

Childhood Obesity Incidence in the United States: A Systematic Review

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Abstract

Background: This systematic review synthesizes the literature on incidence of obesity during childhood.

Methods: We searched PubMed, Excerpta Medica database (EMBASE), and Cumulative Index to Nursing and Allied Health Literature (CINAHL), and used the Web of Science tool in June 2015. Studies were included if they were published in English, presented results from primary or secondary analyses, used data about children in the US, provided obesity incidence data on children 0 to 18 years born after 1970, and did not pertain to clinically defined populations (disease, medication use, etc.). Author(s), study year, study design, location, sample size, age, and obesity incidence estimates were abstracted.

Results: Nineteen studies were included, three of which used nationally representative data. The median study-specific annual obesity incidences among studies using U.S. Centers for Disease Control and Prevention (CDC) growth charts were 4.0%, 3.2%, and 1.8% for preschool (2.0–4.9 years), school aged (5.0–12.9 years), and adolescence (13.0–18.0 years), respectively. This pattern of declining obesity incidence with age was consistent between and within studies.

Conclusions: Studies of childhood obesity in the US indicate declining incidence with age. Childhood obesity prevention efforts should be targeted to ages before obesity onset. Longitudinal data and consistent obesity definitions that correlate with long-term morbidity are needed to better characterize the life history of obesity.

Introduction

Childhood obesity is a major public health concern, as the prevalence of obesity worldwide is believed to be increasing.¹ In the United States, obesity prevalence among children ages 6–11 years more than tripled from 4.2%–15.3% between 1963–1965 and 1999–2000.¹ Although recent studies have reported decreased obesity prevalence among younger children, in 2011–2012, 16.9% of children in the United States were classified as obese, with prevalence being highest at ages 12–19 and lowest at ages 2–5 years.² In the past three decades, increases in obesity prevalence have been observed among children of all ages,^{2,3} though differences in obesity prevalence have been documented by age,² race and ethnicity,¹ gender,² and geographic region.⁴ Obesity in childhood has been associated with subsequent obesity in adulthood, other chronic diseases, and high medical costs,^{5–9} so understanding the emergence of obesity in childhood may offer opportunities to improve health at all ages.

While the prevalence of obesity among children in the United States has been well documented,^{2,3} less is known

about obesity incidence. Prevalence of obesity for a given age group is a composite of preceding and concurrent incidence and remission for children. Detailing age-specific obesity incidence is important for elucidating peak periods of obesity onset to identify and maximize intervention opportunities and minimize healthcare costs. Tracking of childhood obesity into adulthood calls for intervention efforts to prevent obesity that are timed to precede onset, and age-specific incidence estimates contribute to this perspective.^{13,14} Estimating incidence for racial, ethnic, and socioeconomic groups may be useful for understanding the disparities in obesity that have been observed across age groups.^{6,10–12} We present results from a systematic review of studies that have estimated the incidence of obesity among children in the United States.

Methods

The procedures used in this review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement. We conducted systematic searches of peer-reviewed journals in June 2015 using

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PubMed, Excerpta Medica database (EMBASE), and Cumulative Index to Nursing and Allied Health Literature (CINAHL). Key words used for all searches were “obesity” and “incidence.” Incidence was searched as a medical subject heading (MeSH) term in PubMed. “Child: birth-18 years” was used as a search filter. Searches were not restricted by publication date. The studies identified through these search criteria were reviewed independently by two authors according to the following criteria: (1) published in English; (2) presented findings from analysis of primary or secondary data; (3) presented data from the United States; (4) provided estimates of obesity incidence among children ages 0–18 years or provided data from which incidence could be calculated; and (5) used data from individuals born after 1970. Studies of clinically defined populations, specifically those with a particular disease or medication regimen, were excluded, but control arms of intervention trials were included. Hand searches of the references of these articles were performed and the Web of Science Cited Reference Search tool, which identifies other articles referencing a specific study, was used for key articles. This review protocol was not registered prior to its outset.

A data extraction spreadsheet was used to assess whether articles met inclusion criteria and to compare studies. For each study, the first author collected the following information: author(s) and year of publication; years of data collection; study design (cohort versus randomized trial; representativeness); location in the United States; sample size; age at baseline and follow-up; years of birth; and obesity incidence estimates. If the study included data for individuals both younger and older than 18, only data for children less than 18 years were retained if age categorization permitted such subsetting. If subsetting was not possible, the study was excluded. Among intervention studies, only data on the control or nonintervention group were abstracted. One study did not estimate incidence but provided sufficient data for us to perform the calculation (number of children at risk for obesity at baseline and number of children obese at a later point). We reported cumulative incidence (incidence proportion) from each study, defined as the number of newly obese children during study follow-up divided by the number of nonobese children potentially at risk for obesity at baseline. Because studies varied in length of follow-up, we estimated annualized incidence proportions using cumulative incidence estimates from each study divided by years of follow-up.

Studies included convenience and representative samples, used differing study designs (*e.g.*, observational cohort or randomized controlled trial), measures of adiposity (body mass index [BMI] or skin fold thickness), and definitions of obesity (cutpoints defined by the Centers for Disease Control and Prevention [CDC] International Obesity Task Force [IOTF], etc.). Such heterogeneity made formal statistical meta-analysis impractical. Similarly, this variation in study design and obesity measurement made it difficult to use uniform criteria or a single measurement to systematically assess bias. Potential biases at study and outcome levels are discussed in the limitations section.

The majority (15 of 19) of studies measured adiposity with BMI and defined obesity according to CDC cutpoints for BMI-for-age-and-sex at or above 95th percentile, or used CDC weight-for-length charts for infants. Due to the small number of studies within each age group, studies using the current CDC cutpoints or weight-for-length charts for infants were summarized by the median study-specific annualized incidence for each of the following age groups: infancy (0–1.9 years), preschool (2.0–4.9 years), school aged (5.0–12.9 years), and adolescence (13.0–18.0 years). These age groups were selected because they capture major developmental stages. Studies on children whose ages spanned two groups were included in median calculations of both age groups. To visualize age-specific trends in incident obesity, we plotted the annualized cumulative incidence of obesity against the age range of study follow-up. This was summarized with a weighted simple linear regression with weights for each study, defined as the inverse of the variance of the study-specific incidence estimate. Study-specific baseline risk varied by known demographic factors, so studies were categorized into two groups: (1) predominantly high-risk population (> 50% racial/ethnic minorities or a single high-risk socioeconomic community) and (2) not predominantly high-risk population (all other studies).

To consider temporal changes in environments that may have been linked with obesity patterns over the decades being studied, a sensitivity analysis was performed by decade of birth. In the 2000s, a shift in the obesity category definition occurred, so we examined whether the change influenced our findings. A second sensitivity analysis examined only studies using the CDC obesity definition published during and after 2007.^{15,16}

Results

Literature Identification and Selection

We identified 2135 articles: 1068 in PubMed, 698 in EMBASE, and 369 in CINAHL (Figure 1). After discarding duplicate articles, titles and abstracts were screened for inclusion criteria, resulting in 126 articles. After review and application of exclusion criteria, 19 articles were retained (Table 1).

Literature Overview

Eight articles were published during and after 2010, and only two studies were published before 2000. Only three used nationally representative data.^{17,18,30} Studies reporting incidence included one study among children under 2 years of age,²⁹ two among children between 2.0–4.9 years,^{24,29} seven among children 5.0–12.9 years,^{6,10,11,18,23,28,31} and two among adolescents 13.0–18.0 years.^{6,21} Many studies spanned age groups, including infancy through the preschool ages,^{22,29} preschool through school age,^{17,25,26,27,30} and school age through adolescence.^{6,10,18–20,26,32}

Many studies were based on secondary analysis of datasets, including the Pediatric Nutrition Surveillance System

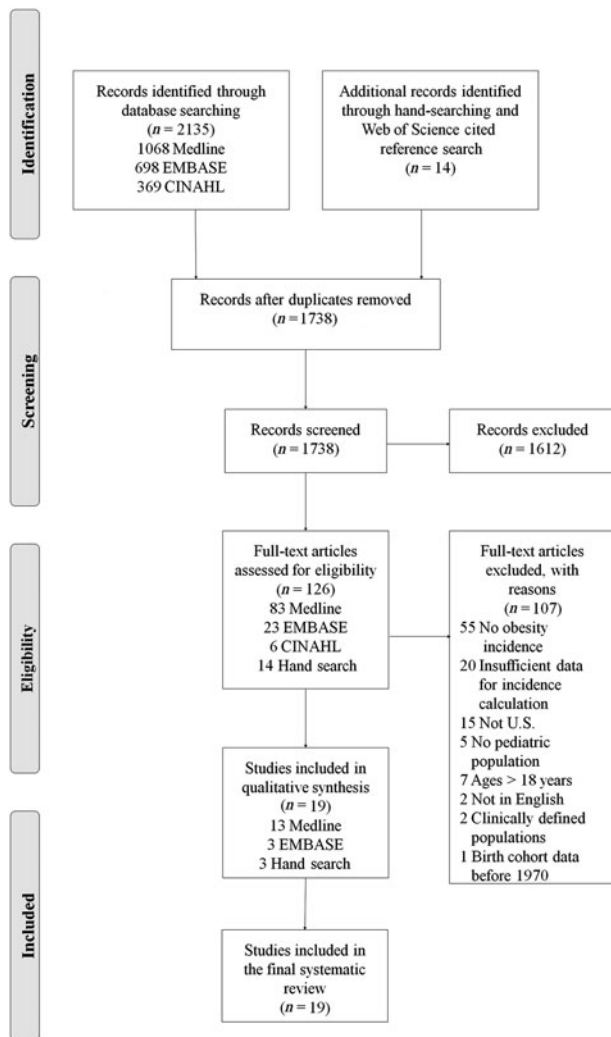


Figure 1. Preferred reporting items for systematic reviews and meta-analyses flow diagram describing article acquisition of 19 studies involving childhood obesity incidence in the United States. Articles ($n=2135$) were identified through database searches, and 14 articles were identified through hand searching. Among these studies, 1612 articles were excluded based on title and abstract review. After the remaining 126 articles were reviewed, 19 articles met the inclusion criteria and were included in the analysis.

(PedNSS; $n=3$); National Longitudinal Survey of Youth (NLSY; $n=2$), Cambridge Public School Health Surveillance System ($n=2$); or others ($n=3$). Nine studies analyzed primary data, including five intervention studies randomized at the school level and providing control arm data.^{20,23,28,31,32} Of the three nationally representative studies, two used the NLSY- Child Cohort data. One of these three representative studies included follow-up data from 1980–1988, finding an annual incidence of 1.3% for children 4–10 years old.³⁰ Another study included follow-up from 1980–1998, reporting annual incidence of 1.7% for children ages 4.5–10.5 years.¹⁷ The most recent study used data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998/9, which followed a cohort of

children born in 1993 from an average age of 5.6–14.1 years.¹⁸ Obesity incidence was estimated at 11.9% over the entire age range and annualized obesity incidences were estimated at 5.4% at mean ages of 5.6–6.1 years, 2.7% at 6.1–7.1 years, 3.0% at 7.1–9.1 years, 3.1% at 9.1–11.1 years, and 1.7% at 11.1–14.1 years. Sample sizes for studies included in this review ranged between 109 and 380,518 children.^{23,29} Follow-up was on average 2.0 years (range: 0.5–9.0 years).

Height and weight were measured by medical personnel (physicians, nurses, nutritionists, dieticians) or trained researchers using stadiometers or tape measures and scales in all but two nationally representative studies (which used parent-reported data for a subset of participants.^{17,30}) Fifteen studies used the CDC definition of obesity (BMI-for-age-and-sex ≥ 95 th percentile for children 2 years or older) or CDC gender-specific weight-for-length charts (≥ 95 th percentile for children less than 2 years). One used a combination of BMI and triceps skinfolds measurements (both ≥ 95 th percentile),²⁰ two used IOTF cutpoints,^{11,21} and one used BMI > 95 th percentile derived from the first and second National Health and Nutrition Examination Surveys (NHANES).³⁰

Age-Specific Obesity Incidence

Across studies measuring adiposity with CDC BMI-for-age-and-sex or weight-for-length percentile definitions of obesity, the median annualized obesity incidence was 4.0% for infants 0–1.9 years (range: 2.1%–8.2%), 4.0% for preschool-aged children 2.0–4.9 years (range: 1.1%–6.7%), 3.2% for school-aged children 5.0–12.9 years (range: 1.1%–6.8%), and 1.8% for adolescents 13.0–18.0 years (range: 0.4%–4.4%). As an approximation of the trend, the weighted regression demonstrated a steady decline in incidence with age (Figure 2).

Five studies, including one nationally representative cohort, reported decreasing incidence with increasing age.^{6,10,18,22,29} One study, using the PedNSS, a study of low-income children in 39 states and the District of Columbia, reported annual obesity incidence of 4.7% at ages 0–1 years and 4.1% at ages 1–2 years among children born in 2006–2008.²² Another study, also using the PedNSS but among children born 1985–1990, reported annual incidence at baseline of 8.2% at ages 0–1 years, 5.5% at 1–2 years, 4.5% at 2–3 years, and 4.1% at 3–4 years.²⁹ A study using a nationally representative cohort reported an annual incidence ranging from 5.4% within kindergarten (5.6–6.1 years) to 1.7% between fifth and eighth grades (11.1–14.1 years).¹⁸ A study of the Cambridge Public School Health Surveillance System in Cambridge, Massachusetts, reported that annual incidence peaked at 5.4% at 7–9 years at baseline, but declined between ages 9–11 years.¹⁰ Finally, a study using data from the National Heart, Lung, and Blood Institute Growth and Health Study, a sample of urban Black and white girls, reported the annual incidence of obesity to be 3.1% at ages 10–11 years and 1.4% at 17–18 years among

Table 1. Summary of 19 Studies Reporting Child Obesity Incidence in the United States: Predominantly High Risk Denotes Studies Conducted among Socioeconomically Disadvantaged or >50% Racial/Ethnic Minority Groups. (Not predominantly high risk denotes all other studies.)

Author, year of publication	Location	Sample size	Age at baseline in years, mean \pm SD (range) ^a	Length of follow-up in months, mean (range)	Birth cohort	Reported obesity incidence	Annual obesity incidence
Not predominantly high risk							
Williamson et al., ¹¹ 2011 ^b	Rural Louisiana	451	10.5 \pm 1.1	27.6	1996	4.3% ^e Boys: 1.1% ^e Girls: 7.3% ^e	1.9% 0.5% 3.2%
Van Cleave et al., ¹⁷ 2010 ^{b,c}	United States	Cohort 1: 905 Cohort 2: 1759 Cohort 3: 2337	4.9 \pm 1.5 (2–8) 4.5 \pm 1.6 (2–8) 4.4 \pm 1.8 (2–8)	72 72 72	1993–1998 1987–1992 1980–1986	10.6% ^f 13.7% ^f 6.5% ^f	1.8% 2.3% 1.1%
Cunningham et al., ¹⁸ 2014 ^{b,c}	United States	7738	5.6	6	1992	5.4% ^f Boys: 5.4% ^f Girls: 5.4% ^f	5.4% 5.4% 5.4%
			6.1	12		2.7% ^f Boys: 2.8% ^f Girls: 2.6% ^f	2.7% 2.8% 2.6%
			7.1	24		3.0% ^f Boys: 2.9% ^f Girls: 3.2% ^f	3.0% 2.9% 3.2%
			9.1	24		3.1% ^f Boys: 3.3% ^f Girls: 2.9% ^f	3.1% 3.3% 2.9%
			11.1	36		1.7% ^f Boys: 1.9% ^f Girls: 1.4% ^f	1.7% 1.9% 1.4%
Stevens et al., ¹⁹ 2007 ^d	United States	984	11.9 \pm 0.4	24	1991	3.8% ^g	1.9%
Gortmaker et al., ²⁰ 1999 ^d	Boston, MA	654	11.7 \pm 0.7	21	1983–1984	8.8% ^h Boys: 9.6% ^h Girls: 8.0% ^h	5.0% 5.5% 4.6%

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Table 1. Summary of 19 Studies Reporting Child Obesity Incidence in the United States: Predominantly High Risk Denotes Studies Conducted among Socioeconomically Disadvantaged or >50% Racial/Ethnic Minority Groups. (Not predominantly high risk denotes all other studies.) continued

Author, year of publication	Location	Sample size	Age at baseline in years, mean \pm SD (range) ^a	Length of follow-up in months, mean (range)	Birth cohort	Reported obesity incidence	Annual obesity incidence
Thompson et al., ⁶ 2007 ^b	United States	1098 ⁱ 1024 ⁱ 1010 ⁱ	10 11 12	12 12 12	1976–1977	3.1% ^g 2.5% ^g 2.1% ^g	3.1% 2.5% 2.1%
		958 ⁱ 856 ⁱ 811 ⁱ	13 14 15	12 12 12		1.8% ^g 2.0% ^g 0.4% ^g	1.8% 2.0% 0.4%
		852 ⁱ 904 ⁱ	16 17	12 12		1.1% ^g 1.4% ^g	1.1% 1.4%
Huh et al., ²¹ 2012 ^b	Southwest United States	496 ⁱ	13 (11–15)	12	Not reported	1.8% ^g	1.8%
Predominantly high risk							
Pan et al., ²² 2013 ^b	WIC participants in the United States	1,204,839	(0–1.9)	(24–35)	2006–2008	11.0% ^{fj} Boys: 11.3% ^{fj} Girls: 10.7% ^{fj}	4.5% 4.6% 4.4%
Story et al., ²³ 2012 ^d	Pine Ridge Reservation, SD	109	(0–0.9) (1–1.9) 5.8 \pm 0.5	(24–35) (24–35) 21	1999–2000	11.6% ^{fj} 10.2% ^{fj} 5.5% ^{f, k}	4.7% 4.1% 3.1%
Welsh et al., ²⁴ 2005 ^b	WIC participants in Missouri	10,904	2.8 (2.0–3.0)	12 (11–13)	1996–1999	6.0% ^g	6.0%
Lim et al., ²⁵ 2009 ^b	Low-income African Americans in Detroit, MI	365	3–5	24	1997–2000	13.4% ^f	6.7%
Kim et al., ²⁶ 2005 ^b	Cambridge, MA	6297	5.7, 9.1, 13	12	1988–1998	4.5% ^g Boys: 4.0% ^g Girls: 5.0% ^g	4.5% 4.0% 5.0%

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Table 1. Summary of 19 Studies Reporting Child Obesity Incidence in the United States: Predominantly High Risk Denotes Studies Conducted among Socioeconomically Disadvantaged or >50% Racial/Ethnic Minority Groups. (Not predominantly high risk denotes all other studies.) continued

Author, year of publication	Location	Sample size	Age at baseline in years, mean \pm SD (range) ^a	Length of follow-up in months, mean (range)	Birth cohort	Reported obesity incidence	Annual obesity incidence
Kim et al., ¹⁰ 2005 ^b	Cambridge, MA	5301	5–7	12	1986–1997	4.6% ^g Boys: 4.6% ^g Girls: 4.5% ^g 5.4% ^g Boys: 5.4% ^g Girls: 5.5% ^g 3.9% ^g Boys: 4.3% ^g Girls: 3.4% ^g 3.2% ^g Boys: 3.3% ^g Girls: 3.1% ^g	4.6% 4.6% 4.5% 5.4% 5.4% 5.5% 3.9% 4.3% 3.4% 3.2% 3.3% 3.1%
Robbins et al., ²⁷ 2007 ^b	Philadelphia, PA	386	11–14	12	1994–1996	9.5% ^g	4.3%
Rappaport et al., ²⁸ 2013 ^d	Philadelphia, PA	3675	5–13	30 (18–41)	1988–1996	17.0% ^f	6.8%
Mei et al., ²⁹ 2003 ^b	WIC participants in United States	380,518	0–1	12	1985–1990	8.2% ^h	8.2%
			0–1	24		7.9% ^h	4.0%
			0–1	36		7.7% ^h	2.6%
			0–1	48		8.3% ^h	2.1%
			1–2	12		5.5% ^h	5.5%
			1–2	24		5.8% ^h	2.9%
			1–2	36		6.6% ^h	2.2%
			2–3	12		4.5% ^h	4.5%
			2–3	24		5.5% ^h	2.8%
			3–4	12		4.1% ^h	4.1%
Strauss et al., ³⁰ 1999 ^{b,c}	United States	3320	0–8	72	1980–1988	8.0% ⁱ Boys: 8.6% ⁱ Girls: 7.1% ⁱ	1.3% 1.4% 1.2%

Table 1. Summary of 19 Studies Reporting Child Obesity Incidence in the United States: Predominantly High Risk Denotes Studies Conducted among Socioeconomically Disadvantaged or >50% Racial/Ethnic Minority Groups. (Not predominantly high risk denotes all other studies.) continued

Author, year of publication	Location	Sample size	Age at baseline in years, mean \pm SD (range) ^a	Length of follow-up in months, mean (range)	Birth cohort	Reported obesity incidence	Annual obesity incidence
Thompson et al., ⁶ 2007 ^b	United States	1159 ⁱ	10	12	1976–1977	2.7% ^g	2.7%
		1092 ⁱ	11	12		4.8% ^g	4.8%
		1100 ⁱ	12	12		4.2% ^g	4.2%
		1074 ⁱ	13	12		1.8% ^g	1.8%
		967 ⁱ	14	12		1.0% ^g	1.0%
		931 ⁱ	15	12		2.2% ^g	2.2%
		940 ⁱ	16	12		0.7% ^g	0.7%
		934 ⁱ	17	12		0.8% ^g	0.8%
Klish et al., ³¹ 2012 ^d	Low-income Hispanics in Houston, TX	510	7.9 \pm 2.1	9	Not reported	4.2% ^f	5.3%
Foster et al., ³² 2008 ^d	Low-income schools in Philadelphia, PA	365	11.2 \pm 1.0	24	Not reported	6.4% ^f	3.2%

^aAge was reported differently across studies. Available information was reported in this table.

^bCohort study.

^cNationally representative study population.

^dRandomized study or quasi-experimental study.

^eBased on sex- and age-specific reference values of the IOTF.

^fBased on 2000 CDC sex- and age-specific growth charts where obese was classified as BMI \geq 95th percentile.

^gBased on 2000 CDC age- and sex-specific growth charts as BMI \geq 95th percentile, which was previously the definition of overweight.

^hBased on NHANES I references, where obesity is defined as BMI and triceps skinfolds \geq 85%.

ⁱStudy only included girls only.

^jBased on 2000 CDC sex-specific weight-for-length charts \geq 95th percentile.

^kDenominator for calculating incidence did not include overweight children.

^lBased on combined data of NHANES I and II, where obese was classified as BMI \geq 95th percentile.

IOTF, International Obesity Task Force; CDC, Centers for Disease Control and Prevention; NHANES, National Health and Nutrition Examination Survey; SD, standard deviation; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

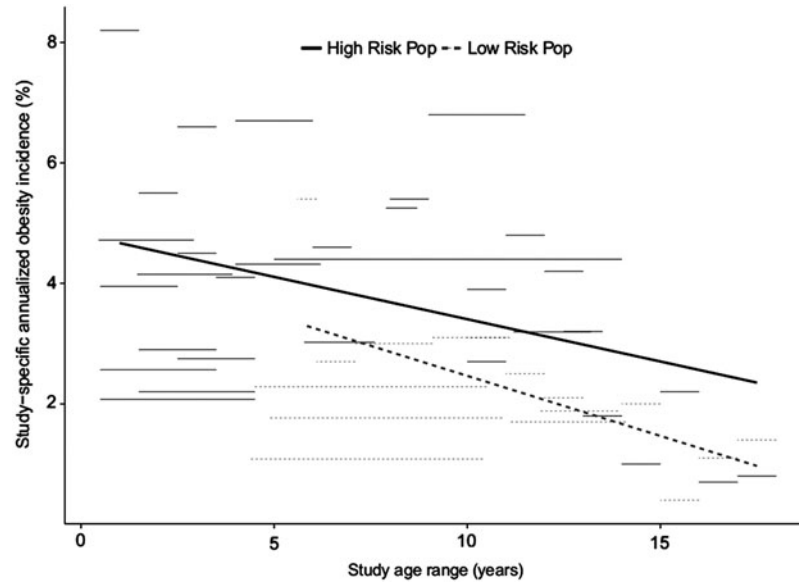


Figure 2. Annual obesity incidence by age across 19 studies in the United States. High-risk population denotes studies conducted among socioeconomically disadvantaged or >50% racial/ethnic minority groups. Low-risk population denotes all other studies. Trendlines are weighted by the inverse of the variance of each study-specific incidence estimate.

white girls;⁶ for Black girls, incidences were 4.8% between 11–12 years and 0.7% between 16–17 years, but the incidence trends with age were less clear for this study.⁶

Child Obesity Incidence by Demographics and Baseline Weight

Children from socioeconomically disadvantaged families and some racial and ethnic minorities experienced higher median obesity incidence than whites. Studies conducted among socioeconomically disadvantaged or >50% racial/ethnic minority groups and using CDC percentile definitions of obesity reported obesity incidences of 4.0% at ages 0–1.9 years (range: 2.1%–8.2%), 4.1% at 2.0–4.9 years (range: 2.1–6.7%), 4.4% at 5.0–12.9 years (range: 2.7–6.8%), and 2.2% at 13.0–18.0 years (range: 0.7%–4.4%). Six studies analyzed obesity incidence by race and ethnicity. Four of these studies, including two using nationally representative data,^{18,30} showed higher obesity incidence rates among Blacks and Hispanics compared with Whites.^{10,18,21,30} One study using data on girls in the Southwest reported annual incidences of 4.5% among Black, 2.0% among Hispanic, and 0.7% among white girls at ages 13–19 years.²¹ Among low-income children across 39 states and the District of Columbia, incidences at 0–1.9 years were 6.3% among American Indians/Alaskan Natives, 5.5% among Hispanics, 3.7% among Asian Pacific Islanders, 3.5% among Blacks, and 3.9% among whites.²² Among urban Black and white girls born in 1976–1977, incidence was higher among Black girls at some but not all ages.⁶

Six studies, including one nationally representative cohort, examined incidence rates stratified by children's weight at baseline weight (*e.g.*, normal weight, over-

weight, etc.). All but one study reported that children who became obese during the study period were more likely to have been overweight at baseline,^{10,18,21,22,27} the other study showed a “regression to the mean” effect, where normal-weight children tended to gain weight, and overweight and obese children generally lost weight over time; but this study population had a high prevalence of overweight (44.3%) and obesity (22.0%) at a baseline.¹¹

Seven studies reported gender-specific obesity incidence. Three of these, including a nationally representative study, reported higher obesity incidences among boys compared with girls,^{20,22,30} with a maximum difference in annual incidence of 0.9% (5.5% and 4.6% for boys and girls, respectively) at ages 11.7–13.5 years.²⁰ Two studies reported higher annual obesity incidence among girls: 3.2% for girls versus 0.5% for boys¹¹ and 5.0% for girls versus 4.0% for boys,²⁶ respectively. Two studies, including a nationally representative study, reported higher incidences for boys at some ages but not others.^{10,18}

One study examined differences in incidence across birth cohorts, estimating obesity incidence at ages 4.6–10.6 years for children born in 1980–1986, 1987–1992, and 1993–1998 in the nationally representative NLSY Youth Cohort. Annual incidence estimates were 1.1% for children born in 1980–1986, 2.3% for children born in 1987–1992, and 1.8% for children born in 1993–1998.¹⁷

Sensitivity analyses showed that the pattern of decreasing childhood obesity incidence with age was consistent across birth cohorts (Figure 3) for children born in the 1970s, 1980s, and 1990s. The same trend of decreasing childhood obesity incidence with increasing age was observed when restricting to studies published during and after 2007 (see online supplementary Figure S1 at

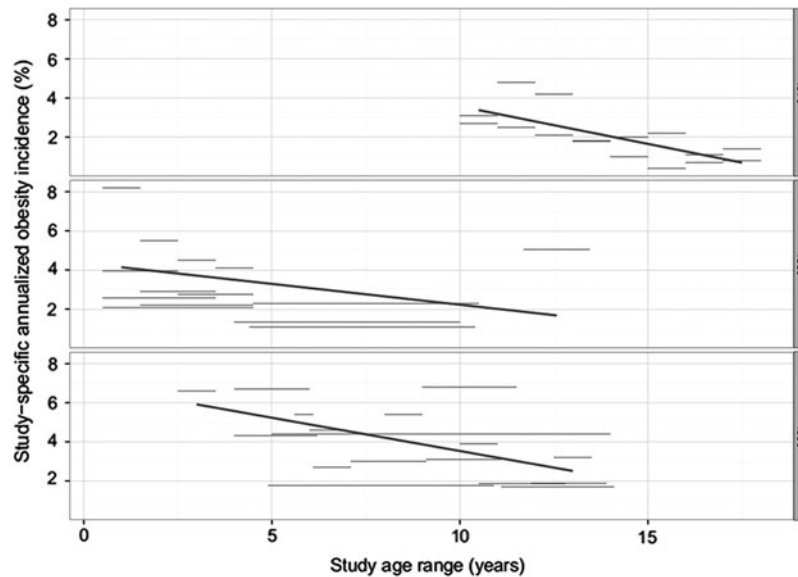


Figure 3. Annual obesity incidence by age stratified by birth cohort decade (1970s, 1980s, and 1990s) across studies in the United States. Trendlines are weighted by the inverse of the variance of each study-specific incidence estimate.

www.liebertpub.com/jpm and at www.liebertonline.com) after most researchers had adopted proposed terminology changes occurring in the 2000s.^{15,16}

Discussion

This systematic review synthesized current knowledge about the incidence of obesity from early childhood through adolescence in the United States. The main finding is that across studies, annual incidence declined with age: the median incidence proportion was 4.0% at ages 0–1.9 years, 4.0% at 2.0–4.9 years, 3.2% at 5.0–12.9 years, and 1.8% at 13.0–18.0 years.

These patterns are also consistent with some studies of obesity incidence among adults in the United States. A study using 2009 Behavioral Risk Factor Surveillance System (BRFSS) data used self-reported height and weight at the time of the study and one year previously to calculate obesity incidence among adults ≥ 18 years in the United States, and found obesity incidence decreased with age: 6.4% at ages 18–29 years, 4.8% at 30–49 years, 3.3% at 50–69 years, and 1.5% at ages 70 years and over.³³ These patterns were robust to adjusting for age, sex, race/ethnicity, education, region, physical activity, fruit and vegetable consumption, smoking, alcohol use, and baseline BMI. However, a study using the nationally representative National Longitudinal Study of Adolescent Health (Add Health Waves II and III) estimated annual incidences at 1.9% at ages 13–15 years, 2.4% at 16–17 years, and 2.4% at 18–20 years.³⁴

The declining incidence with age could suggest exhaustion of the pool of children susceptible to incident obesity, or may reflect aspects of growth dynamics associated with development, such as regression from obese to nonobese states, adiposity rebound, and pubertal changes in body composition. Four studies reported obesity re-

mission rates in addition to incidence. Among obese infants (0–23 months), 63.5% were not obese at follow up 24–35 months later.²² One study reported annual remission rates ranging from 13.3%–20.3% for children ages 5–14 years.¹⁰ A third study reported annual remission rates between 8.0% and 24.1% among adolescents.²¹ The fourth study indirectly reported annual remission for infants (0–1 year) of 64.4% and for ages 3–4 years at 37.5%.²⁹ Relating the observed patterns in age-specific obesity incidence with what is known about patterns in obesity prevalence requires further understanding of the timing and reasons for obesity remission and normal growth dynamics.

The downward trend of obesity incidence with age observed in this study is consistent with some studies from outside the United States. For example, a large prospective cohort in southwest England in 2011 reported annual incidences of 1.2% at 3–11 years and 0.4% at 11–15 years.³⁵ Other studies from outside the United States have shown different patterns. In a 2012 study in northern Germany, annual obesity incidence was 0.6% at mean ages of 2–6 years and 0.7% at mean ages of 6–10 years.³⁶

Incidence patterns may differ by race and ethnicity, with four of the six studies examining incidence by race reporting that Black and Hispanic children experienced higher age-specific incidence rates than white children.^{10,18,21,30} Higher incidence and lower remission rates among Blacks and Hispanics^{10,21} may partially explain the higher obesity prevalence observed among these children.^{10,18}

Limitations

There were several limitations to this review. Many studies used convenience data or data that were not initially designed with the primary intention of studying obesity incidence. Consequently, study designs, measurements of obesity, populations, cohorts, and locations of studies were

not optimal and differed widely. Only three studies used nationally representative data.^{17,18,30} Among the studies drawing on data from intervention programs,^{20,23,28,31,32} many focused on specific populations, such as schools in high-risk areas^{28,31,32} or Native American reservations,²³ limiting the generalizability of the results. The heterogeneity in population was a challenge for literature synthesis, making straightforward comparisons between studies difficult.

Because BMI can easily be calculated using self-reported or directly measured height and weight, BMI-for-age-and-sex and weight-for-length percentile growth charts are a common measure included in large-scale studies. While not an ideal measure, BMI is an acceptable indicator of adiposity.³⁷ However, the potential of BMI categories to predict future health risks remains unclear.^{38,39}

Most studies involving children older than 2 years used the CDC BMI percentile cutoffs for overweight and obesity, but other studies used IOTF cutoffs or other definitions. The use of different definitions across studies impedes comparison. IOTF cutoff points produce lower estimates of obesity prevalence and higher estimates of obesity incidence in comparison to CDC cutoff points.^{34,40,41} It will be important to determine which cutoffs are best suited for identifying future health risks. World Health Organization (WHO) growth standards have been recommended for monitoring weight up to age 2 years, but there is no consensus obesity measure for children younger than 2 years.⁴² Two studies included in this review used CDC weight-for-length ≥ 95 th percentile to define obesity in children under age 2 years.^{22,29} WHO and CDC weight-for-length growth charts are not comparable.⁴³ Identifying a measure of unhealthy weight for children under age 2 years will be useful, since studies have shown that obesity may originate early in life.

Conclusions

The literature on incidence of childhood obesity is relatively sparse and is heterogeneous in populations and study design. The studies to date have indicated that obesity incidence is highest at the youngest ages and declines with age through adolescence. They have also shown that incidence proportions may differ by gender, race, ethnicity, and socioeconomic status. The patterns suggest the need to focus obesity prevention early in life. However, limitations in existing data sources suggest that future surveillance of population-based patterns of obesity incidence will benefit from consistent use of measures with predictive capacity for future health outcomes, carried out in representative populations periodically assembled in order to understand incidence of childhood obesity, risk factors, and changes in these measures over time. The information from such systematized and representative surveillance could make it possible to (1) investigate etiologic explanations for incidence and remission of obesity, (2) identify windows of opportunity for effective intervention, and (3) evaluate the impact of ongoing interventions.

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