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Prevalence and associated factors of acute gastroenteritis in children and adolescents aged from 6 to 17 years old: a cross-sectional study based on the National Health and Nutrition Examination Survey database 1999–2018

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ABSTRACT

Objective To explore the prevalence of acute gastroenteritis (AGE) and associated factors in children and adolescents in the USA from 1999 to 2018 using nationally representative data.

Design A retrospective cross-sectional study.

Setting The National Health and Nutrition Examination Survey (NHANES) database.

Participants 25 361 children and adolescents aged 6–17 years old.

Primary and secondary outcome measures Whether the patient suffered from AGE.

Results Totally 1882 suffered from AGE. The overall monthly prevalence of AGE in children and adolescents was 7.69%. From 1999 to 2018, the prevalence of AGE in the USA had been decreasing over time. The decreasing trend was observed in all subgroups, including age, gender, body mass index (BMI), education level, poverty index and eating food at the restaurant. There were two small upticks from 2003 to 2007 and 2013 to 2015. AGE was negatively associated with male compared with female (OR=0.86, 95% CI: 0.73 to 0.99, p=0.035), Mexican American (OR=0.82, 95% CI: 0.70 to 0.97, p=0.018) and non-Hispanic Black (OR=0.80, 95% CI: 0.69 to 0.93, p=0.003) compared with non-Hispanic White. AGE was positively associated with obesity compared with underweight and normal weight (OR=1.37, 95% CI: 1.15 to 1.62, p<0.001).

Conclusion The monthly prevalence of AGE was 7.69% and showed a downward trend from 1999 to 2018 in the USA.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The disease burden of acute gastroenteritis (AGE) was estimated from nationally representative data (National Health and Nutrition ExaminationSurvey database) with comprehensive population characteristics.
⇒ Our study had a long year span from 1999 to 2018 and also avoided the failure using hospital visit data to capture AGE patients who did not seek medical care.
⇒ The diagnosis of AGE was obtained by self-reporting, limited by the database and the information on the severity and aetiology (viral, bacterial, parasitic, toxin or other non-infectious) of AGE could not be further explored.
⇒ Using a retrospective observational study design, no causal relationship between AGEs and correlated variables could be drawn.
⇒ The study included children and adolescents from the USA, therefore, the samples may not be representative of children and adolescents in general.

INTRODUCTION

Acute gastroenteritis (AGE) is one of the most common diseases affecting paediatric patients.[1] AGE is an important and common public health problem worldwide, and the causative factors of AGE include viruses, bacteria, parasites, toxins and metals.[2] AGE is most commonly seen in patients infected with at least one pathogen through food intake.[2–4] AGE usually presents with vomiting, fever, abdominal pain, nausea and diarrhoea, as well as disturbances in the secretion and absorption processes of the small and large intestines leading to dehydration.[5 6] AGE complicated by dehydration is a major cause of high paediatric morbidity and mortality worldwide.[7]

AGE is also a common cause of emergency department visits and hospitalisations in children.[8] Globally, AGE results in an estimated 89.5 million disabilities and 1.45 million deaths annually.[9] AGE can be fatal and occurs extremely frequently, imposing significant morbidity and economic burden on the populations and healthcare systems.[10–13] In the USA, AGE is one of the major disease

burdens, with approximately 179 million cases reported each year,[10] more than 1.5 million paediatric outpatient visits, more than 200 000 hospitalisations and approximately 300 deaths each year, with a direct cost of 250 million dollars and the total community cost is about 1 billion dollars.[11] A study in France estimated the incidence of AGE at an estimated 0.33 cases per person-year, with more than 21 million AGE events per year.[12] Similarly, AGE is also a serious public health problem in the Chinese population. A population surveillance survey of AGE was carried out in some provinces to initially assess its burden.[13] The survey data showed that the weighted monthly prevalence of AGE was 4.2%, and the incidence rate was 0.56. times per person year.[13]

Most of the international studies on the disease burdens of AGE were based on the healthcare system, but there were few related studies based on population surveys. Therefore, this study used the population from the National Health and Nutrition Examination Survey (NHANES) database to explore the time trends of the prevalence of AGE and associated factors, in order to provide a reference for the study of AGE disease burdens.

METHODS

Patient and public involvement statement

Not applicable.

Study population

The data used in this study came from the NHANES database from 1999 to 2018. NHANES is a cross-sectional survey based on a nationally representative population in the USA. The NHANES survey includes interviews, examinations and laboratory data derived from a complex multistage, stratified, clustered probabilistic sample representing a civilian, non-institutionalised population with sample augmentation, conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease Control (CDC) and Prevention every 2 years. A total of 25 361 children and adolescents under the age of 17 were included in our study.

The NHANES protocol was approved by the CDC Institutional Review Board and the data set used in the analysis was fully deidentified. Informed consent has been obtained from all participants. Our research was exempted by our institution's Institutional Review Board of Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University.

Definition of AGE

In the NHANES database, the medical question (HSQ510): 'Do you have a stomach or intestinal illness with vomiting or diarrhoea that started during the last 30 days?' (yes or no) was used to define AGE.[14] This question was asked in the dietary recall section for participants ages one to 11. This question was asked for respondents aged 12 and older using a computer-assisted personal interview system during a Mobile Examination Centre interview.

Data collection

Demographic information of age, gender (male or female), race (Mexican American, other Hispanics, non-Hispanic White, non-Hispanic Black or others), education level (less than middle school, less than high school or high school complete), insurance status (yes or no) and poverty index (≤1.3, 1.3–1.85 or >1.85) was collected. BMI was weight divided by height squared (kg/m^2). The BMI z-score was calculated[15] to divide the population into underweight and normal weight, overweight and obesity according to the CDC and Prevention growth chart.[16 17] Whether the participant ate at the restaurant was defined by this question 'On average, how many times per week do you eat meals that were prepared in a restaurant?'

Statistical analysis

Measurement data were described by mean (SE), weighted t-test was used for comparison between groups, enumeration data were described by number of cases and constituent ratio (n (%)) and weighted χ^2 test was used for comparison between groups. Missing values were imputed using multiple imputation in R mice. Factors associated with AGE were investigated using univariate and multivariable survey-weighted generalised logistic regression models. Trends of prevalence over survey times were investigated using ggplot2 of R software,[18] the Manner-Kendall Trend test was used for trend testing. Trends of prevalence after disaggregating the population by age, gender, eat food at the restaurant, BMI, poverty index and education level were also investigated. The confidence level is α=0.05, the value of p was two-sided and p<0.05 was statistically significant. Comparisons between groups and multivariate analysis were performed by SAS V.9.4 (SAS Institute, Cary, North Carolina), data imputation and plotting were performed by R V.4.20 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Characteristics of the study population

A total of 25 361 participants in our study. There were 1882 participants with AGE during our survey years. The mean (SE) age was 11.56 (0.03) years old. The proportion of males and females was basically the same, 12 349 (50.86%) and 12 109 (49.14%), respectively. Most of the study population was non-Hispanic white (6611 (56.76%)), followed by non-Hispanic blacks (6904 (14.43%)), Mexican-Americans (6780 (13.63%)), others (2246 (8.18%)) and other Hispanic (1917 (7.00%)). There were 14 825 (63.34%) participants with underweight and normal weight, 5320 (21.10%) participants were overweight and 4313 (15.56%) participants were obese. Characteristics of participants with AGE compared with those without AGE are summarised in table 1. Significant differences were found in age (p=0.016), gender (p=0.034), race (p=0.022), BMI (p=0.006) and education level (p=0.050) (table 1).

Table 1 Characteristics of the study population

Variables	Total (n=24 458)	With AGE (n=1882)	Without AGE (n=23 576)	Statistics	P value
Age, years, mean (SE)	11.56 (0.03)	11.29 (0.12)	11.58 (0.03)	t=−2.44	0.016
Gender, n (weighted %)				χ^2=4.483	0.034
Male	12 349 (50.86)	892 (47.87)	11 457 (51.12)		
Female	12 109 (49.14)	990 (52.13)	11 119 (48.88)		
Race, n (weighted %)				χ^2=11.495	0.022
Mexican American	6780 (13.63)	522 (12.37)	6258 (13.74)		
Other Hispanic	1917 (7.00)	141 (7.01)	1776 (7.00)		
Non-Hispanic White	6611 (56.76)	566 (60.68)	6045 (56.42)		
Non-Hispanic Black	6904 (14.43)	489 (12.63)	6415 (14.59)		
Others	2246 (8.18)	164 (7.31)	2082 (8.25)		
BMI, kg/m^2, n (weighted %)				χ^2=10.290	0.006
Underweight and normal weight	14 825 (63.34)	1055 (59.80)	13 770 (63.65)		
Overweight	5320 (21.10)	410 (21.41)	4910 (21.07)		
Obesity	4313 (15.56)	417 (18.79)	3896 (15.28)		
Insurance, n (weighted %)				χ^2=0.203	0.652
Yes	21 273 (90.39)	1636 (90.78)	19 637 (90.35)		
No	3185 (9.61)	246 (9.22)	2939 (9.65)		
Eat food at the restaurant, n (weighted %)				χ^2=1.226	0.268
No	4106 (15.55)	286 (14.34)	3820 (15.66)		
Yes	20 352 (84.45)	1596 (85.66)	18 756 (84.34)		
Education level, n (weighted %)				χ^2=5.982	0.050
Less than middle school	12 324 (51.27)	986 (55.16)	11 338 (50.93)		
Less than high school	6545 (26.10)	503 (23.90)	6042 (26.29)		
High school complete	5589 (22.64)	393 (20.94)	5196 (22.78)		
Poverty index, n (weighted %)				χ^2=3.892	0.143
≤1.30	10 452 (31.50)	743 (29.06)	9709 (31.71)		
1.30–1.85	3399 (11.92)	289 (13.05)	3110 (11.82)		
>1.85	10 607 (56.58)	850 (57.89)	9757 (56.47)		

AGE, acute gastroenteritis; BMI, body mass index.

Prevalence of AGE among the study population

Prevalence trend of AGE in the study population from the NHANES is demonstrated in figure 1. Although the prevalence of AGE has not changed significantly after the Manner-Kendall trend test (Z=−1.61, p=0.089), it could be seen from figure 1 that the prevalence of AGE showed a downward trend from 1999 to 2018 (from approximately 8.98% to 7.20%). There were two small upticks in 2003 to 2005 (from about 7.50% to 10.47%) and 2013 to 2015 (from about 6.16% to 7.87%). Figure 2 shows proportion of the population grouped by age (A), gender (B), BMI (C), education level (D), poverty index (E) and eating food at the restaurant (F). The prevalence was higher in younger age (<12 years old) group in 2007–2017 (figure 2A). The prevalence of AGE was roughly equal in males and females (figure 2B). Higher prevalence was observed in underweight and normal weight participants (figure 2C), participants with an education level less than middle school (figure 2D), participants eating in a restaurant (figure 2F). The lowest prevalence of AGE was in poverty index of 1.30–1.85 than poverty index of <1.30 and >1.85 (figure 2E). The decreasing trend was observed in all subgroups, including age (figure 3A), gender (figure 3B), BMI (figure 3C), education level (figure 3D), poverty index (figure 3E) and eating food at the restaurant (figure 3F).

Factors associated with AGE

Results in the univariate analysis showed that gender (p=0.036), age (p=0.016), race (p<0.05) and BMI (p<0.05) were significantly associated with AGE (table 2). Using multivariable analysis to find significantly associated factors in AGE with OR) and 95% CI, the following factors remained statistically significant: gender (OR=0.86, 95% CI: 0.73 to 0.99, p=0.035 in male compared with female); race group (OR=0.82, 95% CI: 0.70 to 0.97,

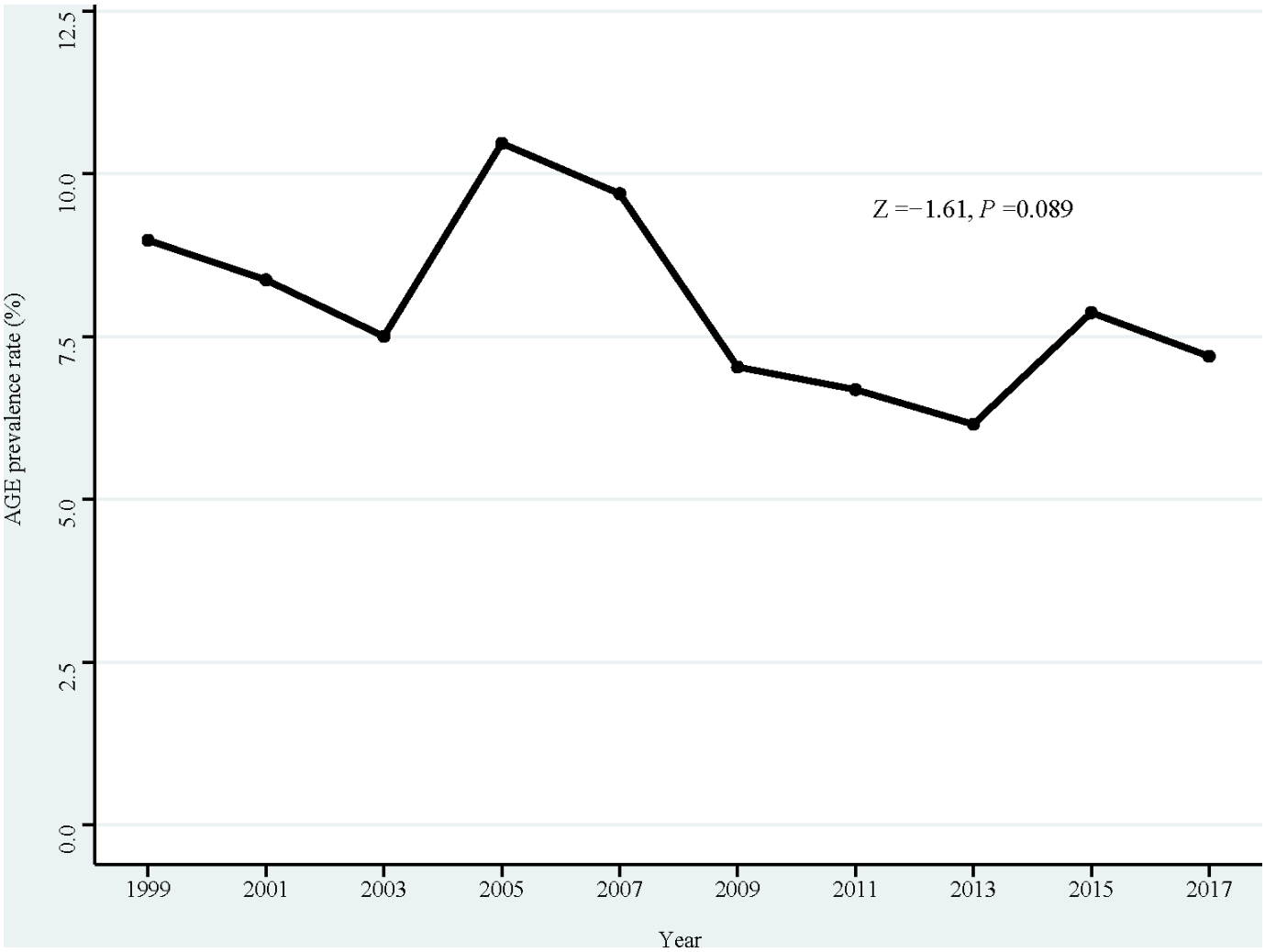

Figure 1 Prevalence trend in the study population from the NHANES 1999–2018. AGE, acute gastroenteritis; NHANES, The National Health and Nutrition Examination Survey.

p=0.018 in Mexican American, OR=0.80, 95% CI: 0.69 to 0.93, p=0.003 in non-Hispanic Black compared with non-Hispanic White) and BMI group (OR=1.37, 95% CI: 1.15 to 1.62, p<0.001 in obesity compared with underweight and normal weight) (table 2).

DISCUSSION

Our findings suggested that the overall monthly prevalence of AGE in children and adolescents between 1999 and 2018 was 7.69%. AGE was negatively associated with male compared with female, Mexican American and non-Hispanic Black compared with non-Hispanic White. AGE was positively associated with obesity compared with underweight and normal weight. From 1999 to 2018, the prevalence of AGE in the USA had been decreasing over time.

The decreasing trend of AGE prevalence we found was similar to previous studies.[19–21] From 2006 to 2011, the number of AGE patients declined by about 30%, according to a report based on national emergency room visit data.[19] In the Chinese population, Huo *et al*[21] reported a monthly prevalence of AGE of 3.54% in the investigated population, which was slightly lower than that in the American population. Kim *et al*[20] found that the monthly prevalence of AGE was 8.31% and has been significantly decreasing over time in the USA from 2005 to 2014. Similarly, our study also found a decreasing trend in the prevalence of AGE from 2005 to 2014 and had a larger study time interval.

In general AGE prevalence trend, a slight downward trend could be seen from 1999 to 2003, possibly due to widespread initiatives and recommendations by experts from the American Academy of Paediatrics (AAP) and CDC and Prevention.[22 23] Subsequently, the prevalence of AGE continued to rise, peaking in 2005 and declining year by year thereafter. The reason for the increase may be that existing interventions have not been able to effectively control the prevalence of AGE. Oral rehydration therapy (ORT) has been instrumental in improving health outcomes among children in developing countries, its use has lagged behind in the USA before 2003.[24] Most children with AGE have only mild or moderate

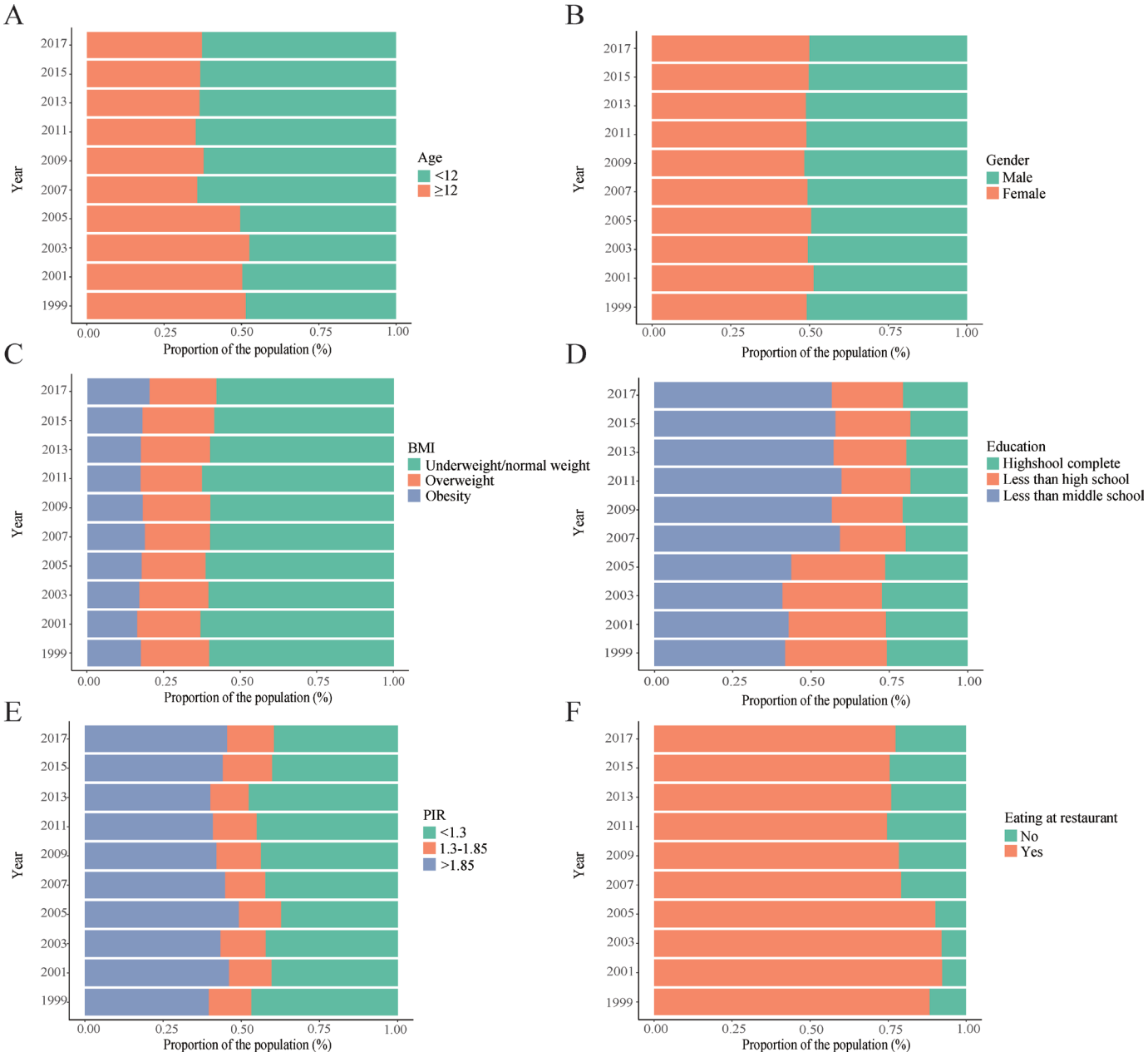

Figure 2 Proportion of the population grouped by age (A), gender (B), BMI (C), education level (D), poverty index (E) and eating food at the restaurant (F). BMI, body mass index.

dehydration, and the success rate of ORT treatment is approximately 96%.[25] Although ORT is recommended as the primary treatment for children with mild or moderate dehydration, many children still receive unnecessary tests and intravenous fluids.[26] In response to this situation, the Children's International Medical Center in Washington, DC, USA has designated the Outpatient Paediatric Acute Gastroenteritis Treatment Guidelines, which set forth the basic principles of disease assessment and management.[27] We hypothesised that the epidemic was partly controlled by the improvement in the AGE of children with primary family treatment. After reaching a low point in 2013, the prevalence of AGE fluctuated slightly again. We speculated that the likely reason was that the causes of AGE such as norovirus was common in all ages globally,[28] and norovirus infection occurs in people of all ages and multiple reinfections may occur over the course of a lifetime.[29] The specific mechanism still needs more etiological exploration.

AGE was negatively associated with male compared with female. One speculation is that women's gut microbiota may be influenced by hormonal factors that affect the physiology of the digestive tract, making them more susceptible to infection.[30] Findings of Kim *et al*[20] were similar to ours, and they also found that AGE was associated with gender. In this study, results showed that AGE was positively associated with obesity compared with underweight and normal weight. Ecollan *et al*[31] showed that obese individuals had more AGE episodes, which was consistent with our results. This association between

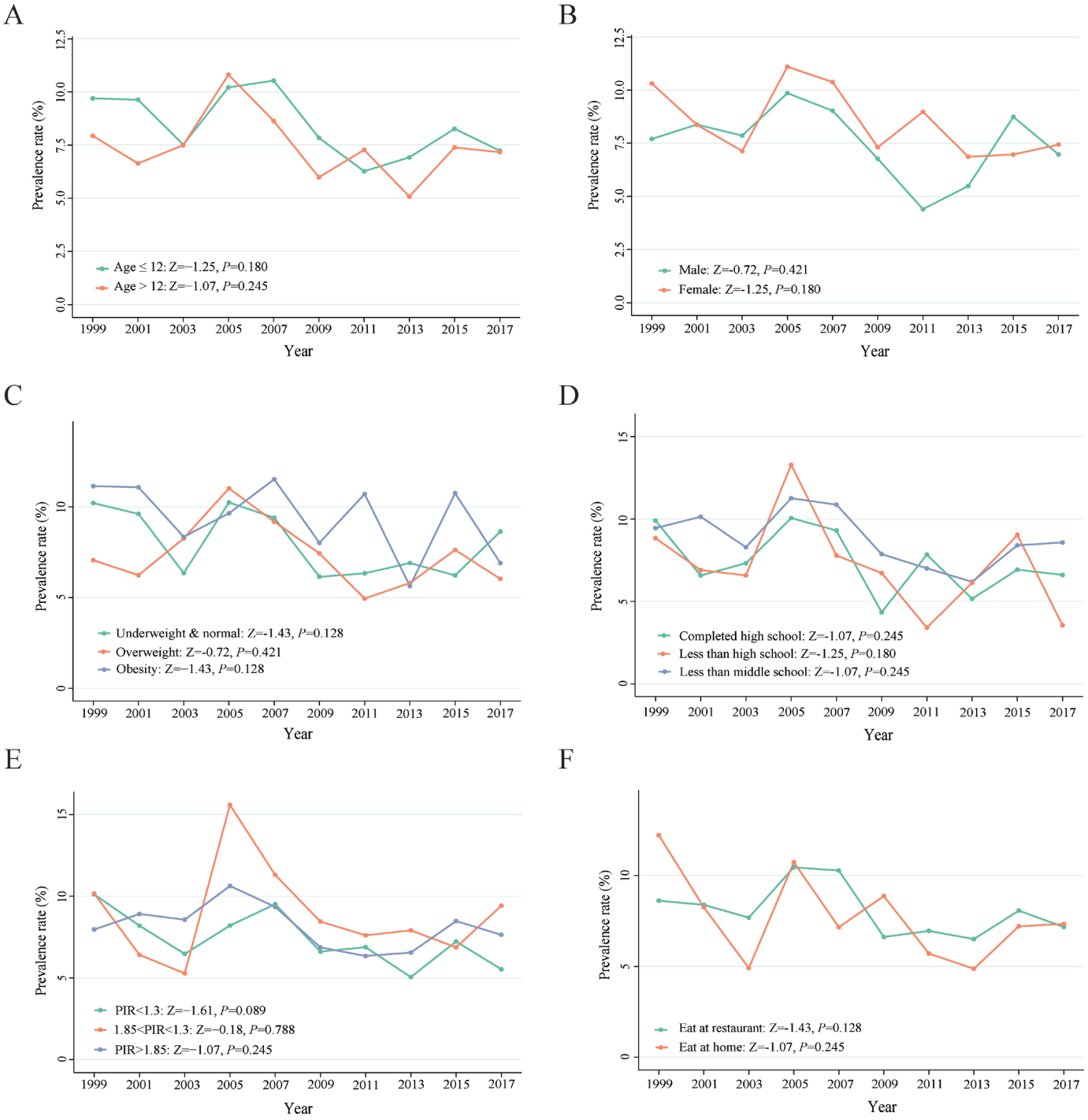

Figure 3 Prevalence trend of the study population in terms of age (A), gender (B), BMI (C), education level (D), poverty index (E) and eating food at the restaurant (F). BMI, body mass index.

obesity and AGE may be due in part to an increased frequency of functional bowel disease in obese people.[32]

To reduce the disease burden of AGE, on the one hand, it is necessary to strengthen food safety supervision and strengthen publicity and education on personal hygiene and food safety. On the other hand, immune prevention is important, such as vaccination, etc., and clinicians should pay attention to the high-risk groups of AGE.

The strength of this study was that the disease burden of AGE was estimated from nationally representative data (NHANES database) with comprehensive population characteristics. Our study had a long year span and also avoided the failure using hospital visit data to capture AGE patients that did not seek medical care. However, there were a few limitations in our study. First, the diagnosis of AGE was obtained by self-reporting, limited by the database and the information on the severity and aetiology (viral, bacterial, parasitic, toxin or other non-infectious) of AGE could not be further explored. Second, using a retrospective observational study design, no causal

Table 2 Exploring factors associated with AGE using univariate and multivariable logistic regression models

	Univariate analysis		Multivariate analysis (1999–2018)	
Variables	OR (95% CI)	P value	OR (95% CI)	P value
Gender (male)*	0.88 (0.78 to 0.99)	0.036	0.86 (0.73 to 0.99)	0.035
Age	0.98 (0.96 to 0.99)	0.016	0.97 (0.93 to 1.02)	0.265
Race				
Non-Hispanic White	Ref		Ref	
Mexican American	0.84 (0.72 to 0.97)	0.020	0.82 (0.70 to 0.97)	0.018
Other Hispanic	0.93 (0.74 to 1.18)	0.547	0.93 (0.73 to 1.18)	0.533
Non-Hispanic Black	0.81 (0.70 to 0.93)	0.003	0.80 (0.69 to 0.93)	0.003
Others	0.82 (0.65 to 1.05)	0.118	0.83 (0.65 to 1.05)	0.123
BMI				
Underweight and normal weight	Ref		Ref	
Overweight	1.08 (0.92 to 1.27)	0.346	1.11 (0.94 to 1.30)	0.231
Obesity	1.31 (1.11 to 1.55)	0.002	1.37 (1.15 to 1.62)	<0.001
Insurance (yes)†	1.05 (0.85 to 1.31)	0.653	1.01 (0.81 to 1.26)	0.926
Eating food at restaurant (no)‡	1.05 (0.85 to 1.31)	0.653	0.93 (0.77 to 1.12)	0.431
Education				
Less than middle school	Ref		Ref	
Less than high school	0.85 (0.71 to 1.01)	0.365	1.00 (0.68 to 1.48)	0.805
High school complete	0.84 (0.71 to 0.99)	0.256	0.93 (0.72 to 1.20)	0.366
Poverty index (2005–2018)				
≤1.30	Ref		Ref	
1.30–1.85	1.21 (0.99 to 1.46)	0.059	1.19 (0.98 to 1.45)	0.078
>1.85	1.12 (0.96 to 1.30)	0.143	1.08 (0.92 to 1.27)	0.323

*Female as the reference.
†Participants did not have insurance as the reference.
‡Participants ate food at the restaurant as the reference.
AGE, acute gastroenteritis; BMI, body mass index; Ref, reference.

relationship between AGEs and correlated variables could be drawn. Third, the study included children and adolescents from the USA, therefore, the samples may not be representative of children and adolescents in general, and further studies on the prevalence of AGEs with larger samples from multiple centres may be required.

CONCLUSION

The monthly prevalence of AGE in children and adolescents was 7.69% in the USA from 1999 to 2018 and had been decreasing over time. Further follow-up studies to confirm the decreasing trend of AGE in following years to estimate the true burden of AGE and investigate predictors in prospective studies to take appropriate preventive actions are warranted.

Contributors HC and WY designed the study. HC wrote the manuscript. YS collected, analysed and interpreted the data. WY critically reviewed, edited and approved the manuscript and is responsible for the overall content as the guarantor. All authors read and approved the final manuscript.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

Patient consent for publication Consent obtained directly from patient(s).

Provenance and peer review Not commissioned; externally peer reviewed.

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