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Prevalence of Childhood Obesity in the United States in 1999–2018: A 20-Year Analysis

Man-Fung Tsoi[a] Hang-Long Li[a] Qi Feng[a] Ching-Lung Cheung[b, c]
Tommy T. Cheung[d] Bernard M.Y. Cheung[a, c, d]

[a]Division of Clinical Pharmacology and Therapeutics, Department of Medicine, The University of Hong Kong, Hong Kong, China; [b]Department of Pharmacology and Pharmacy, The University of Hong Kong, Hong Kong, China; [c]Partner State Key Laboratory of Pharmaceutical Biotechnology, The University of Hong Kong, Hong Kong, China; [d]Institute of Cardiovascular Science and Medicine, The University of Hong Kong, Hong Kong, China

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Abstract
Introduction: Obesity is a public health crisis in the USA. This study aimed to estimate the prevalence of obesity and severe obesity in US children and adolescents and identify novel targetable risk factors associated with childhood obesity. ***Methods:*** From the US National Health and Nutrition Examination Survey from 1999 to 2018, 35,907 children aged 2–19 with body mass index (BMI) data were included. Obesity and severe obesity were defined as BMI ≥95th percentile and ≥120% of 95th percentile of US Centers for Disease Control and Prevention growth charts, respectively. Trends in the prevalence of obesity and subgroup analyses according to socioeconomic factors and language used in the interview were analyzed. ***Results:*** The prevalence of obesity and severe obesity increased from 14.7 [95% confidence interval: 12.9–17.0]% to 19.2 [17.2–21.0]% and 3.9 [2.9–5.0]% to 6.1 [4.8–8.0]% in 1999–2018, respectively (p = 0.001 and p = 0.014, respectively). In 2017–2018, the prevalence of obesity among children from Spanish-speaking households was 24.4 [22.4–27.0]%, higher than children from English-speaking households (p = 0.027). ***Conclusion:*** The prevalence of childhood obesity kept increasing in 1999–2018. The problem is worse in children from Spanish-speaking households. Novel and targeted public health intervention strategies are urgently warranted to effectively halt the rising epidemic of childhood obesity.

Introduction

Obesity is a global health problem that affects over 650 million adults as well as 340 million children [1]. The etiology of childhood and adolescent obesity is manifold and includes genetic predisposition, environmental factors, lifestyle, and complex interactions among them [2]. Excessive caloric intake and physical inactivity are well-known modifiable factors and have been extensively studied [2, 3]. The harmful consequences of childhood obesity include early onset of type 2 diabetes mellitus, hypertension, dyslipidemia, metabolic syndrome, asthma, and cardiovascular diseases, as well as psychological impacts such as low self-esteem [4–8]. Furthermore, obesity

Karger@karger.com
www.karger.com/ofa

Correspondence to:
Bernard M.Y. Cheung, mycheung@hku.hk

in early childhood is a risk factor for obesity in adolescence and adulthood [9, 10]. Obesity and its associated diseases pose an enormous economic burden and were estimated to cost USD 147 billion in the USA in 2008 [11].

The prevalence of obesity varies across different sections of the population. It is higher in children aged 6–11 years and 12–19 years compared to children aged 2–5 years [12]. Compared to non-Hispanic White children, non-Hispanic Black and Hispanic children had a higher prevalence of obesity [12]. Children with a low socioeconomic status are more likely to have obesity [12]. Other factors associated with the prevalence of childhood obesity include immigrant status [13, 14], cultural factors such as perception of body image [15], and maternal factors such as mothers' awareness of weight control [16].

While previous studies have generally shown a rising trend of childhood obesity, another study on obesity prevalence in 2007–2016 suggested that there had not been a significant increase [17]. A recent report found that the prevalence of childhood obesity varied according to age and ethnicity [18], but the overall long-term trends and other factors associated with childhood obesity were not evaluated. Whether the prevalence of childhood obesity increased over the last 20 years remains uncertain, and whether newly introduced campaigns and policies reduced childhood obesity remains controversial. Therefore, with the latest data from the National Health and Nutrition Examination Survey (NHANES) available, we investigated the latest trend in the prevalence of childhood obesity in the USA. The second objective was to examine the complicated and often neglected effects of ethnicity, native language, parental education, and income on childhood obesity.

Materials and Methods

The US NHANES is a surveillance system of continuous studies designed to assess the health and nutrition status of the US population. A complex, multistage, probability sampling design is adopted to achieve national representativeness of the samples. NHANES began collecting data continuously starting from 1999, and data are released every 2 years as a cycle. Data from multiple cycles can be combined because of the low prevalence of the health condition or the small sample size of the subgroup. More details on its study design and application are summarized elsewhere and in our previous studies [6, 19]. The study was approved by the Research Ethics Review Board at the National Center for Health Statistics. Informed consent was given by all participants aged 18 years or older and parent(s) of participants 17 years or younger. For the examination component in children aged 1–19 years, the response rate was 55% in 2017–2018, compared to response rates ranging from 65% to 87% in previous years.

All body measurements were performed in accordance with a standardized protocol using calibrated instruments. The weight and height of participants were measured. BMI, which is the weight in kilograms divided by the square of the height in meters, was calculated and reported in NHANES.

In our analysis, we included children and adolescents aged 2–19 years in NHANES 1999–2018. For simplicity, we refer to all of them as children. Cycles from 1999 to 2018 were included to achieve a larger sample size and to study long-term trends. Pregnant participants or those without BMI measurements were excluded from the analysis. The variables retrieved included BMI, age, sex, ethnicity, the language used in the family interview, the education level of the household reference person, and the ratio of family income to poverty.

Overweight was defined as BMI at or above the 85th and below the 95th sex-specific percentile of the BMI-for-age growth chart from the Centers for Disease Control and Prevention (CDC) [20, 21]. Obesity was defined as BMI at or above the sex-specific 95th percentile of the CDC BMI-for-age growth charts. Severe obesity was defined as a subgroup within obesity in which the BMI was ≥120% of the 95th percentile of the CDC BMI-for-age growth charts [12]. In the sensitivity analysis, severe obesity was defined as BMI ≥120% of the 95th percentile or an absolute BMI ≥35 kg/m^2, whichever is lower [22].

Participants were classified into three age groups: 2–5, 6–11, and 12–19 years [12]. Household education levels were stratified according to the household reference person's education level, which comprised three categories: low (less than a high school degree), middle (high school graduate, or General Educational Development or high school equivalency or some college, or associate degree), and high (college graduate or above). Income levels were defined according to the poverty-income ratio and coded as low income (poverty-income ratio <1.3), middle income (poverty-income ratio ≥1.3 and <3.5), and high income (poverty-income ratio ≥3.5) [23]. Children were defined to be from Spanish-speaking families if the household reference person chose Spanish for the family interview and were otherwise defined as coming from English-speaking families as there were the only two languages used in the study. In evaluating the relationship between language and obesity, the language for family interview was selected instead of ethnicity or language used in Mobile Examination Center interview because it best reflects the main language used in daily family interactions.

Statistical Analysis

Sample weights were applied to adjust for unequal probability of selection, nonresponse bias, and oversampling. The original sample weights were divided by 10, because 10 cycles of survey data were included; in accordance with recommendations by the CDC, sample weights in 1999–2002 were first multiplied by 2 since 4-year cycle weights were provided in this period. The prevalence of overweight, obesity, and severe obesity with 95% confidence intervals (CIs) were calculated for each 2-year cycle in NHANES for each sub-group. Temporal trends in the prevalence of overweight, obesity, and severe obesity from 1999 to 2018 were examined. Data on non-Hispanic Asians were not available until the 2011–2012 cycle [19], so the trends and ethnic differences between non-Hispanic Asians and other ethnicities were compared from 2011 onward. Subgroup analyses were conducted in the following prespecified subgroups: age group, sex, ethnicity, household education

Table 1. Characteristics of participants included in this study

	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018	*p* value
N	4,050	4,017	3,908	4,180	3,254	3,418	3,365	3,535	3,350	2,830	
Age, years	10.35±0.11	10.74±0.11	10.54±0.18	10.54±0.16	10.57±0.18	10.46±0.11	10.46±0.15	10.55±0.15	10.51±0.11	10.65±0.16	0.536
Male	51.5 [48.8–54.0]	54.2 [52.5–56.0]	52.4 [50.2–55.0]	52.0 [50.1–54.0]	51.5 [49.0–54.0]	51.4 [48.6–54.0]	51.2 [48.5–54.0]	51.0 [48.5–54.0]	51.1 [49.0–53.0]	50.7 [47.7–54.0]	0.083
Ethnicity											
Mexican American	14.3 [9.2–21.0]	9.8 [7.5–13.0]	12.4 [7.8–19.0]	13.3 [10.6–17.0]	13.5 [9.1–20.0]	15.0 [10.0–22.0]	14.8 [9.7–22.0]	16.2 [11.2–23.0]	15.1 [9.1–24.0]	16.8 [11.6–24.0]	
Other Hispanic	7.9 [3.7–16.0]	7.7 [4.2–14.0]	5.1 [3.4–8.0]	4.5 [2.8–7.0]	6.6 [3.7–11.0]	6.5 [3.9–10.0]	8.1 [5.2–13.0]	7.3 [5.0–11.0]	8.9 [6.8–12.0]	8.0 [6.2–10.0]	
Non-Hispanic white	56.4 [49.3–63.0]	62.1 [55.9–68.0]	61.3 [52.2–70.0]	59.6 [52.4–66.0]	58.6 [49.8–67.0]	56.4 [49.1–63.0]	53.6 [43.5–63.0]	52.4 [42.1–62.0]	51.9 [40.0–63.0]	50.1 [42.5–58.0]	
Non-Hispanic black	14.5 [9.9–21.0]	14.4 [9.9–21.0]	14.7 [10.5–20.0]	14.9 [10.6–21.0]	14.7 [10.5–20.0]	13.8 [11.5–16.0]	15.0 [9.8–22.0]	14.0 [10.1–19.0]	13.9 [8.4–22.0]	13.0 [9.6–17.0]	0.715
Other ethnicities	6.9 [4.2–11.0]	6.0 [4.7–8.0]	6.4 [4.2–10.0]	7.8 [5.3–11.0]	6.6 [4.4–10.0]	8.4 [6.4–11.0]	8.5 [6.4–11.0]	10.0 [8.1–12.0]	10.3 [7.3–14.0]	12.2 [9.5–15.0]	
Non-Hispanic Asian	NA	NA	NA	NA	NA	NA	4.6 [3.4–6.0]	4.7 [3.5–6.0]	4.8 [2.7–8.0]	4.9 [3.1–8.0]	
Other races	NA	NA	NA	NA	NA	NA	3.8 [2.4–6.0]	5.3 [4.1–7.0]	5.6 [4.4–7.0]	7.3 [5.7–9.0]	
English-speaking)	NA	NA	95.5 [93.2–97.0]	94.8 [92.8–96.0]	93.8 [92.0–95.0]	92.5 [88.9–95.0]	92.6 [88.8–95.0]	94.8 [93.1–96.0]	91.1 [85.7–95.0]	89.8 [84.7–93.0]	0.005
BMI,kg/m^2	19.87±0.14	20.19±0.12	20.35±0.20	20.15±0.18	20.29±0.20	20.38±0.13	20.44±0.15	20.62±0.16	20.60±0.20	20.71±0.15	<0.001
Obesity status											
Overweight	14.1 [12.4–16.0]	14.0 [12.8–15.0]	16.1 [14.5–18.0]	14.4 [12.5–16.0]	14.7 [13.4–16.0]	14.7 [13.0–17.0]	14.9 [13.0–17.0]	16.2 [15.0–17.0]	16.6 [14.9–18.0]	16.1 [14.4–18.0]	0.626$^{\#}$ 0.010^
Obesity	14.7 [12.9–17.0]	15.4 [13.4–18.0]	16.8 [14.2–20.0]	15.6 [13.1–19.0]	17.2 [14.5–20.0]	17.3 [15.8–19.0]	16.9 [14.8–19.0]	17.1 [14.9–20.0]	18.4 [15.9–21.0]	19.2 [17.2–21.0]	0.938$^{\#}$ 0.001^
Severe obesity	3.9 [2.9–5.0]	5.1 [4.1–6.0]	5.0 [3.9–7.0]	5.0 [3.7–7.0]	5.0 [3.8–7.0]	5.8 [4.6–7.0]	5.6 [4.3–7.0]	5.9 [4.8–7.0]	5.6 [4.1–5.0]	6.1 [4.8–8.0]	0.500$^{\#}$ 0.014^

Data are presented as *n*, mean ± standard error, or percentage [95% CI]. BMI, body mass index; NA, not available. $^{\#}$Quadratic regression. ^ Linear regression.

level, household poverty-income ratio, and language used in the interview. Linear and quadratic regression were used to characterize the temporal trends, adjusted for age, sex, and ethnicity. Data analysis was performed using the R statistical package "*survey*" (version 3.6.3).

Results

There were 35,907 participants included in the analysis. Their characteristics are summarized in Table 1. In 2017–2018, the age (mean ± SE) was 10.65 ± 0.16 years and 50.7 [47.7–54.0]% were male, similar to the characteristics of participants in previous years. Non-Hispanic White children made up the highest proportion (50.1 [42.5–58.0]%), followed by Mexican American (16.8 [11.6–24.0]%) and non-Hispanic Black (13.0 [9.6–17.0]%) children.

The BMI (mean ± SE) increased from 19.87 ± 0.14 kg/m^2 in 1999–2000 to 20.71 ± 0.15 kg/m^2 in 2017–2018 (p < 0.001). Over the same period, the prevalence of obesity and severe obesity increased from 14.7 [12.9–17.0]% to 19.2 [17.2–21.0]% and 3.9 [2.9–5.0] to 6.1 [4.8–8.0]%, respectively (p = 0.001 and p = 0.014 for obesity and severe obesity, respectively, Table 1). There was no quadratic trend in the increase in the prevalence of obesity and severe obesity.

The prevalence of overweight, obesity, and severe obesity according to sex are summarized in Table 2. Compared to girls, boys had a higher prevalence of obesity (p = 0.002) and severe obesity (p = 0.004). Increases in the prevalence of obesity were observed in both boys (p = 0.019) and girls (p = 0.004) from 1999–2000 to 2017–2018. The prevalence of severe obesity in girls also increased (p = 0.025), but not in boys. No quadratic trends were observed in any sex or age group.

The prevalence of obesity according to age and ethnicity are summarized in Tables 3 and 4, respectively. The prevalence of overweight, obesity, and severe obesity increased with age. In 2017–2018, the prevalence of obesity and severe obesity in participants aged 12–19 were 21.3 [18.6–24.0]% and 7.5 [6.0–9.0]%, respectively, and were higher than that in participants aged 2–5. There was ethnic variation in the prevalence of childhood obesity (Fig. 1). In Mexican American children, the prevalence of overweight, obesity, and severe obesity increased (p =

Table 2. Prevalence of overweight, obesity, and severe obesity in children and adolescent according to sex in NHANES 1999–2018

	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018	*p* value
Boys	2,082	2,134	2,014	2,122	1,702	1,784	1,719	1,798	1,703	1,404	
Overweight	15.0 [11.8–19.0]	13.8 [12.5–15.0]	16.4 [14.6–18.0]	14.6 [12.2–17.0]	14.0 [12.6–16.0]	14.3 [12.3–17.0]	15.3 [12.7–18.0]	16.4 [14.7–18.0]	15.6 [13.6–18.0]	14.7 [12.3–17.0]	0.916[#] 0.609[^]
Obesity	15.0 [12.7–18.0]	16.3 [14.1–19.0]	18.2 [15.3–21.0]	16.2 [13.3–20.0]	18.0 [15.2–21.0]	19.0 [16.9–21.0]	16.6 [13.9–20.0]	17.2 [14.7–20.0]	19.0 [15.7–23.0]	20.5 [18.3–23.0]	0.948[#] 0.019[^]
Severe obesity	4.0 [2.7–6.0]	6.1 [4.6–8.0]	5.4 [3.9–7.0]	5.1 [3.6–7.0]	5.6 [4.1–8.0]	6.5 [4.7–9.0]	5.7 [4.1–8.0]	5.6 [4.6–7.0]	6.3 [4.5–9.0]	6.9 [5.2–9.0]	0.838[#] 0.083[^]
Girls	1,968	1,883	1,894	2,058	1,552	1,634	1,646	1,737	1,647	1,426	
Overweight	13.1 [11.7–15.0]	14.1 [11.9–17.0]	15.7 [13.8–18.0]	14.2 [12.2–16.0]	15.5 [12.7–19.0]	15.1 [13.3–17.0]	14.4 [11.6–18.0]	15.9 [13.9–18.0]	17.6 [15.2–20.0]	17.6 [15.3–20.0]	0.520[#] 0.001[^]
Obesity	14.3 [12.2–17.0]	14.3 [11.5–18.0]	15.2 [12.2–19.0]	15.0 [12.1–18.0]	16.2 [13.2–20.0]	15.4 [13.6–17.0]	17.1 [14.7–20.0]	17.0 [13.9–21.0]	17.8 [15.4–21.0]	18.0 [15.1–21.0]	0.850[#] 0.004[^]
Severe obesity	3.8 [2.7–5.0]	3.9 [2.9–5.0]	4.6 [3.3–6.0]	4.9 [3.5–7.0]	4.4 [3.0–6.0]	5.0 [3.9–7.0]	5.5 [4.0–8.0]	6.2 [4.5–9.0]	4.9 [3.3–7.0]	5.2 [3.9–7.0]	0.329[#] 0.025[^]

Data are presented as *n*, or percentage [95% CI]. [#] Quadratic regression. ^ Linear regression.

Table 3. Prevalence of overweight, obesity, and severe obesity according to age in NHANES 1999–2018

	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018	*p* value
2–5 years	739	811	833	975	859	912	883	855	827	687	
Overweight	10.3 [8.0–13.0]	12.2 [9.7–15.0]	12.2 [9.5–16.0]	12.2 [8.8–16.0]	10.4 [8.8–12.0]	13.9 [11.0–18.0]	14.3 [10.6–19.0]	16.1 [14.0–18.0]	12.4 [8.7–17.0]	16.3 [13.0–20.0]	0.789[#] 0.002[^]
Obesity	10.4 [7.3–15.0]	10.3 [7.1–15.0]	13.7 [10.7–17.0]	11.2 [8.5–15.0]	10.1 [7.9–13.0]	12.5 [10.2–15.0]	8.3 [5.9–12.0]	9.4 [7.0–13.0]	13.9 [11.6–17.0]	13.4 [10.8–17.0]	0.208[#] 0.503[^]
Severe obesity	1.8 [0.8–4.0]	2.7 [1.2–6.0]	2.9 [1.7–5.0]	1.5 [0.8–3.0]	1.8 [0.8–4.0]	3.0 [2.1–4.0]	1.6 [0.8–3.0]	1.8 [1.0–3.0]	1.7 [0.9–3.0]	2.9 [1.5–5.0]	0.632[#] 0.832[^]
6–11 years	1,054	946	943	1,102	1,210	1,213	1,268	1,307	1,269	1,024	
Overweight	15.2 [11.6–20.0]	15.0 [12.0–18.0]	17.2 [14.2–21.0]	13.3 [10.1–17.0]	16.0 [13.2–19.0]	15.0 [12.7–18.0]	16.6 [14.2–19.0]	15.8 [13.5–18.0]	16.0 [13.9–18.0]	16.9 [14.1–20.0]	0.679[#] 0.482[^]
Obesity	15.8 [12.7–19.0]	16.2 [12.9–20.0]	18.2 [15.5–21.0]	15.6 [11.7–21.0]	19.9 [17.4–23.0]	18.2 [16.4–20.0]	18.1 [14.6–22.0]	17.5 [14.2–21.0]	18.4 [15.0–22.0]	20.2 [16.8–24.0]	0.702[#] 0.111[^]
Severe obesity	3.4 [2.0–5.0]	6.1 [4.2–9.0]	5.2 [4.1–7.0]	4.4 [3.1–6.0]	5.8 [4.4–7.0]	5.0 [3.7–7.0]	6.9 [5.3–9.0]	4.4 [3.1–6.0]	5.3 [3.8–7.0]	6.2 [4.2–9.0]	0.482[#] 0.287[^]
12–19 years	2,257	2,260	2,132	2,103	1,185	1,293	1,214	1,373	1,254	1,119	
Overweight	15.1 [13.0–18.0]	14.0 [12.0–16.0]	17.2 [14.4–20.0]	16.2 [13.8–19.0]	15.9 [14.0–18.0]	14.8 [12.3–18.0]	13.9 [11.9–16.0]	16.5 [13.7–20.0]	19.0 [16.8–22.0]	15.4 [12.9–18.0]	0.887[#] 0.312[^]
Obesity	16.0 [14.1–18.0]	17.0 [14.6–20.0]	17.2 [13.9–21.0]	17.8 [14.1–22.0]	18.6 [15.2–23.0]	19.0 [16.4–22.0]	20.2 [17.0–24.0]	20.4 [16.2–25.0]	20.6 [16.7–25.0]	21.3 [18.6–24.0]	0.771[#] 0.001[^]
Severe obesity	5.4 [4.0–7.0]	5.6 [4.3–7.0]	5.9 [4.2–8.0]	7.1 [5.2–10.0]	6.0 [4.1–9.0]	7.7 [5.2–11.0]	6.6 [4.6–9.0]	9.0 [7.1–11.0]	7.7 [5.3–11.0]	7.5 [6.0–9.0]	0.502[#] 0.003[^]

Data are presented as *n*, or percentage [95% CI]. [#] Quadratic regression ^ Linear regression

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Table 4. Prevalence of overweight, obesity, and severe obesity according to ethnicity in NHANES 1999–2018

	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018	*p* value
Mexican American	1,667	1,177	1,163	1,387	832	949	642	787	713	490	
Overweight	16.3 [13.7–19.0]	17.3 [15.2–20.0]	17.6 [16.0–19.0]	16.0 [14.4–18.0]	17.7 [15.5–20.0]	17.9 [14.8–22.0]	17.3 [14.9–20.0]	20.3 [16.4–25.0]	21.7 [18.9–25.0]	19.6 [14.8–26.0]	0.610[#] 0.018[^]
Obesity	20.7 [17.9–24.0]	19.7 [16.9–23.0]	19.0 [15.2–23.0]	22.7 [19.0–27.0]	20.9 [16.5–26.0]	21.4 [19.1–24.0]	22.7 [20.6–25.0]	21.7 [17.7–26.0]	26.7 [23.9–30.0]	26.9 [22.0–32.0]	0.141[#] 0.001[^]
Severe obesity	5.8 [4.5–7.0]	6.6 [4.9–9.0]	6.0 [4.4–8.0]	8.2 [6.1–11.0]	7.4 [5.3–10.0]	7.4 [5.8–9.0]	8.4 [5.6–12.0]	7.9 [6.2–10.0]	10.1 [7.9–13.0]	9.1 [5.9–14.0]	0.914[#] 0.006[^]
Other Hispanic	202	189	134	142	411	392	394	360	416	221	
Overweight	14.0 [9.7–20.0]	18.0 [11.7–27.0]	17.7 [12.0–25.0]	12.5 [7.8–20.0]	15.3 [11.7–20.0]	16.8 [13.4–21.0]	15.1 [11.9–19.0]	20.6 [15.8–26.0]	16.5 [13.6–20.0]	15.9 [12.4–20.0]	0.873[#] 0.493[^]
Obesity	16.0 [11.1–22.0]	19.5 [13.1–28.0]	18.9 [10.6–31.0]	21.8 [15.2–30.0]	21.5 [18.5–25.0]	22.1 [18.2–27.0]	21.8 [17.4–27.0]	20.3 [15.5–26.0]	24.1 [17.4–32.0]	22.8 [16.7–30.0]	0.452[#] 0.090[^]
Severe obesity	2.1 [0.9–5.0]	9.5 [5.7–15.0]	4.9 [1.9–12.0]	6.1 [2.5–14.0]	7.1 [4.9–10.0]	5.3 [3.4–8.0]	6.1 [3.9–9.0]	7.1 [4.3–12.0]	7.2 [4.0–13.0]	5.3 [3.0–9.0]	0.183[#] 0.577[^]
Non-Hispanic white	882	1,218	1,078	1,093	1,031	1,146	730	922	927	886	
Overweight	13.6 [10.4–18.0]	12.8 [10.9–15.0]	16.5 [14.4–19.0]	14.7 [12.0–18.0]	14.0 [12.5–16.0]	13.7 [10.8–17.0]	14.3 [11.5–18.0]	14.2 [12.5–16.0]	15.8 [13.6–18.0]	16.1 [13.9–19.0]	0.641[#] 0.176[^]
Obesity	11.7 [9.2–15.0]	14.1 [11.0–18.0]	15.9 [12.3–20.0]	13.2 [9.9–17.0]	15.7 [11.8–20.0]	14.5 [12.2–17.0]	14.0 [10.8–18.0]	15.2 [12.0–19.0]	14.0 [11.9–16.0]	16.1 [13.1–20.0]	0.612[#] 0.193[^]
Severe obesity	2.7 [1.5–5.0]	4.4 [3.0–6.0]	4.2 [2.8–6.0]	3.6 [2.1–6.0]	3.8 [2.3–6.0]	4.6 [2.8–7.0]	3.7 [2.1–6.0]	5.2 [3.6–8.0]	3.6 [2.6–5.0]	4.3 [2.9–6.0]	0.596[#] 0.335[^]
Non-Hispanic black	1,134	1,268	1,354	1,318	818	685	1,010	906	769	649	
Overweight	15.6 [13.2–18.0]	14.2 [13.0–15.0]	15.5 [13.0–18.0]	13.3 [11.1–16.0]	15.8 [12.9–19.0]	14.9 [12.2–18.0]	15.0 [13.3–17.0]	17.8 [16.4–19.0]	15.7 [13.4–18.0]	14.1 [11.0–18.0]	0.865[#] 0.534[^]
Obesity	18.9 [16.9–21.0]	16.7 [14.5–19.0]	19.7 [17.4–22.0]	21.3 [18.1–25.0]	20.5 [18.0–23.0]	24.5 [20.4–29.0]	20.1 [16.6–24.0]	18.7 [15.6–22.0]	22.0 [16.5–29.0]	24.2 [20.2–29.0]	0.797[#] 0.020[^]
Severe obesity	6.9 [5.5–9.0]	6.0 [4.2–9.0]	8.4 [7.0–10.0]	9.0 [6.6–12.0]	7.3 [5.5–10.0]	10.6 [8.6–13.0]	9.8 [7.4–13.0]	7.3 [4.9–11.0]	8.4 [5.6–12.0]	10.2 [7.3–14.0]	0.412[#] 0.050[^]
Other ethnicities	165	165	179	240	162	246	589	560	525	584	
Overweight	10.6 [6.4–17.0]	15.0 [10.1–22.0]	9.4 [3.4–24.0]	12.4 [8.5–18.0]	11.8 [7.5–18.0]	13.6 [9.0–20.0]	13.7 [9.3–20.0]	13.9 [10.0–19.0]	14.3 [10.3–20.0]	13.3 [9.9–18.0]	0.648[#] 0.257[^]
Obesity	16.7 [9.7–27.0]	13.6 [7.4–24.0]	12.1 [9.3–16.0]	8.2 [5.1–3.0]	11.1 [7.3–17.0]	12.8 [8.4–19.0]	14.0 [10.9–18.0]	14.7 [10.0–21.0]	18.6 [12.1–27.0]	14.1 [9.8–20.0]\	0.253[#] 0.258[^]
Severe obesity	5.1 [2.4–11.0]	2.7 [1.0–7.0]	3.3 [1.6–7.0]	2.4 [0.9–6.0]	3.1 [1.0–9.0]	3.5 [1.5–8.0]	4.9 [2.2–11.0]	3.8 [1.9–8.0]	4.4 [1.8–11.0]	5.5 [3.3–9.0]	0.371[#] 0.226[^]
Non-Hispanic Asian							409	324	291	305	
Overweight	NA	NA	NA	NA	NA	NA	10.8 [8.3–14.0]	12.2 [8.0–18.0]	11.8 [8.4–16.0]	13.5 [9.3–19.0]	0.881[#] 0.368[^]
Obesity	NA	NA	NA	NA	NA	NA	8.5 [5.6–13.0]	8.6 [5.7–13.0]	10.9 [7.4–16.0]	8.7 [6.6–11.0]	0.529[#] 0.676[^]
Severe obesity	NA	NA	NA	NA	NA	NA	1.4 [0.5–4.0]	1.3 [0.4–4.0]	1.4 [0.4–5.0]	2.1 [1.1–4.0]	0.494[#] 0.484[^]
Other races	NA	NA	NA	NA	NA	NA	180	236	234	279	
Overweight	NA	NA	NA	NA	NA	NA	17.2 [9.4–29.0]	15.4 [9.4–24.0]	16.5 [9.8–26.0]	13.1 [7.6–22.0]	0.734[#] 0.460[^]
Obesity	NA	NA	NA	NA	NA	NA	20.7 [14.5–29.0]	20.1 [11.7–32.0]	25.3 [15.1–39.0]	17.7 [11.6–26.0	0.304[#] 0.603[^]
Severe obesity	NA	NA	NA	NA	NA	NA	9.1 [3.6–21.0]	6.1 [2.4–15.0]	7.0 [2.3–19.0]	7.7 [4.4–13.0]	0.663[#] 0.850[^]

Data are presented as *n*, or percentage [95% CI]. NA, not available. [#] Quadratic regression. ^ Linear regression.

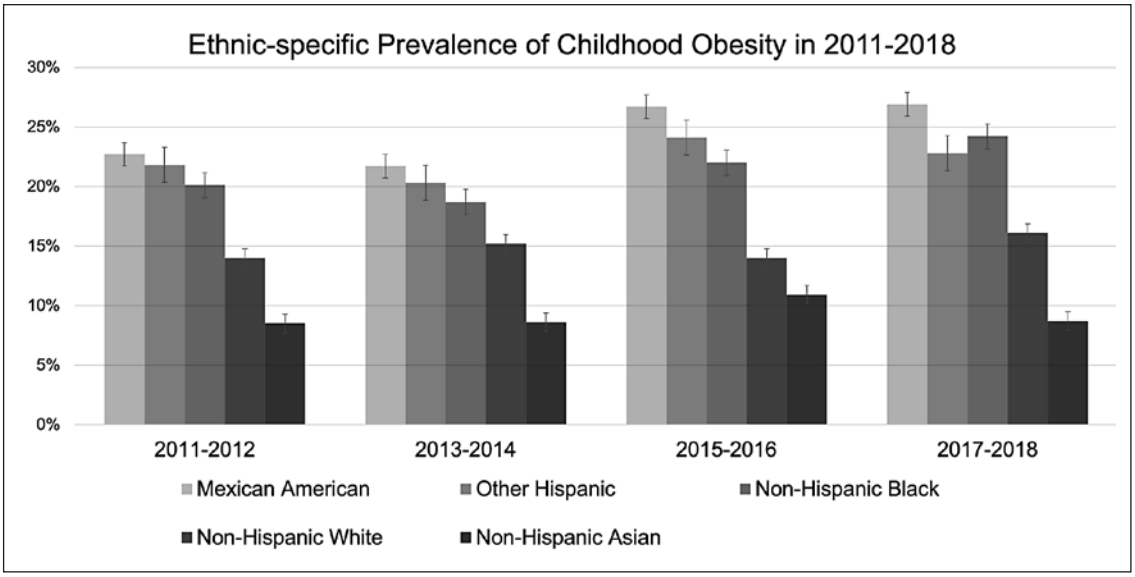

Fig. 1. Ethnic-specific prevalence of childhood obesity in 2011–2018.

0.018, $p = 0.001$, and $p = 0.006$, respectively). The prevalence of obesity in Mexican American (26.9 [22.0–32.0]%) and non-Hispanic Black children (24.2 [20.2–29.0]%) were both higher than in non-Hispanic White children (16.1 [13.1–20.0]%) in 2017–2018 ($p = 0.004$ and $p = 0.011$ for Mexican American and non-Hispanic Black children, respectively). In 2017–2018, the prevalence of obesity in non-Hispanic Asian children was 8.7 [6.6–11.0]%, which was lower than that in non-Hispanic White children ($p = 0.006$).

The prevalence of childhood overweight, obesity, and severe obesity and characteristics of the participants according to language used in the interview are shown in Table 5 and online supplementary Table 1 (see www.karger.com/doi/10.1159/000524261 for all online suppl. material), respectively. Across the years, children from Spanish-speaking families had an overall higher prevalence of obesity (24.4 [22.4–27.0] %), compared to children from English-speaking families (16.8 [16.0–18.0]%), even after adjustment for age, sex, and ethnicity (adjusted odds ratio 1.03, 95% CI: 1.00–1.05, $p = 0.027$). Further analysis revealed that the language used in the interview was related to the household reference person's education level and household income level ($p < 0.001$ and $p < 0.001$, respectively). However, the difference in the prevalence of childhood obesity between Spanish- and English-speaking families persisted after further adjustment for household reference person's education level and household income level (adjusted odds ratio 1.12, 95% CI: 1.06–1.18, $p = 0.014$) in 2017–2018. There was an increasing temporal trend in the prevalence of obesity among children from Spanish-speaking families ($p = 0.001$). There was no quadratic trend.

The prevalence of overweight, obesity, and severe obesity according to the household reference person's education level and poverty-income ratio are shown in online supplementary Tables 2 and3, respectively. In children from households with a low education level and middle education level, both the prevalence of obesity and severe obesity increased from 1999–2000 to 2017–2018 ($p = 0.021$ and $p = 0.048$ for the low education level, $p < 0.001$ and $p = 0.001$ for the middle education level, respectively). In children from households with low income, the prevalence of overweight, obesity, and severe obesity increased from 1999–2000 to 2017–2018 ($p = 0.031$, $p < 0.001$, and $p = 0.005$, respectively). In children from households with middle income, there was an increase in the prevalence of obesity ($p = 0.018$), but not of severe obesity. In 2017–2018, children from households with a high education level and high income level had a lower prevalence of obesity compared to those from households with a low education level and low income level ($p = 0.003$ and $p = 0.002$ for education level and income level, respectively). All trends were adjusted for age, sex, and ethnicities, and no quadratic trends were observed.

In the sensitivity analysis where BMI ≥35 kg/m^2 was added as an alternative criterion for severe obesity, the trends were largely unchanged overall and in subgroups

according to age group, sex, ethnicity, language used in the interview, education level, and income level, except for the prevalence of severe obesity in children from Spanish-speaking households, where the *p* value for the linear trend changed from 0.052 to 0.048 (Table 3).

Discussion

In the current study, we used the latest data from NHANES 2017–2018 to estimate the most recent prevalence of overweight and obesity in US children. Our study highlights a rising trend in the prevalence of obesity among children in the USA. The steady rise in prevalence of obesity was evidenced by the increasing trend which was linear and not quadratic. The problem of obesity was more severe in children from households that had a low socioeconomic status and in ethnic minorities. This study is the first to uncover the association between language and childhood obesity: children from Spanish-speaking families had a higher prevalence of obesity compared to those from English-speaking families. This nationally representative survey provides more accurate measures than self-reported obesity status or body weights and heights reported by parents.

We found an increasing trend in the prevalence of obesity in the USA in the last two decades, in line with previous studies [12, 24] and extending the finding to the latest data available. One out of 5 children and adolescents in the USA had obesity in 2017–2018, equivalent to 705,282 children and adolescents having obesity. In the UK, a similar prevalence of childhood obesity has been reported [25]. Despite increasing awareness of the problem and continuous efforts in public health policies, such as the Childhood Obesity Research Demonstration (CORD) program supported by the CDC [26], the prevalence of obesity in children remains high and continues to increase.

We found that the prevalence of obesity in children is not uniform. There are ethnic variations: the prevalence of obesity was more than 20% in children of Mexican American, Other Hispanic, and non-Hispanic Black children origin in 2017–2018, compared to 16.1% in non-Hispanic White children. This is consistent with the findings in previous studies [12, 18]. The finding of a lower prevalence of obesity among non-Hispanic Asian children is also consistent with previous studies [12], but it should be noted that Asians have a different body composition and an Asian child with a BMI in the normal range for White children may already be at risk from the

Table 5. Prevalence of overweight, obesity, and severe obesity according to language used in family interviews in NHANES 1999–2018

	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018	*p* value
English-speaking families	NA	NA	3,507	3,661	2,830	2,929	2,999	3,230	2,827	2,442	
Overweight	NA	NA	16.2	14.1	14.6	14.2	14.5	15.6	16.6	15.7	$0.063^{\#}$
			[14.5–18.0]	[12.1–16.0]	[13.2–16.0]	[12.4–16.0]	[12.5–17.0]	[14.3–17.0]	[14.6–19.0]	[14.2–17.0]	$0.256^{\wedge}$
Obesity	NA	NA	16.6	15.4	16.9	16.9	16.3	16.9	17.3	17.8	$0.613^{\#}$
			[14.0–20.0]	[12.7–18.0]	[14.2–20.0]	[15.3–19.0]	[14.0–19.0]	[14.7–19.0]	[14.8–20.0]	[15.9–20.0]	$0.295^{\wedge}$
Severe obesity	NA	NA	5.0	4.9	4.9	5.8	5.4	6.0	5.3	5.5	$0.580^{\#}$
			[3.8–7.0]	[3.6–7.0]	[3.7–7.0]	[4.5–7.0]	[4.1–7.0]	[4.8–7.0]	[3.7–7.0]	[4.2–7.0]	$0.362^{\wedge}$
Spanish-speaking families	NA	NA	364	478	387	473	334	277	433	297	
Overweight	NA	NA	14.7	19.0	16.1	20.5	18.5	23.6	17.0	19.0	$0.218^{\#}$
			[12.2–18.0]	[14.5–24.0]	[10.9–23.0]	[16.3–26.0]	[15.2–22.0]	[19.0–29.0]	[13.4–21.0]	[12.8–27.0]	$0.431^{\wedge}$
Obesity	NA	NA	16.6	22.0	20.5	22.2	22.1	22.7	28.5	32.3	$0.269^{\#}$
			[8.0–31.0]	[16.8–28.0]	[15.6–27.0]	[18.6–26.0]	[17.7–27.0]	[18.0–28.0]	[23.7–34.0]	[25.1–40.0]	$0.001^{\wedge}$
Severe obesity	NA	NA	5.4	7.8	5.5	6.1	6.9	6.1	8.7	11.5	$0.197^{\#}$
			[1.5–18.0]	[5.1–12.0]	[3.6–8.0]	[3.7–10.0]	[4.0–12.0]	[3.9–9.0]	[6.2–12.0]	[6.8–19.0]	$0.052^{\wedge}$

Data are presented as *n*, or percentage [95% CI]. NA, not available. # Quadratic regression. ^ Linear regression.

adverse effects of obesity on health [27]. Furthermore, there were notable sex differences in childhood obesity: we found that the prevalence was slightly higher in boys. This is in line with previous reports, although a sex difference has not been found in all studies [12]. The difference in the prevalence of obesity between boys and girls is remarkably small despite differences in onset of puberty, body build, hobbies, and sports. The current study further reinforces the ethnic and sexual variations in childhood obesity, allowing identification of the population groups at higher risk and requiring more attention from future public health initiatives.

There are several public health policy implications arising from the alarming findings in this study. Despite programs such as CORD, the continuously increasing trend in childhood obesity shows that current measures are not effective enough and need to be strengthened. To improve the effectiveness of school-based programs, better training and involvement of staff, offering incentives to teachers, providing support for teachers from research nurses, and maximizing sustainability through institutional adoption are required [28]. Inculcating a correct perception of childhood obesity and reducing the high consumption of nutrient-rich carbonated drinks can help to reduce obesity [29–32]. Less than 30% of children achieved optimal overall physical activity in 2018, and more programs to promote school-based physical education are needed [32, 33].

It is important to intervene early as early-life home and preschool environments are strong components determining the trajectory to obesity [34, 35]. Patterns of children's behavior are formed in early childhood, so it is important to instill a correct concept of health and obesity during this developmental stage [36]. Television viewing time in childhood is positively associated with BMI and overweight status [37], and reducing screen time has been shown to prevent childhood obesity and should begin from early childhood [32, 38]. To effectively bring about the above changes, interventions at the public health level, for instance, circulation of health promotion materials, might be considered [32].

As the most important caregivers of children, parents play a critical role in reducing their children's risk of developing obesity. They can encourage exercise in family activities, and limit children's diet to the healthier spectrum with low calories. To enhance parents' awareness, parent-child sporting events and carnivals could be organized.

To our knowledge, this study is the first to report that children from Spanish-speaking families have a higher prevalence of obesity. As language used in the interview is related to household education and the income level, the latter factors might explain some of the difference in prevalence of childhood obesity in Spanish- and English-speaking families. However, after additionally adjusting for ethnicity, education level, and income level, the language used in the interview remained an independent predictor of childhood obesity. This highlights the importance of targeting not only the children, but also the parents, when formulating policies to reduce childhood obesity in Spanish-speaking families.

Furthermore, the prevalence of obesity in children from Spanish-speaking families increased, despite the introduction of Spanish health education resources in recent years, such as the NIH Spanish Health Information Portal [39]. This suggests a suboptimal delivery of important health messages to Spanish-speaking families. Indeed, recent studies have found that even though Spanish health education materials are available, the readability was low and the content were written at levels too high for an average patient [40, 41]. This is not to mention that Spanish-speaking families generally have a lower education level, as shown in the current and previous studies [42]. Accessibility, dissemination, and promotion of these education resources need to be improved, and other means of promoting the health awareness among Spanish-speaking communities are required. Health talks and activities should be conducted in Spanish as well as English. Food labels in Spanish would allow parents to make better choices for their children.

This study was not without limitations. First, children and adolescents are only a subgroup in NHANES and so statistical power is less than in the full set of participants. Therefore, trends in the prevalence of obesity may fluctuate. Second, NHANES is cross-sectional so we cannot assess the change in BMI of the same individual over time. Third, although BMI is a standard measure of obesity, it is not an accurate measure of adiposity [43, 44]. Americans of Asian descent may have a seemingly normal BMI but may already be at risk of metabolic syndrome [27]. Fourth, like all observational studies, there might be residual confounding. Fifth, the low response rate might introduce bias and reduce the power. However, the NHANES survey was designed to account for these issues and the results are as accurate and nationally representative as one can expect. Sixth, Spanish may not be the only language that was spoken in Spanish-speaking families. Nevertheless, as these families chose to be interviewed in Spanish, we believe that it is the predominant language used in their daily communications.

In conclusion, the prevalence of obesity among children and adolescents kept increasing in the USA in the period 1999–2018. It was higher in ethnic minorities and in children from households with a low socioeconomic status. This study is the first to identify that children from Spanish-speaking families were more likely to have obesity, and public health measures catering to the Spanish community are urgently needed. The problem of childhood obesity is a serious public health concern and is getting worse.

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Statement of Ethics

Ethical approval was not required for this study in accordance with local/national guidelines. Our study used data from the National Health and Nutrition Examination Survey, publicly available from the Center for Disease Control and Prevention. Our study group had no direct contact with the participants. All the participants gave informed consent before participation and ethics approval (for collection of information etc.) for the study was obtained from the Research Ethics Review Board at the National Centre for Health Statistics.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Man-Fung Tsoi, Hang-Long Li, and Bernard M.Y. Cheung designed the study. Man-Fung Tsoi and Hang-Long Li carried out data analysis, and all the authors interpreted the data. Man-Fung Tsoi and Hang-Long Li drafted the manuscript, and all the authors were responsible for critical revision of the manuscript for important intellectual content. Bernard M.Y. Cheung was responsible for supervising the project.

Data Availability Statement

Data are available from https://www.cdc.gov/nchs/nhanes/index.htm. The R script would be made available upon reasonable request to the corresponding author.

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