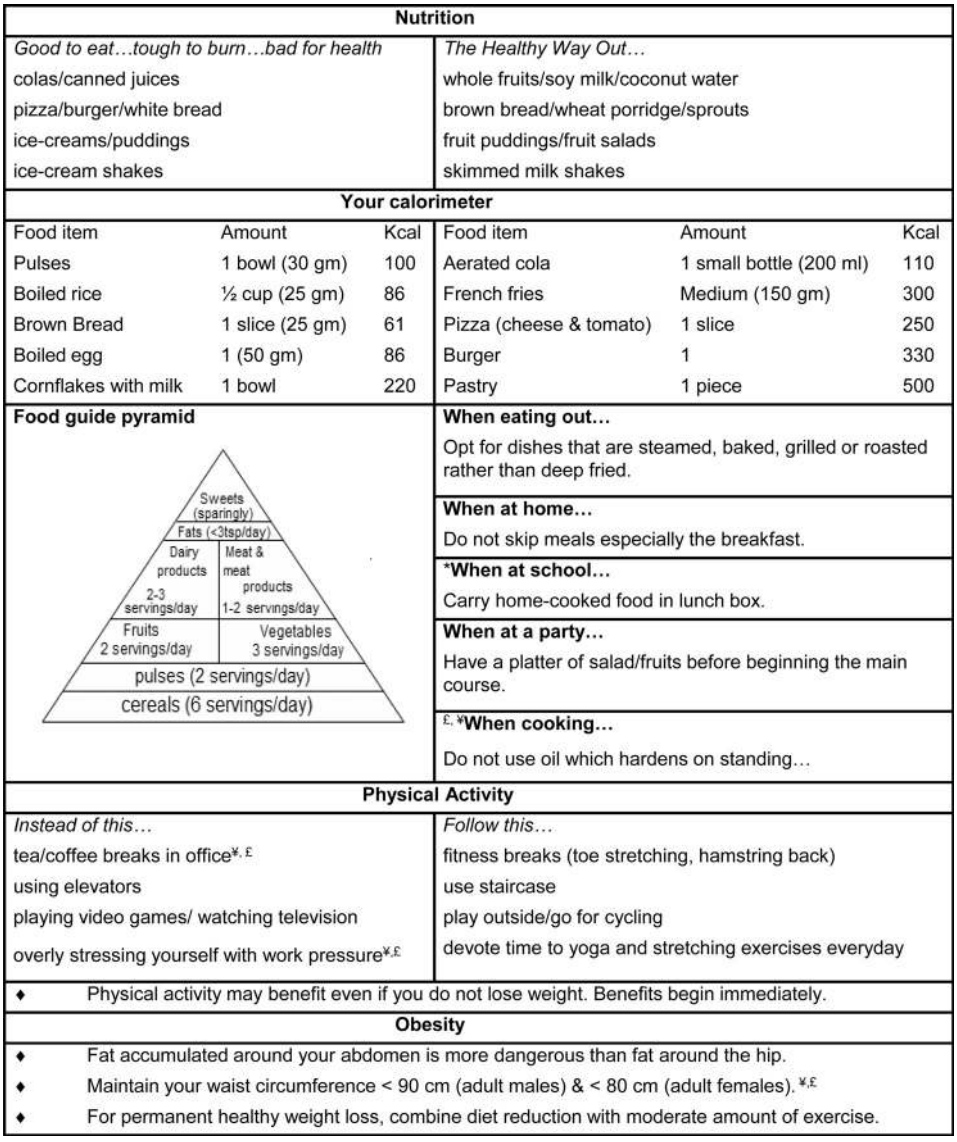
D. Intervention studies and campaigns

Several awareness programs have recently been initiated in developing countries to impart education on health, nutrition, diseases, and physical activity to children. These programs vary with regard to the age of children targeted, activities initiated, and the budget allocated to implement these projects. Yet most programs use schools as an important setting for health promotion activities. Efforts along these fronts have shown favorable results in specific study populations but have not yet decreased the overall prevalence of childhood obesity in developed or developing countries, underscoring the need for such a comprehensive approach. Some of these interventions are short term and aim at obesity prevention, whereas some are long term and focus on effective obesity treatment. Results from a few campaigns have not yet been evaluated rigorously. High quality intervention campaigns that incorporate sound strategies to curb the ongoing obesity epidemic and cost-effective programs for primary and community care are required in developing countries.

1. India: MARG (Hindi for path)

MARG is a school-based intervention program, involving children and adolescents (aged 8–18 yr, n = 80,000), parents (n = 30,000), and teachers (n = 2,000) from five major cities of India. Over the last 4 yr, education about optimal dietary and lifestyle practices has been imparted in 50 schools, using innovative and age-appropriate education strategies and informative booklets (Fig. 5). Healthy food counters were also established in school cafeterias. Surveys conducted at the beginning and end of the project in each school recording the children's level of knowledge about healthy lifestyle provided encouraging evidence of its impact (140).

Figure 5.



Nutrition

Good to eat…tough to burn…bad for health	*The Healthy Way Out…*
colas/canned juices	whole fruits/soy milk/coconut water
pizza/burger/white bread	brown bread/wheat porridge/sprouts
ice-creams/puddings	fruit puddings/fruit salads
ice-cream shakes	skimmed milk shakes

Your calorimeter

Food item	Amount	Kcal	Food item	Amount	Kcal
Pulses	1 bowl (30 gm)	100	Aerated cola	1 small bottle (200 ml)	110
Boiled rice	½ cup (25 gm)	86	French fries	Medium (150 gm)	300
Brown Bread	1 slice (25 gm)	61	Pizza (cheese & tomato)	1 slice	250
Boiled egg	1 (50 gm)	86	Burger	1	330
Cornflakes with milk	1 bowl	220	Pastry	1 piece	500

Food guide pyramid

When eating out…

Opt for dishes that are steamed, baked, grilled or roasted rather than deep fried.

When at home…

Do not skip meals especially the breakfast.

***When at school…**

Carry home-cooked food in lunch box.

When at a party…

Have a platter of salad/fruits before beginning the main course.

£, ¥When cooking…

Do not use oil which hardens on standing…

Physical Activity

Instead of this…	*Follow this…*
tea/coffee breaks in office¥, £	fitness breaks (toe stretching, hamstring back)
using elevators	use staircase
playing video games/ watching television	play outside/go for cycling
overly stressing yourself with work pressure¥,£	devote time to yoga and stretching exercises everyday

- Physical activity may benefit even if you do not lose weight. Benefits begin immediately.

Obesity

- Fat accumulated around your abdomen is more dangerous than fat around the hip.
- Maintain your waist circumference < 90 cm (adult males) & < 80 cm (adult females).¥,£
- For permanent healthy weight loss, combine diet reduction with moderate amount of exercise.

Figure 5. Key statements from educational posters and booklets used in the MARG study. *, Specific for schoolchildren; £, specific for parents; ¥, specific for teachers. [Reproduced from P. Shah, *et al.*: Improvement in nutrition-related knowledge and behaviour of urban Asian Indian school children: findings from the 'Medical education for children/Adolescents for Realistic prevention of obesity and diabetes and for healthy aGeing' (MARG) intervention study. *Br J Nutr* 104:427–436, 2010 (140), with permission. © British Medical Association.]

In another study conducted in the MARG project, significant improvement in nutrition and physical activity profiles of children was seen in the intervention group (intensive education) compared with control group at 6 months follow-up: increased intake of fresh fruits (10%), decreased daily consumption of white bread (made of refined flour) (11%), lower consumption of aerated drinks (15%) and energy-dense foods such as burgers, pizzas, and french fries (9%) ($P < 0.05$ for all) (138). Significant decrease in mean WC, sagittal abdominal diameter, waist-to-hip circumference ratio, and fasting blood glucose was also seen in intervention as compared with control group schoolchildren ($P < 0.05$ for all) (138).

2. United Arab Emirates: the Fat Truth Campaign

The Fat Truth Campaign, under the slogan "Get Involved So They Can Too" was launched from April 20 to July 20, 2009 (142), to combat childhood obesity in the United Arab Emirates through involving and educating parents, caregivers, healthcare and educational sectors, and government bodies. In this campaign, several school-based activities were implemented, workshops were or-

ganized, and an intensive media campaign was launched. Educational leaflets were distributed in shopping malls and clinics. The impact of this campaign has not been documented yet.

3. Malaysia: school health program and school canteen guidelines

The Ministry of Education in Malaysia launched The Healthy Lifestyle Campaign in May 1991 to protect, promote, and maintain optimum health of pupils and school personnel, promote healthy school living, and develop desirable knowledge, attitudes, and practices pertaining to health (143). Another series of activities, The Healthy Eating Campaign (1997–2002), emphasized dietary practices, body weight, food, and nutrition labeling as well as food hygiene.

4. Brazil: World Heart Federation Campaign

The program was conducted from February 2008 to December 2009 in schoolchildren in two Brazilian counties. Data collection was then followed by intervention. Evaluation of this program remains to be done (144).

5. Indonesia: Jump Rope for Heart

The Indonesia Heart Foundation runs a Jump Rope for Heart school program. It was initially started in Jakarta (two schools from each district), with the plan to roll it out nationally. In the first stages, the focus was on physical activity and tobacco cessation (144).

6. Iran: Isfahan Healthy Heart Program-Heart Health Promotion from Childhood

The program began with a baseline survey during 2000–2001, and program interventions have been running since then (145). It involves children aged 2–18 yr (n = 600,000), their parents, teachers, related healthcare providers in schools, health centers, and kindergartens. The goal of the program is to improve lifestyle habits, knowledge, and behavior toward healthy nutrition and reduce the prevalence of obesity and cardiovascular risk factors. Evaluation of this program has shown an increase in the knowledge of the population about the issues explored and a decrease in mean WC and total and low-density lipoprotein-cholesterol in children in the intervention community (146).

7. Mexico: CAMBIO program

CAMBIO (Canada-Mexico Battling Childhood Obesity) is an international, multidisciplinary team of researchers developed to investigate and address childhood obesity in Mexico, within the context of nutrition transition (147). The network promotes cooperation and knowledge transfer among educational institutions, government ministries, and nongovernmental organizations, whose focus is health, nutrition, physical activity, and promotion of healthy communities.

8. South Africa: The Community Children's Program

The program started by The Heart and Stroke Foundation in 1997 targets children from 3–6 yr in primary schools, with a specific focus on children from low SES. The program, which covers 2.1 million children, involves the community through parents and educators and has developed modules on physical activity, nutrition, effects of smoking, and rheumatic heart disease. The project also developed the Sow-a-Seed concept, whereby crèches grow fruits and vegetables so that healthy food is available (144).

IX. Conclusion

Childhood obesity is a grave issue that needs to be addressed urgently. This is because childhood obesity leads to several medical (hypertension, T2DM, the metabolic syndrome, and hypercholesterolemia) and psychosocial health problems in children. Recently, high prevalence of overweight and obesity has been reported in children and adolescents in several developing countries, and these figures have been projected to increase further in coming years. Therapeutic lifestyle changes and maintenance of regular physical activity through parental initiative and social support interventions are the most important strategies to tackle childhood obesity. High prevalence of overweight and obesity in preschool children confirm the need for effective interventions starting as early as infancy to reverse anticipated trends. Finally, high-risk screening and effective health educational programs are urgently needed in developing countries.

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