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ORIGINAL ARTICLE

Rising Rates of Severe Obesity in Adults Younger Than 50 Correspond to Rise in Hospitalizations for Non-malignant Gastrointestinal Disease

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Abstract

Background Colorectal cancer incidence is rising in adults < 50 years old, possibly due to obesity. Non-malignant colorectal conditions are understudied in this population. We hypothesize that developing severe obesity in young adulthood also corresponds with increased hospitalization rates for non-malignant colorectal conditions.

Methods We examined annual percent change (APC) in the prevalence of obesity in adults < 50 using the 2009–2014 National Health and Nutrition Examination Survey. Using the 2010–2014 Nationwide Readmission Database, we then compared yearly hospitalization trends for various gastrointestinal conditions and their outcomes in adults < 50 with severe obesity vs. no obesity.

Results The prevalence of obesity increased in adults < 50 years in 2009–2014. This increase was most pronounced for severe obesity (APC of + 12.8%). The rate of patients with severe obesity < 50 who were admitted for gastrointestinal diseases has increased by 7.76% per year in 2010–2014 ($p < 0.001$). This increase was > 10% per year for colorectal conditions such Clostridium difficile infections (APC + 17.3%, $p = 0.002$), inflammatory bowel disease (APC + 13.1%, $p = 0.001$), and diverticulitis (APC + 12.7%, $p = 0.002$). The hospitalization rate for chronic liver diseases and acute pancreatitis also increased by 12.2% and 10.0% per year, respectively ($p < 0.01$). In contrast, young adults without obesity had lower hospitalization rate for most gastrointestinal diseases. Furthermore, adults with no obesity had lower mortality rates for appendicitis, diverticulitis, pancreatitis and chronic liver diseases than adults with severe obesity.

Conclusion Our data suggest that increased adiposity in young adults is associated with more hospitalization and worse outcomes for infectious/inflammatory gastrointestinal conditions. Future prevention strategies are warranted to ameliorate these trends.

Keywords Obesity · Gastrointestinal · Trends · Outcomes · Young · Colorectal

Abbreviations

NRD	Nationwide Readmission Database
HCUP	Healthcare Cost Utilization Project
SID	State inpatient databases
IRB	Institutional Review Board

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ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
GI	Gastrointestinal
IBD	Inflammatory bowel disease
APC	Annual percent change
aOR	Adjusted odds ratio

Introduction

One in 4 adults will suffer from severe obesity by 2030 [1]. Young adults (aged 18–49 years old) compose almost 48% of the U.S. population and are particularly vulnerable to this epidemic. For instance, individuals in early and middle adulthood may gain weight at a rate of 0.5 to 1.0 kg per year [2]. This translates to more than 20 kg of excess body weight in 13% of young men and 23% of young women [3]. In accordance with the rise in the prevalence of adults with obesity < 50 years, there has been also an increase in incidence of colorectal cancer. Currently, more than one-tenth of all CRC cases in the USA occur in adults < 50 years of age and the rate of early onset CRC incidence is expected to double by 2030 [4, 5]. Although clear drivers for the increase in incidence have not been elucidated, obesity is believed to play a major role [6, 7].

Obesity is also believed to play a significant role in worsening outcomes of non-malignant colorectal diseases, specifically diverticular disease, inflammatory bowel disease and *Clostridium Difficile* infections [8–12]. While a large amount of research has been appropriately dedicated to studying trends of obesity and early onset CRC, there is a dearth of information regarding obesity and its impact on trends of non-malignant gastrointestinal diseases among the young adult population. Thus, in this study, we focused on young adults < 50 years and hypothesized that the rise in obesity in adults < 50 corresponds with increasing admissions of non-malignant colorectal diseases in young adults with obesity (specifically severe obesity). We also propose that young patients with severe obesity have worse outcomes as compared to young adults without obesity. We aim to test our hypothesis by examining the impact of severe obesity on trends and outcomes of various gastrointestinal disease admissions in adults between the ages of 18–49 in the USA via large, nationally representative databases.

Methods

Data Source

We used data from the Nationwide Readmission Database (NRD) to examine the trends of gastrointestinal disease admissions in the USA. The NRD belongs to the Healthcare Cost and Utilization Project (HCUP). The NRD utilizes verified patient linkage numbers in the state inpatient databases (SID) to track each patient across hospitals within a state. The NRD contains all SID discharges from participating states that can be used to provide nationally representative estimates. Weighted admissions in the NRD represent approximately 36 million discharges annually across 21 states. We included the years 2010–2014 in our study for two reasons: the NRD starts in 2010 and to reduce bias from transition to ICD-10 CM codes that occurred in 2015.

The NRD database only provides information on hospitalized patients which may not be reflective of the general population. Therefore, in order to assess the US obesity trends in adults < 50 during the same study period, we utilized data from the National Health and Nutrition Examination Survey (NHANES). The NHANES is conducted by the National Center for Health Statistics of the Center for Disease Control and Prevention. It is a continuing population-based survey that uses a complex, multistage probability sampling design to select a representative sample of the noninstitutionalized civilian U.S. population [13]. The survey collects information from approximately 5000 people per year. Each survey consists of standardized household interviews, physical examinations, and collection of blood samples. We included the years 2009–2010, 2011–2012, 2013–2014 in NHANES since it is surveyed every 2 years. Both the NRD and NHANES are publicly available databases of de-identified patients; thus our study was exempt from The Ohio State University's Institutional Review Board (IRB) oversight.

Cohort

We focused our study on adults aged 18–49 years of age by excluding patients < 18 or ≥ 50 years of age. Body mass index (BMI) is defined using actual weight and height in the NHANES database. BMI and gastrointestinal conditions are defined within the NRD using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes. ICD-9-CM codes were shown to have a good accuracy for severe obesity (defined as BMI ≥ 35 kg/m^2 with comorbidities or BMI ≥ 40 kg/m^2) but lesser sensitivity for lower BMI categories [14, 15]. Thus, we mainly focused on gastrointestinal conditions in adults with a diagnosis of severe obesity, defined as above using ICD-9-CM codes (Supplementary Table 1). In a supplemental analysis, we also investigated our outcomes in patients with mild-moderate obesity (BMI 30–39.9 kg/m^2). Our comparison control group was defined by excluding adults with an accompanying diagnosis of obesity or underweight (ICD-9-CM codes for BMI ≥ 30 kg/m^2 or < 19 kg/m^2). These methods and ICD-9-CM codes were used similarly to previously published studies [16–24]. Gastrointestinal admissions were classified

based on principal discharge diagnosis as published before [25]: (1) gastrointestinal hemorrhage, (2) cholelithiasis with cholecystitis, (3) acute pancreatitis, (4) intestinal obstruction, (5) appendicitis, (6) chronic liver disease and viral hepatitis, (7) diverticulitis without hemorrhage, (8) noninfectious gastroenteritis/colitis, (9) Clostridium difficile infection, 10) GI infection, (11) functional/motility disorder, (12) inflammatory bowel disease (IBD).

Outcomes

The primary outcome of this study was comparing yearly trends of obesity in adults < 50 as well as yearly gastrointestinal disease hospitalization rates of adults with severe obesity compared to controls < 50 during the years 2010–2014. In order to assess the adverse effect of increasing obesity in adults < 50, we compared index mortality and 30-day readmission for gastrointestinal diseases between adults with severe obesity and controls. 30-day readmission was defined as a subsequent admission for any reason within 30 days after an index admission with a primary diagnosis of any gastrointestinal disease mentioned above. The following additional exclusions were applied in our cohort order to assure precise assessment of 30-day readmission: (1) absent index of admission length of stay or days to event of index admission or readmission, (2) December index admission for each calendar year to allow a 30-day period follow up for readmission analyses.

Statistical Analysis

Figure 1 shows the flow diagram for study inclusion. From the 2009–2014 NHANES data, Joinpoint regression analysis [26] was used to calculate the annual percent change (APC) within the study period for the number of people within the national population from ages 18 to 50 with a BMI ≥ 30, ≥ 35, and ≥ 40 kg/m^2 separately. Overall demographic characteristics were summarized with means and standard errors or frequencies and percentages.

We summarized young adults with gastrointestinal diseases as frequencies and percentages or means and standard errors, as appropriate in the 2010–2014 NRD database. The APC of gastrointestinal disease admissions from 2010 to 2014 was calculated. We examined admissions, 30-day

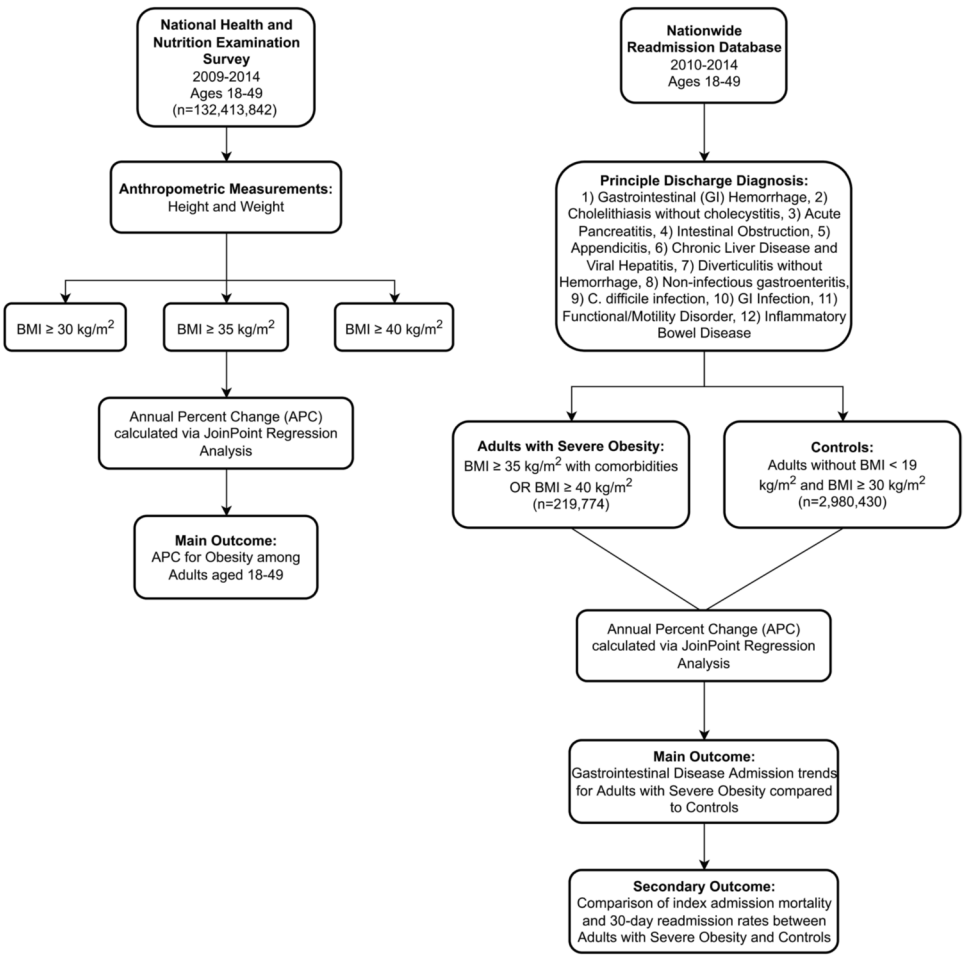

Fig. 1 Study design

readmissions and mortality trends for all gastrointestinal diseases as well as individual diseases. Subsequently, the trend analyses for admissions were repeated in both controls and adults with severe obesity, and in a supplemental analysis in patients with mild-moderate obesity.

Logistic regression models were fit for mortality and 30-day readmission for gastrointestinal diseases overall and individually to assess the impact of severe obesity as compared to controls. The models were adjusted for age, gender, insurance, hospital type, and Elixhauser comorbidity index. In the few cases where the sample size was insufficient to support adjustment for all desired terms backwards selection was employed to remove terms as necessary. Less than 1% of the NRD data was missing for all variables included in the study, participants with missing data were excluded as necessary. For all analyses a p value < 0.05 was considered to be statistically significant. Analyses were performed with Joinpoint Regression Program Version 4.6.0.0 (Statistical Methodology and Applications Branch, Surveillance Research Program, National Cancer Institute) and SAS 9.4 (SAS Institute Inc., Cary, NC) with survey procedures to produce national estimates for both the NHANES and NRD analyses.

Results

Obesity Trends in Adults < 50 in 2019–2014

A total of 132,413,842 patients were included in this analysis using NHANES. The average age of patients was 33.53 years (SE = 0.24) with approximately 49.42% of them being male. The majority of patients were non-Hispanic Whites (59.46%), followed by non-Hispanic Blacks (12.66%), Mexican American (11.66%), other Hispanics (7.17%), and all other races (9.06%). The annual percent changes (APC) for BMI categories in adults < 50 years of age is shown in Fig. 2. Overall, we found a rise in obesity rates, most prominently with higher BMI. For instance, for those patients with a BMI ≥ 35 kg/m^2, the APC in prevalence was 9.69% while there was a 12.84% annual increase in patients with a severe obesity defined as BMI ≥ 40 kg/m^2.

Gastrointestinal Hospitalization Trends for Adults < 50 Stratified by Obesity

A total of 3.5 million adults < 50 years were admitted for gastrointestinal conditions in 2010–2014 (mean age of 30.09 years, 45.7% men). Most of those young adults had minimal comorbidities and were admitted to large, urban hospitals (Table 1). Private insurance was predominately used (47.1%), followed by Medicaid (22.3%) for these admissions, which reflects a working-age cohort with

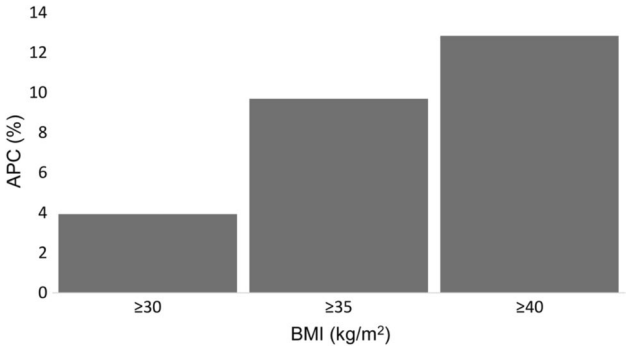

Fig. 2 Annual Percent Change for Obesity rates among Adults aged 18–49 based on NHANES

minimal disabilities. Adults with severe obesity accounted for 6.27% of the young population admitted for gastrointestinal conditions. Almost all gastrointestinal admissions increased in patients < 50 years old with severe obesity, demonstrated in Fig. 3 (overall increase of + 0.76% per year, $p < 0.001$). The uptrend in admission rates was > 10% per year for certain colorectal conditions such as *Clostridium difficile* infections (APC + 17.27%, $p = 0.002$), inflammatory bowel disease (APC + 13.1%, $p = 0.001$), diverticulitis (APC + 12.65%, $p = 0.002$) and intestinal obstruction (APC + 11.67, $p = 0.005$). Furthermore, admissions rates were pronounced for liver disease (APC + 12.22%, $p = 0.01$) and acute pancreatitis (APC + 10.04, $p < 0.001$). In contrast, we observe a decreased admission rate in young adults without obesity or underweight (overall APC of − 5.37%, $p < 0.001$). Specifically, admissions rates were decreased for appendicitis (APC − 11.47, $p = 0.001$) and non-infectious colitis (APC − 7.91, $p = 0.003$) (Fig. 4). In a supplementary analysis, a similar pattern of increased gastrointestinal admissions was observed in patients with mild-moderate obesity when compared to severe obesity, although the trend was less pronounced (overall APC + 4.35%, $p = 0.001$). Exceptions were appendicitis, motility disorders and viral gastroenteritis that did not increase in 2010–2014 in adults with obesity (Supplementary Fig. 1).

Impact of Severe Obesity on Gastrointestinal Disease Outcomes

When compared to controls, severe obesity was associated with increased mortality for acute pancreatitis [adjusted odds ratio (aOR) 3.02; 95% CI 2.19, 4.17], appendicitis (aOR 3.79; 95% CI 1.21, 11.81), diverticulitis (aOR 2.56; 95% CI 1.07, 6.13), and chronic liver disease (aOR 1.19; 95% CI 1.001, 1.42) (Table 2). Young patients with severe obesity were more likely to be readmitted after appendicitis (aOR 1.31, 95% CI 1.15, 1.49), diverticulitis (aOR 1.22, 95%

Table 1 Baseline characteristics for young adult patients admitted with gastrointestinal disease based on NRD

	Overall ($n = 3,504,596$)	
	n	%
Age (mean, SE)	30.09	0.02
Gender		
Male	1,601,544	45.70
Female	1,903,052	54.30
Type of insurance		
Medicare	277,293	7.93
Medicaid	778,463	22.27
Private	1,646,026	47.09
Other	793,703	22.71
Type of hospital		
Urban non-teaching	1,461,534	41.70
Urban teaching	1,639,196	46.77
Rural	403,866	11.52
Hospital size		
Small	475,343	13.56
Medium	888,044	25.34
Large	2,141,209	61.10
AHRQ-Elixhauser index		
< 3	2,657,161	75.82
≥ 3	847,435	24.18
Obesity (Not severe obesity)		
No	3,263,978	93.13
Yes	240,618	6.87
Severe obesity		
No	3,284,822	93.73
Yes	219,774	6.27
Index mortality		
No	3,488,478	99.58
Yes	14,602	0.42
Readmission[a]		
Not within 30 days	2,886,335	89.42
Within 30 days	341,342	10.58
Length of stay (mean, SE)	3.58	0.01
Hospital costs (mean, SE)	8987	43

SE standard error

[a]Index mortality and December discharges excluded

CI 1.10, 1.35), and chronic liver disease (aOR 1.14, 95% CI 1.03, 1.27) (Table 3).

Discussion

The prevalence of early onset colorectal cancer, a major public health concern, is rapidly rising and recent evidence links obesity to this trend. The impact of obesity on admissions and outcomes of non-malignant colorectal diseases among young adults, however, has scarcely been studied. This population witnesses a rapid increase in obesity which may increase the risk of other obesity-related gastrointestinal conditions. Therefore, we aimed to investigate this effect by examining the trends of obesity and comparing admission rates for various gastrointestinal disease admission rates in young adults with severe obesity and those without obesity using nationally representative databases. We identified for the first time an increase in adults < 50 with severe obesity that was up to 12.84% per year in 2009–2014. Corresponding with that, we see an increase that is more than 10% for infectious/inflammatory colorectal admissions in young adults with severe obesity during same period. Chief among these were *Clostridium difficile* infections, inflammatory bowel disease, diverticulitis, and noninfectious gastroenteritis/colitis. The increase in admissions of more than 10% per year for colorectal conditions is similar to trends of early onset CRC in adults with severe obesity [6]. In contrast, we found no such increase in *Clostridium difficile* infections or inflammatory bowel disease and a statistically significant decrease in incidence of diverticulitis and noninfectious gastroenteritis/colitis among young adults without obesity. Obesity is known to induce systemic inflammation [27] which could potentially serve as a nidus for developing and potentiating many of the colorectal diseases we investigated. Furthermore, obesity is associated with altered microbiome composition and decreased diversity when comparing obese and lean individuals [28, 29]. This in turn can increase the risk of *Clostridium difficile* infections [30] and colitis [31]. These findings suggest that visceral obesity, microbiome changes, chronic inflammation and others factors unique to patients with severe obesity are specifically worsening colorectal conditions.

In addition to higher morbidity, we demonstrate higher rates of index admission mortality and readmission for young patients with severe obesity. Specifically, we found higher mortality rates for acute pancreatitis, diverticulitis, and appendicitis as well as higher 30-day readmission rates for appendicitis and diverticulitis among adults with severe obesity compared to controls without obesity. Notably, the overall rates of index admission mortality and 30-readmission for all gastrointestinal disease admissions were not statistically significant between adults with severe obesity compared to adults without obesity, likely because obesity had an adverse effect on mortality and readmission in selected, but not all gastrointestinal conditions. These findings shed a new light on the negative impact of obesity on the severity of non-malignant colorectal diseases in younger ages. These young adults comprise a significant portion of the U.S population and are most prone to the economic consequences of hospitalization (spending, unpaid bills, bankruptcy, and reduced income) [32]. As the prevalence of obesity is expected to increase, particularly in younger ages, it is

Index Admissions	2010	2011	2012	2013	2014	APC	p-value
Overall	37,569	39,917	44,555	47,577	50,157	7.76	<0.001
Gastrointestinal hemorrhage	2,399	2,705	2,860	3,211	3,500	9.77	<0.001
Cholelithiasis with cholecystitis	14,083	14,842	16,174	16,841	17,345	5.50	0.003
Acute pancreatitis	5,231	5,958	6,475	7,168	7,765	10.04	<0.001
Intestinal obstruction	1,650	1,655	1,978	2,303	2,439	11.67	0.005
Appendicitis	3,596	3,654	3,929	3,921	3,897	2.23	0.075
Chronic liver disease and viral hepatitis	1,650	1,575	1,907	2,183	2,417	12.22	0.010
Diverticulitis without hemorrhage	3,197	3,348	4,157	4,532	5,008	12.65	0.002
Noninfectious gastroenteritis/colitis	1,529	1,773	2,032	1,905	2,063	6.78	0.050
Clostridium difficile infection	509	581	736	874	945	17.27	0.002
Gastrointestinal infection	1,364	1,341	1,598	1,778	1,761	7.93	0.024
Function/motility disorders	1,676	1,680	1,825	1,903	1,863	3.44	0.045
Inflammatory bowel diseases	685	805	885	957	1,153	13.10	0.001

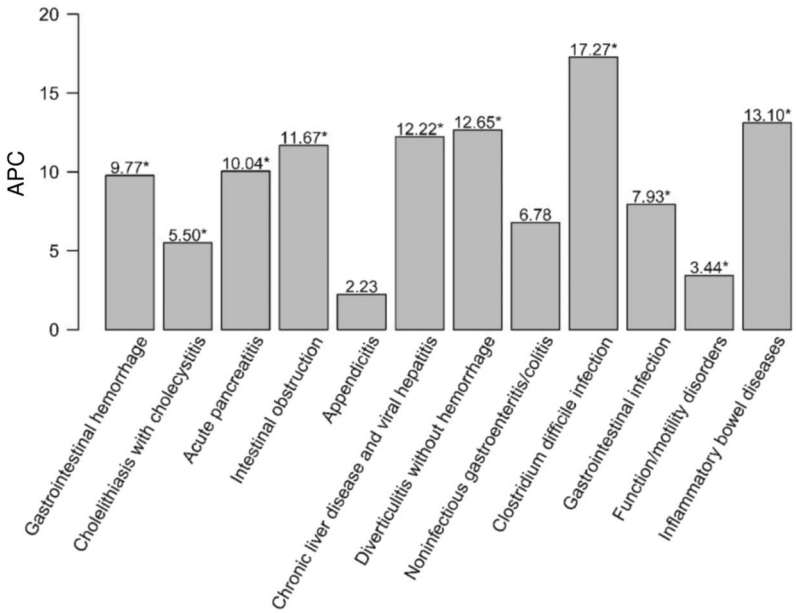

Fig. 3 National annual percent change (APC) of gastrointestinal admissions among all young adults with severe obesity during the years 2010–2014 with graph illustrations. *$P < 0.05$

reasonable to assume admissions for colorectal diseases will increase as well and thus place a significant health and financial strain on young adults in the USA. Therefore, future studies targeting prevention of obesity would be of great importance to reduce the incidence, mortality, and economic burden of non-malignant colorectal diseases in the USA.

We also identify significant increases in the admissions and readmissions of chronic liver diseases among young patients with severe obesity. This is likely due to complications of nonalcoholic fatty liver disease (NAFLD), a major health concern [33, 34]. Additionally, we demonstrate an increasing incidence as well as index admission mortality for acute pancreatitis among young patients with severe obesity. Obesity is an established risk factor for acute pancreatitis and previous studies have shown worse outcomes and higher mortality in this population [35]. Our data adds to this literature by

Index Admissions	2010	2011	2012	2013	2014	APC	p-value
Overall	667,864	638,312	610,371	568,899	537,924	-5.37	<0.001
Gastrointestinal hemorrhage	51,338	50,337	48,470	46,487	45,549	-3.14	0.001
Cholelithiasis with cholecystitis	132,788	125,834	118,252	107,607	96,612	-7.67	0.001
Acute pancreatitis	80,390	77,562	76,356	75,712	75,770	-1.32	0.042
Intestinal obstruction	36,557	35,451	36,003	36,476	35,206	-0.49	0.452
Appendicitis	128,996	120,011	107,869	92,979	79,344	-11.47	0.001
Chronic liver disease and viral hepatitis	37,145	36,411	36,681	36,330	35,600	-0.88	0.046
Diverticulitis without hemorrhage	45,271	42,378	40,230	38,753	37,021	-4.72	0.001
Noninfectious gastroenteritis/colitis	43,239	39,326	37,127	32,202	31,528	-7.91	0.003
Clostridium difficile infection	10,276	11,340	12,399	11,981	12,059	2.90	0.159
Gastrointestinal infection	33,164	30,519	29,914	27,136	25,782	-6.03	0.002
Function/motility disorders	28,512	28,690	27,900	24,662	24,543	-4.56	0.028
Inflammatory bowel diseases	40,189	40,454	39,170	38,575	38,912	-1.06	0.073

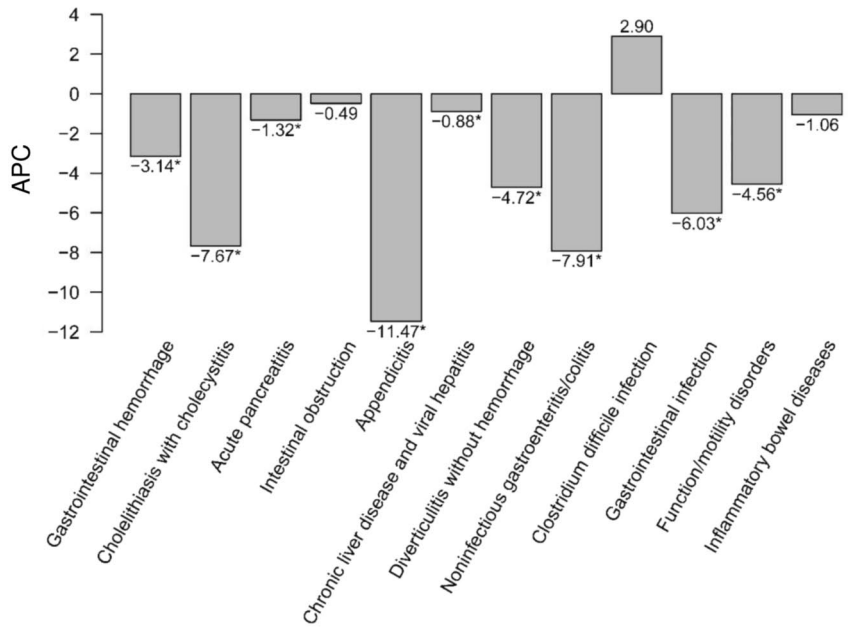

Fig. 4 National annual percent change (APC) of gastrointestinal admissions among all young adults with no obesity during the years 2010–2014 with graph illustrations. *$P < 0.05$

demonstrating rising admissions rates, specifically among young adults with obesity in the USA.

In a supplementary analysis, we examined admission trends and mortality of various colorectal diseases among patients with mild-moderate obesity. Interestingly, we found admission rates for many of the colorectal diseases studied, including *Clostridium difficile* infections, inflammatory bowel disease, and diverticulitis, increased for patients with obesity though to a lesser degree than patients with severe obesity. This suggests a possible dose–response effect of obesity on incidence of certain colorectal diseases. Therefore, given patients with severe obesity appear to be at highest risk for colorectal disease incidence and mortality, focusing targeted and early initiatives towards this population to achieve sustained weight loss is of the utmost importance.

Our study is the first evaluation of obesity and gastrointestinal disease trends in young adults based on a nationwide U.S. database. This national representation gives our data

Table 2 Logistic regression models for mortality among each of the gastrointestinal disease populations of interest based on NRD

Population	aOR[a]	95% CI	*p* value
Overall	1.10	(0.97, 1.24)	0.141
Gastrointestinal hemorrhage	1.25	(0.90, 1.73)	0.185
Cholelithiasis with cholecystitis	1.12	(0.61, 2.05)	0.719
Acute pancreatitis	3.02	(2.19, 4.17)	< 0.001
Intestinal obstruction	1.35	(0.87, 2.09)	0.182
Appendicitis[b]	3.79	(1.21, 11.81)	0.022
Chronic liver disease and viral hepatitis	1.19	(1.001, 1.42)	0.049
Diverticulitis without hemorrhage[c]	2.56	(1.07, 6.13)	0.036
Noninfectious gastroenteritis/colitis[d]	2.23	(0.75, 6.62)	0.150
Clostridium difficile infection[e]	1.93	(0.75, 4.93)	0.173
Gastrointestinal infection[d]	1.06	(0.30, 3.78)	0.926
Function/motility disorders[f]	1.49	(0.63, 3.52)	0.359
Inflammatory bowel diseases[g]	3.40	(0.75, 15.32)	0.112

Adjusted odds ratios (aOR) compare patients with severe obesity to those with no obesity

[a]Adjusted for age, gender, insurance, hospital type, hospital size, and Elixhauser comorbidity index unless otherwise noted

[b]Adjusted for age, insurance, and Elixhauser comorbidity index

[c]Adjusted for gender, hospital size, and Elixhauser comorbidity index

[d]Adjusted for insurance and Elixhauser comorbidity index

[e]Adjusted for age, insurance, hospital type, and Elixhauser comorbidity index

[f]Adjusted for gender, insurance, and Elixhauser comorbidity index

[g]Adjusted for age and Elixhauser comorbidity index

Table 3 Logistic regression models for 30-day readmission among each of the gastrointestinal diseases of interest based on NRD

Population	aOR[a]	95% CI	*p* value
Overall	0.93	(0.90, 0.96)	< 0.001
Gastrointestinal hemorrhage	1.02	(0.92, 1.13)	0.665
Cholelithiasis with cholecystitis	0.96	(0.90, 1.02)	0.151
Acute pancreatitis	0.93	(0.86, 0.997)	0.042
Intestinal obstruction	0.91	(0.79, 1.04)	0.166
Appendicitis	1.31	(1.15, 1.49)	< 0.001
Chronic liver disease and viral hepatitis	1.14	(1.03, 1.27)	0.013
Diverticulitis without hemorrhage	1.22	(1.10, 1.35)	< 0.001
Noninfectious gastroenteritis/colitis	0.95	(0.82, 1.09)	0.440
Clostridium difficile infection	1.15	(0.96, 1.38)	0.127
Gastrointestinal infection	0.97	(0.81, 1.15)	0.699
Function/motility disorders	0.92	(0.81, 1.04)	0.173
Inflammatory bowel diseases	1.04	(0.87, 1.25)	0.678

Adjusted odds ratios (aOR) compare patients with severe obesity to those with no obesity

[a]Adjusted for age, gender, insurance, hospital type, hospital size, and Elixhauser comorbidity index

advantage over single-center studies which may not accurately capture national trends. NHANES utilizes objectively measured height and weight data making our BMI trends an accurate estimate of the general population. Our ICD-9 CM codes used within the NRD were also shown to have good reliability when used to study gastrointestinal diseases and severe obesity and our methods were used in multiple publications [14, 15, 36, 37]. However, despite using robust coding and the national representation, we recognize some limitations when using the NRD database. First, given the overall retrospective design of the study, we cannot definitively state obesity is the sole cause of the rising admission rates for non-malignant gastrointestinal diseases during the time period studied. Nevertheless, we do identify a strong, positive association between severe obesity and hospital admission/mortality for these diseases which warrants further study. Next, obesity may be undercoded which may underestimate our trend in adults with obesity and severe obesity [15]. We attempted to reduce this bias by focusing on severe obesity which is more reliably coded as opposed to obesity. Fortunately, the ICD-9-CM coding trend for obesity and severe obesity seems relatively stable over time between 2011 and 2014 [14]. Thus, any increase in gastrointestinal admissions for adults with severe obesity is likely a true representation of reality and is less likely a confounder from increased obesity coding over time. Third, the NRD does not include information such as medication administration, objective laboratory values, and outpatient follow up, and therefore the effects of these factors on mortality or early admission was not assessed. Fourth, our analysis did not include additional factors that may influence gastrointestinal admissions due to limitations of the database. For instance, our analysis is limited by the lack of race/ethnicity data within NRD, which may be an important factor since the obesity epidemic has disproportionately affected African-Americans and Hispanics [38]. Also, while the NRD does provide information on tobacco and alcohol use, the coding for both variables within claims-based databases such as the NRD is unreliable and prone to bias [39, 40]. We recognize this is a limitation to our analysis, however, we believe our findings are still valid, particularly given the overall low co-occurrence of obesity and tobacco use as well as obesity and heavy alcohol use among the general population [41, 42]. Fifth, we used BMI to define obesity. Prior research has shown BMI does not take into account the composition of body fat. Visceral adiposity is more hormonogenic and thus has a stronger association with gastrointestinal, liver, and pancreatic disease [43–45]. As we were not able to study these patients exclusively, our results may have been affected. Still, adults with severe obesity are more likely to suffer from increased visceral obesity compared to adults without obesity [46].

In conclusion, our data suggest an increased rate of obesity and corresponding admissions for non-malignant colorectal, pancreatic and liver diseases in young adults with severe obesity. Those admissions are also more likely to have worsened outcomes in certain cases and potentially higher rates of early readmission. Consequently, this data support enacting programs and policies to curtail the obesity epidemic in the young adult population. Doing so may prevent future admissions for all colorectal diseases, as well as improve outcomes, and limit early readmissions. Therefore, it is imperative that further research determines specific methods, programs, and policies to curtail this epidemic.

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Author's contribution Dr. HH and Dr. AP were involved in the conception, design, and interpretation of data and the manuscript's drafting and critical revision. Dr. AH was involved in the study's design, acquired and statistically analyzed the data, and provided a critical revision of the manuscript. The above authors had full access to all the data in the study and take responsibility for the data's integrity and the data analysis' accuracy. Drs. KP, DMG, PPS, and SGK were involved in the design, data interpretation, and critical revision of the manuscript. All gave final approval of the submitted manuscript and take responsibility for the integrity of the work.

Declarations

Conflict of interest The authors have no relevant conflicts of interest, including relevant financial interests, activities, relationships, or affiliations.

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