TECHNICAL REPORT

American Academy of Pediatrics
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Appraisal of Clinical Care Practices for Child Obesity Treatment. Part II: Comorbidities

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The objective of this technical report is to provide clinicians with actionable evidence-based information upon which to make treatment decisions. In addition, this report will provide an evidence base on which to inform clinical practice guidelines for the management and treatment of overweight and obesity in children and adolescents.

To this end, the goal of this report was to identify all relevant studies to answer 2 overarching key questions: (KQ1) "What are effective clinically based treatments for obesity?" and (KQ2) "What is the risk of comorbidities among children with obesity?" See Appendix 1 for the conceptual framework and a priori Key Questions.

INTRODUCTION

Obesity is a common concern in pediatric practice. In caring for patients with obesity or patients who may be at risk for developing obesity, clinicians have many unanswered questions. Examples of these questions include: What is the best way to identify excess adiposity, and does the identification of obesity provide opportunities for treatment? If so, what evidence-based interventions for obesity treatment, delivered at least in part by clinicians in office-based settings, are most effective? Among children and adolescents identified as having obesity, does screening for comorbidities result in improved health outcomes?

Many previous studies, most notably conducted by the US Preventive Services Task Force, have synthesized research regarding the treatment of obesity.[1] Unfortunately, some important gaps remain unfilled. The US Preventive Services Task Force recommendation was that obesity treatment should include at least 26 hours of contact, including clinical care and other behavioral intervention (eg, guided physical activity).

abstract

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To cite: Skinner AC, Staiano AE, Armstrong SC, et al. AAP Appraisal of Clinical Care Practices for Child Obesity Treatment. Part II: Comorbidities. *Pediatrics*. 2023;151(2): e2022060643

However, subsequent studies have failed to demonstrate a consistent hours-based dose-response. In addition, feasibility studies have clearly shown how unrealistic it is for primary care or tertiary care providers to deliver this many hours of treatment in real-world, clinical settings.[2] Additional information is needed about resources or partnerships that help reach that contact hour goal, the essential components delivered during these contact hours, the period of time over which this care is delivered, and information about lower-intensity strategies with some effectiveness.

Of particular concern for primary care pediatricians is the need to understand how to approach recommendations for screening comorbidities in their patients with obesity. Although previous recommendations have supported screening for common comorbidities, such as dyslipidemia and diabetes, there has been conflicting evidence regarding timing and effectiveness of screening. Additional data are now available that provide clinicians and researchers with information about comorbidity prevalence and severity by obesity class. The intent is to help the clinician screen for comorbidities when there is a high likelihood of detecting an abnormality and when detection of that abnormality leads to treatment options that can improve child health. Obesity classifications, including a more granular categorization of obesity as classes I through III, might assist clinicians in determining for whom screening would be most useful rather than viewing screening as a homogeneous approach for anyone whose BMI is >95th percentile.

METHODS

Scope of the Review

This review was designed to answer 2 overarching key questions: (KQ1) "What are effective clinic-based treatments for obesity?" and (KQ2) "What is the risk of comorbidities among children with obesity?" We developed this focus based on the needs of clinicians and the evidence required to inform the future development of clinical practice guidelines. This review will not attempt to quantify the magnitude of the effect of obesity on child or adult outcomes. It will also not attempt to address treatment strategies for comorbidities (eg, hypertension), as other guidelines and reviews are available to guide such treatment.

Rationale for KQ1 (Intervention Studies)

Clinicians are a regular source of trusted information for parents, including issues related to nutrition and activity, which are key components of obesity prevention and treatment. Clinicians need to know what strategies have high-quality evidence for effectiveness in preventing and treating obesity. Additionally, physicians need guidance on which treatments are effective for their patient population and how to use available resources. The full results of KQ1 are reported in an accompanying technical report.[3]

Rationale for KQ2 (Comorbidity Studies)

Previous recommendations have included assessments of comorbidities, including hypertension, dyslipidemia, glucose, and others. It is not clear whether these assessments identify important health conditions or lead to improved treatment strategies. Additionally, it is not clear whether conducting these assessments would result in an adverse patient outcomes, such as further investigation for false-positive screening results. We will examine specific conditions previously recommended or that would reasonably require screening, as identified by the authors: dyslipidemia, hypertension, diabetes, liver function, depression, sleep apnea, and asthma. This is not intended to be a comprehensive list of all conditions comorbid with obesity but represents those most common and for which screening is potentially helpful.

Search Strategy

We searched Pubmed and CENTRAL (for trials), completing the final search on April 6, 2018. An additional search was conducted to update the review, covering the time period April 7, 2018, through February 15, 2020. We combined the searches for both key questions because of significant overlap and to more efficiently review studies. Because our focus was on interventions that are relevant to primary care, we did not search other databases, such as ERIC or PsycInfo.

The complete search strategies are included in Appendix 2. Briefly, we searched for studies of children or adolescents, with a focus on overweight, obesity, or weight status; involving clinicians, health care, or other treatment or screening (KQ1); and examining common comorbidities (KQ2). For both questions, we limited only using key words, not filters, to ensure we included the newest studies that were not yet fully indexed. No date limits were placed on searches. In practice, this meant we reviewed studies from 1950 to 2020, although <2% were published before 1980.

Inclusion Criteria

The complete inclusion criteria are included in Appendix 3.

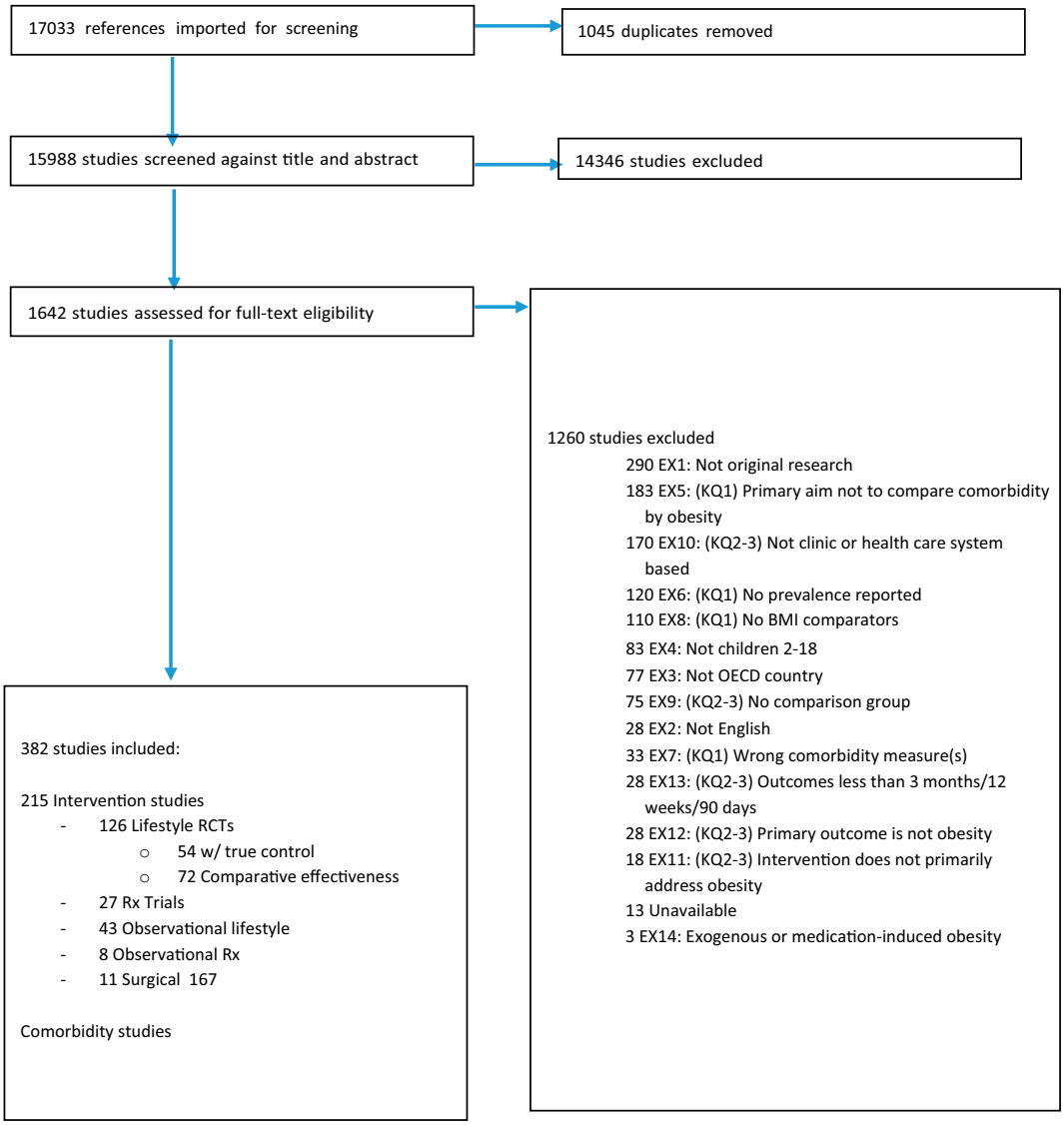

FIGURE 1
PRISMA Diagram.

Inclusion Criteria Common to All Studies

All studies were required to include children ages 2 to 18 years, although studies could also include young adults up to age 25 if stratified from older adult participants, as long as children under 18 were also included. Children could have other conditions (eg, asthma) as long as they were not known to cause obesity, such as Prader-Willi syndrome, obesogenic medication (eg, antipsychotics), or known genetic mutations (eg, MC4R) associated with obesity. All studies had to originate from the Organization for Economic Cooperation and Development member countries and had to be available in English.

Inclusion Criteria for KQ2 (Comorbidity Studies)

We included studies with a primary aim of comparing comorbidities among those with and without obesity or by severity of obesity. Obesity and the comorbidity had to be measured contemporaneously to reflect the practice of clinical screening. Obesity had to be categorized using a BMI-based measure into accepted categories (ie, healthy weight, overweight, class I obesity, class II obesity, class III obesity).

These categories could be based on percentiles or z-scores and could use the distributions relevant to the studied population (eg, World Health Organization [WHO] or the US Centers for Disease Control and Prevention [CDC]). Comorbidities

TABLE 1 Prevalence of Abnormal HDL (n = 39)

First Author	Country	Ages (y)	N	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	P	Weight Definitions	Population Info
Kim	Korea	10–19	931	<40 mg/dL		35.8	31.2	50.6	55.0			<.0001		
Halley Castillo	Mexico	7–24	1366	<45 mg/dL males; <50 mg/dL females			83%	90.8%				<.000		
Ice	USA	Mean 10.8	23263	<40 mg/dL		18.7	9.7	18.7	30.5		42.7	<.05		
Ice	USA	9–13	29286	<40 mg/dL			10.2	18.7	32.5			<.01		
Duncan	USA	12–19	991	<40 mg/dL			18.6	29.1	39.1					NHANES 1999–2000
Davis	USA	7–18	160	<50 mg/dL females, <40 mg/dL males			30	56	57			<.005		
Bell	Australia	6–13	283	<0.9 mmol/L			5.8	5.0	15.8			.203		
Bindler	USA	11–14	151	<35 mg/dL			13.6		29.3			.026		
NCHS	USA	12–19	3125	<35 mg/dL		7.6	4.3	8.3	20.5			<.05		1999–2006 NHANES
Turchiano	USA	14–18	1185	<40 mg/dL			13.2	23.8	38.9			<.001		Patients of urban minoritized groups
Skinner	USA	6–17	NR	<35 mg/dL		6.0	3.0	8.7	15.5			<.01		NHANES 2001–2002
Simsek	Turkey	Mean 10.8	115	<35 mg/dL			0		9			.089		
Salvatore	USA	3–18	101	<50 mg/dL				33.3	67.9	85.7	87.1	.123		
Propst	USA	Mean 12.7	1111	<45 mg/dL					17.9	20.7		.3169		
Perez	USA	12–18	101				24.5	52.1				<.004		
O'Hara	USA	3–19	382	<45 mg/dL		55		54	50	48	66	NS		Pediatric weight management program patients
Nguyen, D	USA	6–19	NR	<40 mg/dL		13.4%	6.8%	14.8%	33.2%			<.05		NHANES 2011–2014
Marcus	USA	Mean 11.2	1305	<40 mg/dL					27.2	38.9		<.0001		
Michalsky	USA	13–19	242	<30 mg/dL		16			17.7	15.6	12.5	.76	1: BMI 30–50, 2: BMI 50–60, 3: BMI >60	Bariatric surgery patients
Yoshinaga	Japan	6–12	471	<40 mg/dL	Male			5.4	6.1					
					Female			8.3	8.8					
Skinner	USA	3–19	8579	<35 mg/dL				6.13	11.40	18.18	19.53	<.001		NHANES 1999–2012
Maximova	Canada	6–19	2087	<25th	6–11 y		20.4	36.9				NR		
				<25th	12–19 y		20.6	41.4				NR		
Li	USA	3–19	20905	<40 mg/dL			8.86	18.23	25.78	39.97		<.05		
Park	Korea	10–19	1554	<35 mg/dL			21.2	26.9	41.2			<.05 OB		2007–2008 KNHANES
Laurson	USA	12–18.9	3385	Joliffe standards	Males		17.2	30.7	56.1			NR		NHANES
					Females		32.9	48.2	58.6			NR		
Park	Korea	12–19	664	<40 mg/dL			36.8	63.7	59.8					
Caserta	Italy	11–13	646	<40 mg/dL	Males		12.4	23.3	37.7			<.05		
				<40 mg/dL	Females		8.3	18.0	31.0			<.05		
Marcus	USA	Mean 11.8	6358	<35 mg/dL			1.1	4.3	8.8		16.4	<.001		
Kim	Korea	10–18	1412	<35 mg/dL	1998 KHANES		2.5	8.1	9.2			<.05		
			1158		2001 KHANES		4.9	8.7	14.4			<.05		
Botton	France	8–17	452	<0.9 mmol/L			0.5	13			<0.001			

TABLE 1 Continued

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Weight Definitions	Population Info
Serap	Turkey	6–16	284	NCEP values	Males		3.8		28.1			<.001		
					Females		6.5		44.3			<.001		Pediatric endocrinology patients
Pan	USA	12–19	4450	<35 mg/dL		8.5%	5.6	12.7	25.6			<.05 both		NHANES 1999–2002
Messiah	USA	8–14	1698	<40 mg/dL	8–11 y		11.04	31.81	36.21					

NR, not reported; NS, not significant; NHANES, National Health and Nutrition Examination Survey; KNHANES, Korean National Health and Nutrition Examination Survey.

had to include 1 or more of: lipids, blood pressure, liver function, glucose metabolism, obstructive sleep apnea, asthma, or depression.

See the other technical report for a detailed description of KQ1 inclusion criteria.[3]

Review Process

We used Covidence (Melbourne, Australia) to manage the review process. Covidence is a program for online collaboration and management of systematic reviews. All abstracts were reviewed by 2 independent reviewers for inclusion in full-text review. Articles were reviewed by 2 reviewers, with conflicts discussed and resolved. Articles excluded at this stage were assigned an exclusion reason, with a hierarchy as shown in Appendix 4.

Data Extraction and Quality Assessment

All articles deemed relevant for full text inclusion were categorized into different data extraction strategies. We did not include a specific quality assessment for the comorbidity studies.

KQ2 (Comorbidity Studies) Extraction

All studies were extracted by 2 reviewers. Extraction of these studies included reporting prevalence of comorbidities or mean values of laboratory parameters by weight classification. We included healthy weight, overweight, class I obesity, class II obesity, and class III obesity. However, because all classes of obesity severity are not always reported, these classes may include higher groups. For example, reporting of ≥95th percentile would only be considered class I obesity, although children at higher levels may be included. (See other technical report for detailed description of KQ1 extraction procedures.)

Data Synthesis and Analysis

Our primary method of data synthesis is narrative. To allow broad inclusion, we did not limit to specific designs or measures that would facilitate meta-analysis. We report on studies in each group, based on their type and design, and we report findings for outcomes other than BMI.

RESULTS

A total of 15 988 studies were screened in the title and abstract stage. Of these, 1642 were given a full-text review. Excluded studies (n = 1260) were most commonly not original research, did not compare comorbidities by obesity (KQ2), or were not health-care system based (KQ1). See Fig 1 for the complete PRISMA diagram. Of the 382 studies included, 215 were intervention studies and 167 were comorbidity studies. This paper focuses on the 167 comorbidity studies.

Lipids

HDL Cholesterol

A total of 39 studies examined the prevalence of abnormal high-density lipoprotein (HDL),[4–42] whereas 49 provided mean values for HDL.[5–8,10,13,18,22,24,32,33,35,36,40–74] Table 1 reports the prevalence of abnormal HDL. Different countries report significantly different prevalence of abnormal HDL, with Korea having the highest prevalence[18,30] and Japan the lowest.[42] The majority of the 39 reported studies reporting the prevalence of abnormal HDL were conducted in the United States (24 of 39). Abnormal HDL was defined variably as <35 mg/dL, <40 mg/dL, and <50 mg/dL or <1.0 mmol/L. The most consistent findings were seen when using the definition of <40 mg/dL and when larger sample sizes were included. There was consistency of an inverse dose-response relationship, with

TABLE 2 Mean HDL (n = 49)

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P* value	Notes	Weight Definitions	Population Info
Kollias	Greece	6–13	780	mg/dL			61.3	58.3	51.9			<.01			
Friedland	Israel	6–17	142	mg/dL			37.6	44.0	45.7			NS			89 OB were treatment-seeking
Davis	USA	7–18	211 (160 for lipids)	mg/dL			52	43	43			<.005			Rural Georgia
Bonet	Spain	Mean 10.7	101	mmol/L			1.7		1.3			<.05			Patients were all white
Bell	Australia	6–13	283	mmol/L			1.62	1.44	1.21			<.001			
Baer	USA	12–22	173	mg/dL		47.8	59.3	48.0	44.6			.01			Females with PCOS
Aylanc	Turkey	Mean 13.5	88	mg/dL			53.5		52.9			.870			
Bindler	USA	11–14	151	mg/dL			48.26		40.59			<.001			
Akinci	Turkey	6–17	41	mmol/L			1.49	1.35				.087		HW: 25th–75th	
Zabarsky	USA	7–20	2244	mg/dL				50	43	43	41	<.001	IV = 41	Includes class IV	
Valerio	Italy	3–16	150	mg/dL	Children		51.8		53.2			NS			
					Adolescents		50.9		46.9			NS			
Valentini	Italy	5–18	84	mg/dL			51.12	47.66				.047			Patients with Down syndrome
Watts	Australia	6–13	148	mmol/L			1.6	1.4	1.2			<.05		Assume CDC	
Turchiano	USA	14–18 y	1185	mg/dL			52.5	48.4	43.4			<.05			Patients of urban minoritized groups
Simsek	Turkey	Mean 10.8	115	mg/dL			52.5		47			<.001			
Salawi	Canada	6–19	345	mmol/L				1.1			1	<.001			Referred to pediatric weight management program
Puri	USA	10–18	198	mg/dL			66	48				<.001			General pediatrics and endocrinology patients
Propst	USA	Mean 12.7	1111	mg/dL					44.9	43.1		.0334			Endocrinology and pediatric weight management program patients
Rank	Germany	6–19	463	mg/dL	Males				55.1	44.2		<.001			
				mg/dL	Females				53.1	47.0		<.001			
Raman	USA	9–13	121	mg/dL				62.2	51.9			<.001			African American children

TABLE 2 Continued

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P* value	Notes	Weight Definitions	Population Info
Perichart-Perera	Mexico	9–12	88	mg/dL			29.64	27.13	29.06			NS			
Perez	USA (Puerto Rico)	12–18	101	mg/dL			49.0	39.0				<.001			
Nystrom	Spain	8–11	1247	mg/dL			62.3	56.9	51.4	47.4				Severe obesity >99.8th	
Nascimento	Portugal	5–18	181	mmol/L			1.25		1.09			<.001			148 obese patients, 33 controls
Olza	Spain	6–12	446	mg/dL	Males		66.96		53.78			<.001			
				mg/dL	Females		64.13		49.25			<.001			
Marcus	USA	Mean 11.2	1305	mg/dL					47.1	43.8		<.0001			
Yoshinaga	Japan	6–12	471	mg/dL	Males			56	54						
				mg/dL	Females			54	52						
Venegas	USA (Puerto Rico)	12–16	352	mg/dL		44.0	42.0	54.0				.4178			
Maximova	Canada	6–19	2087	mmol/L	6–11 y		1.4	1.3				NR			
					12–19 y		1.3	1.2				NR			
Manios	Turkey	12–13	510	mg/dL	Males		57.0	59.0				NS			
					Females		58.5	53.1				<.05			
Sur	Turkey	12–13	1044	mmol/L	Males		1.42	1.36				NS			
					Females		1.40	1.30				<.05			
Buchan	UK	5–12	223	mmol/L			1.50	1.35				.008			
Bocca	Netherlands	3–5	75	mmol/L		1.28		1.30	1.27			NS			
Bindler	USA	Mean 12.5	150	mg/dL			48.09		40.54			<.001			
Garces	Spain	6–8	1048	mg/dL	Males		60.1		52.5			<.001			
					Females		58.5		54.8			.05			
Cizmecioglu	Turkey	10–19	310	mg/dL			45	44	42			NS			
Norris	USA	Mean 13.5	225	mg/dL			49.5	42.7		39.8		<.0001			
Kim	Korea	10–18	1412	mg/dL	Males 1998 KNHANES		54.0	46.6	47.6			<.0001			
					Females 1998 KNHANES		54.7	48.6	46.2			<.0001			
			1158		Males 2001 KNHANES		46.5	45.5	42.2			.011			
					Females 2001 KNHANES		50.2	47.0	45.8			.003			
Botton	France	8–17	452	mmol/L	Males	1.55	1.58	1.29				<.01			
					Females	1.55	1.58	1.40				<.01			
Serap	Turkey	6–16	284	mg/dL	Males		51.6		40.4			<.05			Endocrinology patients
					Females		48.6		38.0			<.05			
Craig	UK	4–18	1944	mmol/L	4–10 y males		1.37	1.21				.005			
					4–10 y females		1.30	1.21				.085			
					11–18 y males		1.23	1.08				.001			
					11–18 y females		1.32	1.09				<.001			
Valery	Australia	5–17	158	mmol/L	No		1.23	1.18				.449			Indigenous youth
Avnieli Velfer	Israel	2–18	1027	mg/dL	Males				49	42		0.01		OB 95th, SO 120%/95th	Obesity clinic patients
					Females				45	45		.01		OB 95th, SO 120%/95th	Obesity clinic patients

TABLE 2 Continued

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P* value	Notes	Weight Definitions	Population Info
Hadjiyannakis	Canada	5–17	847	mmol/L		1.12			1.15	1.11	1.08	NR			Pediatric weight management program patients
Higgins	Canada	5–19	1332	mmol/L	Males		1.26	1.18	1.07			<.05		OW = 85th–97th %ile, OB > 97	Community
				See males	Females		1.30	1.27	1.15			NS		OW = 85th–97th %ile, OB > 97	Community
Kim	Korea	12–13	120	mg/dL			58.9	54.4				.047			School based
Kloppenberg	Denmark	Median 12	3978	mmol/L	Males		1.5	1.3	1.14			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
					Females		1.5	1.3	1.14			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
Seth	USA	Mean 13	767	mg/dL				44	38	38	38.5	.072			Steatohepatitis clinic patients
Sougawa	Japan	12–18	1679	mg/dL	Males	64.0	65.2	58.3				<.001			Schools
				mg/dL	Females	68.4	68.5	67.7				.709			Schools

HW, healthy weight; KNHANES, Korean National Health and Nutrition Examination Survey; NR, not reported; NS, not significant; OB, obese; OW, overweight; PCOS, polycystic ovary syndrome; SO, severe obesity.

increasing weight category associated with lower HDL. Few studies provided detailed information by obesity class, so less could be concluded when examining the prevalence of abnormal HDL within samples of increasing severity of obesity status. In general, overall prevalence of abnormal HDL increases from about 10% to 40% when children's weight category was healthy weight versus obesity. The prevalence varied by age, with younger ages associated with lower prevalence of abnormal HDL. For example, in a study of 9- to 13-year-olds, those who had healthy weight had a prevalence of abnormal HDL of 10.2%, whereas those with obesity had a prevalence of abnormal HDL of 32.5%.[15] In a study of 14- to 18-year-olds, those who had healthy weight had a prevalence of abnormal HDL of 13.2% and those with obesity had a prevalence of abnormal HDL of 38.9%.[40] When studies report larger age ranges, it is difficult to see these distinctions, and the mean prevalence might be obfuscating the differences in prevalence at the younger versus older ages. A few studies stratified their findings by biological sex. In 2 US-based studies, there appears to be a higher prevalence of abnormal HDL in female children of both healthy weight and overweight, but the prevalence is similar regardless of sex once children are categorized as obese.[12,20] Studies conducted in other countries also report differences by biological sex, but not always in the same direction or to the same degree.[9,19,35,42] Caution should be used in interpreting these results when small sample sizes were used.

Table 2 reports the mean HDL values. Mean HDL values corroborate the findings regarding the prevalence of abnormal HDL, highlighting that age, sex, and

TABLE 3 Prevalence of Abnormal LDL ($n = 26$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Weight Definitions	Population Info
Ice	USA	Mean 10.8	23263	>130 mg/dL		8.7	5.9	10.2	13.3		11.4	<.05, normal to others		
Ice	USA	9–13	29286	>130 mg/dL			6.3	10.9	13.2			<.01		Appalachian population school-aged children
Davis	USA	7–18	211 (160 for lipids)	>110 mg/dL			19	25	19			NS		
Bell	Australia	6–13	283	>2.9 mmol/L			35.1	41.3	42.1			.584		
Bindler	USA	11–14	151	>110 mg/dL			26.4		31.7			.515		
NCHS	USA	12–19	3125	>130 mg/dL		7.6	5.8	8.4	14.2			Obese <.05		1999–2006
Skinner	USA	6–17	NR	>130 mg/dL		8.7	7.7	10.9	11.4			<.05		NHANES 2001–2002
Simsek	Turkey	Mean 10.8	115	>130 mg/dL			0		10.7			.049		
Salvatore	USA	3–18	101	>110 mg/dL					55.6	44.4	23.3	.041	Class 1: >100% to 120%; class II/III: standard	Pediatric gastroenterology patients
O'Hara	USA	3–19	382	≥110 mg/dL		29		29	27	34	26	NS		Rural pediatric weight management program patients
Marcus	USA	Mean 11.2	1305	>130 mg/dL					6.6	6.3		.8243		
Michalsky	USA	Mean 17	242	>130 mg/dL					6.2	11.7	8.3	NS	1: BMI 30–50, 2: BMI 50–60, 3: BMI >60	Bariatric surgery patients
Skinner	USA	3–19	8579	≥130 mg/dL				8.16	12.08	11.63	10.46	.11		
Maximova	Canada	6–19	2087	>75th percentile	6-11 y		21.3	35.5				NR		
					12-19 y		22.7	30.9				NR		
Li	USA	3–19	20905	>130 mg/dL			6.08	8.66	11.15	12.96		<.05		
Park	Korea	10–19	1554	>130 mg/dL			5.0	6.1	15.3			<.05 obesity		
Caserta	Italy	11–13	646	>130 mg/dL	Males		3.4	7.8	17.0			<.05 obesity		
					Females		6.5	6.7	3.4			NS		
Marcus	USA	Mean 11.8	6358	>110 mg/dL			10.9	18.2	21.7		20.1	<.001		
Kim	Korea	10–18	1412	>130 mg/dL	1998 KNHANES		4.3	8.1	27.6			<.05		
			1158		2001 KNHANES		6.5	11.5	15.8			<.05		
Botton	France	8–17	452	>3.4 mmol/L	Yes		5.9	5.1			1.0			
Serap	Turkey	6–16	284	NCEP values	Males		0		3.4			<.001		Pediatric endocrinology patients
					Females		4.3		4.1			<.001		
Lambert	Canada	9–16	3613	>2.6 mmol/L	Males		18.0	28.3	37.8			<.0001		
					Females		31.2	42.9	40.5			.014		
Valery	Australia	5–17	158	>3.4 mmol/L	No		15	16				.891		Indigenous youth
Avnieli Velfer	Israel	2–18	1027	>95th percentile	Males							NS	OB 95th, SO 120%/95th	Obesity clinic patients
					Females							NS	OB 95th, SO 120%/95th	Obesity clinic patients

TABLE 3 Continued

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Weight Definitions	Population Info
Gunes	USA	11–18	363	>130 mg/dL	Males			96.5	86.4			.135		Adolescent clinic patients
					Females			86.4	89			.612		Adolescent clinic patients
Hadjiyannakis	Canada	5–17	847	>3.4 mmol/L		10			11	11	7	NR		Pediatric weight management program patients

NR, not reported; NS, not significant; OB, obese; SO, severe obesity.

country affect the findings of mean HDL values. Also apparent is the importance of sample size to lead to a stable mean value. Several of these studies reported mean values for large age ranges. In almost all of these studies, mean HDL decreases as weight category increases, validating the association between the 2.

LDL Cholesterol

A total of 26 studies examined the prevalence of abnormal low-density lipoprotein (LDL),[4–10,12,13,15,16,18,19,21–24,26,28,31,34–38,41] whereas 41 provided mean values for LDL.[5–8,10,13,18,22,24,33,35,36,40,41,43–46,50–52,54–67,69,70,72–75] Table 3 reports the prevalence of abnormal LDL. Approximately half ($n = 13$) of the studies evaluated children 9 years or older, a time point associated with physiologic increases in LDL cholesterol.[76] The remaining studies included children as young as 3 and up to 19 years of age. Sample size varied from 101 to 29 286; 13 of 23 studies reported sample sizes of 1000 or greater. One challenge in interpreting these data are the variation in definition of and reported units for abnormal LDL. Authors defined abnormal LDL as >110 mg/dL or >2.6 mmol/L through >130 mg/dL or >3.4 mmol/L. In 1 instance, authors used >75th percentile of National Cholesterol Education Program (NCEP) standards.[24] In nearly all the studies, abnormal LDL was more prevalent in children with increasing BMI, and when comparing healthy weight with obesity, this difference consistently achieved statistical significance. The majority of studies did not include a significant number of children in each obesity classification; therefore, it is difficult to conclude whether abnormal LDL is more common by obesity classification. Among the 3 studies that reported male and female LDL separately, there was not a significant difference at any weight classification.[5,9,12,19,35] Similarly to the LDL prevalence studies, the most evidence for mean LDL in populations includes children of school age and older (Table 4). Only 1 of the identified studies exclusively included children younger than 5 years[46]; therefore, it is difficult to draw conclusions in this younger age group. Sample size of the reported studies ranged from 41 to 2244. Several, but not all, studies reported male and female LDL levels separately. Mean LDL was reported in some cases in mg/dL and in other cases as mmol/L. Across all studies, mean LDL tended to increase with increasing BMI; however, only the difference between healthy weight and obese consistently achieved statistical significance. In 1 Korean study that evaluated mean LDL in 1998 and again in 2001, secular increases in mean LDL were also observed.[17] Although in some cases, females have higher mean LDL than males at matched age and BMI, this difference was inconsistent and did not achieve statistical significance. However, the difference between mean LDL when comparing healthy weight and obesity was more pronounced in males than females. It is interesting to note that in all studies, even in the highest BMI subcategories, mean LDL values did not exceed commonly accepted definitions for normal.

Triglycerides

A total of 38 studies examined the prevalence of abnormal triglycerides (TG),[4–26,28–32,34–42] whereas 48 provided mean values for TG.[5–8,10,13,18,22,24,32,35,36,40–60,62–75,77] Table 5 reports the prevalence of abnormal TG. About half of the 38 reported studies were conducted in the United States (20 of 38). Country comparisons are not possible given the variety of cutoff values employed. However, there is

TABLE 4 Mean LDL ($n = 41$)

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Kollias	Greece	6–13	780	mg/dL			90.6	93.4	95.6			NS			
Friedland	Israel	6–17	142	mg/dL			90.2	103.3	104.6			<.05			
Davis	USA	7–18	211 (160 for lipids)	mg/dL			87	91	93			NS			Rural Georgia
Bell	Australia	6–13	283	mmol/L			2.56	2.48	2.84			.065			
Baer	USA	12–22	173	mg/dL		102	92.9	101.1	104.9			.59			Females with PCOS
Aylanc	Turkey	Mean 13.5	88	mg/dL			69.51		109.4			<.001			
Bindler	USA	11–14	151	mg/dL			96.65		96.44			.961			
Akinci	Turkey	6–17	41	mmol/L			2.09	2.19				.322		HW: 25th–75th	
Zabarsky	USA	7–20	2244	mg/dL				90	92	94	95	.86	IV = 90	Includes class IV	
Valentini	Italy	5–18	84	mg/dL			96.25	110.77				.013			Patients with Down syndrome
Watts	Australia	6–13	148	mmol/L			2.5	2.6	2.7			NS			
Turchiano	USA	14–18	1185	mg/dL			85.4	92.0	98.0			<.05			Patients of urban minoritized groups
Simsek	Turkey	Mean 10.8	115	mg/dL			66.3		92			<.001			
Salawi	Canada	6–19	345	mmol/L				2.7			2.6	.1			Pediatric weight management program patients
Puri	USA	10–18	198	mg/dL			80	94				NS			Minority youth
Propst	USA	Mean 12.7	1111	mg/dL					103.2		102.1	.6520		SO > 99th	Endocrinology and pediatric weight management program patients
Rank	Germany	6–19	463	mg/dL	Males				98.8	110.0		.026			
					Females				97.6	102.6		.229			
Raman	USA	9–13	121	mg/dL				100.1	97.9			.732			African American children
Perichart-Perera	Mexico	9–12	88	mg/dL			114.04	101.88	112.21			NS			
Nystrom	Spain	8–11	1247	mg/dL			94.7	100.8	101.8		101.8			SO > 99.8th	
Nascimento	Portugal	5–18	181	mmol/L			2.31		2.63			.001			
Olza	Spain	6–12	446	mg/dL	Males		93.82		94.58			.835			
					Females		94.44		98.07			.282			
Marcus	USA	Mean 11.2	1305	mg/dL					91.7	92.5		.5745			
Venegas	USA (Puerto Rico)	12–16	352	mg/dL		73.5	65.0	75.5				.3367			
Maximova	Canada	6–19	2087	mmol/L	6–11 y		2.2	2.6				NR			
					12–19 y		2.2	2.5				NR			

TABLE 4 Continued

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Manios	Turkey	12–13	510	mg/dL	Males		77.6	95.3				<.01			
					Females		87.1	88.4				NS			
Sur	Turkey	12–13	1044	mmol/L	Males		2.39	2.71				<.001			
					Females		2.57	2.64				NS			
Bocca	Netherlands	3–5	75	mmol/L	No	2.48		2.41	2.52			NS			
Bindler	US	Mean 12.5	150	mg/dL			96.91		96.64			.95			
Garces	Spain	6–8	1048	mg/dL	Males		108.8		112.5			.42			
					Females		111.5		104.3			.07			
Norris	USA	Mean 13.5	225	mg/dL			78.9	87.2		99.0		<.001			
Kim	Korea	10–18	1412	mg/dL	1998 Males		84.6	94.2	105.5			<.0001			
					1998 Females		93.0	98.0	103.2			.026			
			1158		2001 Males		91.1	100.4	101.0			.001			
					2001 Females		97.1	104.6	107.5			.004			
Botton	France	8–17	452	mmol/L	Males	2.16	2.14	2.36				NS			
					Females	2.36	2.34	2.51				NS			
Serap	Turkey	6–16	284	mg/dL	Males		79.4		101.1			<.001			Endocrinology patients
					Females		78.6		99.4			<.001			
Craig	UK	4–18	1944	mmol/L	4–10 y males		2.81	3.07				.059			
					4–10 y females		3.02	3.15				0.440			
					11–18 y males		2.70	2.81				.308			
					11–18 y females		2.83	2.97				.148			
Valery	Australia	5–17	158	mmol/L			2.77	2.87				.341			Indigenous youth
Avnieli Velfer	Israel	2–18	1027	mg/dL	Males				100	100		.26		OB 95th, SO 120%/95th	Obesity clinic patients
				mg/dL	Females				96	102		.18		OB 95th, SO 120%/95th	Obesity clinic patients
Hadjiyannakis	Canada	5–17	847	mmol/L		2.42			2.41	2.42	2.44	NR			Pediatric weight management program patients
Kim	Korea	12–13	120	mg/dL			80.6	92.6				.009			School based
Kloppenberg	Denmark	Median 12	3978	mmol/L	Males		1.9	2.15	2.26			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
					Females		2.0	2.2	2.3			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
Seth	USA	Mean 13	767	mg/dL				151	195.5	207	178	.78			Steatohepatitis clinic patients

HW, healthy weight; KNHANES, Korean National Health and Nutrition Examination Survey; NR, not reported; NS, not significant; OB, obese; OW, overweight; PCOS, polycystic ovary syndrome; SO, severe obesity.

TABLE 5 Prevalence of Abnormal Triglycerides ($n = 38$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Weight definitions	Population Info
Kim	Korea	10–19	931	>110 mg/dL		22.1	17.1	33.7	46.1			<.0001		
Halley Castillo	Mexico	7–24	1366	>100 mg/dL			33%	64.1%				<.000		
Ice	USA	Mean 10.8	23263	>150 mg/dL		12.2	4.4	12.4	25.0		31.3	<.05		
Ice	USA	9–13	29286	>110 mg/dL			14.2	29.8	49.1			<.01		Appalachian population school-aged children
Duncan	USA	12–19	991	>110 mg/dL			17.1	27.8	45.5					NHANES 1999–2000
Davis	USA	7–18	211 (160 for lipids)	>150 mg/dL			11	9	18			NS		Rural Georgia
Bell	Australia	6–13	283	>1.6 mmol/L			9.9	11.3	26.3			.104		
Bindler	USA	11–14	151	>150 mg/dL			6.4		14.6			.107		
NCHS	USA	12–19	3125	>150 mg/dL		10.2	5.9	13.8	24.1			<.05		1999–2006
Turchiano	USA	14–18	1185	>110 mg/dL			6.7	13.2	23.3			<.001		Patients of urban minoritized groups
Skinner	USA	6–17	NR	>200 mg/dL		3.5	2.1	6.1	6.7			<.05		NHANES 2001–2002
Simsek	Turkey	Mean 10.8	115	>150 mg/dL			2.5		61.3			<.001		
Salvatore	USA	3–18	101	>130 mg/dL					22.2	42.9	38.7	.236	Class 1: >100% to 120%; class II/III: standard	Pediatric gastroenterology patients
Perez	USA (Puerto Rico)	12–18	101	≥100 mg/dL			18.9	41.7				.012		
O'Hara	USA	3–19	382	>75 mg/dL 0–9 y; >90 mg/dL 10–19 y		72		63	55	74	76	NS		Rural pediatric weight management program patients
Marcus	USA	Mean 11.2	1305	>130 mg/dL					26.6	34.3		.0037		
Michalsky	USA	13–19	242	≥130 mg/dL		40.3			41.6	40.3	37.5	.90	1: BMI 30–50, 2: BMI 50–60, 3: BMI >60	Bariatric surgery patients
Yoshinaga	Japan	6–12	471	>120 mg/dL	Males			20.5	33.5					
					Females			26.7	40.2					
Skinner	USA	3–19	8579	≥150 mg/dL	No			12.16	20.35	18.81	28.82	<.001		NHANES 1999–2012
Maximova	Canada	6–19	2087	>75th percentile	6–11 y		20.3	39.7				NR		
					12–19 y		20.6	31.7				NR		
Li	USA	6–19	20905	≥130 mg/dL		13.67	9.71	16.36	25.25	29.77		<.05		
Park	Korea	10–19	1554	>150 mg/dL			6.0	21.2	30.5			<.05		2007–2008 KNHANES
Laurson	USA	12–18.9	3385	Joliffe standards	Males		7.6	17.9	31.4			NR		NHANES
					Females		8.4	10.7	18.3			NR		
Park	Korea	12–19	664	≥150 mg/dL			4.8	11.6	24.3					Only reporting Korea, US is NHANES
Caserta	Italy	11–13	646	>150 mg/dL	Males		1.4	7.8	5.66			<.05 OW		
					Females		1.2	5.6	13.8			<.05		

TABLE 5 Continued

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Weight definitions	Population Info
Marcus	USA	Mean 11.8	6358	>110 mg/dL			11.5	25.4	40.7		44.3	<.001		
Kim	Korea	10–18	1412	>130 mg/dL	1998 KNHANES		10.4	23.1	38.2			<.05		
			1158		2001 KNHANES		15.6	29.8	35.1			<.05		
Botton	France	8–17	452	>1.5 mmol/L			3.7	10			0.08			
Serap	Turkey	6–16	284	NCEP values	Males		1.9		27			<.001		Pediatric endocrinology patients
					Females		8.6		24.7			<.001		
Del- Rio-Navarro	Mexico	6–13	1819	>150 mg/dL	Males		7.2	12.0	18.5			<.05 OB		
					Females		9.6	22.6	22.2			<.05		
Pan	USA	12–19	4450	>110 mg/dL	No	22.20%	19.2	24.7	48.9			<.05 OB		NHANES 1999–2002
Messiah	USA	8–14	1698	>110 mg/dL	No		12–14: 17.50	12–14: 15.47	12-14: 52.40					
Lambert	Canada	9–16	3613	>1.7 mmol/L	Males		1.0	11.7	17.5			<.0001		
					Females		3.7	10.4	11.8			.002		
Valery	Australia	5–17	158	NR	No		7	20				.134		Indigenous youth
Avnieli Velfer	Israel	2–18	1027	>95th percentile	Males				45	58.5		.001	OB 95th, SO 120%/95th	Obesity clinic patients
					Females							NS	OB 95th, SO 120%/95th	Obesity clinic patients
Gunes	USA	11–18	363	>130 mg/dL	Males			58.6	70.4			.223		Adolescent clinic patients
					Females			72.4	79.8			.247		Adolescent clinic patients
Hadjiyannakis	Canada	5–17	847	>1.5 mmol/L		36			30	40	39	NR		Pediatric weight management program patients
Stolzman	USA	12–17	62	>125 mg/dL			10		7			NS		Community recruitment

KNHANES, Korean National Health and Nutrition Examination Survey; NR, not reported; NS, not significant; OB, obese; OW, overweight; SO, severe obesity.

consistency of a dose-response relationship with increasing weight category associated with higher TG prevalence in most settings studied. Few studies provide detailed information broken down by obesity class, so less can be concluded when examining the prevalence of abnormal TG and increasing severity of obesity status. When studies report larger age ranges, it is difficult to see these distinctions, and the mean prevalence might be masking any potential differences in prevalence at the younger versus older ages. A few studies stratified their findings by gender, but the pattern of high TG prevalence was not always in the same direction or to the same degree. Caution should be used in interpreting these results when small sample sizes were used.

Table 6 reports the mean TG values. The sample sizes of the studies presented vary from 41 to 3978. In almost all of these studies, mean TG value increases as weight category increases, validating the association between the 2. In the majority of studies, the mean TG value is <130 mg/dL.

Total Cholesterol

A total of 23 studies examined the prevalence of abnormal total cholesterol,[6–10,12,13,15,16,18,19,21–24,27,28,34–38,78] whereas 42 provided mean values for total cholesterol.[5–8,10,13,18,22,24,32,33,35,36,43–47,49–55,57–59,61–66,69–75,79] In large (>20 000) population based studies, the prevalence of abnormal cholesterol (>200 mg/dL) in children of normal weight ranged from 7.5% to 8.3%, in children with overweight ranged from 10.0% to 12.7%, and in children with obesity ranged from 14.5% to 16.9% (Table 7).[15,16,21] There was a significant difference in prevalence of elevated cholesterol between children of normal weight and children with overweight and

TABLE 6 Mean Triglycerides ($n = 48$)

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight definitions	Population Info
Kollias	Greece	6–13	780	mg/dL			71.7	80.9	93.8			<.01			
Friedland	Israel	6–17	142	mg/dL			94.3	89.6	127.2			<.05			
Davis	USA	7–18	211 (160 for lipids)	mg/dL			88	89	111			NS			Rural Georgia
Bonet	Spain	Mean 10.7	101	mM			0.4		0.8			<.001			
Bell	Australia	6–13	283	mmol/L			0.80	0.91	1.25			<.001			
Baer	USA	12–22	173	mg/dL		120.3	94.6	143.0	121.7			.22			Females with PCOS
Aylanc	Turkey	Mean 13.5	88	mg/dL			67.1		119			<.001			
Bindler	USA	11–14	151	mg/dL			87.14		111.54			.002			
Akinci	Turkey	6–17	41	mmol/L			0.72	0.82				.411		HW: 25th–75th	
Zabarsky	USA	7–20	2244	mg/dL				96	117	113	114	.007	IV = 102	Includes class IV	
Valerio	Italy	3–16	150	mg/dL	Children		59.7		80.6			.005			
					Adolescents		58.5		80.4			0.015			
Valentini	Italy	5–18	84	mg/dL			71.05	97.16				.014			Patients with Down syndrome
Watts	Australia	6–13	148	mmol/L			0.8	0.9	1.1			<.05			
Turchiano	USA	14–18	1185	mg/dL			66.2	73.4	90.6			<.05	HW versus OB		Patients of urban minoritized groups
Simsek	Turkey	Mean 10.8	115	mg/dL			78.5		160			< .001			
Salawi	Canada	6–19	345	mmol/L				1.4			1.5	.2			Patients referred to pediatric weight management program
Puri	USA	10–18	198	mg/dL			78	113				<.001			Youth of minoritized groups
Rank	Germany	6–19	463	mg/dL	Males				53.7	70.9		<.001			
					Females				59.8	77.0		<.001			
Raman	USA	9–13	121	mg/dL				59.5	75.1			.018			African American children
Perichart-Perera	Mexico	9–12	88	mg/dL			106.12	156.22	181.25			.002	HW versus OB		
Perez	USA (Puerto Rico)	12–18	101	mg/dL			83.0	94.0				.022			
Nystrom	Spain	8–11	1247	mg/dL			60.5	74.6	92.2	111.7				SO > 99.8th	
Nascimento	Portugal	5–18	181	mmol/L			0.72		0.86			.017			
Marcus	USA	Mean 11.2	1305	mg/dL					108.8	125.9		<.0001			
Yoshinaga	Japan	6–12	471	mg/dL	Males			93	116						
					Females			100	116						
Venegas	USA (Puerto Rico)	12–16	352	mg/dL		58.0	57.0	58.0				.6971			

TABLE 6 Continued

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight definitions	Population Info
Maximova	Canada	6–19	2087	mmol/L	6–11 y		0.7	1.0				NR			
					12–19 y		0.9	1.1				NR			
Manios	Turkey	12–13	510	mg/dL	Males		82.1	126.6				<.001			
					Females		93.4	109.7							
Sur	Turkey	12–13	1044	mmol/L	Males		0.93	1.31				<.001			
					Females		1.07	1.24				<.05			
Buchan	UK	5–12	223	mmol/L			0.75	0.87				.032			
Bocca	Netherlands	3–5	75	mmol/L		0.78		0.70	0.83			NS			
Bindler	USA	Mean 12.5	150	mg/dL			87.24		112.18			.002			
Garces	Spain	6–8	1048	mg/dL	Males		69.9		88.8			<.001			
					Females		75.1		83.5			.03			
Cizmecioglu	Turkey	10–19	310	mg/dL			69	84	104			<.001			
Norris	USA	Mean 13.5	225	mg/dL			72.0	94.1		121.9		<.0001			
Kim	Korea	10–18	1412	mg/dL	1998 Males		77.7	100.4	117.8			<.0001			
					1998 Females		88.6	100.0	114.2			<.0001			
			1158		2001 Males		89.7	125.4	138.5			<.0001			
					2001 Females		91.4	106.7	129.3			<.0001			
Botton	France	8–17	452	mmol/L	Males	0.662	0.64	0.93				<0.001			
					Females	0.735	0.72	0.83				NS			
Serap	Turkey	6–16	284	mg/dL	Males		73.1		101.8			<.05			Endocrinology patients
					Females		73.9		99.8			<.001			
Craig	UK	4–18	1944	mmol/L	4–10 y males		0.72	0.98				<.001			
					4–10 y females		0.86	1.03				.072			
					11–18 y males		0.96	1.28				.035			
					11–18 y females		0.96	1.21				.033			
Del- Rio-Navarro	Mexico	6–13	1819	mg/dL	Males		84.9	94.6	108.7			<.05			
					Females		88.7	106.8	108.9			<.05			
Valery	Australia	5–17	158	mmol/L			Median = 0.80	Median = 0.90				.070			Indigenous youth
Avnieli Velfer	Israel	2–18	1027	mg/dL	Males				120	120		.93		OB 95th, SO 120%/ 95th	Obesity clinic patients
					Females				126	126		.01		OB 95th, SO 120%/ 95th	Obesity clinic patients
Hadjiyannakis	Canada	5–17	847	mmol/L		1.24			1.15	1.32	1.31	NR			Pediatric weight management
Higgins	Canada	5–19	1332	mmol/L	Males		1.23	1.39	1.74			<.05		OW = 85th–97th %ile, OB >97	Community
					Females		1.23	0.45	1.56			<.05		OW = 85th–97th %ile, OB > 97	Community
Kim	Korea	12–13	120	mg/dL			68.5	94.0				.008			School based

TABLE 6 Continued

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight definitions	Population Info
Kloppenberg	Denmark	Median 12	3978	mmol/L	Males		0.5	2.2	0.89			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
					Females		0.6	0.8	1.01			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
Seth	USA	Mean 13	767	mg/dL				102	133	135	127	.072			Steatohepatitis clinic patients
Sougawa	Japan	12–18	1679	mg/dL	Males	60.0	55.3	81.4				<.001			Schools
					Females	59.1	58.8	62.5				.236			Schools

HW, healthy weight; NR, not reported; NS, not significant; OB, obese; OW, overweight; PCOS, polycystic ovary syndrome; SO, severe obesity.

obesity. In 6 medium-sized studies of children (n = 2000–9000), 2 studies did not provide statistical testing. In the remaining 4 studies, 2 studies used >200 mg/dL as a cutoff for abnormal cholesterol, and 2 studies used >170 mg/dL and >4.4 mmol/L. One study showed a significant difference in the prevalence of elevated cholesterol among children of normal weight and children with obesity; a second study was significant only for males. One study did not report results for normal weight children. The range of prevalence of elevated total cholesterol for children with healthy weight was 16.9% to 31%, for children who were overweight was 10.0% to 34.5%, and for children with obesity was 14.3% to 35.5%. There were 16 studies of children including 100 to 1412 children. Three studies did not provide statistical testing. Of the remaining 13 studies, 6 used 200 mg/dL as a cutoff for abnormal values, 4 used 170 mg/dL, and 2 used NCEP guidelines. Five studies did not include children with healthy weight. In the 7 studies remaining, 4 showed significant differences in total cholesterol between children with healthy weight and children with obesity.

Of the 42 studies reporting mean cholesterol levels, 3 studies did not report statistical testing (Table 8). Of the remaining 39 studies, 13 reported significant differences between mean cholesterol levels in children with healthy weight and children with obesity. One study reported significant differences in males but not females, 1 study reported significant differences in females but not males, and a third reported differences in both sexes.

Dyslipidemia

An additional 6 studies examined the prevalence of dyslipidemia.[13,26,80–83] Table 9 reports the prevalence

TABLE 7 Prevalence of Abnormal Total Cholesterol ($n = 23$)

First Author	Country	Ages (y)	N	Definition of Abnormal	Subgroup	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Weight Definitions	Population Info
Ice	USA	Mean 10.8	23263	>200 mg/dL		10.7	7.5	11.5	16.3		15.0	<.05	99% SO	
Ice	USA	9–13 (5th grade)	29286	>200 mg/dL			8.3	12.7	16.9			<.01		Appalachian population school-aged children
Davis	USA	7–18	211 (160 for lipids)	>170 mg/dL			23	21	34			NR		Rural Georgia
Bell	Australia	6–13	283	>4.5 mmol/L			57.9	58.8	63.2			.906		
Bindler	USA	11–14	151	>170 mg/dL			34.5		34.1			.963		
Skinner	USA	6–17	NR	>200 mg/dL		9.4	7.2	12.4	15.7			<.01		NHANES 2001–2002
Simsek	Turkey	Mean 11	115	>200 mg/dL			0		24			<.001		
Salvatore	USA	3–18	101	>170 mg/dL				66.7	67.9	48.1	29.0	.012	Class 1: >100% to 120%	Pediatric gastroenterology patients
O'Hara	USA	3–19	382	≥170 mg/dL		25		40	42	47	37	NR		Referred to PWMP
Nguyen, D	USA	6–19	NR	≥200 mg/dL		7.4%	6.3%	6.9%	11.6%			<.05		NHANES 2011–2014
Marcus	USA	Mean 11.2	1305	>200 mg/dL					9.5	8.5		.5535		
Skinner	USA	3–19	8579	≥200 mg/dL				10.02	14.27	16.19	18.59	<.001		NHANES 1999–2012
Maximova	Canada	6–19	2087	>75th %ile	6–11 y		27.9	35.5				NR		
					12–19 y		20.4	29.2				NR		
Li	USA	6–19	20905	≥200 mg/dL		9.38	7.62	10.02	14.47	16.53		<.05		
Caserta	Italy	11–13	646	>200 mg/dL	Males		4.8	8.9	9.4			NR		
					Females		5.3	5.6	6.9			NR		
Marcus	USA	Mean 11.8	6358	>170 mg/dL			26	31.4	35.5		34.1	<.001	SO > 99th	
Kim	Korea	10–18	1412	>200 mg/dL	1998 KNHANES		7.1	11.3	23.7			<.05		1998 KNHANES, 2001 reported separately
			1158		2001 KNHANES		7.3	14.4	18.6			<.05		2001 KNHANES
Botton	France	8–17	452	>5.2 mmol/L			10	13			0.58	NR	OW > 90th	
Serap	Turkey	6–16	284	NCE values	Males		1.9		15.7			<.001		Pediatric endocrinology patients
					Females		6.5		7.2			<.001		
Lambert	Canada	9–16	3613	>4.4 mmol/L	Males		16.9	29.4	31.8			<.0001		
					Females		31.0	34.5	30.8			.715		
Hadjiyannakis	Canada	5–17	847	>5.2 mmol/L		11			14	14	5	NR		Pediatric weight management program patients
Fyfe-Johnson	USA	8–17	300	>170 mg/dL		35	26	41		41				Clinic patients
Gunes	USA	11–18	363	>200 mg/dL	Males			84	100			.023		Adolescent clinic patients
					Females			81.3	88.4			.180		Adolescent clinic patients

KNHANES, Korean National Health and Nutrition Examination Survey; NR, not reported; NS, not significant; OW, overweight; PWMP, pediatric weight management program; SO, severe obesity.

TABLE 8 Mean Total Cholesterol ($n = 42$)

First Author	Country	Ages (y)	*N*	Units	Subgroup	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Friedland	Israel	6–17	142	mg/dL			143.3	164.1	177.6			<.05			
Davis	USA	7–18	211 (160 for lipids)	mg/dL			155	153	159			NS			Rural Georgia
Bonet	Spain	Mean 10.7	101	mM			4.1		4.2			NS			Patients were all white
Bell	Australia	6–13	283	mmol/L			4.55	4.62	4.64			.795			
Baer	USA	12–22	173	mg/dL		167.7	160.2	169.9	169.6			.63			Females with PCOS
Aylanc	Turkey	Mean 13.5	88	mg/dL			137.6		171.3			<.001			
Bindler	USA	11–14	151	mg/dL			162.25		159.39			.569			
Akinci	Turkey	6–17	41	mmol/L			3.94	4.03				.548		HW: 25th–75th	
Zabarsky	USA	7–20	2244	mg/dL				160	158	159	159	.007	IV = 151		
Valerio	Italy	3–16	150	mg/dL	Children		152.4		165.1			NS			
					Adolescents		155.6		163.3			NS			
Valentini	Italy	5–18	84	mg/dL			151.20	163.45				.046			Patients with Down syndrome
Watts	Australia	6–13	148	mmol/L			4.4	4.5	4.4			NS			
Simsek	Turkey	10.8 SD: 2.03	115	mg/dL			101		175			<.001		OB > 97th	
Salawi	Canada	6–19 y	345	mmol/L				4.3			4.5	.2		SO > 99th	Referred to pediatric weight management program patients
Puri	USA	10–18	198	mg/dL			161	165				NS			Youth of minoritized groups
Propst	USA	Mean 12.7	1111	mg/dL					173.8	168.9		.2631		SO > 99th	Pediatric endocrinology patients
Rank	Germany	6–19	463	mg/dL	Males				154.7	161.7		.147			
					Females				153.9	155.5		.679			
Raman	USA	9–13	121	mg/dL				177.7	165.9			.111			African American children
Perichart-Perera	Mexico	9–12	88	mg/dL			164.00	160.26	177.53			NS			
Perez	USA (Puerto Rico)	12–18	101	mg/dL			140.0	153.5				.011			
Nascimento	Portugal	5–18	181	mmol/L			4.29		4.11			.241			
Olza	Spain	6–12	446	mg/dL	Males		173.87		163.69			.018			
					Females		171.02		164.87			.094			
Marcus	USA	Mean 11.2	1305	mg/dL					160.5	161.2		.6190			
McCarthy	USA	11–14	199	mg/dL			163.38	176.17	188.57			<.05 OB versus HW			Children of minoritized groups
Venegas	USA (Puerto Rico)	12–16	352	mg/dL		137.0	122.0	143.0				.0516			
Maximova	Canada	6–19	2087	mmol/L	6–11 y		4.2	4.4				NR			
					12–19 y		4.0	4.2				NR			
Manios	Turkey	12–13	510	mg/dL	Males		150.7	179.2				<.001			
				mg/dL	Females		164.8	163.6							
Sur	Turkey	12–13	1044												
Bocca	The Netherlands	3–5	75	mmol/L				3.79	3.89			NS			
Bindler	USA	Mean 12.5	150	mg/dL			162.44		159.67			.59			
Garces	Spain	6–8	1048	mg/dL	Males		182.9		182.5			.92			
					Females		184.7		175.8			.03			
Cizmecioglu	USA	10–19	310	mg/dL			147	153	166			.007			
Norris	USA	Mean 13.5	225	mg/dL			142.0	148.7		163.2		<.0001			
Kim	Korea	10–18	1412	mg/dL	1998 Males		154.1	160.9	176.6			<.0001			
					1998 Females		165.3	166.4	172.2			0.381			
			1158		2001 Males		155.4	171.0	169.7			<.0001			
					2001 Females		165.6	172.9	179.1			.002			

TABLE 8 Continued

First Author	Country	Ages (y)	*N*	Units	Subgroup	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Botton	France	8–17	452	mmol/L	Males	4.05	4.04	4.14				NS			
					Females	4.30	4.29	4.32				NS			
Serap	Turkey	6–16	284	mg/dL	Males		129.8		161.3			<0.05			Pediatric endocrinology patients
					Females		132.1		162.1			<.05			
Craig	UK	4–18	1944	mmol/L	4–10 y males		4.18	4.29				.477			
					4–10 y females		4.33	4.36				.826			
					11–18 y males		3.94	3.89				.945			
					11–18 y females		4.15	4.06				.458			
Avnieli Velfer	Israel	2–18	1027	mg/dL	Males				168	156		.16		OB 95th, SO 120%/95th	Obesity clinic patients
					Females				156	156		.8		OB 95th, SO 120%/95th	Obesity clinic patients
Hadjiyannakis	Canada	5–17	847	mmol/L		4.20			4.20	4.20	4.14	NR			Pediatric weight management program patients
Higgins	Canada	5–19	1332	mmol/L	Males		3.66	3.55	3.76			NS		OW = 85th–97th %ile, OB >97th	Community
					Females		3.83	4.03	3.78			NS		OW = 85th–97th %ile, OB >97th	Community
Kim	Korea	12–13	120	mg/dL			156.5	170.0				.014			School based
Kloppenberg	Denmark	Median 12	3978	mmol/L	Males		3.7	3.9	3.94			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
					Females		3.9	3.9	3.94			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based

HW, healthy weight; NR, not reported; NS, not significant; OB, obese; OW, overweight; PCOS, polycystic ovary syndrome; SO, severe obesity.

of dyslipidemia ($n = 6$). The likely reason for the low number of studies in this category is the high variance in how dyslipidemia is defined. In 2 of these studies, similar criteria were listed: low HDL, high LDL, and high TG. In 1 study, a total cholesterol >200 mg/dL was also required for the diagnosis of dyslipidemia. In another study, being on a cholesterol-lowering medication also allowed patients to meet criteria. A third study relied on physician diagnosis of dyslipidemia only. The sample sizes for 2 of these studies were more than 10 000 participants. In general, the prevalence of dyslipidemia increased when comparing healthy weight with overweight and overweight with obesity. When comparing healthy weight with obesity, the prevalence (or odds ratio) nearly doubled. Caution should be used when interpreting these results given the inconsistent definition of dyslipidemia.

Glucose Metabolism

Hemoglobin A1c

A total of 7 studies examined the prevalence of abnormal hemoglobin A1c (HbA1c),[13,26,28,34,37,38,41] whereas 12 provided mean values for HbA1c.[6,13,40,41,46,55,63,67,73,79,81,82] The participants in the 6 studies reporting abnormal HbA1c ranged in age from 3 to 19 years, with 1 study only reporting the mean age of 17 years (Table 10).[26] This same study also deviated from the standard definitions of weight classification and defined an abnormal HBA1c level as greater than 6.5%, whereas the other 5 studies ranged from greater than 5.6% to 6%. One study did not report the sample size whereas others ranged in size from 101 to 8579. The prevalence of abnormal glucose in overall cohorts ranged from 1% to 17%, with the latter reported in a cohort of children 3 to

TABLE 9 Prevalence of Dyslipidemia ($n = 6$)

First Author	Country	Ages (y)	*N*	Subgroup (eg, M/F)	Definition of Abnormal	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Michalsky	USA	13–19	242		High LDL or TG, low HDL, or medication	50.4			52.2	53.2	41.7	NS	N = 238	1: BMI 30–50, 2: BMI 50–60, 3: BMI >60	Bariatric surgery patients
Redonco	USA	2–17.9	11348		Physician diagnosed	3.8%	OR = 1.0	OR = 1.4	OR = 2.2			<.05			Patients with type 1 diabetes mellitus
Jayawardene	USA	12–19	23438	Males	HDL < 40, LDL > 130, TG > 130, or TC > 200		22.7	38.0	53.7	68.7					NHANES 1999–2014
				Females			20.0	26.3	32.5	40.2					
Tsao-Wu	US	2–5	154		Guided by 2011 NHLBI statement				27.6	17.0	30.8	NR			Weight management clinic patients
									37.2	36.3	36.1	NR			Weight management clinic patients
									34.8	38.4	35.2	NR			Weight management clinic patients
Lennerz	Germany	14–24	431		Any abnormal lipid				28	24	37	.02			Weight management program patients + some community
Hadjiyannakis	Canada	5–17	847		Any lipid abnormality	20			17	23	21	NR			Pediatric weight management program patients

NHLBI, National Heart, Lung, and Blood Institute; NR, not reported; NS, not significant; OR, odds ratio.

19 years of age. Using data from the National Health and Nutrition Examination Survey (NHANES) 1999 to 2012, 1 study cited a statistically significant difference between glucose levels among the overweight and obese groups (class I, II, and/or III obesity).[38]

Most studies of mean HbA1c values did not report significant differences by weight, although none examined differences by obesity severity (Table 11). The only study with a large sample size ($n = 11\,348$) included children with type 1 diabetes mellitus seen in an endocrine clinic; there were no differences in mean HbA1c by weight status.[82] An additional study showed statistically significant, but very small, differences by weight category.[55]

Glucose

A total of 37 studies examined the prevalence of abnormal glucose,[5,6,8–14,17–23,25,26,28–32,37–42,71,77,78,80,84–86] whereas 39 provided mean values for glucose.[5,6,8,10,13,18,22,32,35,36,40,41,43,44,46–49,52,54–56,58–62,65,66,68,70,71,73–75]

Thirty-seven studies reported prevalence of abnormal glucose across weight groups in cohorts ranging from 3 to 19 years of age (Table 12). Twelve of these studies reported significant differences, with 9 of these studies including a healthy group comparator. Of those studies indicating significant differences, prevalence sharply increased across increasing weight category, including a multifold higher prevalence in youth with obesity versus those with healthy weight. Eight studies reported data from nationally representative datasets, including in the United States and Korea, with 5 of these studies reporting significant differences in prevalence across weight categories.

TABLE 10 Prevalence of Abnormal HbA1c ($n = 7$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Skinner	US	6–17	NR	>5.7%		1.0	0.5	0.3	3.7			<.05			NHANES 2001–2002
Salvatore	US	3–18	101	>5.6				25	40.9	35.7	42.3	.873			Pediatric endocrinology patients
O'Hara	US	3–19	382	>5.7%		17		9	13	15	18	NS			Stage 3 pediatric weight management program patients
Michalsky	US	Mean 17	242	>6.5%		6.1			3.7	[Typo]	4.2	NS		1: BMI 30–50, 2: 50–60, 3: >60	Bariatric surgery patients
Skinner	US	3–19	8579	>5.7%				1.87	3.40	6.38	13.19	<.001			NHANES 1999–2012
Valery	Australia	5–17	158	<6.0%			8	12				.539			Indigenous youth
Hadjiyannakis	Canada	5–17	847	>5.7%		15			13	15	16	NR			Pediatric weight management program patients

NR, not reported; NS, not significant.

Prevalence of abnormal glucose in overall cohorts ranged from 0% to 26.1%, with the latter reported in a cohort of adolescents undergoing bariatric surgery.[26] This study also reported the highest prevalence of abnormal glucose among the studies reviewed, with 37.5% of adolescents with class III obesity indicated with abnormal glucose. Seven studies reported prevalence separately by biological sex, although there were no consistent differences, with males having higher prevalence in 4 studies and females having higher prevalence in 2 studies. Importantly, studies varied in definition of abnormal glucose, with 18 studies using the threshold of ≥100 mg/dL, 7 studies using the threshold of ≥110 mg/dL, and 2 studies using the threshold of ≥126 mg/dL.

Thirty-nine studies reported mean glucose levels across weight groups in cohorts ranging from 3 to 20 years of age, with 12 studies detecting significant differences (Table 13). Eight of these studies included a healthy weight comparator, whereas 4 demonstrated significant differences in glucose levels among the overweight and obese (class I, II, and/or III obesity) groups. Significant differences in mean glucose level across weight groups were observed in multiple age ranges, including studies that consisted of both children and adolescents, as well as a study of exclusively preschool-aged children.[46] However, none of the subgroups had a mean glucose value above the standard threshold of ≥100 mg/dL (≥5.5 mmol/L) to indicate elevated fasting glucose.

Insulin

A total of 14 studies examined the prevalence of abnormal insulin,[6,9,12,19,22–24,26,28,34,39,41,42,84] whereas 32 provided mean values for insulin.[6,8,22,24,32,35,36,40–44,46,

TABLE 11 Mean HbA1c ($n = 12$)

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Bell	Australia	6–13	283	%			4.96	4.97	5.16			.053			
Watts	Australia	6–13	148	%			4.9	4.9	4.9			NS		Assume CDC	
Turchiano	USA	14–18	1185				5.43	5.35	5.4			<.05			Youth of urban minoritized groups
Puri	USA	10–18	198				5.4	5.5				NS			Youth of minoritized groups
McCarthy	USA	11–14	199	%			4.60	4.66	4.65			NS			Children of minoritized groups
Redondo	USA	2–17	11 348	%	2–5 y		8.2	8.1	8.2			.75			Patients with type 2 diabetes mellitus
					6–12 y		8.3	8.4	8.4			.43			
					13–17 y		8.8	8.8	8.8			.03			
Bocca	Netherlands	3–5	75	%, median		5.3		5.3	5.4						
Valery	Australia	5–17	158	%			5.39	5.55				.037			Indigenous youth
Hadjiyannakis	Canada	5–17	847	%		5.3			5.3	5.3	5.4	NR			Pediatric weight management program patients
Kloppenberg	Denmark	Median 12	3978	mmol/mol	Males		34	33.92	34.24			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
					Females		33.7	34	34.18			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
Lennerz	Germany	14–24	431	%					5.24	5.37	5.48	.01			Weight management + some community
Seth	USA	Mean 13	767	%				5.1	5.2	5.2	5.3	.14			Steatohepatitis clinic patients

HW, healthy weight; NR, not reported; NS, not significant ; OB, obese; OW, overweight.

47,49,52,54,55,58–62,65,66,70,71,73,75,84,87,88

Table 14 indicates that 8 of 12 studies observed significant differences in prevalence of abnormal insulin across weight categories, with a range of 0% in a sample of 3- to 18-year-old participants who were overweight in the United States[34] to 80% among 9- to 16-year-old participants with obesity in Canada.[19] Prevalence estimates were reported from samples enrolled in the United States (8 studies), 2 studies each in Australia and Canada, and 1 study each in Italy and Japan; however, none of the studies were indicated as nationally representative. Eight studies had less than 500 participants, but the sample sizes ranged from 62 to 6358. Three studies enrolled participants from clinic-based settings, including a pediatric gastroenterology clinic, a pediatric weight management program, and a bariatric surgery program. Several definitions of abnormal insulin were used, making it difficult to compare actual prevalence estimates across studies. In several studies, youth with obesity had a four- to fivefold higher prevalence of abnormal insulin compared with youth with healthy weight. There were also differences observed within obesity classification: for example, youth with class II or higher obesity had a threefold higher prevalence of abnormal insulin than their peers with class I obesity.[22] One study that did not observe significant differences in abnormal insulin prevalence across weight categories comprised patients who were all enrolled in a bariatric surgery program, so patients had comorbidities at the time of entry.[26] The 1 study that examined abnormal insulin prevalence by age did not observe differences between 6- to 11-year-old versus 12- to 19-year-old youth.[24] Three studies reported prevalence stratified by

TABLE 12 Prevalence of Abnormal Glucose ($n = 31$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Kim	Korea	10–19	931	>110 mg/dL		0.2	0.2	1.2	NA			NA			
Halley Castillo	Mexico	7–24	1366	110-126 mg/dL			0.32	0.47				0.664			Patients in Central Mexico
Duncan	USA	12–19	991	≥110 mg/dL		1.1	0.6	4.0	0.1			NR			NHANES 1999–2000
Davis	USA	7–18	211	>100 mg/dL			12	15	18			NR			Patients in rural Georgia
Bell	Australia	6–13	283	>7.0 mmol/L			0	1.3	5.3			.037			
Valerio	Italy	3–16	150	110–126 mg/dL		0	0		0					OB >95th	
Turchiano	USA	14–18	1185	>100 mg/dL			0.6	0.3	2.0			.03			Youth of urban minoritized groups
Skinner	USA	6–17	NR			0.4	0.0	0.0	2.9			<.05			NHANES 2001–2002
Perez	USA (Puerto Rico)	12–18	101	>100 mg/dL			1.9	1.9				1.0			
O'Hara	USA	3–19	382	≥100 mg/dL		8		4	7	7	11	NR			Stage 3 pediatric weight management program patients
Marcus	USA	Mean 11.2	1305	>100 mg/dL					20.4	19.8		.7791			
Michalsky	USA	13–19	242	≥100 mg/dL		26.1			17.7	31.2	37.5	.01		1: 30 < 50 BMI, 2: 50 < 60; 3: >60	Bariatric surgery patients
Yoshinaga	Japan	6–12	471	>100	Males			0.9	2.0						
					Females			6.7	0						
Williams	USA	12–19	915	100-125 mg/dL			5.4	2.8	17.8			<.05			NHANES
Skinner	USA	3–19	8579	≥100 mg/dL				15.56	19.42	31.77	24.27	.003			NHANES 1999–2012
Li	USA	12–19	20905	>100 mg/dL		13.64	11.93	14.66	16.94	26.80		<.05			
Jayawardene	USA	12–19	23438	>126	Males		0.6	0.9	0.3	4.2					NHANES 1999–2014
	USA				Females		0.6	1.1	0.5	0.8					
Park, S	Korea	10–19	1554	>100 mg/dL			5.6	5.2	12.2			<.05			2007-2008 KNHANES
Laurson	USA	12–18.9	3385	Joliffe standards	Males		16.4	19.5	24.1			NR			NHANES
	USA				Females		6.5	8.3	12.1			NR			NHANES
Baranowski	USA	13.6	1740	>110 mg/dL		6.2	4.4	6.7	8.9			NR			
Guerrero-Romero	Mexico	6–18	1534	100-126 FG		18.3	17.1	18.8	19.1						
Park	Korea	12–19	664	≥100 mg/dL			3.4	0	5.8						
Caserta	Italy	11–13	646	>100 mg/dL	Males		0.7	3.3	3.8			NR			
					Females		0.0	0.0	3.5			NR			
Marcus	USA	Mean 11.8	6358	>100 mg/dL	No		13.5	15.5	20.2		22.5	.0003			
Kim	Korea	10–18	1412	>110	1998 KNHANES		8.2	9.4	5.3			NR			
			1158		2001 KNHANES		7.7	5.8	9.3			NR			
Botton	France	8–17	452	>6.1 mmol/L			1.0	0.0				NR			
Del-Rio-Navarro	Mexico	6–13	1819	>100 mg/dL			1.3	4.4	3.5						
Pan	US	12–19	4450	>100 mg/dL		13.3%	9.5	14.2	17.2			<.05 OB			NHANES 1999–2002
Messiah	USA	8–14	1698	>100 mg/dL			12–14: 12.30	12–14: 9.61	12–14: 21.83						
Lambert	Canada	9–16	3613	>5.6 mmol/L	Males		16.4	24.4	24.7			.02			
					Females		9.1	9.1	17.3			.075			
Valery	Australia	5–17	158	NR			4	3				.829			Indigenous youth

TABLE 12 Continued

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Avnieli Velfer	Israel	2–18	1027	>100 mg/dL	Males							NR		OB 95th, SO 120%/95th	Obesity clinic patients
					Females							NR		OB 95th, SO 120%/95th	Obesity clinic patients
Fyfe-Johnson	USA	8–17	300	>100 mg/dL		3	3	1		3					Clinic patients
Gunes	USA	11–18	363	>100 mg/dL	Males			21.2	14.5			.867			Adolescent clinic patients
					Females			11.2	13.9			.493			Adolescent clinic patients
Hadjiyannakis	Canada	5–17	847	>6.1 mmol/L		3			4	2	4	NR			Pediatric weight management program patients
Lennerz	Germany	14–24	431	>110 mg/dL					9	19	20	.005			Weight management clinic patients + some community
Stolzman	USA	12–17	62	>100 mg/dL			0		0			NR			Community recruitment

KNHANES, Korean National Health and Nutrition Examination Survey; NR, not reported; NS, not significant ; OB, obese; SO, severe obesity.

biological sex; in 2 of the studies, females had higher prevalence of abnormal insulin compared with males.

Thirty of the 32 studies (Table 15) reporting mean values of insulin observed significant differences across weight categories; the other 2 studies did not statistically test for differences among weight categories. Although most (22 of 32) studies examined differences between 2 weight categories (healthy versus combined overweight and obese), 10 of the 32 studies reported mean insulin values for at least 3 weight categories; in every case, there was a noticeable dose-gradient relationship of insulin across the multiple weight categories and the *P* value was significant. These differences were noted among healthy versus overweight versus obesity groups as well as a study of adolescents that observed differences among healthy, overweight, obesity class I, and obesity class II+.[24] Most of the cohorts spanned the age range from childhood to adolescence, although 1 study observed significant differences in insulin values among 3- to 5-year-old children who were overweight versus those who had obesity,[46] and a second study also observed significant differences among 6- to 8-year-old children with healthy weight versus those with obesity.[52] Two studies reported mean values by age[24,71]; in both cases, the insulin levels were higher in adolescents versus children, and the insulin values were noticeably higher among the youth with higher weight status.

HOMA-IR

A total of 10 studies examined the prevalence of abnormal homeostatic model assessment for insulin resistance (HOMA-IR),[7,9,12,26,32,35,40,71,88,89] whereas 25 provided mean values for HOMA-IR.[7,32,35,36,40,41,43,

TABLE 13 Mean Glucose ($n = 39$)

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Kollias	Greece	6–13	780	mg/dL			90.8	92.2	90.7			NS			
Davis	USA	7–18	211	mg/dL			90	90	92			NS			Patients in rural Georgia
Bonet	Spain	Mean 10.7	101	mM			4.0		4.2			NS			Patients were all white
Bell	Australia	6–13	283	mmol/L			4.67	4.67	4.75			.783			
Baer	USA	12–22	173	mg/dL		83.8	83.7	82.0	84.4			.61			Females with PCOS
Aylanc	Turkey	Mean = 13.5	88	mg/dL			87.9		93.8			.004			
Akinci	Turkey	6–17	41	mmol/L			5.17	4.94				.665		Control: 25th–74th percentile	
Zabarsky	USA	7–20	2244	mg/dL				91	92	93	93	.006	IV = 93	Includes class IV	
Valerio	Italy	3–16	150	mg/dL	Children		80.6		81			NS		OB >95th	
					Adolescents		73.8		82.8			<.001			
Valentini	Italy	5–18	84	mg/dL			83.38	88.32				.017			Patients with Down syndrome
Watts	Australia	6–13	148	mmol/L			4.5	4.5	4.5			NS			
Turchiano	USA	14–18	1185	mg/dL			79.2	79.4	81.4			<.05			Youth of urban minoritized groups
Simsek	Turkey	Mean 11	115	mmol/L			4.7		4.8			.737			
Salawi	Canada	6–19	345	mmol/L				4.9			4.9	.7			
Rank	Germany	6–19	463	mg/dL	Males				70.2	71.5		.480			
					Females				71.9	75.5		.051			
Perichart-Perera	Mexico	9–12	88	mg/dL			75.30	77.13	75.91			NS			
Perez	USA (Puerto Rico)	12–18	101	mg/dL			85.4	86.4				.40			
Nystrom	Spain	8–11	1247	mg/dL			83.4	84.3	85.6	85.9				SO >99.8th	
Nascimento	Portugal	5–18	181	mmol/L			4.90		5.00			.174			
Olza	Spain	6–12	446	mg/dL	Males		84		85			.340			
					Females		83		84			.629			
Marcus	USA	Mean 11.2	1305	mg/dL					94.6	94.2		.3075			
Weiss	USA	12–17	1418	mg/dL			90	90	93	94		<.001			
Buchan	UK	5–12	223	mmol/L			4.83	4.93				.182			
Bocca	The Netherlands	3–5	75	mmol/L		4.2		4.0	4.3			<.05			
Baranowski	USA	Mean 13.6	1740	mg/dL		98.2	97.3	98.3	99.9			.0172			
Garces	Spain	6–8	1048	mg/dL	Males		91.6		93.8			.08			
					Females		89.5		90.1			.74			
Guerrero-Romero	Mexico	6–18	1534	mg/dL			90.2	90.7	93.6						
Cizmecioglu	USA	10–19	310	mg/dL			886	89.6	89.6			NS			
Norris	USA	Mean 13.5	225	mg/dL			85.1	88.7		92.5		.770			
Kim	Korea	10–18	1412	mg/dL	1998 males		94.7	94.3	95.9			.813			
					1998 females		92.4	94.9	93.4			.174			
			1158		2001 males		94.6	95.6	97.7			.183			
					2001 females		93.6	92.0	93.7			.668			

TABLE 13 Continued

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Botton	France	8–17	452	mmol/L	Males	4.76	4.75	4.82				NS			
					Females	4.65	4.63	4.80				NS			
Serap	Turkey	6–16	284	mg/dL	Males		92.1		92.4			NS			Pediatric endocrinology patients
					Females		92.6		92.2			NS			
Del- Rio-Navarro	Mexico	6–13	1819	mg/dL	Males		79.5	82.1	83.0			<.05			
					Females		77.2	78.7	79.8			<.05			
Valery	Australia	5–17	158	mmol/L			4.66	4.89				.318			Indigenous youth
Avnieli Velfer	Israel	2–18	1027	mg/dL	Males				90	90		.93		OB 95th, SO 120%/95th	Obesity clinic patients
					Females				84	91		.04			
Hadjiyannakis	Canada	5–17	847	mmol/L		4.90			4.80	4.90	4.90	NR			Pediatric weight management program patients
Kim	Korea	12–13	120	mg/dL			90.0	90.0				.707			School based
Kloppenberg	Denmark	Median 12	3978	mmol/L	Males		5.0	5.1	5.2			<.005	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic patients + population-based
					Females		5.0	5.0	5.1			0.005			
Sougawa	Japan	12–18	1679	mg/dL	Males	89.3	89.0	90.7				.014			Schools
					Females	88.0	87.9	88.8				.215			

HW, healthy weight; NR, not reported; NS, not significant; OB, obese; OW, overweight; PCOS, polycystic ovary syndrome; SO, severe obesity.

45,46,49,52,54,58,59,61–63,65,66,70,71,73,75,81,90 Prevalence of abnormal HOMA-IR ranged from 0% in healthy adolescents[71] to 70.8% in adolescents with class III obesity who were enrolled in a bariatric surgery program[26] (Table 16). However, definitions of abnormal HOMA-IR differed in every study, so it is difficult to compare prevalence estimates. Prevalence was reported for cohorts from the United States (5 studies) and Europe (5 studies); however, none were indicated as nationally representative cohorts. Prevalence of abnormal HOMA-IR was significantly different across weight categories in 7 of the 9 studies; 1 study did not statistically examine differences across weight categories and another study did not observe differences, but the sample only consisted of adolescents with obesity who were undergoing bariatric surgery (with no differences among class I, class II, or class III obesity; Michalsky/US).[26] One study reported prevalence by age group with a stark difference in abnormal HOMA-IR in both children and adolescents with obesity (approximately 41%) versus participants with healthy weight (0% to 3%) (Valerio/Italy).[71] Two studies reported prevalence stratified by biological sex; in both cases, prevalence of abnormal HOMA-IR was higher among females compared with males (Caserta/Italy; Serap/Turkey).[9,35]

Studies reporting mean HOMA-IR across weight categories (Table 17) corroborated the findings of the prevalence of abnormal HOMA-IR. Twenty-three of the 25 studies reported significant differences in HOMA-IR value across weight categories. Most of these studies examined differences between healthy weight versus overweight and obesity combined. However, 6 studies examined differences

TABLE 14 Prevalence of Abnormal Insulin ($n = 14$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Bell	Australia	6–13	283	>12 mIU/L			8.0	19.5	38.9			<.001			
Salvatore	USA	3–18	101	>10				0	47.4	56.5	72.2	.301			Pediatric gastroenterology patients
O'Hara	USA	3–19	382	>20 mIU/mL		42		29	34	40	57	NS			Stage 3 pediatric weight management program patients
Marcus	USA	Mean 11.2	1305	>30					10.5	35.7		<.0001			
Michalsky	USA	13–19	242	>17.0 uIU/mL		74.1			73.9	74.0	75.0	>.99		1: 30 < 50 BMI, 2: 50 < 60; 3: >60	Bariatric surgery patients
Yoshinaga	Japan	6–12	471	>90th	Males	20.5	47.7					<.05			
					Females			45	60.8			<.05			
Maximova	Canada	6–11	2087	>75th	6–11 y		18.0	50.2				NR			
					12–19 y		11.6	49.3				NR			
Baranowski	USA	Mean 13.6	1740	>30 uU/mL		36.2	16.0	36.2	72.3			NR			
Caserta	Italy	11–13	646	>11 males, >13.2 females	Males		12.4	25.6	60.4			<.05			
					Females		11.2	38.2	65.5			<.05			
Marcus	USA	Mean 11.8	6358	>30 uU/mL			0.8	3.0	13.4		40.0	<.001			
Lambert	Canada	9–16	3613	>38 9 y, >60 13–16 y	Males		11.3	37.2	72.1			<.0001			
					Females		23.2	46.3	80.1			<.0001			Indigenous youth
Valery	Australia	5–17	158	<15.0 mU/L			30	56				.021			Adolescent clinic patients
Gunes	USA	11–18	363	>30 uU/mL	Males			6.6	12.8			.347			
					Females			1.7	24.5			<.001			Adolescent clinic patients
Stolzman	USA	12–17	62	>15 uU/mL			3		33			<.05			Community recruitment

NR, not reported; NS, not significant.

across 3 weight categories, showing a gradient of HOMA-IR values among healthy weight, overweight, and obesity. One study reported mean values separately by age group, with adolescents having higher HOMA-IR values than children in both the healthy weight and obesity categories.[71] Four studies reported mean HOMA-IR values stratified by sex; there was not a consistent pattern in differing values between females and males.

Most cohorts included both children and adolescents or only adolescents; however, the 1 cohort that did include young children (ages 3–5 years) did not observe a significant differences in HOMA-IR across weight categories.[46] A cohort of children ages 6 to 8 years did observe significantly higher HOMA-IR values among children with obesity versus children with healthy weight.[52]

Other Glucose Metabolism

Additional studies reported the prevalence of prediabetes ($n = 3$),[13,85,91] diabetes mellitus ($n = 8$),[13,26,33,71,83,85,87,92] and metabolic syndrome ($n = 16$).[10,11,14,17,20,29–32,35,42,49,93–96] Three studies reported prevalence of prediabetes (Table 18). The population-based study in Mexico defined prediabetes as 2-hour glucose tolerance test result of 140 to 200 mg/dL. Prediabetes was higher in children with overweight or obesity versus children with healthy weight.[85] A second population-based Canadian study showed greater risk of prediabetes for children with obesity versus children with healthy weight.[91]

The 8 studies reporting the prevalence of diabetes (Table 19) used varying definitions of diabetes, based on fasting plasma glucose, glucose tolerance tests, HbA1c, diagnosis, or use of medications.

TABLE 15 Mean Insulin ($n = 32$)

First Author	Country	Ages (Y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight definitions	Population Info
Bonet	Spain	Mean = 10.7	101	mU/l			6.1		14.3			<.001			
Bell	Australia	6–13	283	mU/L			5.96	8.21	14.67			<.001			
Baer	USA	12–22	173	uU/mL		21.7	9.6	14.3	26.7			<.001			Females with PCOS
Aylanc	Turkey	Mean = 13.5	88	uU/mL			10.38		25.61			<.001			
Akinci	Turkey	6–17	41	uU/mL			4.28	7.50				.005		HW:25th–75th	
Valerio	Italy	3–16	150	uU/mL	Children		6.8		12.4			.0001		OB > 95th	
					Adolescents		7.6		20.8			.0001			
Valentini	Italy	5–18	84	mU/L			10.28	16.9				.001			Patients with Down syndrome
Watts	Australia	6–13	148	mU/L			5.9	7.7	9.8			<.05		Assume CDC	
Turchiano	USA	14–18	1185	uU/mL			10.0	12.0	18.6			<.05			Youth of urban minoritized groups
Simsek	Turkey	Mean = 11	115	uU/mL			6.6		14.5			<.001			
Salawi	Canada	6–19	345	μ/L				18.5			31.3	.02			Patients referred to pediatric weight management program
Rank	Germany	6–19	463	μ/l	Males				8.7	12.0		<.001			
					Females				10.1	14.6		<.001			
Perichart-Perera	Mexico	9–12	88	uU/mL			29.73	38.16	53.11			.001			
Perez	USA (Puerto Rico)	12–18	101	uU/mL			8.3	18.5				<.001			
Nystrom	Spain	8–11	1247	uU/L			6.6	9.0	12.9	15.9				SO >99.8th	
Nascimento	Portugal	5–18	181	mmol/l			5.28		12.95			<.001			
Olza	Spain	6–12	446	μ/l	Males		4.99		10.38			<.001			
					Females		5.41		12.21			<.001			
Marcus	USA	Mean = 11.2	1305	uU/mL					17.9	28.7		<.0001			
Yoshinaga	Japan	6–12	471	uU/mL	Males			10.0	12.1			<.05			
					Females			13.2	14.3			NR			
Weiss	USA	12–17	1418	uU/mL			18	25	34	40		<.001			
Maximova	Canada	6–19	2087	pmol/L	Age 6–11		45.4	75.3				NR			
					Age 12–19		53.5	109				NR			
Bocca	The Netherlands	3–5	75	mU/L		7.9		6.2	8.9			<.01			
Baranowski	USA	Mean = 13.6	1740	uU/mL		30.1	22.5	28.9	44.8			<.0001			
Garces	Spain	6–8	1048	uU/mL	Males		3.02		5.32			<.001			
					Females		3.46		5.33			<.001			
Cizmecioglu	USA	10–19	310	μ/L			8.55	10.2	12.2			<.001			
Norris	USA	Mean = 13.5	225	mU/L			8.1	12.0		20.9		<.0001			
Botton	France	8–17	452	pmol/L	Males	33.1	31.3	54.8				<.0001			
					Females	39.3	37.7	52.3				<.05			
Serap	Turkey	6–16	284	uU/mL	Males		7.2		15.1			<.001			Pediatric endocrinology patients
					Females		6.7		17.7			<.001			
Manios	Greece	10–12	522	uU/mL			4.5		8.5			<.001			
Valery	Australia	5–17	158	μ/L			11.96	18.74				.001			Indigenous youth
Kim	Korea	12–13	120	uU/mL			8.8	14.4				<.001			School based
Kloppenberg	Denmark	Median 12	3978	pmol/L	Males		51.2	69.4	105.4			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic patients + population-based
					Females		62.2	85.4	122.8			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic patients + population-based

HW, healthy weight; NR, not reported; OB, obese; OW, overweight; PCOS, polycystic ovary syndrome; SO, severe obesity.

TABLE 16 Prevalence of Abnormal HOMA-IR ($n = 10$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight definitions	Population Info
Bindler	USA	11–14	151	>2.7	No		22.7		62.5			<.001			
Valerio	Italy	3–16	150	>2.5 children; >4.0 adolescents	Children		3		40.8			<.001			
					Adolescents		0		41.2			<.002			
Turchiano	USA	14–18	1185	>3.99			4.5	12.4	37.8			<.001			Youth of urban minoritized groups
Perez	US (Puerto Rico)	12–18	101	≥3.16			35.6	81.3				<.001			
Peplies	Europe	3–10.9	3348	>95th		17.8	10.9	36.5	66.7						
Michalsky	USA	13–19	242	≥4.0		71.1			71.2	71.2	70.8	>.99		1: 30 < 50 BMI, 2: 50 < 60; 3: >60	Bariatric surgery patients
Caserta	Italy	11–13	646	>2.28 males, >2.67 females	Males		13.1	26.7	54.7			<.05			
					Females		11.8	37.1	65.5			<.05			
Serap	Turkey	6–16	284	>2.5	Males		3.8		47.2			<.001			Pediatric endocrinology patients
					Females		8.6		56.7			<.001			
Manios	Greece	10–12	522	>2.10 (97.5th %ile of NW)	No	9.2	2.9	10.5	31.0			<.001			
Gunes	USA	11–18	363	3.16	Males			60	68			.402			Adolescent clinic patients
					Females			48.2	44.7			<.001			Adolescent clinic patients

NW, normal weight.

Most studies showed significantly higher prevalence of diabetes among children with obesity or severe obesity, although overall prevalence was low. Prevalence of diabetes >3% was seen only in a pediatric endocrinology clinic[33] and among bariatric surgery candidates.[26]

Of the 16 studies assessing the prevalence of metabolic syndrome (Table 20), the largest sample size was 4450 and the smallest sample was 101. Seven studies reported the prevalence of metabolic syndrome as the presence of 3 or more components of metabolic syndrome in cohorts ranging from 6 to 24 years of age, with 3 of the studies conducted in the United States. The remainder of the studies (8) reported the presence of metabolic syndrome using the following criteria: Adult Treatment Panel (ATP) III (2 studies), NCEP ATP III (2 studies), 3 components plus risks (2 studies), 3 components plus abnormalities (1 study), and International Diabetes Foundation (IDF) (1 study). Of the 16 studies, 14 included a healthy weight comparison, and 11 of the studies reported a significant association between the prevalence of metabolic syndrome and overweight. Of the studies that defined the presence of metabolic syndrome as having 3 or more components and compared prevalence across children with normal weight, overweight, and obesity, the prevalence of metabolic syndrome ranged from 0% to 4.7% among children with healthy weight and increased to 14.5% to 35% among children and adolescents with class I obesity. Of the 2 studies that defined metabolic syndrome as ATP III and compared prevalence across children with healthy weight, overweight, and obesity, the prevalence of metabolic syndrome ranged from 0.3% to 1.6%, which increased to 39% for children with class I obesity in 1 study. One of

TABLE 17 Mean HOMA-IR ($n = 25$)

First Author	Country	Ages (y)	*N*	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight definitions	Population Info
Aylanc	Turkey	Mean = 13.5	88			1.43		5.80			<.001			
Bindler	USA	11–14	151			2.32		4.61			<.001			
Akinci	Turkey	6–17	41			1.01	1.67				.031		HW: 25th–75th	
Valerio	Italy	3–16	150	Children		1.4		2.5			.0001			
				Adolescents		1.4		4.2			.0001			
Valentini	Italy	5–18	84			2.18	3.69				.002			Patients with Down syndrome
Watts	Australia	6–13	148			1.1	1.6	2.0			<.05			
Turchiano	USA	14–18	1185			2.0	2.3	3.8			<.05			Youth of urban minoritized groups
Simsek	Turkey	Mean = 10.8	115			1.38		3.11			<.001			
Salawi	Canada	6–19	345				4.0			6.8	.03			Patients referred to pediatric weight management program
Puri	USA	10–18	198			2.1	6.4				<.001			Youth of minoritized groups
Rank	Germany	6–19	463	Males				1.5	2.2		<.001			
				Females				1.8	2.7		<.001			
Perichart-Perera	Mexico	9–12	88			5.90	7.23	9.97			.001			
Perez	US (Puerto Rico)	12–18	101			1.8	4.1				<.001			
Nascimento	Portugal	5–18	181			1.14		2.90			<.001			
Olza	Spain	6–12	446	Males		1.04		2.21			<.001			
				Females		1.14		2.58			<.001			
Buchan	UK	12–17	387			1.4	1.1				.064			
Bocca	The Netherlands	3–5	75				0.79	1.14			<.01			
Bindler	US	Mean = 12.5	150			2.32		4.66			<.001			
Garces	Spain	6–8	1048	Males		0.69		1.26			<.001			
				Females		0.76		1.18			<.001			
Cizmecioglu	USA	10–19	310	No		2.3	2.4	2.7			.006			
Norris	USA	Mean = 13.5	225	No		1.7	2.6		4.4		<.0001			
Serap	Turkey	6–16	284	Males		1.7		3.5			<.001			Pediatric endocrinology patients
				Females		1.6		3.8			<.001			
Valery	Australia	5–17	158	No		2.25	3.58				.002	Median		Indigenous youth
Lennerz	Germany	14–24	431					4.23	5.57	7.37	<.001			Weight management program patients + some community
Kim	Korea	12–13	120			2.0	3.2				<.001			School based

HW, healthy weight.

TABLE 18 Prevalence of Prediabetes ($n = 3$)

First Author	Country	Ages (y)	*N*	Subgroup (eg, M/F)	Definition of Abnormal	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Guerrero-Romero	Mexico	6–18	1534		140–200 2-h glucose		1.4	3.5	5.7						
Rodd	Canada	6–19	3449		Canadian Diabetes Association		Ref		aOR = 1.53			<.05		WHO	Population based
Hadjiyannakis	Canada	5–17	847		>6.1 FPG or >7.8 OGTT	4			3	5	6	NR			Pediatric weight management program patients

aOR, adjusted odds ratio; FPG, fasting plasma glucose; OGTT, oral glucose tolerance test.

the 2 studies did not report prevalence for class I obesity. Of the 2 studies that defined metabolic syndrome as NCEP ATP III and compared prevalence across children with healthy weight, overweight, and obesity, the prevalence of metabolic syndrome ranged from ranged from 1% to 1.5%, which increased to 28.6% to 41% for children with class 1 obesity. Of the 2 studies that defined metabolic syndrome using 3 components plus risk and compared prevalence across children with healthy weight, overweight, and obesity, the reported prevalence of metabolic syndrome ranged from 0% to 0.8% for females and 1.7% for males, which increased to 1.6% to 24.6% for female children and 35% for male children with class 1 obesity. One study defined metabolic syndrome as 3 components plus abnormalities and the reported prevalence across children with healthy weight, overweight, and obesity was 0.2% among children with healthy weight and 25.6% among children and adolescents with class 1 obesity. When using the IDF definition of metabolic syndrome, the reported prevalence was 1.6% among children with healthy weight and 28% among children and adolescents with class 1 obesity. In addition, 3 studies reported statistical comparisons by biological sex. However, only 1 supported a significant relationship between metabolic syndrome and unhealthy weight status for both males and females. Prevalence comparisons were not available within studies for different age subgroups.

Blood Pressure

Systolic Blood Pressure

A total of 21 studies examined the prevalence of abnormal systolic blood pressure (SBP),[5,7,8,10,13,15,18,19,24,35–39,63,97–101] whereas 52 provided mean values for SBP.[5,7,8,10,13,18,22,24,32,33,35,36,39,40,42–46,48–50,54–56,59–66,68,71–75,77,79,83,90,97,99,102–108] Twenty-one studies, including children ages 3 to 19 years, examined the prevalence of elevated SBP in relation to excess weight (Table 21). Within the 17 studies formally testing such an association, 14 included a healthy weight comparison group, and all but 1 of these reported a significant association between the prevalence of elevated SBP and overweight or obesity.

Reported frequencies further suggest a progressive increase in the prevalence of high SBP with increasing adiposity, although limited information is available regarding differences across classes of obesity, because only 1 study specifically focused on such categories. Studies supporting an association between elevated SBP and unhealthy weight status included samples based within the United States ($n = 7$) and other countries ($n = 10$) as well as population-based and more targeted samples. Five studies reported statistical comparisons by biological sex, all of which supported a significant relationship between elevated SBP and unhealthy weight status for both males and females. Five studies based on samples within a preteen or young-teenage range (eg, 9–13 years) supported an association between higher SBP and unhealthy weight. Prevalence comparisons were not available within studies for different age subgroups, and no studies focused specifically on young children (eg, ≤8 years).

Fifty-two studies including children ages 2 to 19 years provided mean values for SBP across different weight groups, including 21 studies from the United States (with 2 from Puerto Rico) and studies from 15 other countries, spanning 4 continents (Table 22). Within the

TABLE 19 Prevalence of Diabetes ($n = 8$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Valerio	Italy	3–16	150	FPG > 126 mg/dL or 2-h >200 mg/dL		0	0		0						
Propst	USA	Mean 12.7	1111	>6.4					39.8		52.4	<.001			Pediatric endocrinology patients
Michalsky	USA	13–19	242	Diagnosis, medication, A1c ≥6.5%, FPG ≥126 mg/dL; or 2-h OGTT ≥200 mg/dL		13.6			11.3	15.6	16.0	.55		1: 30 < 50 BMI, 2: 50 < 60; 3: >60	Bariatric surgery patients
Weiss	USA	12–17	1418	ADA definitions		0	0	0	0.028985507	0.022452504		<.001			
Bar Dayan	Israel	17	76732	Type 2	Males	0.036%	0.02%	0.05%	0.4%		0%	<.001			Military recruits
					Females	0.01%	0.001%	0.03%	0.1%		0%	.015			
Guerrero-Romero	Mexico	6–18	1534	≥200 mg/dL 2-h postload		0.6	0.0	0.5	1.3						
Hadjiyannakis	Canada	5–17	847	>7.0 FPG, >11.0 OGTT		2			1	2	2	NR			Pediatric weight management program patients
Tsao-Wu	USA	2–5	154	HgA1c >6.5%					0	0	0	NR			Weight management clinic patients
		6–11	880						1.0	4.0	4.0	NR			Weight management clinic patients
		12–17	1004						2.0	1.4	6.2	NR			Weight management clinic patients

ADA, American Diabetes Association; FPG, fasting plasma glucose; NR, not reported; OGTT, oral glucose tolerance test.

46 studies formally testing differences across means, 37 included a healthy weight comparison group, 32 of which reported significant increases in mean SBP with excess weight. Among studies with a healthy weight comparator, 8 specifically compared the healthy weight and overweight group or tested a trend, with 6 supporting significant increases in SBP with unhealthy weight. Seven other studies compared only groups with overweight and obesity or different classes of obesity, with 6 reporting significant increases in SBP with increasing adiposity. These findings and reported means add support to observed differences in prevalence by weight status group—that is, that SBP increases progressively with the degree of overweight or obesity. Studies reporting mean SBP also add to previous insights by providing additional comparisons within sex and age subgroups. Of the 18 studies including formal subgroup comparisons, 16 compared weight status categories within both males and females. Most reported significant differences across weight groups in the expected direction for both males and females. Only 3 studies reported comparisons for subgroups by age, and 2 of these only compared younger and older children and adolescents, although 2 studies also compared means by age for both males and females. Also, 1 study compared means for 4 age subgroups, ranging from 2 to 5 years to 16 to 19 years.[102] In addition to the general observation of increased SBP with age, significant differences in SBP were reported by weight status for all comparisons, regardless of age or sex. Although few studies addressed changes in SBP for very young children, it should also be noted that 2 other studies reported similar findings for cohorts 6 years or

TABLE 20 Prevalence of Metabolic Syndrome ($n = 16$)

First Author	Country	Ages (y)	*N*	Definition of abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Kim	Korea	10–19	931	3+ components		6.4	1.7	9.4	35.0			<.0001			
Halley Castillo	Mexico	7–24	1366	3+ components			4.7	52.8				<.000			
Galera-Martinez	Spain	12–16.9	379	NCEP ATP III		5.7%	1.5%	12.0%	28.6%			<.001			
Duncan	USA	12–19	991	3+ components		6.4	0	7.1	32.1			<.001			NHANES
Davis	USA	7–18	211	NCEP ATP III			1	15	41			<.001			Patients in rural Georgia
Vissers	Belgium	16–19	506	ATP III		4.1%	0.3%	2.8%	39.1%			<.001			
Ryu	Korea	12–13	1393	ATP III	Males	6.1	1.6	21.3				<.001			
					Females	5.0	1.6	22.3				<.001			
Perez	US (Puerto Rico)	12–18	101	3+ components			0	35.4				<.001			
Yoshinaga	Japan	6–12	471	3+ components	Males			8.9	16.2						
					Females			8.3	20.6						
Park	Korea	10–19	1554	3+ components			0.0	2.8	23.7			<.05			2007–2008 KNHANES
Laurson	USA	12–18.9	3385	3+ risks	Males	7.9	0.8	6.8	35.4			NR			NHANES
					Females	6.7	1.7	9.2	24.6			NR			
Cizmecioglu	Turkey	10–19	310	IDF		1.6		5.5	28.1			NR			
Park	Korea	12–19	664	3+ abnormalities			0.2	5.8	25.6						Pediatric endocrinology patients
Serap	Turkey	6–16	284	3+ risks			0		1.6						
Pan	USA	12–19	4450	3+ components			0.9	2.1	14.5			<.0001 OB			NHANES 1999–2002
Bacopoulou	Greece	12–17	1578	IDF criteria		2.6	0.1	2.9	31.6					IOTF thresholds	School

IOTF, International Obesity Task Force; KNHANES, Korean National Health and Nutrition Examination Survey; NR, not reported; OB, obese.

younger.[46,105] Combined prevalence and mean tables for SBP support progressive increases in SBP and the prevalence of elevated SBP with increasing adiposity. The available studies further suggest that this finding holds in males and females and is likely generalizable across age, although limited evidence is still available relevant to younger subgroups.

Diastolic Blood Pressure

A total of 19 studies examined the prevalence of abnormal diastolic blood pressure (DBP),[5,7,8,10,13,15,18,24,25,35–39,63,97,98,100,101] whereas 51 provided mean values for DBP.[5,7,8,10,13,18,22,24,32,33,35,36,39,40,42–46,48–50,54–56,59–66,68,71–75,77,79,83,90,97,99,102,103,105–108] Sixteen studies reported on the prevalence of abnormal DBP across weight groups in cohorts ranging from 3 to 19 years of age, with 7 of the studies conducted in the United States (Table 23). The majority of the studies (13 of 19) defined abnormal DBP as a DBP >95th percentile for age, height, and biological sex. Five studies defined abnormal DBP as DBP >90th percentile, and 1 study from Canada defined abnormal DBP as DBP >75th percentile. Of the studies that defined abnormal DBP as >95th percentile and compared prevalence across children with healthy weight, overweight, and obesity, the prevalence of abnormal DBP ranged from 0% to 9.4% among children with healthy weight and increased to 4% to 20% among children and adolescents with class 1 obesity. Of the studies that defined abnormal DBP as >90th percentile, prevalence of abnormal DBP for children with normal weight ranged from 4% to 9.7%, which increased to 9% to 29.4% (among males) for children with class 1 obesity. Across all studies, age ranged from 3 to 19 years, with only 2 studies examining abnormal DBP by age group.[24,25]

TABLE 21 Prevalence of Abnormal Systolic Blood Pressure ($n = 21$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Ice	USA	9–13	29286	>95th			7.9	13.4	23.4			<.01			Appalachian population
Davis	USA	7–18	211 (160 for lipids)	>90th			6	16	45			<.001			Rural Georgia
Bindler	USA	11–14	151	>90th			2.9		17.1			.003			
Turconi	Italy	14–17	532	>95th	Males		10.1	35.4							
					Females		4.8	22.7							
Skinner	USA	6–17	NR	>95th		3.4	1.6	4.5	9.0			<.01			NHANES 2001–2002
Simsek	Turkey	Mean 10.8	115	>95th			0		13.3			<.001		OB >97th	
Puri	USA	10–18	198	>95th			3	28				.002			General pediatrics and endocrinology patients
Maggio	Switzerland	Mean 8.8	66	>95th			0		20.5			.029		OB >97th	
Skinner	USA	3–19	8579	>95th				3.22	5.02	8.52	11.10	<.001			NHANES 1999–2012
Maximova	Canada	6–19	2087	>75th	6–11 y		18	33.2				NR			
					12–19 y		18	38.2				NR			
Krzyzaniak	Poland	10–18	4904	≥90th, 3 d	Males	11.6	7.8	18.8	45.1			.000			
					Females	11.8	8.9	21.1	50.9			.000			
Stray-Pederson	Norway	15–18	2156	>95th		16.6%	ref	OR = 3.8	OR = 28.3						
Kim	Korea	10–18	1412	>95th	1998 KNHANES		9.1	20.0	28.9			<.05			
			1158		2001 KNHANES		5.2	9.6	22.7			<.05			
Botton	France	8–17	452	>95th			3.2	13			0.01			OW >90th	
Harding	UK	11–13	6407	>95th	Males	2.7	OR = 1.0	OR = 2.50	OR = 4.31			<.05			
					Females	3.8	OR = 1.0	OR = 3.39	OR = 5.68			<.05			
Serap	Turkey	6–16	284	>95th	Males		3.8		19.1			<.001			Pediatric endocrinology patients
					Females		4.3		16.5			<.001			
Messiah	USA	8–14	1698	>90th	8–11 y		4.97	14.81	19.02						
					12–14 y		2.26	11.36	20.87						
Lambert	Canada	9–16	3613	>90th	Males		16.5	28.8	39.6			<.0001			
				>90th	Females		11.8	27.4	40.6			<.0001			
Avnieli Velfer	Israel	2–18	1027	>95th	Males				32.5	41.5		.03		OB 95th, SO 120%/95th	Obesity clinic patients
					Females				32.4	46.6		<.001		OB 95th, SO 120%/95th	Obesity clinic patients
Hadjiyannakis	Canada	5–17	847	>95th		14			10	9	26	NR			Pediatric weight management program patients
Stolzman	USA	12–17	62	>90th			3		13			NS			Community recruitment

NR, not reported; NS, not significant; OB, obese; OR, odds ratio; OW, overweight; SO, severe obesity.

TABLE 22 Mean Systolic Blood Pressure (n = 52)

First Author	Country	Ages (y)	N	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	P	Notes	Weight definitions	Population Info
Avnieli Velfer	Israel	2–18	1027	mm Hg	Males				116	120		<.001		OB 95th, SO 120%/95th	Obesity clinic patients
					Females				116	116		.01		OB 95th, SO 120%/95th	Obesity clinic patients
Hadjiyannakis	Canada	5–17	847	mm Hg		116			113	117	120	NR			Pediatric weight management program patients
Kim	Korea	12–13	120	mm Hg			100	110				<.001			School based
Kloppenberg	Denmark	Median 12	3978	z-score	Males		1.23	1.55	1.75			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
					Females		1.25	1.24	1.75			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
Sougawa	Japan	12–18	1679	mm Hg	Males	114.3	112.8	121.0				<.001			Schools
					Females	105.8	104.8	113.3				<.001			Schools
Stolzman	USA	12–17	62	mm Hg			106.9		114.1			<.05			Community recruitment
Tsao-Wu	USA	2–5	154	percentile					66.9	60.1	66.8	NR			Weight management clinic patients
		6–11	880	percentile					53.9	59.9	67.4	NR			Weight management clinic patients
		12–17	1004	percentile					67.4	64.3	69.8	NR			Weight management clinic patients

HW, healthy weight; NR, not reported; OB, obese; OW, overweight; SO, severe obesity.

Two studies reported data from NHANES, the larger study of which (n = 8579) showed a significant increase in prevalence of abnormal DBP among children with increasing weight status (overweight and class III obesity).[37,38] For studies that examined significant differences in abnormal DBP across weight categories (13 of 19), 8 showed a significantly higher prevalence of abnormal DBP among children in a higher weight category compared with children in a lower weight category. Among the largest study (n = 29 286), prevalence increased from 9.4% in children with healthy weight to 20.1% in children with class I obesity.[15]

A total of 51 studies examined mean DBP (Table 24); 28 of them reported significant differences in mean DBP by weight status. Notably, of the population-based studies, none reported consistently higher DBP among those with obesity. One reported higher DBP among females[8] and another only in 11- to 18-year-old males.[50] Studies showing a significant difference in DBP by weight status indicated a stepwise increase in DBP as weight increased from healthy weight to obesity. Only 1 school-based study included severe obesity, reporting significantly higher DBP in children with class II obesity compared with those with class I obesity.[22] With the exception of some clinic samples, the mean reported DPB was <70 mm Hg, even among children with obesity.

Hypertension

An additional 61 studies examined the prevalence of hypertension (Table 25).[6,7,9,11–14,16,17,20–23,26,29–33,37,40,42,77,78,80–83,92,102,108–137] All studies reported on the prevalence across weight groups, with the majority of studies comparing

TABLE 23 Prevalence of Abnormal Diastolic Blood Pressure ($n = 19$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Weight Definitions	Population Info
Ice	USA	9–13	29286	>95th			9.4	12.8	20.1			<.01		
Davis	USA	7–18	211	>90th			4	0	9			NS		
Bindler	USA	11–14	151	>90th			9.7		22.0			.050		
Turconi	Italy	14–17	532	>95th	Males		4.8	6.1						
					Females		9.2	6.8						
Skinner	USA	6–17	NR	>95th		1.8	1.4	0.8	4.0			NS		NHANES 2001–2002
Simsek	Turkey	Mean = 10.8	115	>95th			0			14.7		<.001	OB >97th	
Puri	USA	10–18	198	>95th			0	4				NS		General pediatric and endocrinology patients
Skinner	USA	3–19	8579	>95th				0.45	1.20	0.60	4.66	.004		NHANES 1999–2012
Maximova	Canada	6–19	2087	>75th	6–11 y		20.4	27.6				NR		
					12–19 y		21.9	29.3				NR		
Krzyzaniak	Poland	10–18	4904	≥90th, 3 d	Males	7.4	6.5	13.8	29.4			.000		
					Females	10.1	8.4	16.8	25.4			.000		
Stray-Pederson	Norway	15–18	2156	>95th		0.4%	ref	OR = 1.0	OR = 5.1					
Kim	Korea	10–18	1412	>95th	1998 KNHANES		5.4	8.8	13.2			<.05		
			1158		2001 KNHANES		3.2	3.8	4.1			NS		
Botton	France	8–17	452	>95th			0.7	2.6			0.31		OW >90th	
Harding	UK	11–13	6407	>95th	Males	5.1	OR = 1.0	OR = 2.50	OR = 5.74			<.05		
					Females	3.7	OR = 1.0	OR = 1.66	OR = 5.05			<.05		
Serap	Turkey	6–16	284	>95th	Males		1.9		12.4			<.001		Pediatric endocrinology patients
					Females		2.1		17.5			<.001		
Messiah	USA	8–14	1698	>90th	8–11 y		3.23	7.59	10.39					
					12–14 y		4.93	4.56	7.63					
Avnieli Velfer	Israel	2–18	1027	>95th	Males				10.7	18.5		.01	OB 95th, SO 120%/95th	Obesity clinic patients
					Females							NS	OB 95th, SO 120%/95th	Obesity clinic patients
Hadjiyannakis	Canada	5–17	847	>95th		8			7	6	10	NR		Pediatric weight management program patients
Stolzman	USA	12–17	62	>90th			3		6			NS		Community recruitment

KNHANES, Korean National Health and Nutrition Examination Survey; NR, not reported; NS, not significant ; OB, obese; OR, odds ratio; OW, overweight; SO, severe obesity.

TABLE 24 Mean Diastolic Blood Pressure ($n = 51$)

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Avnieli Velfer	Israel	2–18	1027	mm Hg	Males				66.5	70		.003		OB 95th, SO 120%/95th	Obesity clinic patients
					Females				67.5	67.5		.31		OB 95th, SO 120%/95th	Obesity clinic patients
Hadjiyannakis	Canada	5–17	847	mm Hg		70			69	70	72	NR			Pediatric weight management program patients
Kim	Korea	12–13	120	mm Hg			60	60				.039			School based
Kloppenberg	Denmark	Median 12	3978	*z*-score	Males		0.09	0.21	0.54			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
					Females		0.40	0.5	0.78			<.001	*P* value includes differences by sex	HW: <90th, OW: 90th–99th, OB: >99th	Weight management clinic + population-based
Sougawa	Japan	12–18	1679	mm Hg	Males	60.5	59.7	64.3				<.001			Schools
					Females	60.8	60.3	65.4				<.001			Schools
Stolzman	USA	12–17	62	mm Hg			71.9		74.1			NS			Community recruitment
Tsao-Wu	USA	2–5	154						69.5	70.1	71.1	NR			Weight management clinic patients
		6–11	880						51.3	56.1	60.9	NR			Weight management clinic patients
		12–17	1004						55.6	56.8	62.9	NR			Weight management clinic patients

HW, healthy weight; NR, not reported NS, not significant; OB, obese; SO, severe obesity.

hypertension prevalence between children of healthy weight and those with obesity. Fifteen studies reported on prevalence of hypertension among children and teenagers with increasing obesity severity (class I to class III), whereas 4 studies examined prevalence of hypertension among children with healthy weight and overweight. All studies except 1[33] that examined the association between hypertension and weight group showed significant differences in the prevalence of hypertension between weight categories, with increasing prevalence of hypertension with increasing weight category. The studies were conducted in various countries; 34 reported US data. The majority of the studies ($n = 37$) defined hypertension as SBP or DBP >95th percentile for age, biological sex, and height. Of these studies, hypertension prevalence for children of healthy weight across age groups ranged from 1% to 14% compared with 4% to 30% for children with obesity. As expected, prevalence was lowest in early childhood (4% to 6% for children with healthy weight and 8% for children with obesity) and highest among teenagers (2% to 10% for teenagers with healthy weight and 3% to 39% among teenagers with obesity). Studies that defined hypertension as SBP or DBP >90th percentile for age, sex, and height ($n = 13$) showed similar prevalence both for children with healthy weight (5% to 12%) and those with obesity (18% to 24%) across all age groups. For studies ($n = 2$) with the large population samples ($n > 20\,000$) of children ages 6 to 19 years and the most rigorous definition of hypertension (SBP or DBP >95th percentile on 3 repeated measures), hypertension prevalence was ~1% for children with healthy weight and ~5% for children with

TABLE 25 Prevalence of Hypertension ($n = 61$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Koebnick	USA	6–17	237248	>95th 3 times		2.1	0.9	2.0	3.8	9.2		<.05			
King	USA	5–18	1121	Assume >90th	5–8 y white		6	20				<.05			
					5–8 y AA		10	28				<.05			
					9–12 y white		8	26				<.05			
					9–12 y AA		14	28				<.05			
					13–18 y white		12	47				<.05			
					13–18 y AA		20	38				<.05			
Kim	Korea	10–19	931	<90th		13.4	11.6	15.9	23.5			.0070			
Israeli	Israel	16–19	560588	>120/80	Males		56.5	64.7	66.4			<0.01			Army recruitment exam
					Females		34.3	46.9	55.6			0.01			
Halley Castillo	Mexico	7–24	1366	>90th			8.4%	18.4%				<.000			Central Mexican
Ice	USA	Mean 10.8	23263	>95th		20.0	14.4	20.8	29.8		51.0	<.05			
Genovesi	Italy	5–11	5131	>95th	Males	3.1	0.8	5.8	21.5			<.001			
					Females	3.8	1.9	5.5	20.1			<.001			
Falkner	USA	2–19	6331	>95th	2–5 Males	6.2	5.7	6.6	7.8						
					2–5 Females	4.3	3.4	4.4	7.9						
			6399		6–10 Males	6.3	4.6	6.6	10.8						
					6–10 Females	6.5	4.3	9.0	11.2						
			4923		11–15 Males	9.9	6.6	8.8	20.0						
					11–15 Females	9.5	5.5	7.8	19.8						
			965		16–19 Males	11.8	9.6	13.3	18.5						
					16–19 Females	10.1	4.6	16.3	20.8						
Gokler	Turkey	14–18	3918	>95th	Urban	9.7	ref	OR = 2.25	OR = 3.88			<.05			
					Rural	2.9	ref	OR = 5.71	OR = 22.09			<.05			
Duncan	USA	12–19	991	>90th		8.0	4.4	6.0	25.6			NR			NHANES 1999–2000
Cheung	USA	10–19	21062	>95th 3 times			1.6	2.6	6.6			<.001			
Bloetzer	Switzerland	Mean 12	5207	>95th		2.2	1.4	3.8	14.9			<.001			
Bell	Australia	6–13	283	>95th			3.4	7.3	19.0			.012			
Bindler	USA	11–14	151	>95th			11.7		36.6			.001			
Wirix	The Netherlands	4–17	1407	>95th				3.5	3.5	7.8					
Turchiano	USA	14–18	1185	>90th			11.8	25.6	30.3			<.001			Youth of urban minoritized groups
Stiefel	USA	14–18	7705	>95th		21.2%	OR = 1		aOR = 2.33			<.05			Student athletes
Skinner	USA	6–17	NR	>95th		4.8	2.8	5.0	12.6			<.01			NHANES 2001–2002
Propst	USA	Mean 12.7	1111	>95th					33.2		36.7	.2989		SO >99th	Pediatric endocrinology patients
Perez	USA (Puerto Rico)	12–18	101	>90th			15.1	35.4				.018			
Ovbiagele	United States	14–21	603	>95th, 140/90		14%	8%	15%	31%						
Nguyen	USA	3 to 17	691	NHBP		17.5	12	23	25	38		NR			
Moore	USA	5–17	745	>90th		18.4%	aOR = 1.0	aOR = 1.87	aOR = 3.76			<.05			
Moore	USA	5–17	1829	>95th	Males	14.5%	OR = 1.0	aOR = 2.48	aOR = 4.33			<.05			
					Females	13.0%	OR = 1.0	OR = 1.69	OR = 4.01			<.05 OB			
Marcus	USA	Mean 11.2	1305	>90th					23.8	37.4		<.0001			
Michalsky	USA	13–19	242	>95th, 140/90		49.0			38.6	56.6	61.2	<.01		1: BMI 30–50, 2: BMI 50–60, 3: BMI >60	Bariatric surgery patients
Mavrakanas	Greece	4–10	572	>95th		7.9	4.1		21.1			NR			
Meininger	USA		1070	>90th			4.7	7.3	19.2			<.05			
Yoshinaga	Japan	6–12	471	>120–130, >70–80	Males			10.7	24.9						
					Females			11.7	26.5						
Voorhees	USA	11–13	426	>90th		12%	1.0	1.2	9.7			<.05 OB			Hmong + white patients
Schwandt	Germany	3–18	22051	>95th	Males		5.7	10.4	18.6						
					Females		5.0	9.1	24.0						
Rivera-Soto	USA (Puerto Rico)	Mean 8.9	249	>95th		12.6%	7.9%	18.3%				<.05			
Redonco	USA	2–17.9	11348	Physician diagnosed		1%	OR = 1.0	OR = 1.0	OR = 3.5			<.05 OB			Patients with type 1 diabetes mellitus

TABLE 25 Continued

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Menghetti	Italy	6–17	2007	>95th		5.5 F, 6.9 M	OR = 1.0		OR = 4.22			<.05			
Li	USA	3–19	20905	>95th		3.11	2.06	3.09	5.46	9.85		<.05			
Jayawardene	USA	12–19	23438	>95th, 140/90	Males		2.5	3.6	8.0	9.7		NR			NHANES 1999–2014
					Females		2.0	2.9	3.3	8.4		NR			
Polat	Turkey	7–12	2826	>95th			2.5	10.9	32.8			<.001			
Park, S	Korea	10–19	1554	>130/85			2.1	6.1	10.8			<.05			2007–2008 KNHANES
Onsuz	Turkey	6–15	2166	>95th		9.0%	OR = 1.0	OR = 1.6	OR = 2.8			<.05		WHO reference standards	
Laurson	USA	12–18.9	3385	Joliffe standards	Males		6.6	11.5	22.7			NR			NHANES
					Females		2.9	2.2	9.0			NR			
Bar Dayan	Israel	17	76732	>140/90	Males	0.4%	0.2%	0.75%	3.5%		8.3%	<.001			Reporting for military service
					Females	0.074%	0.04%	0.08%	0.8%		4.2%	<.001			
Acosta	USA	Mean 15.4	1010	>95th 3 times		2.5%	OR = 1	aOR = 4.88	aOR = 38.37			<.05			
Levin	Israel	17	1 021 211	>180/110	Males		0.03		0.26			<.001	Severe hypertension		Reporting for military service
					Females		0.03		0.16			.053			
Park	Korea	12–19	664	130/85			5.3	7.1	16.2						NHANES
Caserta	Italy	11–13	646	>90th	Males		9.0	13.3	13.2			NS			
					Females		9.5	10.1	20.7			NS			
Marcus	USA	Mean 11.8	6358	>95th			8.9	9.8	20.3		31.6	<.001			
Maldonado	Portugal	4–18	5381	>95th		12.8%	OR = 1.0	aOR = 1.50	aOR = 1.94			Both <.05			
Chiolero	Switzerland	6th grade	5207	>95th		11.4%	OR = 1.0	OR = 2.7	OR = 12.0			<.001 Both			
Del- Rio-Navarro	Mexico	6–13	1819	>95th	Males		1.7	5.3	10.0			<.05			
					Females		2.9	7.4	11.2			<.05			
Pan	USA	12–19	4450	>90th		20.1%	15.8	20.1	33.9			<.05 OB			NHANES 1999–2002
Nur	Turkey	14–18	1020	>95th repeated		4.4	4.0	18.4				.00			
Salvadori	Canada	4–17	675	>95th			4.0	13.1	19.5						
Adams	USA	14–19	4263	≥120/80		31.9		61.7				<.0001			Rural population
Fyfe-Johnson	USA	8–17	300	>90th percentile		33	8	31		62					Clinic patients
Gunes	USA	11–18	363	>95th percentile	Males			10.7	24.6			.111			Adolescent clinic patients
					Females			20.6	29.5			.198			Adolescent clinic patients
Hadjiyannakis	Canada	5–17	847	>95th SBP or DBP		4			3	3	7	NR			Pediatric weight management program patients
Jackson	USA	12–19	2440	AAP Guidelines		4.11	1.88	1.86	5.89	14.7		NR			NHANES
Lennerz	Germany	14–24	431	>95th					42	55	64	<.001			Weight management + some community
Rodrigues	Portugal	6–9	1555	>95th percentile	Males	3.1	1.0 (ref)	aOR = 1.26, *P* = .69	aOR = 3.40, *P* = .08						Schools
				>95th percentile	Females	4.3	1.0(ref)	aOR = 2.43, *P* = .03	aOR = 5.26, *P* < .01						Schools
				"High-normal," 90th-95th	Males	3.4	1.0	aOR = 2.34, *P* = .09	aOR = 6.13, *P* < .01				Hypertension in separate submission		Schools
				"High–normal," 90th–95th	Females	5.6	1.0(ref)	aOR = 1.28, *P* = .53	aOR = 4.25, *P* < .01						Schools
Silverio	USA	2–17	421	ICD-10			0.93		5.7			.006			Family medicine clinic patients
Tsao-Wu	USA	2–5	154	>95th percentile					0	0	0	NR			Weight management clinic patients
		6–11	880						0	1.6	3.4	NR			Weight management clinic patients
		12–17	1004						1.6	2.2	7.7	NR			Weight management clinic patients

aOR, adjusted odds ratio; NR, not reported; NS, not significant; OB, obese; OR, odds ratio; OW, overweight; SO, severe obesity.

TABLE 26 Prevalence of Abnormal ALT ($n = 8$)

First Author	Country	Ages (y)	*N*	Subgroup (eg, M/F)	Definition of Abnormal	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Kopping	USA	Mean 9.6	226	No	>90th	14.9	OR = 1.0		OR = 2.51			.009			
Bell	Australia	6–13	283	No	>30 U/L		3.8	9.0	31.6			<.001			
Salvatore	USA	3–18	101	No	>36				16.7	41.4	38.2	.082			
Purcell	Mexico	8–19	1262	Yes	>40 U/L		3.9	22.9	38.1			<.001			
Booth	Australia	14–17	496	Males	>32 U/L	9.0	2.9	19.7	42.1						
				Females	>20 U/L	5.3	3.0	19.4	0.0						
Lennerz	Germany	14–24	431		>50 U/L				15	26	30	.002			Weight management clinic patients + some community
Seth	USA	Mean 13	767		>80 U/L			13	25	31	36	.002			Steatohepatitis clinic patients
Tsao-Wu	USA	2–5	154		>22 U/L females; <26 U/L males				6.9	6.4	6.4	NR			Weight management clinic patients
		6–11	880						6.6	7.0	10.5	NR			Weight management clinic patients
		12–17	1004						6.4	7.1	9.0	NR			Weight management clinic patients

NR, not reported; OR, odds ratio.

obesity, increasing to 9% for children with class II obesity.

Liver Function

Alanine Aminotransferase

A total of 8 studies examined the prevalence of abnormal alanine aminotransferase (ALT),[6,34,67,81,83,104,138,139] and 8 provided mean values for ALT.[6,13,53,54,66,67,70,74] Three additional studies examined the prevalence of nonalcoholic fatty liver disease (NAFLD).[5,67,70] The 8 studies examining the prevalence of abnormal ALT (Table 26) used a range of definitions from >20 U/L to >40 U/L and each of the 5 studies used a different cut point. Four studies found significant differences in prevalence of abnormal ALT between children with healthy weight and children with obesity.[6,67,104,139] Two studies included only children with obesity; 1 found no significant difference between class I, II, or III obesity in prevalence of abnormal ALT,[34] whereas another did.[81] Two additional studies did not provide statistical analysis of prevalence.[83,138]

Four studies provided mean values for ALT (Table 27). Three studies compared mean ALT between children with healthy weight and children with overweight and obesity and found a significant difference in mean ALT between groups.[6,53,54] A study of children with Down syndrome found no difference between mean ALT in children with healthy weight and children who were overweight.[70] Four studies compared mean ALT in children with overweight and class I, II, III obesity, and 3 found significant differences in mean ALT between children with overweight and children with obesity.[66,67,74]

Aspartate Aminotransferase and NAFLD

A total of 2 studies examined the prevalence of abnormal aspartate aminotransferase (AST),[34,138] whereas

TABLE 27 Mean ALT ($n = 8$)

First Author	Country	Ages (y)	N	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	P	Notes	Weight definitions	Population Info
Bell	Australia	6–13	283	UI/L			15.94	21.15	24.90			<.002			
Zabarsky	USA	7–20	2244	U/L				17	24	25	29	<.001	IV = 26		
Valentini	Italy	5–18	84	UI/L			27.57	28.74				NS			Patients with Down syndrome
Salawi	Canada	6–19	345	U/L				24.9			31.6	.001			
Hadjiyannakis	Canada	5–17	847	IU/L		25.0			21.0	25.5	30.5	NR			Pediatric weight management program patients
Higgins	Canada	5–19	1332	U/L	Males		17	189	23			<.05		OW = 85th–97th %ile, OB > 97th	Community
					Females		16	16	17			NS		OW = 85th–97th %ile, OB > 97th	Community
Kim	Korea	12–13	120	IU/L			11	19				<.001			School based
Seth	US	Mean 13	767	U/L				41	59	61	64	.001			Steatohepatitis clinic patients

NR, not reported; NS, not significant; OB, obese; OW, overweight.

4 provided mean values for AST.[53,54,67,70] Of the 2 studies examining the prevalence of abnormal AST (Table 28), 1 from a pediatric endocrine clinic found no significant difference abnormal AST among children with class I, II, or III obesity.[34] The other study did not provide statistical analysis of prevalence.[138] A study of children with Down syndrome showed a significant difference between mean AST (Table 29) for children with healthy weight (35.00 U/L) and children with overweight (30.12 U/L).[70] This same study showed almost double the prevalence of NAFLD (Table 30) in children who were overweight. Another study showed no significant differences by obesity severity for mean AST or NAFLD.[67] A third study demonstrated greater prevalence of NAFLD among those with severe obesity, compared with class I obesity.[5]

Obstructive Sleep Apnea

Eight studies examined the prevalence of obstructive sleep apnea (OSA) (Table 31).[5,6,13,83,135,140] By parent report, there was no significant difference in the prevalence of OSA among children with healthy weight, overweight, or obesity.[6] Studies using polysomnography results show increasing prevalence of OSA as obesity severity increases.[5,83,140,141] Studies using diagnosis of OSA also find increased OSA as obesity worsens.[135,142]

Asthma

A total of 26 studies reported the prevalence of asthma (Table 32).[135,142–166] Virtually all studies used parent-reported or self-reported asthma, although they varied in the reporting of current asthma or ever having asthma, as well as specifically asking for report of a physician diagnosis. Most studies showed significantly higher asthma in children with obesity compared with children healthy

TABLE 28 Prevalence of Abnormal AST ($n = 2$)

First Author	Country	Ages (y)	*N*	Subgroup (eg, M/F)	Definition of Abnormal	Total	Healthy	Overweight	Weight Definitions: Class I	Class II	Class III	*P*	Notes	Population Info
Salvatore	US	3–18	101		>46			0	13.3	31.0	11.8	.099		Pediatric endocrinology patients
Booth	Australia	14–17	496	Males	>33 U/L	7.2	4.3	11.5	26.3					
				Females	>26 U/L	4.9	4.2	9.7	0.0					

weight. One nationally representative US study of children 2 to 19 years of age showed 15.7% children with obesity had asthma, compared with 10.3% of children with healthy weight.[144] Only 2 studies, both of a health plan population, included children with severe obesity, demonstrating a stepwise increase in asthma incidence and prevalence as weight status increased.[148,149]

Depression

A total of 6 studies examined the prevalence of depression,[6,13,81,135,167,168] whereas 3 provided mean values for depression inventories.[167,169,170] The studies of the prevalence of depression (Table 33) showed conflicting findings. Three, based on Center for Epidemiologic Studies Depression Scale (CES-D) scores, self-report, and *International Classification of Diseases, 10th Revision* (ICD-10), codes showed no difference by weight status.[81,135,167] Two others, using parent report and depression inventory, showed significantly higher depression as weight status increased.[6,168] The mean values for depression inventories (Table 34) were more consistent; 2 demonstrated significantly higher scores at higher weight status,[169,170] whereas another smaller study examining class III obesity did not.[167]

DISCUSSION

Overall, across most laboratory values, diagnoses, and age groups, obesity was associated with increased prevalence of abnormal values and/or greater comorbidity prevalence. In addition, more severe degrees of obesity were associated with greater abnormalities, in concordance with prior evidence.[38] However, population-based data showed smaller differences, compared with samples drawn from clinical care. Additionally, these population-based samples typically showed that the great majority of children have normal values, even children with obesity, although abnormal values were more frequently observed in the higher age categories.

Implications for Lipid Screening

In general, prevalence of abnormal lipid values varied with weight classification. For HDL cholesterol, values decreased as weight classification increased, with prevalence of abnormal HDL approximately 10% in children with healthy weight and 40% for children with obesity. There were not enough data to determine whether prevalence of abnormal HDL varied within the obesity classification by severity. Mean HDL values also showed a decrease (worsening) with increasing weight classification. Similarly, the prevalence of abnormal LDL cholesterol also increased with increasing weight classification.

The prevalence of abnormal TG increased with increasing weight classification, with the magnitude differing depending on the abnormal cutoff value chosen. Mean TG also increased as weight classification increased.

Abnormal total cholesterol values were more common in children with obesity than in children with healthy weight. There was also a significant difference in mean total cholesterol between children with healthy weight and children with obesity. In these studies, a variety of cutoffs for abnormal lipid values were used, but although prevalence varied with the cutoffs, having obesity was in all studies associated with a higher prevalence of abnormal lipid levels.

Choosing the cutoff point considered to be clinically relevant is important to understanding the potential application of these data. For example, for the studies reporting TG abnormalities, many studies selected >110 mg/dL, whereas others selected >130 mg/dL or >150 mg/dL. The prevalence varies considerably

TABLE 29 Mean AST ($n = 4$)

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight definitions	Population Info
Valentini	Italy	5–18	84	UI/L	No		35.00	30.12				0.03			Patients with Down syndrome
Higgins	Canada	5–19	1332	U/L	Males		26	24	25			NS		OW = 85th–97th %ile, OB > 97th	Community
					Females		23	23	23			NS		OW = 85th–97th %ile, OB > 97th	Community
Kim	Korea	12–13	120	IU/L			18	20.5				0.004			School based
Seth	USA	Mean 13	767	U/L				29	35	35	37	0.16			Steatohepatitis clinic patients

NS, not significant; OB, obese; OW, overweight.

depending on the cut-point selected. Multiple organizations, including the National Lipid Association and the Endocrine Society, indicate ≥150 mg/dL as elevated TG, and other organizations, such as the American Academy of Pediatrics and the American Heart Association, indicate that the value depends on age. High TG is considered to be >100 mg/dL for children younger than 10 years and >130 mg/dL for children 10 years and older. This cutoff is important to understand patterns of high TG in children, especially when the study samples included both younger and older children. An example of the effect of the cutoff value used on prevalence differences can be seen by 2 studies conducted by Ice et al. When conducting their study with a large sample of children ages 9 to 13 years and using the cutoff of >110 mg/dL, the prevalence of high TG was 14.2% (healthy weight), 29.8% (overweight), and 49.1% (obese). However, in their other study with a large sample size of children with a mean age of 10.8 and the cut-point of >150 mg/dL, the prevalence of abnormal TG was 4.4% (healthy weight), 12.4% (overweight), and 25% (obese). There were not enough data to determine whether the prevalence of abnormal values varied within the classification of obesity.

Implications for Glucose Screening

Most of the studies that reported prevalence or mean values related to glucose metabolism observed that children and adolescents with obesity had a multifold higher prevalence of abnormal glucose, insulin, and other glucose-related values compared with children of healthy weight. These differences by weight status were reported in preschool-aged children up to adolescents. However, there was limited information on the extent to which glucose and related measures varied across categories of obesity. A few studies noted a dose-response relationship between increasing obesity classification and fasting insulin level, but many studies only compared children with healthy weight versus children with obesity, so it is less clear when glucose metabolism aberrations occur or worsen across specific severities of obesity.

There was a wide range of prevalence of abnormal HbA1c (1% to 17%), abnormal glucose (0% to 26%), abnormal insulin (0% to 80%), elevated HOMA-IR (0% to 71%), and metabolic syndrome (0% to 41%), depending on the weight status and age range of the sample and the definition used to classify abnormal values. Surprisingly, there were few studies reporting prevalence of prediabetes (1 study) or overt diabetes mellitus (6 studies) in this age range. There was great variability of mean glucose-related values within samples. However, for the most part, the reported subgroups did not have a majority of participants classified as abnormal, nor did the subgroups have a mean glucose or glucose-related value outside of the healthy range. An exception is a sample of Canadian youth ages 9 to 16 years with obesity that had an 80% prevalence of abnormal insulin, and 71% of adolescents with class III obesity entering a bariatric surgery program had abnormal HOMA-IR.[26] The samples with higher prevalence and higher abnormal values were typically clinic-based, including from subspecialist clinics and/or weight management specialty clinics, including a bariatric surgery program. Among these more advanced cases of obesity, elevated insulin level was consistently high and was not differentiated by class of obesity.

There were no consistent sex differences in glucose-related measures. In general, glucose abnormalities increased in prevalence with increasing age,

TABLE 30 Prevalence of NAFLD (n = 3)

First Author	Country	Ages (y)	N	Subgroup (eg, M/F)	Definition of Abnormal	Total	Healthy	Overweight	Class I	Class II	Class III	P	Notes	Weight Definitions	Population Info
Valentini	Italy	5–18	84	No	Diagnosis	64.3	45	82							Patients with Down syndrome
Seth	US	Mean 13	767		Stiffness >2.71 kPa			20	22	27	30	.13			Steatohepatitis clinic patients
Avnieli Velfer	Israel	2–18	1027	Males	Sonographic evidence of fatty infiltration				4.1	19.7		<.001		OB 95th, SO 120%/95th	Obesity clinic patients
				Females					4.9	18.6		<.001		OB 95th, SO 120%/95th	Obesity clinic patients

OB, obese; SO, severe obesity.

although there were noticeable elevations by obesity status in samples as young as preschool-aged children. There was a dearth of prevalence data available on nationally representative datasets, particularly for HOMA-IR. The presence of glucose abnormalities among youth with obesity supports the need for screening, but given the wide variability observed across population and clinic-based studies, taking into account other risk factors may be important to avoid unnecessary tests.

Implications for Blood Pressure Screening

The prevalence of elevated SBP was higher in children with overweight and obesity compared with children with healthy weight. This association was true in both males and females. Mean values of SBP were significantly different between children with healthy weight and children with overweight and obesity. Within the obesity classification, mean SBP increased with increasing BMI. The association between SBP and BMI was observed in all age groups study and in both males and females. DBP prevalence also varied with BMI across age groups and increased within increasing obesity classifications. Hypertension (defined as elevated SBP or DBP) prevalence increased with increasing BMI. Prevalence also increased with age.

The association of increased prevalence of SBP, DBP, and hypertension in children in children with overweight and obesity in addition to increased mean SBP and DBP supports BP screening these groups.

Implications for Other Screening

There are a limited number of studies examining prevalence of abnormal AST and ALT. Increases in prevalence were found between children with healthy weight and children with obesity. Two studies examined prevalence within obesity classifications and found no difference in prevalence. Differences in mean ALT were found between children with normal weight and those with obesity in addition to increases in mean ALT with increasing obesity classification.

One study of mean AST did not find any difference within obesity classification. Only 1 study documented prevalence of NAFLD, pointing to an important area of future research, particularly because this study observed a doubled prevalence of NAFLD in children with overweight compared with children with normal weight. Further, only 1 study reported prevalence of OSA. With so few data, it is difficult to make screening recommendations.

Asthma is consistently associated with obesity in children at a variety of ages. In contrast to the previously discussed comorbidities, however, asthma presents symptomatically.

Therefore, it is unclear whether the data demonstrate a need for increased asthma screening.

Data regarding the relationship between obesity and depression are particularly limited.

These data suggest there may be a relationship between obesity depression but are not adequate to make statements regarding the need for screening, specifically for children with obesity. All children 12 years and older should be screened for depression, regardless of weight status.[171]

Limitations of Current Research

There are several limitations of the current literature that warrant attention. First, the cross-sectional design of these studies prevented an examination of within-individual changes in comorbidity prevalence as

TABLE 31 Prevalence of obstructive sleep apnea ($n = 8$)

First Author	Country	Ages (y)	*N*	Subgroup (eg, M/F)	Definition of Abnormal	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight definitions	Population Info
Andersen	Denmark	7–18	172		Apnea–Hypopnea Index ≥2		9.1	44.6				.0002		Overweight 90th, obesity 99th	Clinic patients
Avnieli Velfer	Israel	2–18	1027	Males	AHI >1				41	17.3		<.001		OB 95th, SO 120%/95th	Obesity clinic patients
				Females					1.3	13.9		<.001		OB 95th, SO 120%/95th	Obesity clinic patients
Frye	US	5–12	421		Persistent SDB over 8 y		1.0 (ref)	aOR = 2.00	aOR = 2.75			OW = .101, OB <.001			Population-based
Hadjiyannakis	Canada	5–17	847		Chart review	9			4	8	17	NR			Pediatric weight management program patients
Kelly	UK	5–8	9443		Diagnosis (3 y following BMI)		1.0 (ref)		aOR = 2.50			<.05			Population based
Silverio	US	2–17	421		ICD-10		0.46		2.8			.05			Family medicine clinic patients
Tsao-Wu	US	2–5	154		AHI >1				3.4	8.5	12.8	NR			Weight management clinic patients
		6–11	880						1.7	5.4	11.4	NR			Weight management clinic patients
		12–17	1004						4.4	4.4	13.6	NR			Weight management clinic patients

AHI, xxx; aOR, adjusted odds ratio; NR, not reported; OB, obese; OW, overweight; SO, severe obesity.

it relates to fat accumulation and obesity and comorbidity incidence across the age range. This limitation makes it difficult for a primary care provider to determine when during a young patient's life these screenings are most efficient, useful, and necessary. Many studies examined samples with wide age ranges and did not stratify by age group, making it difficult to identify a window of opportunity when screening may be most useful for early detection of a patient's transition into pathophysiology. Further, although there were distinct differences in prevalence of abnormalities and mean laboratory values between children with normal weight versus those who were overweight and obese, more information is needed on the specific amount of body fat or level of BMI at which aberrations occur. Although screening youth with severe obesity may be commonly practiced, we currently have too few data to determine whether youth in the overweight range or at the low end of obesity should be screened.

The inconsistency in definitions of comorbidities is also challenging in this age range. It is difficult to compare prevalence estimates when studies use different thresholds for a clinically abnormal or pathologic level. Further, it is challenging for the primary care provider to develop treatment strategies without more concrete guidelines on how to interpret screening results. The inconsistency in definitions made it difficult to compare prevalence across countries, across race and ethnic groups, and across a variety of settings. There are insufficient data on national prevalence estimates, with many studies using convenience samples via school-based screening or specialty clinical settings. Less is known about the occurrence of

TABLE 32 Prevalence of Asthma ($n = 26$)

First Author	Country	Ages (y)	*N*	Definition of Abnormal	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Guibas	Greece	2–5, 9–13	1622	Physician diagnosis	2–5 y	10.5	1.0	OR = 1.29	OR = 1.54			NS			
			2015	Physician diagnosis	9–13 y	13.5	OR = 1.0	OR = 1.45	OR = 1.69			<.05			
Gilliland	US	7–18	3792	Physician diagnosis	Males		IR = 20.0/1000	IR = 25.2/1000	IR = 36.6/1000						
				Physician diagnosis	Females		25.2/1000	34.5/1000	25.6/1000						
Black	US	6–19	623358	Incident physician diagnosis		IR 18.1/1000	1	aHR = 1.16	aHR = 1.23	aHR = 1.37		<.001			Kaiser
Bibi	Israel	2nd grade	5984	Parent report of physician diagnosis	Males		7		14.6			<.001			
					Females		5.8		10.1			<.05			
Vasquez-Nava	Mexico	4–5	1160	Parent report of diagnosis			4.7%	7.3%	5.4%			NR			
Wickens	New Zealand	11–12	3052	Parent report ever asthma			OR: 1.0 (ref)	OR: 1.08	OR: 1.39			.08			
Saha	US	5–18	2544	Physician diagnosis	Males		23%	22.8%	31.9%			<.001			
					Females		12.6%	21.8%	21.3%			<.001			
Noonan	US	9–22	1852	Parent report current asthma		9.5%	7.1	12.1	11.6			<.05			Northern Plains American Indian patients
Sybilski	Poland	6–7, 13–14	4510	Physician diagnosis	6–7 y	11.44	1.00 (ref)	OR = 1.99	OR = 2.17			<.05			
			4721		13–14 y	11.36	1.00 (ref)	OR = 1.43	OR = 0.57			NS			
Lu	US	12–19	4828	Parent report current asthma	Males	6.5%	aOR = 1.0	aOR = 0.90				NS			NHANES sample
					Females	8.5%	aOR = 1.0	aOR = 1.73				<.05			
James	Australia	4–6	18999	Parent report current asthma		13.11%	OR = 1.0	1.29	1.29			<.05			
Black	US	6–19	681122	Physician diagnosis		10.9	1.00 (ref)	1.220	1.367	1.682		<.001			Kaiser
Bedolla-Barajas	Mexico	15–18	1600	Incidence of asthma			7.5	9.7	6.5			NS			
Alvarez-Zallo	Spain	6–7, 13–14	3360	Parent report ever asthma	6–7 y	9.8	OR = 1.0	OR = 1.14	OR = 2.29			<.05 OB			
			5247		13–14 y	10.4	OR = 1.0	OR = 1.14	OR = 1.18			NS			
Akinbami	US	2–19	9437	Parent report current asthma	NHANES 1998–1994	7.3	6.3	8.4	13.4			.03			1988–1994
			6112		NHANES 2011–2014	10.9	10.3	8.2	15.7			.001			2011–2014 sample
Tai	Australia	4–5	1509	Parent report current asthma	Males		19.2	29.9	37.1			.005			
					Females		15.3	15.2	37.5			<.001			
Yoo	Korea	15–17	717	Parent report current asthma	Males		6.9%	9.5%				.285			
					Females		3.7%	3.6%				.973			
Kwon	US	2–11	853	Parent-report asthma diagnosis plus self-report	Males		19.1	24.3	34.8			.014			Black and Hispanic patients
					Females		16.4	33.3	27.3			.005			
Musaad	US	5–18	1123	Moderate or severe physician diagnosis			38.17	40.69				NS		HW: 25th–85th	
Cibella	Italy	10–16	708	Self-report asthma		11.9	10.3	21.0				.0008			
Akinbami	US	2–19	40644	Parent report		7.1–10.3 (across years)	1.0	1.2	1.7						NHANES 1988-2014
Karachaliou	Greece			Parent report of any asthma symptoms			29.7	33.2				<.001			Schools
Kelly	UK	5–8	9443	Diagnosis (3 y following BMI)			1.0 (ref)		aOR = 1.46			<.05			Population based
Linthavong	US	10	871	Physician diagnosis			34	44	55			<.05			Former extremely low gestational age neonates
Machluf	Israel	16–19	113671	Mild asthma from medical history	Males		1.0 (ref)		aOR = 1.61			<.001			Military conscripts
					Females		1.0 (ref)		aOR = 1.54			<.05			Military conscripts
Machluf	Israel	16–19	113671	Moderate-severe asthma from medical history	Males		1.0 (ref)		aOR = 1.63			<.001			Military conscripts
					Females		1.0 (ref)	aOR = 1.21	aOR = 1.54			<.05			Military conscripts
Silverio	US	2–17	421	ICD-10			26.7		27.8			.79			Family medicine clinic patients

aHR, adjusted hazard ratio; aOR, adjusted odds ratio; HW, healthy weight; IR, incidence rate; NR, not reported; NS, not significant; OB, obese; OR, odds ratio.

TABLE 33 Prevalence of Depression ($n = 6$)

First Author	Country	Ages (y)	*N*	Subgroup (eg, M/F)	Definition of Abnormal	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Goodman	USA	Grade 7–12	102		High CESD	9.8	9.8				9.8	1.00			
Bell	Australia	6–13	283		Parent report	NR	1.0	8.95	18.8			.001			
Hadjiyannakis	Canada	5–17	847		Chart review	10			6	13	12	NR			Pediatric weight management program patients
Lennerz	Germany	14–24	431		Self-reported				11	10	11	.99			Weight management clinic patients + some community
Silverio	USA	2–17	421		ICD-10		2.3		2.4			.97			Family medicine clinic patients
Tas	Turkey	12–18	165		BSI Depression		23.6	42.7				.026			Primary care patients

BSI, Brief Symptom Inventory; CESD, Center for Epidemiologic Studied Depression Scale; NR, not reported.

TABLE 34 Mean Depression Score ($n = 3$)

First Author	Country	Ages (y)	*N*	Units	Subgroup (eg, M/F)	Total	Healthy	Overweight	Class I	Class II	Class III	*P*	Notes	Weight Definitions	Population Info
Goodman	USA	Grade 7–12	102	CESD			11.9				14.0	.10			
Hammerton	UK	11–17	4845	DAWBA			0.55	0.65	0.73			.007			Adolescents at risk for depression
Goldfield	Canada	Grade 7–12	1490	CDI			10.2	10.3	12.1			<.05			

CESD, Center for Epidemiologic Studies Depression Scale; CDI, Children's Depression Inventory; DAWBA, Development and Well-Being Assessment.

obesity comorbidities in primary care settings as detected by providers. The utilization of large electronic medical record databases may be an efficient remedy to this lack of data.

CONCLUSIONS

Overall, across most laboratory values and diagnoses, obesity was associated with higher mean values and/or greater comorbidity prevalence. However, population-based data showed smaller differences, compared with samples drawn from clinical care. Additionally, these population-based samples typically showed that the great majority of children have normal values, even children with obesity.

ACKNOWLEDGMENT

We thank Chelsea Kracht, PhD, for her help in reviewing abstracts.

ABBREVIATIONS

ALT: alanine aminotransferase
AST: aspartate aminotransferase
ATP: Adult Treatment Panel
CDC: Centers for Disease Control and Prevention
DBP: diastolic blood pressure
HbA1c: hemoglobin A1c
HDL: high-density lipoprotein
HOMA-IR: homeostatic model assessment for insulin resistance
IDF: International Diabetes Foundation
KQ: key question
LDL: low-density lipoprotein
NCEP: National Cholesterol Education Program
NHANES: National Health and Nutrition Examination Survey
OSA: obstructive sleep apnea
SBP: systolic blood pressure
TG: triglycerides
WHO: World Health Organization

taking into account individual circumstances, may be appropriate.

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DOI: https://doi.org/10.1542/peds.2022-060643

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FUNDING: Some support for the technical report came from the Strengthening Public Health Systems and Services QT18-1802 through the National Partnerships to Improve and Protect the Nation's Health grant from the Centers for Disease Control and Prevention.

FINANCIAL/POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

COMPANION PAPERS: Companions to this article can be found at http://www.pediatrics.org/cgi/doi/10.1542/peds.2022-060640, http://www.pediatrics.org/cgi/doi/10.1542/peds.2022-060641, and http://www.pediatrics.org/cgi/doi/10.1542/peds.2022-060642.

REFERENCES

1. O'Connor EA, Evans CV, Burda BU, Walsh ES, Eder M, Lozano P. Screening forobesity and intervention for weight management in children and adolescents: evidence report and systematic review for the US Preventive Services Task Force. *JAMA*. 2017;317(23): 2427–2444
2. Kirk S, Armstrong S, King E, et al. Establishment of the Pediatric Obesity Weight Evaluation Registry: a national research collaborative for identifying the optimal assessment and treatment of pediatric obesity. *Child Obes*. 2017;13(1):9–17
3. Cockrell Skinner A, Staiano A, Armstrong S, et al. Appraisal of clinical care practices for child obesity treatment. Part I: interventions. *Pediatrics*. 2023;151(2)e2022060642
4. Centers for Disease Control and Prevention. Prevalence of abnormal lipid levels among youths—United States, 1999-2006. *MMWR Morb Mortal Wkly Rep*. 2010;59(2):29–33
5. Avnieli Velfer Y, Phillip M, Shalitin S. Increased prevalence of severe obesity and related comorbidities among patients referred to a pediatric obesity clinic during the last decade. *Horm Res Paediatr*. 2019;92(3):169–178
6. Bell LM, Curran JA, Byrne S, et al. High incidence of obesity co-morbidities in young children: a cross-sectional study. *J Paediatr Child Health*. 2011;47(12): 911–917
7. Bindler RC, Daratha KB. Relationship of weight status and cardiometabolic outcomes for adolescents in the TEAMS study. *Biol Res Nurs*. 2012;14(1):65–70
8. Botton J, Heude B, Kettaneh A, et al. Cardiovascular risk factor levels and their relationships with overweight and fat distribution in children: the Fleurbaix Laventie Ville Sante II study. *Metabolism*. 2007;56(5):614–622
9. Caserta CA, Pendino GM, Alicante S, et al. Body mass index, cardiovascular risk factors, and carotid intima-media thickness in a pediatric population in southern Italy. *J Pediatr Gastroenterol Nutr*. 2010;51(2):216–220
10. Davis CL, Flickinger B, Moore D, Bassali R, Domel Baxter S, Yin Z. Prevalence of cardiovascular risk factors in schoolchildren in a rural Georgia community. *Am J Med Sci*. 2005; 330(2):53–59
11. Duncan GE, Li SM, Zhou XH. Prevalence and trends of a metabolic syndrome phenotype among U.S. adolescents, 1999-2000. *Diabetes Care*. 2004;27(10): 2438–2443
12. Gunes AO, Alikasifoglu M, Erginoz E, et al. The relationship between cardiometabolic risks and vitamin D levels with the degree of obesity. *Turk Pediatri Ars*. 2019;54(4):256–263
13. Hadjiyannakis S, Ibrahim Q, Li J, et al. Obesity class versus the Edmonton Obesity Staging System for Pediatrics to define health risk in childhood obesity: results from the CANPWR cross-sectional study. *Lancet Child Adolesc Health*. 2019;3(6):398–407
14. Halley Castillo E, Borges G, Talavera JO, et al. Body mass index and the prevalence of metabolic syndrome among children and adolescents in two Mexican populations. *J Adolesc Health*. 2007;40(6):521–526
15. Ice CL, Cottrell L, Neal WA. Body mass index as a surrogate measure of cardiovascular risk factor clustering in fifth-grade children: results from the coronary artery risk detection in the Appalachian Communities Project. *Int J Pediatr Obes*. 2009;4(4):316–324
16. Ice CL, Murphy E, Cottrell L, Neal WA. Morbidly obese diagnosis as an indicator of cardiovascular disease risk in children: results from the CARDIAC Project. *Int J Pediatr Obes*. 2011;6(2):113–119
17. Kim HM, Park J, Kim HS, Kim DH, Park SH. Obesity and cardiovascular risk factors in Korean children and adolescents aged 10-18 years from the Korean National Health and Nutrition Examination Survey, 1998 and 2001. *Am J Epidemiol*. 2006;164(8):787–793
18. Kim SJ, Lee J, Nam CM, Lee SY. Impact of obesity on metabolic syndrome among adolescents as compared with adults in Korea. *Yonsei Med J*. 2011;52(5):746–752
19. Lambert M, Delvin EE, Levy E, et al. Prevalence of cardiometabolic risk factors by weight status in a population-based sample of Quebec

children and adolescents. *Can J Cardiol*. 2008;24(7):575–583

20. Laurson KR, Welk GJ, Eisenmann JC. Diagnostic performance of BMI percentiles to identify adolescents with metabolic syndrome. *Pediatrics*. 2014;133(2):e330–e338
21. Li L, Perez A, Wu LT, Ranjit N, Brown HS, Kelder SH. Cardiometabolic risk factors among severely obese children and adolescents in the United States, 1999 -2012. *Child Obes*. 2016;12(1):12–19
22. Marcus M, Foster G, Ghormli L. Stability of relative weight category and cardiometabolic risk factors among moderately and severely obese middle school youth. *Obestiys (Silver Spring)*. 2014;22(4):1118–1125
23. Marcus MD, Baranowski T, DeBar LL, et al. Severe obesity and selected risk factors in a sixth grade multiracial cohort: the HEALTHY study. *J Adolesc Health*. 2010;47(6):604–607
24. Maximova K, Kuhle S, Davidson Z, Fung C, Veugelers PJ. Cardiovascular risk-factor profiles of normal and overweight children and adolescents: insights from the Canadian Health Measures Survey. *Can J Cardiol*. 2013;29(8):976–982
25. Messiah SE, Arheart KL, Luke B, Lipshultz SE, Miller TL. Relationship between body mass index and metabolic syndrome risk factors among US 8- to 14-year-olds, 1999 to 2002. *J Pediatr*. 2008;153(2):215–221
26. Michalsky MP, Inge TH, Simmons M, et al. Cardiovascular risk factors in severely obese adolescents: the Teen Longitudinal Assessment of Bariatric Surgery (Teen-LABS) Study. *JAMA Pediatr*. 2015;169(5):438–444
27. Nguyen D, Kit B, Carroll M. Abnormal cholesterol among children and adolescents in the United States, 2011-2014. *NCHS Data Brief*. 2015; 228:1–8
28. O'Hara V, Browne N, Fathima S, et al. Obesity cardiometabolic comorbidity prevalence in children in a rural weight-management program. *Glob Pediatr Health*. 2017; 4:2333794x17729303
29. Pan Y, Pratt CA. Metabolic syndrome and its association with diet and physical activity in US adolescents. *J Am Diet Assoc*. 2008;108(2):276–286
30. Park J, Hilmers DC, Mendoza JA, Stuff JE, Liu Y, Nicklas TA. Prevalence of metabolic syndrome and obesity in adolescents aged 12 to 19 years: comparison between the United States and Korea. *J Korean Med Sci*. 2010; 25(1):75–82
31. Park SH, Park JH, Kang JW, Park HY, Park J, Shin KJ. Prevalence of the metabolic syndrome and abnormal lipid levels among Korean adolescents. *J Paediatr Child Health*. 2013;49(7): 582–587
32. Perez CM, Ortiz AP, Fuentes-Mattei E, et al. High prevalence of cardiometabolic risk factors in Hispanic adolescents: correlations with adipocytokines and markers of inflammation. *J Immigr Minor Health*. 2014;16(5):865–873
33. Propst M, Colvin C, Griffin RL, et al. Diabetes and prediabetes are significantly higher in morbidly obese children compared with obese children. *Endocr Pract*. 2015;21(9):1046–1053
34. Salvatore D, Satnick A, Abell R, Messina CR, Chawla A. The prevalence of abnormal metabolic parameters in obese and overweight children. *JPEN J Parenter Enteral Nutr*. 2014;38(7): 852–855
35. Serap S, Mevlut B, Inanc C, Ender S. Metabolic syndrome in childhood obesity. *Indian Pediatr*. 2007;44(9): 657–662
36. Simsek E, Balta H, Balta Z, Dallar Y. Childhood obesity-related cardiovascular risk factors and carotid intima-media thickness. *Turk J Pediatr*. 2010;52(6):602–611
37. Skinner AC, Mayer ML, Flower K, Weinberger M. Health status and health care expenditures in a nationally representative sample: how do overweight and healthy- weight children compare? *Pediatrics*. 2008; 121(2):e269–e277
38. Skinner AC, Perrin EM, Moss LA, Skelton JA. Cardiometabolic risks and severity of obesity in children and young adults. *N Engl J Med*. 2015; 373(14):1307–1317
39. Stolzman SC, Skelton J, Harkins A, Hoeger Bement M. Does weight status impact metabolic health in adolescents when controlling for physical fitness? *Pediatr Phys Ther*. 2019;31(2):134–140
40. Turchiano M, Sweat V, Fierman A, Convit A. Obesity, metabolic syndrome, and insulin resistance in urban high school students of minority race/ ethnicity. *Arch Pediatr Adolesc Med*. 2012;166(11):1030–1036
41. Valery PC, Moloney A, Cotterill A, Harris M, Sinha AK, Green AC. Prevalence of obesity and metabolic syndrome in Indigenous Australian youths. *Obes Rev*. 2009;10(3):255–261
42. Yoshinaga M, Tanaka S, Shimago A, et al. Metabolic syndrome in overweight and obese Japanese children. *Diabet Med*. 2005;22(9):1199–1205
43. Aylanc H, Aylanc N, Yildirim S, et al. Relationship between abdominal aortic intima media thickness and central obesity in children. *Horm Res Paediatr*. 2016;85(1):43–48
44. Baer TE, Milliren CE, Walls C, DiVasta AD. Clinical variability in cardiovascular disease risk factor screening and management in adolescent and young adult women with polycystic ovary syndrome. *J Pediatr Adolesc Gynecol*. 2015;28(5):317–323
45. Bindler RJ, Bindler RC, Daratha KB. Biological correlates and predictors of insulin resistance among early adolescents. *J Pediatr Nurs*. 2013;28(1):20–27
46. Bocca G, Ongering EC, Stolk RP, Sauer PJ. Insulin resistance and cardiovascular risk factors in 3- to 5-year-old overweight or obese children. *Horm Res Paediatr*. 2013;80(3):201–206
47. Bonet B, Viana M, Sanchez-Vera I, Quintanar A, Martinez J, Espino M. Adipose tissue and liver lipid metabolism in obese children: role of the body mass index and the presence of acanthosis nigricans. *Diabet Med*. 2007;24(11):1192–1198
48. Buchan DS, McLellan G, Donnelly S, Arthur R. Diagnostic performance of body mass index, waist circumference and the waist-to-height ratio for identifying cardiometabolic risk in Scottish pre-adolescents. *Ann Hum Biol*. 2017;44(4):297–302
49. Cizmecioglu FM, Etiler N, Hamzaoglu O, Hatun S. Prevalence of metabolic syndrome in schoolchildren and

adolescents in Turkey: a population-based study. *J Pediatr Endocrinol Metab*. 2009;22(8):703–714

50. Craig LC, Love J, Ratcliffe B, McNeill G. Overweight and cardiovascular risk factors in 4- to 18-year-olds. *Obes Facts*. 2008;1(5):237–242
51. Friedland O, Nemet D, Gorodnitsky N, Wolach B, Eliakim A. Obesity and lipid profiles in children and adolescents. *J Pediatr Endocrinol Metab*. 2002; 15(7):1011–1016
52. Garces C, Gutierrez-Guisado J, Benavente M, et al. Obesity in Spanish schoolchildren: relationship with lipid profile and insulin resistance. *Obes Res*. 2005;13(6):1106–1115
53. Higgins V, Omidi A, Tahmasebi H, et al. Marked influence of adiposity on laboratory biomarkers in a healthy cohort of children and adolescents. *J Clin Endocrinol Metab*. 2020;105(4): e1781–e1797
54. Kim KE, Baek KS, Han S, Kim JH, Shin YH. Serum alanine aminotransferase levels are closely associated with metabolic disturbances in apparently healthy young adolescents independent of obesity. *Korean J Pediatr*. 2019;62(2):48–54
55. Kloppenborg JT, Fonvig CE, Nielsen TRH, et al. Impaired fasting glucose and the metabolic profile in Danish children and adolescents with normal weight, overweight, or obesity. *Pediatr Diabetes*. 2018;19(3):356–365
56. Kollias A, Skliros E, Stergiou GS, Leotsakos N, Saridi M, Garifallos D. Obesity and associated cardiovascular risk factors among schoolchildren in Greece: a cross - sectional study and review of the literature. *J Pediatr Endocrinol Metab*. 2011;24(11-12):929–938
57. Manios Y, Kolotourou M, Moschonis G, et al. Macronutrient intake, physical activity, serum lipids and increased body weight in primary schoolchildren in Istanbul. *Public Health*. 2005;119(5): 385–389
58. Nascimento H, Costa E, Rocha-Pereira P, et al. Cardiovascular risk factors in Portuguese obese children and adolescents: impact of small reductions in body mass index imposed by lifestyle modifications. *Open Biochem J*. 2012;6:43–50
59. Norris AL, Steinberger J, Steffen LM, Metzig AM, Schwarzenberg SJ, Kelly AS. Circulating oxidized LDL and inflammation in extreme pediatric obesity. *Obesity (Silver Spring)*. 2011;19(7):1415–1419
60. Nystrom CD, Henriksson P, Martinez-Vizcaino V, et al. Does cardiorespiratory fitness attenuate the adverse effects of severe/morbid obesity on cardiometabolic risk and insulin resistance in children? a pooled analysis. *Diabetes Care*. 2017;40(11): 1580–1587
61. Olza J, Aguilera CM, Gil-Campos M, et al. Waist-to-height ratio, inflammation and CVD risk in obese children. *Public Health Nutr*. 2014;17(10): 2378–2385
62. Perichart-Perera O, Balas-Nakash M, Schiffman-Selechnik E, Barbato-Dosal A, Vadillo- Ortega F. Obesity increases metabolic syndrome risk factors in school-aged children from an urban school in Mexico City. *J Am Diet Assoc*. 2007;107(1):81–91
63. Puri M, Flynn JT, Garcia M, Nussbaum H, Freeman K, DiMartino-Nardi JR. The frequency of elevated blood pressure in obese minority youth. *J Clin Hypertens (Greenwich)*. 2008;10(2):119–124
64. Raman A, Sharma S, Fitch MD, Fleming SE. Anthropometric correlates of lipoprotein profile and blood pressure in high BMI African American children. *Acta Paediatr*. 2010;99(6):912–919
65. Rank M, Siegrist M, Wilks DC, et al. The cardio-metabolic risk of moderate and severe obesity in children and adolescents. *J Pediatr*. 2013;163(1): 137–142
66. Salawi HA, Ambler KA, Padwal RS, Mager DR, Chan CB, Ball GD. Characterizing severe obesity in children and youth referred for weight management. *BMC Pediatr*. 2014;14:154
67. Seth A, Orkin S, Yodoshi T, et al. Severe obesity is associated with liver disease severity in pediatric non-alcoholic fatty liver disease. *Pediatr Obes*. 2020;15(2):e12581
68. Sougawa Y, Miyai N, Morioka I, et al. The combination of obesity and high salt intake are associated with blood pressure elevation among healthy Japanese adolescents. *J Hum Hypertens*. 2020;34(2):117–124
69. Sur H, Kolotourou M, Dimitriou M, et al. Biochemical and behavioral indices related to BMI in schoolchildren in urban Turkey. *J Pediatr Endocrinol Metab*. 2005;18(5):491–498
70. Valentini D, Alisi A, di Camillo C, et al. Nonalcoholic fatty liver disease in Italian children with down syndrome: prevalence and correlation with obesity-related features. *J Pediatr*. 2017;189:92–97.e91
71. Valerio G, Licenziati MR, Iannuzzi A, et al. Insulin resistance and impaired glucose tolerance in obese children and adolescents from Southern Italy. *Nutr Metab Cardiovasd Dis*. 2006;16(4):279–284
72. Venegas HL, Perez CM, Suarez EL, Guzman M. Prevalence of obesity and its association with blood pressure, serum lipids and selected lifestyles in a Puerto Rican population of adolescents 12-16 years of age. *J Am Coll Cardiol*. 2003;42(2):264–270
73. Watts K, Bell LM, Byrne SM, Jones TW, Davis EA. Waist circumference predicts cardiovascular risk in young Australian children. *J Paediatr Child Health*. 2008;44(12):709–715
74. Zabarsky G, Beek C, Hagman E, Pierpont B, Caprio S, Weiss R. Impact of severe obesity on cardiovascular risk factors in youth. *J Pediatr*. 2018;192:105–114
75. Akinci G, Akinci B, Coskun S, Bayindir P, Hekimsoy Z, Ozmen B. Evaluation of markers of inflammation, insulin resistance and endothelial dysfunction in children at risk for overweight. *Hormones (Athens)*. 2008;7(2):156–162
76. Skinner AC, Steiner MJ, Chung AE, Perrin EM. "Cholesterol curves" to identify population norms by age and sex in healthy weight children. *Pediatric Academic Societies Annual Meeting*. May 2010; Vancouver, Canada
77. Del-Rio-Navarro BE, Velazquez-Monroy O, Lara-Esqueda A, et al. Obesity and metabolic risks in children. *Arch Med Res*. 2008;39(2):215–221
78. Fyfe-Johnson AL, Ryder JR, Alonso A, et al. Ideal cardiovascular health and adiposity: implications in youth. *J Am Heart Assoc*. 2018;7(8):e007467

79. McCarthy WJ, Yancey AK, Siegel JM, et al. Correlation of obesity with elevated blood pressure among racial/ethnic minority children in two Los Angeles middle schools. *Prev Chronic Dis.* 2008;5(2):A46

80. Jayawardene WP, Lohrmann D, Dickinson S, Talagala S, Torabi M. Clinical measures of obesity and cumulative cardiometabolic risk in adolescents. *Clin Obes.* 2017;7(1):11–21

81. Lennerz BS, Moss A, von Schnurbein J, et al. Do adolescents with extreme obesity differ according to previous treatment seeking behavior? The Youth with Extreme obesity Study (YES) cohort. *Int J Obes.* 2019;43(1):103–115

82. Redondo MJ, Foster NC, Libman IM, et al. Prevalence of cardiovascular risk factors in youth with type 1 diabetes and elevated body mass index. *Acta Diabetol.* 2016;53(2):271–277

83. Tsao-Wu M, Williams RJ, Hendy HM, Novick MB. Associations between obesity severity and medical comorbidities for children with obesity in low intensity hospital intervention. *Obes Res Clin Pract.* 2019;13(6):555–560

84. Baranowski T, Cooper DM, Harrell J, et al. Presence of diabetes risk factors in a large U.S. eighth-grade cohort. *Int J Obes.* 2006;30(4):618–626

85. Guerrero-Romero F, Violante R, Rodriguez-Moran M. Distribution of fasting plasma glucose and prevalence of impaired fasting glucose, impaired glucose tolerance and type 2 diabetes in the Mexican paediatric population. *Paediatr Perinat Epidemiol.* 2009;23(4):363–369

86. Williams DE, Cadwell BL, Cheng YJ, et al. Prevalence of impaired fasting glucose and its relationship with cardiovascular disease risk factors in US adolescents, 1999 -2000. *Suicide Life Threat Behav.* 2005;35(5):547–557

87. Weiss R, Magge SN, Santoro N, et al. Glucose effectiveness in obese children: relation to degree of obesity and dysglycemia. *Diabetes Care.* 2015;38(4):689–695

88. Manios Y, Moschonis G, Kourlaba G, et al. Prevalence and independent predictors of insulin resistance in children from Crete, Greece: the Children Study. *Diabet Med.* 2008;25(1):65–72

89. Peplies J, Bornhorst C, Gunther K, et al. Longitudinal associations of lifestyle factors and weight status with insulin resistance (HOMA-IR) in preadolescent children: the large prospective cohort study IDEFICS. *Int J Behav Nutr Phys Act.* 2016;13(1):97

90. Buchan DS, Boddy LM, Despres JP, et al. Utility of the hypertriglyceridemic waist phenotype in the cardiometabolic risk assessment of youth stratified by body mass index. *Pediatr Obes.* 2016;11(4):292–298

91. Rodd C, Feely A, Dart A, Sharma A, McGavock J. Biological and socioeconomic determinants of prediabetes in youth: an analysis using 2007 to 2011 Canadian Health Measures Surveys. *Pediatr Res.* 2018;84(2):248–253

92. Bar Dayan Y, Elishkevits K, Grotto I, et al. The prevalence of obesity and associated morbidity among 17-year-old Israeli conscripts. *J Consult Clin Psychol.* 2005;73(2):195–202

93. Bacopoulou F, Efthymiou V, Palaiologos G, et al. Telemedicine screening adolescent metabolic syndrome in Greek schools. *Eur J Clin Invest.* 2019;49(4):e13075

94. Galera-Martinez R, Garcia-Garcia E, Vazquez-Lopez MA, et al. Prevalence of metabolic syndrome among adolescents in a city in the Mediterranean area: comparison of two definitions. 2015;32(2):627–633

95. Ryu SY, Kweon SS, Park HC, Shin JH, Rhee JA. Obesity and the metabolic syndrome in Korean adolescents. *J Korean Med Sci.* 2007;22(3):513–517

96. Vissers D, Vanroy C, De Meulenaere A, Van de Sompel A, Truijen S, Van Gaal L. Metabolic syndrome in youth: a cross-sectional school-based survey. *Acta Paediatr.* 2007;96(12):1809–1813

97. Harding S, Maynard MJ, Cruickshank K, Teyhan A. Overweight, obesity and high blood pressure in an ethnically diverse sample of adolescents in Britain: the Medical Research Council DASH study. *Int J Obes.* 2008;32(1):82–90

98. Krzyzaniak A, Kaczmarek M, Stawinska-Witoszynska B, Krzywinska-Wiewiorowska M. Prevalence of selected risk factors for cardiovascular diseases in adolescents with overweight and obesity. *Med Wieku Rozwoj.* 2011;15(3):282–287

99. Maggio AB, Aggoun Y, Marchand LM, et al. Associations among obesity, blood pressure, and left ventricular mass. *J Pediatr.* 2008;152(4):489–493

100. Stray-Pedersen M, Helsing RM, Gibbons L, et al. Weight status and hypertension among adolescent girls in Argentina and Norway: data from the ENNyS and HUNT studies. *BMC Public Health.* 2009;9:398

101. Turconi G, Maccarini L, Bazzano R, Roggi C. Overweight and blood pressure: results from the examination of a selected group of adolescents in northern Italy. *Public Health Nutr.* 2008;11(9):905–913

102. Falkner B, Gidding SS, Ramirez-Garnica G, Wiltrout SA, West D, Rappaport EB. The relationship of body mass index and blood pressure in primary care pediatric patients. *J Pediatr.* 2006;148(2):195–200

103. Genovesi S, Antolini L, Giussani M, et al. Hypertension, prehypertension, and transient elevated blood pressure in children: association with weight excess and waist circumference. *Am J Hypertens.* 2010;23(7):756–761

104. Kopping D, Nevarez H, Goto K, Morgan I, Frigaard M, Wolff C. A longitudinal study of overweight, elevated blood pressure, and acanthosis nigricans among low-income middle school students. *J Sch Nurs.* 2012;28(3):214–219

105. Martin-Espinosa N, Diez-Fernandez A, Sanchez-Lopez M, et al. Prevalence of high blood pressure and association with obesity in Spanish schoolchildren aged 4-6 years old. *PLoS One.* 2017;12(1):e0170926

106. Sanchez-Zamorano LM, Salazar-Martinez E, Anaya-Ocampo R, Lazcano-Ponce E. Body mass index associated with elevated blood pressure in Mexican school-aged adolescents. *Prev Med.* 2009;48(6):543–548

107. Smith C, Rinderknecht K. Obesity correlates with increased blood pressures in urban Native American youth. *Acta Paediatr.* 2002;91(12):1283–1285

108. Wirix AJ, Nauta J, Groothoff JW, et al. Is the prevalence of hypertension in overweight children overestimated? *Arch Dis Child.* 2016;101(11):998–1003

109. Acosta AA, Samuels JA, Portman RJ, Redwine KM. Prevalence of persistent prehypertension in adolescents. *J Pediatr.* 2012;160(5):757–761

110. Adams MH, Carter TM, Lammon CA, et al. Obesity and blood pressure trends in rural adolescents over a decade. *Pediatr Nurs.* 2008;34(5): 381–386, 394

111. Bloetzer C, Bovet P, Paccaud F, et al. Performance of targeted screening for the identification of hypertension in children. *Blood Press.* 2017;26(2): 87–93

112. Cheung EL, Bell CS, Samuel JP, et al. Race and obesity in adolescent hypertension. *Pediatrics.* 2017;139(5): e20161433

113. Chiolero A, Cachat F, Burnier M, et al. Prevalence of hypertension in schoolchildren based on repeated measurements and association with overweight. *J Hypertens.* 2007;25(11): 2209–2217

114. Gokler ME, Bugrul N, Metintas S, Kalyoncu C. Adolescent obesity and associated cardiovascular risk factors of rural and urban life (Eskisehir, Turkey). *Cent Eur J Public Health.* 2015;23(1):20–25

115. Israeli E, Schochat T, Korzets Z, et al. Prehypertension and obesity in adolescents: a population study. *Am J Hypertens.* 2006;19(7):708–712

116. Jackson SL, Zhang Z, Wiltz JL, et al. Hypertension among youths—United States, 2001-2016. *MMWR Morb Mortal Wkly Rep.* 2018;67(27):758–762

117. King CA, Meadows BB, Engelke MK, Swanson M. Prevalence of elevated body mass index and blood pressure in a rural school-aged population: implications for school nurses. *J Sch Health.* 2006;76(4):145–149

118. Koebnick C, Black MH, Wu J, et al. High blood pressure in overweight and obese youth: implications for screening. *J Clin Hypertens (Greenwich).* 2013;15(11):793–805

119. Levin A, Morad Y, Grotto I, Ravid M, Bar-Dayan Y. Weight disorders and associated morbidity among young adults in Israel 1990-2003. *Pediatr Int.* 2010;52(3):347–352

120. Maldonado J, Pereira T, Fernandes R, Santos R, Carvalho M. An approach of hypertension prevalence in a sample of 5381 Portuguese children and adolescents. The AVELEIRA registry. "Hypertension in children. *Blood Press.* 2011;20(3):153–157

121. Mavrakanas TA, Konsoula G, Patsonis I, Merkouris BP. Childhood obesity and elevated blood pressure in a rural population of northern Greece. *Rural Remote Health.* 2009;9(2):1150

122. Meininger JC, Brosnan CA, Eissa MA, et al. Overweight and central adiposity in school- age children and links with hypertension. *J Pediatr Nurs.* 2010; 25(2):119–125

123. Menghetti E, Strisciuglio P, Spagnolo A, et al. Hypertension and obesity in Italian school children: the role of diet, lifestyle and family history. *Nutr Metab Cardiovasc Dis.* 2015; 25(6):602–607

124. Moore WE, Eichner JE, Cohn EM, Thompson DM, Kobza CE, Abbott KE. Blood pressure screening of school children in a multiracial school district: the Healthy Kids Project. *Am J Hypertens.* 2009;22(4):351–356

125. Moore WE, Stephens A, Wilson T, et al. Body mass index and blood pressure screening in a rural public school system: the Healthy Kids Project. *Prev Chronic Dis.* 2006;3(4):A114

126. Nguyen JV, Robbins JM, Houck KL, et al. Severe obesity and high blood pressure among children, Philadelphia health centers, 2010. *J Prim Care Community Health.* 2014;5(2):152–155

127. Nur N, Cetinkaya S, Yilmaz A, et al. Prevalence of hypertension among high school students in a middle Anatolian province of Turkey. *J Health Popul Nutr.* 2008;26(1):88–94

128. Onsuz FM, Demir F. Prevalence of hypertension and its association with obesity among school children aged 6-15 living in Sakarya Province in Turkey. *Turk J Med Sci.* 2015;45(4): 907–912

129. Ovbiagele B, Hutchison P, Handschumacher L, et al. Impact of an urban community hypertension screening program on participating high school students. *Ethn Dis.* 2011;21(1):68–73

130. Polat M, Yikilkan H, Aypak C, Gorpelioglu S. The relationship between BMI and blood pressure in children aged 7-12 years in Ankara, Turkey. *Public Health Nutr.* 2014;17(11):2419–2424

131. Rivera-Soto WT, Rodriguez-Figueroa L. Is waist-to-height ratio a better obesity risk- factor indicator for Puerto Rican children than is BMI or waist circumference? *P R Health Sci J.* 2016;35(1):20–25

132. Rodrigues PRM, Pereira RA, Gama A, et al. Body adiposity is associated with risk of high blood pressure in Portuguese schoolchildren. *Rev Port Cardiol.* 2018;37(4):285–292

133. Salvadori M, Sontrop JM, Garg AX, et al. Elevated blood pressure in relation to overweight and obesity among children in a rural Canadian community. *Pediatrics.* 2008;122(4): e821–e827

134. Schwandt P, Scholze JE, Bertsch T, Liepold E, Haas GM. Blood pressure percentiles in 22,051 German children and adolescents: the PEP Family Heart Study. *Am J Hypertens.* 2015;28(5): 672–679

135. Silverio A, Khalili SP, Cunningham A. An exploratory look at comorbidities, utilization, and quality of care among obese and nonobese children in academic family medicine practice. *Int J Pediatr Adolesc Med.* 2018;5(3): 83–87

136. Stiefel EC, Field L, Replogle W, et al. The Prevalence of obesity and elevated blood pressure in adolescent student athletes from the State of Mississippi. *Orthop J Sports Med.* 2016;4(2): 2325967116629368

137. Voorhees J, Goto K, Wolff C. Overweight, elevated blood pressure, acanthosis nigricans and adherence to recommended dietary and physical activity guidelines among Hmong and white middle school students. *J Immigr Minor Health.* 2014;16(2): 273–279

138. Booth ML, George J, Denney-Wilson E, et al. The population prevalence of adverse concentrations and associations with adiposity of liver tests

among Australian adolescents. *J Paediatr Child Health.* 2008;44(12): 686–691

139. Purcell M, Flores YN, Zhang ZF, et al. Prevalence and predictors of alanine aminotransferase elevation among normal weight, overweight and obese youth in Mexico. *J Dig Dis.* 2013; 14(9):491–499

140. Andersen IG, Holm JC, Homoe P. Obstructive sleep apnea in children and adolescents with and without obesity. *Eur Arch Otorhinolaryngol.* 2019;276(3):871–878

141. Frye SS, Fernandez-Mendoza J, Calhoun SL, et al. Childhood obesity, weight loss and developmental trajectories predict the persistence and remission of childhood sleep - disordered breathing. *Pediatr Obes.* 2019;14(1):10.1111/ijpo.12461

142. Kelly B, West J, Yang TC, et al. The association between body mass index, primary healthcare use and morbidity in early childhood: findings from the Born in Bradford cohort study. *Public Health.* 2019;167:21–27

143. Akinbami LJ, Rossen LM, Fakhouri THI, Fryar CD. Asthma prevalence trends by weight status among US children aged 2-19 years, 1988-2014. *Pediatr Obes.* 2018;13(6):393–396

144. Akinbami LJ, Rossen LM, Fakhouri THI, et al. Contribution of weight status to asthma prevalence racial disparities, 2-19 year olds, 1988-2014. *Ann Epidemiol.* 2017;27(8):472–478.e473

145. Alvarez Zallo N, Aguinaga-Ontoso I, Alvarez-Alvarez I, et al. The influence of gender and atopy in the relationship between obesity and asthma in childhood. *Allergol Immunopathol (Madr).* 2017;45(3):227–233

146. Bedolla-Barajas M, Morales-Romero J, Robles-Figueroa M, Fregoso-Fregoso M. Asthma in late adolescents of Western Mexico: prevalence and associated factors. *Arch Bronconeumol.* 2013;49(2):47–53

147. Bibi H, Shoseyov D, Feigenbaum D, et al. The relationship between asthma and obesity in children: is it real or a case of over diagnosis? *J Asthma.* 2004;41(4):403–410

148. Black MH, Smith N, Porter AH, et al. Higher prevalence of obesity among children with asthma. *Obesity (Silver Spring).* 2012;20(5):1041–1047

149. Black MH, Zhou H, Takayanagi M, et al. Increased asthma risk and asthma-related health care complications associated with childhood obesity. *Am J Epidemiol.* 2013;178(7):1120–1128

150. Cibella F, Cuttitta G, La Grutta S, et al. A cross-sectional study assessing the relationship between BMI, asthma, atopy, and eNO among schoolchildren. *Ann Allergy Asthma Immunol.* 2011; 107(4):330–336

151. Gilliland FD, Berhane K, Islam T, et al. Obesity and the risk of newly diagnosed asthma in school-age children. *Am J Epidemiol.* 2003;158(5): 406–415

152. Guibas GV, Manios Y, Xepapadaki P, et al. The obesity-asthma link in different ages and the role of body mass index in its investigation: findings from the Genesis and Healthy Growth Studies. *Allergy.* 2013;68(10): 1298–1305

153. James S, Pezic A, Ponsonby AL, et al. Obesity and asthma at school entry: co - morbidities and temporal trends. *J Paediatr Child Health.* 2013;49(4): e273–e280

154. Karachaliou F, Vlachopapadopoulou E, Psaltopoulou T, et al. Prevalence of asthma symptoms and association with obesity, sedentary lifestyle and sociodemographic factors: data from the Hellenic National Action Plan for the assessment, prevention and treatment of childhood obesity (MIS301205). *J Asthma.* 2020;57(1): 55–61

155. Kwon HL, Ortiz B, Swaner R, et al. Childhood asthma and extreme values of body mass index: the Harlem Children's Zone Asthma Initiative. *J Urban Health.* 2006;83(3):421–433

156. Linthavong O, O'Shea TM, Allred E, et al. Neurocognitive and health correlates of overweight and obesity among ten-year-old children born extremely preterm. *J Pediatr.* 2018; 200:84–90.e84

157. Lu KD, Billimek J, Bar-Yoseph R, Radom-Aizik S, Cooper DM, Anton-Culver H. Sex differences in the relationship between fitness and obesity on risk for asthma in adolescents. *J Pediatr.* 2016;176:36–42

158. Machluf Y, Farkash R, Fink D, Chaiter Y. Asthma severity and heterogeneity: Insights from prevalence trends and associated demographic variables and anthropometric indices among Israeli adolescents. *J Asthma.* 2018;55(8): 826–836

159. Musaad SM, Patterson T, Ericksen M, et al. Comparison of anthropometric measures of obesity in childhood allergic asthma: central obesity is most relevant. *J Allergy Clin Immunol.* 2009;123(6):1321–1327.e1312

160. Noonan CW, Brown BD, Bentley B, et al. Variability in childhood asthma and body mass index across Northern Plains American Indian communities. *J Asthma.* 2010;47(5):496–500

161. Saha C, Riner ME, Liu G. Individual and neighborhood-level factors in predicting asthma. *Arch Pediatr Adolesc Med.* 2005; 159(8):759–763

162. Sybilski AJ, Raciborski F, Lipiec A, et al. Obesity—a risk factor for asthma, but not for atopic dermatitis, allergic rhinitis and sensitization. *Public Health Nutr.* 2015;18(3):530–536

163. Tai A, Volkmer R, Burton A. Association between asthma symptoms and obesity in preschool (4-5 year old) children. *J Asthma.* 2009;46(4): 362–365

164. Vazquez-Nava F, Morales Romero J, Crodova Fernandez JA, et al. Association between obesity and asthma in preschool Mexican children. *ScientificWorldJournal.* 2010;10:1339–1346

165. Wickens K, Barry D, Friezema A, et al. Obesity and asthma in 11 -12 year old New Zealand children in 1989 and 2000. *Thorax.* 2005;60(1):7–12

166. Yoo S, Kim HB, Lee SY, et al. Association between obesity and the prevalence of allergic diseases, atopy, and bronchial hyperresponsiveness in Korean adolescents. *Int Arch Allergy Immunol.* 2011; 154(1):42–48

167. Goodman E, Must A. Depressive symptoms in severely obese compared

with normal weight adolescents: results from a community-based longitudinal study. *J Adolesc Health*. 2011;49(1):64–69

168. Tas D, Tuzun Z, Duzceker Y, Akgul S, Kanbur N. The effects of parental and peer factors on psychiatric symptoms in adolescents with obesity. *Eat Weight Disord*. 2020;25(3):617–625

169. Goldfield GS, Moore C, Henderson K, Buchholz A, Obeid N, Flament MF. Body dissatisfaction, dietary restraint, depression, and weight status in adolescents. *J Sch Health*. 2010; 80(4):186–192

170. Hammerton G, Thapar A, Thapar AK. Association between obesity and depressive disorder in adolescents at high risk for depression. *Int J Obes*. 2014;38(4):513–519

171. Zuckerbrot RA, Cheung A, Jensen PS, Stein REK, Laraque D; GLAD-PC Steering Group. Guidelines for adolescent depression in primary care (GLAD-PC): part I. Practice preparation, identification, assessment, and initial management. *Pediatrics*. 2018;141(3):e20174081