Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Introduction: As the COVID-19 pandemic unfolded, several studies collected small and relatively homogenous samples to track U.S. adult obesity rates and obesity-related risk factors. In this study, a much larger sample from a nationally representative survey was used to investigate changes in average BMI, obesity prevalence rates, and 4 obesity-related risk factors in the U.S. adult population during the COVID-19 pandemic.

Methods: Using a large nationally representative sample of U.S. adults aged ≥20 years from the 2011–2020 Behavioral Risk Factor Surveillance System, linear regression models estimated intra-pandemic changes in average BMI and obesity prevalence rates as well as 4 obesity-related risk factors.

Results: Relative to the 2019 to prepandemic 2020 period, significantly higher average BMI (+0.6%, p<0.05, N=3,555,865) and obesity prevalence rates (+3%, p<0.05, N=3,555,865) were observed among U.S. adults during the COVID-19 pandemic. Significantly higher rates of any exercise participation (+4.4%, p<0.01, N=3,607,272), average sleep hours in a 24-hour period (+1.5%, p<0.01, N=1,907,798), average alcoholic drink days in the past month (+2.7%, p<0.05, N=3,577,090), and lower rates of smoking at least some days (−4%, p<0.01, N=3,625,180) were also observed.

Conclusions: During the COVID-19 pandemic, U.S. adult obesity rates were higher and worsened the pre-existing epidemic of adult obesity in the U.S. Higher rates of alcohol consumption and lower smoking rates may have contributed to the higher rates of adult obesity in the U.S during the COVID-19 pandemic.

Am J Prev Med 2022;63(1):102–106. Published by Elsevier Inc. on behalf of American Journal of Preventive Medicine.
studies using online survey data found that adult participants who reported that they gained weight during the pandemic also reported more frequent snacking and alcohol intake; increased eating in response to sight, smell, and stress; and decreased physical activity.

Though prior studies provide insights into how obesity prevalence changed during the pandemic, it is unclear whether results from nonrepresentative samples generalize to the broader adult population. This study contributes to the literature by using nationally representative data on adults aged ≥ 20 years from the 2011–2020 Behavioral Risk Factor Surveillance System (BRFSS) to analyze changes in average BMI and obesity prevalence rates during the pandemic. Several behaviors that can influence obesity risk—exercise, sleep duration, alcohol use, and smoking—are also examined to help explain observed changes in average BMI and obesity prevalence rates.

METHODS

The BRFSS collects data about U.S. residents from all 50 states, the District of Columbia, and 3 U.S. territories regarding health-related risk behaviors and chronic health conditions. This study used only public-use deidentified BRFSS data. To estimate intra-pandemic changes in average BMI, obesity prevalence rates, and 4 obesity-related risk measures—participation in any physical activity in the past month, average sleep hours in a 24-hour period, number of days in the past month when any amount of alcohol was consumed, and cigarette smoking every day or on some days—among adults aged ≥ 20 years in the 2011–2020 BRFSS, the following linear regression model was estimated by ordinary least squares:

\[ Y_{it} = \alpha + X_{it}' \beta + \gamma_j \sum_{j=2011}^{2018} \text{Interview Year}_j + \delta_{COVID \text{ Pandemic}_{it}} + \epsilon_{it}, \]

where \( Y_{it} \) is either a body weight measure or an obesity-related risk factor for individual \( i \) at time \( t \); \( X_{it} \) is a vector of individual characteristics—age, sex, race/ethnicity, education, income, marital status, and number of children—that account for changing demographic characteristics over time that could affect body weight or obesity risk as well as the survey respondent’s location; \( \sum \text{Interview Year} \) represents 8 indicator variables equal to 1 if the survey respondent was interviewed in a prepandemic year 2011, 2012, …, 2018 and 0 otherwise; \( COVID \text{ Pandemic} \) is an indicator variable equal to 1 if the survey respondent was interviewed after the President of the U.S. declared the spread of the novel coronavirus a pandemic (March 13, 2020) and 0 otherwise; and \( \epsilon_{it} \) is a random error term. All interview period coefficient estimates are estimated relative to the (omitted) 2019 to March 12, 2020 period.

The primary dependent variable of interest, BMI, is derived from self-reported height and weight. As these measures are often misreported, they were adjusted for measurement error using a percentile-based approach with data from the 2011 to March 2020 National Health and Nutrition Examination Survey. The adjusted height and weight data were used to compute an adjusted BMI measure and an adjusted obesity indicator (BMI ≥ 30). Table 1 contains the summary statistics for the dependent and independent variables used in the analysis. For BMI/obesity, the analysis involved 3,555,865 respondents (3,311,457 before the pandemic and 244,408 during the pandemic). Consistent with BRFSS respondents overestimating height and underestimating weight, adjusted BMI and obesity are higher than unadjusted BMI and obesity (Table 1).

There was significant skewness in the continuous dependent variables (BMI, sleep hours, and alcoholic drink days); therefore, they were log-transformed in the regression analysis. The primary independent variable of interest (COVID Pandemic) is a binary variable, so in linear regressions involving logged continuous dependent variables, percentage changes relative to the 2019 to March 12, 2020 period were obtained by applying the formula 100 × exp (linear coefficient estimate) − 100. In linear regressions involving binary dependent variables, coefficient estimates were divided by sample means to obtain percentage changes relative to the 2019 to March 12, 2020 period.

All analyses were conducted using Stata, version 17. To account for the complex survey design of the BRFSS and produce nationally representative estimates, BRFSS sampling weights, strata, and primary sampling units were applied using Stata’s estimation commands for survey data.

RESULTS

Figure 1 shows the linear regression coefficient estimates associated with the indicator for the COVID-19 pandemic period. The analysis reveals that, relative to the 2019 to March 12, 2020 period, average BMI was higher by 0.6% (p < 0.05) and obesity prevalence rates were higher by 1.1 percentage points or 3% relative to the sample mean (p < 0.05). Exercise participation rates were higher by 3.3 percentage points (or 4.4%) (p < 0.01), average sleep hours were higher by 1.5% (p < 0.01), average alcoholic drink days were higher by 2.7% (p < 0.05), and smoking rates were lower by 0.7 percentage points (or 4%) (p < 0.01).

DISCUSSION

Relative to the 2019 to March 12, 2020 period, significantly higher average BMI and obesity prevalence rates during the COVID-19 pandemic were observed among adults. Significant changes in several obesity-related risk indicators were also observed. Higher rates of alcohol consumption and lower smoking rates may have contributed to higher obesity prevalence rates. Indeed, higher alcohol intake has been shown to be a risk factor for obesity in some adults, particularly when it is not compensated for through reductions in intake of other calorie-dense foods and beverages. Quitting smoking has also been shown to lead to weight gain, both in the short and longer term. Higher exercise participation and average sleep duration can reduce obesity risk. However, given...
the observed higher obesity prevalence rates, higher exercise participation rates and average hours of sleep were not enough to offset behavior changes that increased obesity risk. Given that >40% of adults currently have obesity, which raises annual medical costs by approximately $3,632 (2020 dollars), continued surveillance of obesity prevalence rates and obesity-related risk factors can help to inform policy that is designed to mitigate the health and economic burdens of obesity.

A major strength of this study is its ability to estimate intra-pandemic obesity prevalence rates and obesity-related risk factors using a large nationally representative survey. The BRFSS is, however, a cross-sectional data set. Future work exploiting longitudinal data to explore the dynamics of weight status among the same individuals during the pandemic would be useful. Another important limitation is that BRFSS respondents were not asked whether they had COVID-19, which may have affected obesity-related risk factors. Moreover, obesity is a

Table 1. Summary Statistics for the Overall Sample, 2011–2020 Behavioral Risk Factor Surveillance System

| Variables                                      | Mean or %  | SD       |
|------------------------------------------------|------------|----------|
| BMI (unadjusted)                               | 28.139     | 6.315    |
| Obese (unadjusted)                             | 30.8%      |          |
| BMI (adjusted)                                  | 29.051     | 6.620    |
| Obese (adjusted)                                | 36.7%      |          |
| Any physical activity in past month<sup>a</sup> | 75.6%      |          |
| Average hours of sleep in a 24-hour period<sup>b</sup> | 6.958      | 1.469    |
| Number of days in the past month alcohol was consumed<sup>c</sup> | 5.079      | 8.071    |
| Currently, smoking some days or every day<sup>d</sup> | 17.6%      |          |
| Age in years                                   | 48.093     | 16.914   |
| Sex                                            |            |          |
| Female                                         | 49.5%      |          |
| Male                                           | 50.5%      |          |
| Racial/ethnic group                            |            |          |
| Non-Hispanic White                             | 65.4%      |          |
| Non-Hispanic Black                             | 11.7%      |          |
| Hispanic                                       | 15.3%      |          |
| Other                                          | 7.7%       |          |
| Educational attainment                         |            |          |
| Never attended school or only kindergarten     | 0.2%       |          |
| Grades 1 through 8 (elementary)                | 3.8%       |          |
| Grades 9 to 11 (some high school)              | 8.2%       |          |
| Grade 12 or GED (high school graduate)         | 26.8%      |          |
| College 1 year to 3 years (some college)       | 31.5%      |          |
| College 4 years or more (college graduate)     | 29.5%      |          |
| Household income, $                            |            |          |
| <10,000                                        | 5.8%       |          |
| 10,000 to <15,000                              | 5.3%       |          |
| 15,000 to <20,000                              | 7.5%       |          |
| 20,000 to <25,000                              | 9.1%       |          |
| 25,000 to <35,000                              | 10.5%      |          |
| 35,000 to <50,000                              | 13.6%      |          |
| 50,000 to <75,000                              | 15.3%      |          |
| >75,000                                        | 33.0%      |          |
| Marital status                                 |            |          |
| Married or a member of an unmarried couple      | 58.1%      |          |
| Divorced                                       | 11.6%      |          |
| Widowed                                        | 6.6%       |          |
| Separated                                      | 2.6%       |          |
| Never married                                  | 21.1%      |          |
| Number of children under 18 years of age in the household |            |          |
| 0                                              | 63.0%      |          |
| 1                                              | 14.9%      |          |

Note: These are summary statistics corresponding to the regression sample involving BMI obesity as a dependent variable: the overall N=3,555,865, the prepandemic n=3,311,457, and intra-pandemic n=244,408. To produce nationally representative estimates, the appropriate BRFSS sampling weights, strata, and primary sampling units were applied in computing these summary statistics. Because of missing information on the other dependent variables used in the regression analyses summarized in Figure 1, the sample sizes are smaller and are as follows:

- The overall N=3,607,272. The prepandemic n=3,349,482 and intra-pandemic n=257,790.
- The overall N=1,907,798. The prepandemic n=1,652,408 and intra-pandemic n=255,390.
- The overall N=3,577,090. The prepandemic n=3,328,705 and intra-pandemic n=248,385.
- The overall N=3,625,180. The prepandemic n=3,374,039 and intra-pandemic n=251,141.

(continued)
Complex disease, and there are many risky behaviors that could have contributed to the higher obesity prevalence rates documented here, including changes in dietary intake that are unmeasured in the BRFSS data. An important direction for future research is to examine whether adults shifted toward more calorie-dense eating patterns during the pandemic. These results may prove to be useful inputs in policymaking decisions regarding potential actions to combat the exacerbated adult obesity epidemic as the COVID-19 pandemic subsides.

**ACKNOWLEDGMENTS**

The findings and conclusions in this study are those of the author and should not be construed to represent any official U. S. Department of Agriculture or U.S. Government determination or policy.

This research was supported by the Economic Research Service, U.S. Department of Agriculture.

No financial disclosures were reported by the authors of this paper.

**CREDIT AUTHOR STATEMENT**

Brandon J. Restrepo: Conceptualization; Data Curation; Formal Analysis; Investigation; Methodology; Validation; Visualization; Writing - Original Draft; Writing - Review and Editing.

**REFERENCES**

1. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of obesity and severe obesity among adults: United States, 2017-2018. NCHS Data Brief. 2020(360):1–8. https://www.cdc.gov/nchs/products/databriefs/db360.htm. Accessed, March 2, 2022.

2. Flanagan EW, Beyl RA, Fearnbach SN, Altazan AD, Martin CK, Redman LM. The impact of COVID-19 stay-at-home orders on health behaviors in adults. Obesity (Silver Spring). 2021;29(2):438–445. https://doi.org/10.1002/oby.23066.

3. Lin AL, Vittinghoff E, Olgin JE, Fletcher MJ, Marcus GM. Body weight changes during pandemic-related shelter-in-place in a longitudinal cohort study. JAMA Netw Open. 2021;4(3):e212536. https://doi.org/10.1001/jamanetworkopen.2021.2536.

4. Seal A, Schaffner A, Phelan S, et al. COVID-19 pandemic and stay-at-home mandates promote weight gain in US adults. Obesity (Silver Spring). 2022;30(1):240–248. https://doi.org/10.1002/oby.23293.
5. Bhutani S, vanDellen MR, Cooper JA. Longitudinal weight gain and related risk behaviors during the COVID-19 pandemic in adults in the U.S. *Nutrients*. 2021;13(2):671. https://doi.org/10.3390/nu13020671.
6. Zachary Z, Brianna F, Brianna L, et al. Self-quarantine and weight gain related risk factors during the COVID-19 pandemic. *Obes Res Clin Pract.* 2020;14(3):210–216. https://doi.org/10.1016/j.orcp.2020.05.004.
7. Courtemanche C, Pinkston JC, Stewart J. Adjusting body mass for measurement error with invalid validation data. *Econ Hum Biol.* 2015;19:275–293. https://doi.org/10.1016/j.ehb.2015.04.003.
8. Traversy G, Chaput JP. Alcohol consumption and obesity: an update. *Curr Obes Rep.* 2015;4(1):122–130. https://doi.org/10.1007/s13679-014-0129-4.
9. Courtemanche C, Tchernis R, Ukert B. The effect of smoking on obesity: evidence from a randomized trial. *J Health Econ.* 2018;57:31–44. https://doi.org/10.1016/j.jhealeco.2017.10.006.
10. Omer T. The causes of obesity: an in-depth review. *Adv Obes Weight Manag Control.* 2020;10(3):90–94. https://doi.org/10.15406/aowmc.2020.10.00032.
11. Gawley J, Meyerhoefer C. The medical care costs of obesity: an instrumental variables approach. *J Health Econ.* 2012;31(1):219–230. https://doi.org/10.1016/j.jhealeco.2011.10.003.
12. Tremmel M, Gerdtham UG, Nilsson PM, Saha S. Economic burden of obesity: a systematic literature review. *Int J Environ Res Public Health.* 2017;14(4):435. https://doi.org/10.3390/ijerph14040435.