Is Obesity Associated with the Worsening of Blood Pressure Control?

Sreejata Dutta[1] | Xiaosong Shi [1]

[1] Department of Biostatistics & Data Science, University of Kansas Medical Center, Kansas, USA

ABSTRACT

Hypertension, a major risk for cardiovascular diseases, remains prevalent among U.S. adults, with a 2017 redefinition leading to an about 10% increase in cases. Our study is based on a National Health and Nutrition Examination Survey Data Brief in 2017, showcasing a concerning trend of decline in controlled hypertension in the last decade. Focusing on the association between obesity (BMI > 30 kg/m^2) and controlled blood pressure (BP), our study implemented difference-in-differences (DID) models to explore the difference in trends between the obese and non-obese groups from 2011-2012 to 2017-March 2020. We also conducted a subgroup analysis considering antihypertensive medication use. Our findings suggest that although obesity has no significant association in controlling hypertension (systolic and diastolic BP) over time, the use of antihypertensive medications lowers diastolic BP over time, irrespective of obesity status. Despite the challenges associated with observational data, we were able to explore the association by matching data across survey periods and obesity statuses and making them comparable.

KEYWORDS: hypertension, BMI, antihypertensive medication use, DID analysis, propensity score matching

1 | INTRODUCTION

Hypertension poses a significant risk for cardiovascular diseases, which stand as leading causes of death in the U.S. (CDC, 2021). Despite this threat, the prevalence of hypertension among U.S. adults (age>=18 years)has remained persistently high over the past decade. In 2017, the American College of Cardiology and American Heart Association redefined hypertension as having a systolic blood pressure (BP) greater than or equal to 130 mmHg or diastolic BP greater than or equal to 80 mmHg. This adjustment led to an approximately 10% increase in the categorization of hypertension cases.

Our preliminary analysis utilized the National Health and Nutrition Examination Survey (NHANES) data, following a 2017 National Center for Health Statistics (NCHS) Data Brief (Fryar et al., 2017), to reproduce the age-adjusted trends in hypertension and controlled hypertension among U.S. adults from 2011 to March 2020 (Figure 1). Hypertensive adults were defined as survey respondents exhibiting hypertensive BP measures or those taking antihypertensive medications to manage high BP. Figure 1 illustrates a concerning trend over the past decade, with the percentage of adults with hypertension peaking at 45.1% in the latest survey period from 2017 to March 2020. However, the prevalence of controlled hypertension among hypertensive adults has seen a decline, with only 42.9% maintaining controlled BP in the same period.

Bramlage et al., 2004 found that individuals with obesity exhibited suboptimal rates of hypertension control. With the updated definition of hypertension, it is crucial to understand the causal effect of Body Mass Index (BMI) on controlled BP in individuals with hypertension. In this study, we utilize NHANES data from 2011-2012 and 2017-March 2020 (hereinafter 2017-2020) to investigate the association of controlled BP with obesity statuses. We employ a difference-in-differences (DID) model to explore whether obesity is linked to a deterioration in BP control among U.S. adults with hypertension over the past decade. The insights obtained from this analysis are indispensable for the development of effective interventions aimed at controlling BP and preventing cardiovascular diseases in the future.

2 | METHODS

We extracted NHANES data spanning the survey periods from 2011-2012 to 2017-2020 via the cardioStatsUSA R package. For our analyses, we defined obesity as BMI greater than or equal to 30 kg/m^2. Since the focus of this study was on U.S. adults with hypertension, we subset our data with participants with a systolic BP greater than or equal to 130 mmHg or diastolic BP greater than or equal to 80 mmHg or those who are using antihypertensive medication.

The DID method was chosen as it allows us to compare the difference in outcomes between two study groups over two specific time points, which in our case happen to be the survey periods 2011-2012 and 2013-2014. DID is a quasi-experimental method suitable when conducting real-life experiments is infeasible. One of its requirements is a consistent population across time, necessitating data for every observation at both time points.

To ensure population consistency across 2011-2012 and 2017-2020, we divided the dataset based on the obesity status and performed one-to-one greedy matching on survey periods, considering various factors such as age, race, gender, marital status, education level, ratio of family income to poverty, alcohol use, smoking status, awareness of hypertension, BP medication use, number of classes of BP medication, and history of chronic health conditions including diabetes, cardiovascular diseases, and chronic kidney diseases. Our outcomes of interest are systolic and diastolic BP, and they are analyzed separately. The DID model is specified as follows:

$$Y = \beta_0 + \beta_1[\text{survey period}] + \beta_2[\text{obesity status}] + \beta_3[\text{survey period} \times \text{obesity status}] + \epsilon$$

where, Y represents the systolic or diastolic BP measure, β_0 is the average BP measure in the non-obese group in 2011-2012, β_1 indicates the BP change over time in the non-obese group, β_2 is the BP difference between the obese and non-obese groups in 2011-2012, β_3 denotes the DID between groups over time, and ϵ accounts for the error in the model.

Recognizing variations in BP trends among individuals based on antihypertensive medication use, we performed a subgroup analysis using extended DID models to compare participants who use or do not use antihypertensive medications.

We used R version 4.2.1 for data cleaning and creating figures while SAS 9.4 was used to perform the propensity score matching and DID analyses. All analyses are conducted at 0.05 level of significance.

3 | RESULTS

Table 1 displays the distributions of associated variables in our propensity matched dataset. The data distributions across the two groups (obese and non-obese) over the two time periods appear comparable. In evaluating the relationship between mean systolic/diastolic BP and obesity status over time, we adjusted the outcomes for several covariates including race, gender, age, marital status, education, income-to-poverty ratio, history of chronic health conditions, alcohol and smoking habits, and awareness of hypertension. The decision of the adjustment is informed by insights from the existing literature (Erem et al., 2008; Singh, Shankar and Singh, 2017; Oyawa et al., 2022; Sukhram et al., 2022; Kundu et al., 2022; Gupta et al., 2023).

Results from the DID analyses are presented in Table 2 and illustrated by Figure 2. The findings from the models can be summarized as follows:

1. The results of the overall model revealed no significant change in the adjusted mean systolic or diastolic BP over time between the two groups and thus no change in BP control.

2. In general, the obese group had a higher diastolic BP than the non-obese group across time, which is consistent with some prior findings (Jiang et al., 2016). However, the obese group had a lower systolic BP than the other group.

3. Through our subgroup analyses by hypertensive medication use, we found that there was an increase in the adjusted mean diastolic BP over time for participants who used hypertensive medications, such that the obese group showed a decrease in trend over time while the trend remained almost constant for the non-obese group.

4. From Table 2, we observed that there was a significant difference in the SBP/DBP between the two groups. However, the directions of the observed differences were not the same across subgroups. For instance, for the overall SBP model, we observed that the non-obese group had a higher SBP, however for the participants who used hypertensive medications, the obese group exhibited a higher SBP.

5. From Figure 2, we also observed that the use of antihypertensive medication showed a non-increasing trend in both systolic and diastolic BP over time. Conversely, those not taking any antihypertensive medication exhibited no significant change in BP over the observed time.

4 | DISCUSSION

Our study found that obesity is not significantly associated with changes in control BP over the last decade. However, when considering the use of antihypertensive medication, our findings affirm that it is possible that the hypertensive patients' diastolic BP can be lowered over time, irrespective of obesity status (Parikh et al., 2018). It is crucial to note that our approach involved one-to-one greedy matching to create a comparable subset across the survey periods, and the results may vary when employing alternative matching algorithms. Our study encountered limitations in sample size attributed to missing data. A potential avenue for enhancement involves the application of imputation methods before the matching process. Employing imputation techniques could increase the sample size and potentially reveal additional patterns, thereby contributing to a more robust and comprehensive analysis.

In an effort to explore other factors influencing BP control, we extended our study to investigate the relationship between BP control and sodium intake over time, motivated by (Gupta et al., 2023). Unfortunately, challenges arose from suboptimal matching results due to missing dietary data, preventing us from reaching conclusive findings.

REFERENCES

Bramlage, P., Pittrow, D., Pittrow, D., Kirch, W., Boehler, S., Lehnert, H., et al. (2004) Hypertension in overweight and obese primary care patients is highly prevalent and poorly controlled. *American Journal of Hypertension*, **17**, 904–910.

CDC. (2021) National Center for Health Statistics Mortality Data on CDC WONDER. . URL https://wonder.cdc.gov/Deaths-by-Underlying-Cause.html [accessed 14 January 2024]

Erem, C., Hacihasanoglu, A., Kocak, M., Deger, O. and Topbas, M. (2008) Prevalence of prehypertension and hypertension and associated risk factors among Turkish adults: Trabzon Hypertension Study. *Journal of Public Health*, **31**, 47–58.

Fryar, C.D., Ostchega, Y., Hales, C.M., Zhang, G. and Kruszon-Moran, D. (2017) Hypertension Prevalence and Control Among Adults: United States, 2015-2016. *NCHS data brief*, 1–8.

Gupta, D.K., Lewis, C.E., Varady, K.A., Su, Y.R., Madhur, M.S., Lackland, D.T., et al. (2023) Effect of Dietary Sodium on Blood Pressure. *JAMA*, **330**, 2258.

Jiang, S.-Z., Lu, W., Zong, X.-F., Ruan, H.-Y. and Liu, Y. (2016) Obesity and hypertension. *Experimental and Therapeutic Medicine*, **12**, 2395–2399.

Kundu, S., Rahman, Md.A., Kabir, H., Al Banna, Md.H., Hagan Jr., J.E., Srem-Sai, M., et al. (2022) Diabetes, Hypertension, and Comorbidity among Bangladeshi Adults: Associated Factors and Socio-Economic Inequalities. *Journal of Cardiovascular Development and Disease*, **10**, 7.

Oyawa, I., Adhiambo, M., Wesonga, B., Wanzala, M., Adungo, F., Makwaga, O., et al. (2022) Burden of hypertension and associated factors among HIV positive adults in Busia County, Kenya. *Pan African Medical Journal*, **43**.

Parikh, J.S., Randhawa, A.K., Wharton, S., Edgell, H. and Kuk, J.L. (2018) The Association between Antihypertensive Medication Use and Blood Pressure Is Influenced by Obesity. *Journal of Obesity*, **2018**, 1–11.

Singh, S., Shankar, R. and Singh, G.P. (2017) Prevalence and Associated Risk Factors of Hypertension: A Cross-Sectional Study in Urban Varanasi. *International Journal of Hypertension*, **2017**, 1–10.

Sukhram, S.D., Zarini, G.G., Shaban, L.H., Vaccaro, J.A. and Huffman, F.G. (2022) Microalbuminuria and Hypertension among Immigrants with Type 2 Diabetes: A Community-Based Cross-Sectional Study. *Journal of Personalized Medicine*, **12**, 1777.

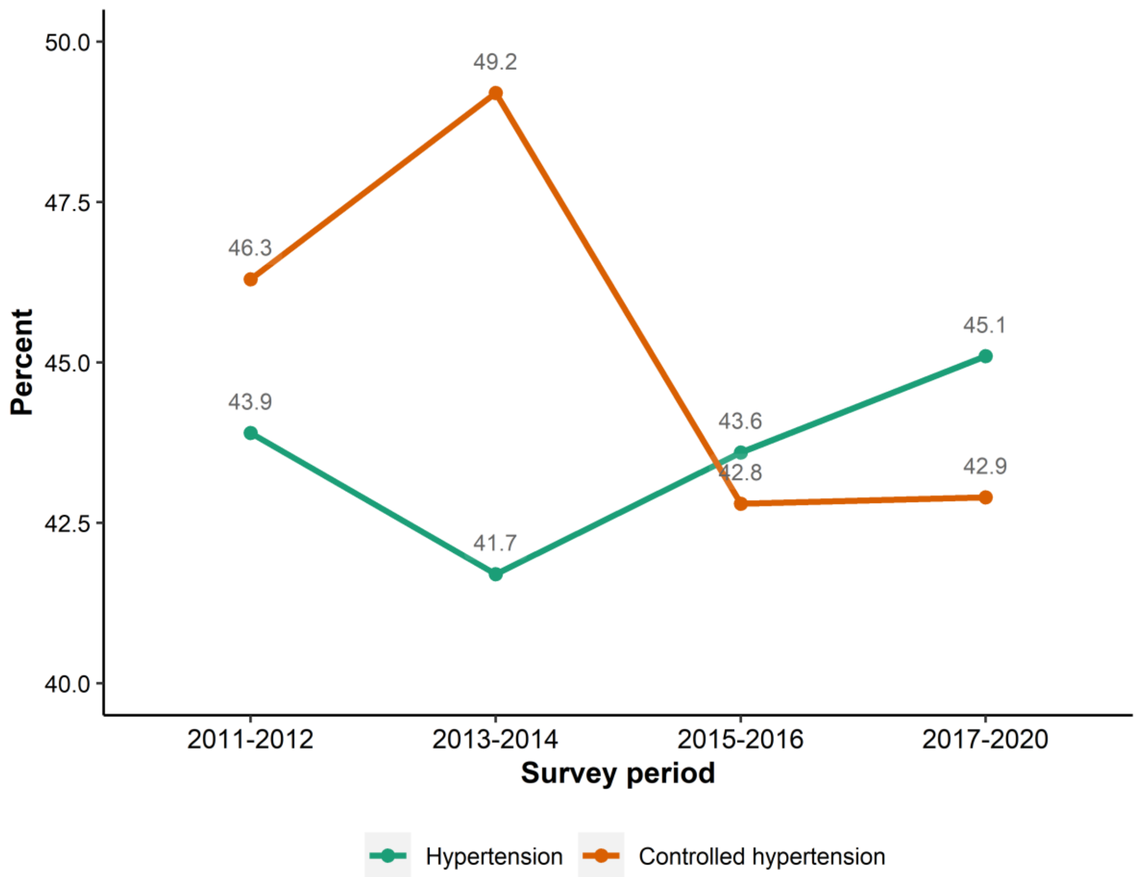

FIGURE 1 Age-adjusted trends in hypertension and controlled hypertension among the U.S. adults aged 18 and over from 2011 to March 2020. Estimates are age adjusted by the direct method to the 2000 U.S. Census population using age groups 18–39, 40–59, and 60 and over. Source: NCHS, NHANES.

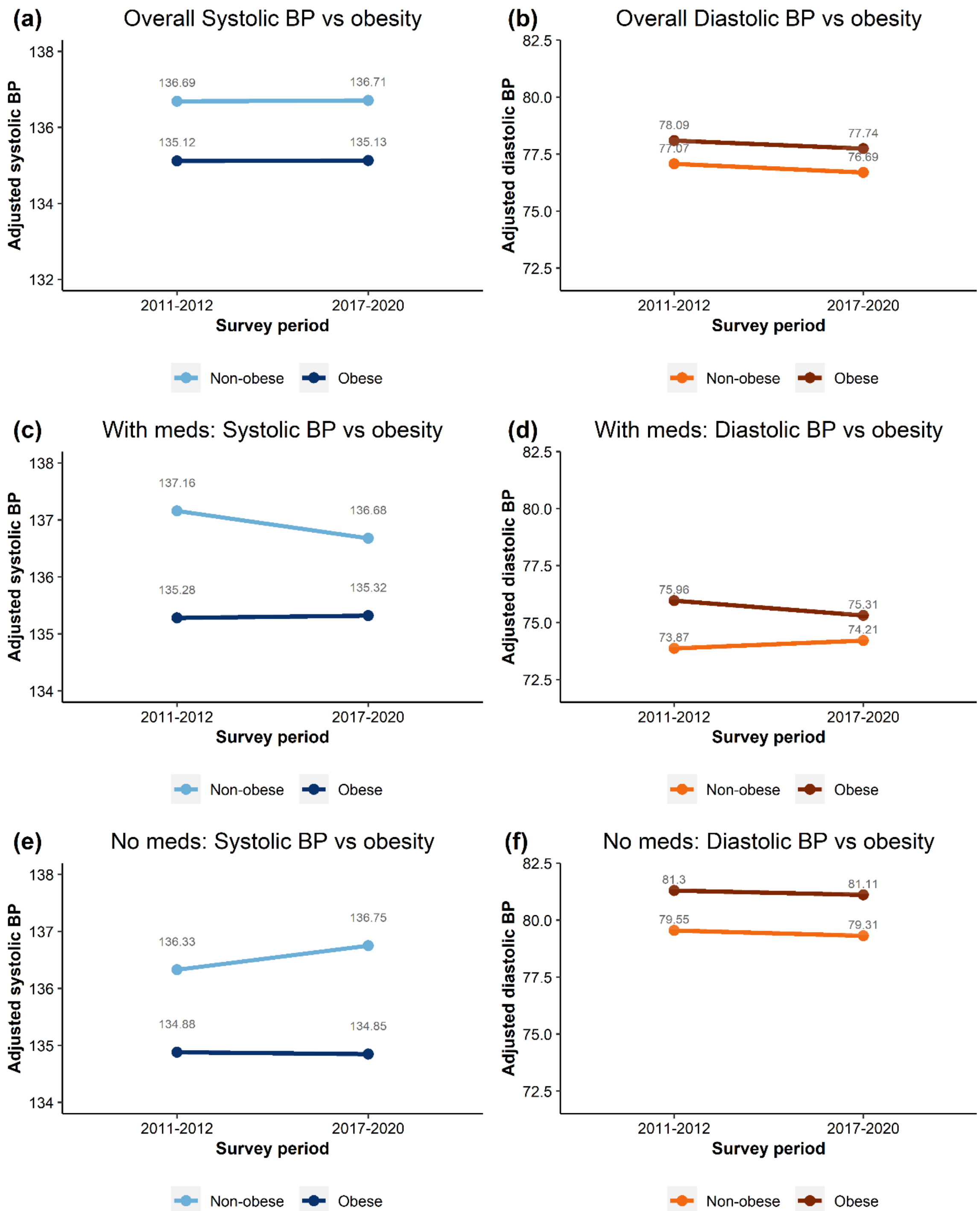

FIGURE 2 Results of the DID analyses on the adjusted systolic BP and diastolic BP. Panels (a) and (b) provide the overall trends over time for the obese and non-obese groups. Panels (c), (d), (e) and (f) present the results of the subgroup analyses by antihypertensive medication use.

TABLE 1 Descriptive characteristics of matched data across the two obesity statuses and 2011-2012 and 2017-2020

Variables	2011-2012 (N=1776)		2017-2020 (N=1776)	
	Obese (N=797)	Non-obese (N=979)	Obese (N=797)	Non-obese (N=979)
Age, n (%)				
18 to 44	227 (28.5%)	197 (20.1%)	232 (29.1%)	191 (19.5%)
45 to 64	347 (43.5%)	410 (41.9%)	336 (42.2%)	406 (41.5%)
65 to 74	138 (17.3%)	196 (20.0%)	146 (18.3%)	197 (20.1%)
75+	85 (10.7%)	176 (18.0%)	83 (10.4%)	185 (18.9%)
Race, n (%)				
Hispanic	155 (19.4%)	126 (12.9%)	153 (19.2%)	127 (13.0%)
Non-Hispanic Asian	21 (2.6%)	120 (12.3%)	19 (2.4%)	123 (12.6%)
Non-Hispanic Black	277 (34.8%)	276 (28.2%)	282 (35.4%)	281 (28.7%)
Non-Hispanic White	322 (40.4%)	434 (44.3%)	317 (39.8%)	422 (43.1%)
Other	22 (2.8%)	1 (0.1%)	33 (3.7%)	2 (0.2%)
Gender: Female, n (%)	384 (48.2%)	369 (37.7%)	389 (48.8%)	348 (35.5%)
Ratio of annual family income to poverty, mean (SD)	2.39 (1.62)	2.54 (1.64)	2.55 (1.61)	2.44 (1.57)
Education level, n (%)				
High school or less	382 (47.9%)	444 (45.4%)	379 (47.6%)	435 (44.4%)
Some college	257 (32.2%)	273 (27.9%)	253 (31.7%)	281 (28.7%)
College or above	158 (19.8%)	262 (26.8%)	165 (20.7%)	263 (26.9%)
Marital status, n (%)				
Married/partnered	431 (54.1%)	537 (59.9%)	507 (56.1%)	454 (56.5%)
Never married	123 (15.4%)	124 (13.8%)	147 (16.3%)	93 (11.6%)
Widowed/divorced/separated	243 (30.5%)	235 (26.2%)	249 (27.6%)	257 (32.0%)
Smoking status, n (%)				
Current	161 (20.3%)	201 (25.3%)	252 (16.3%)	350 (22.6%)
Former	252 (31.7%)	267 (33.6%)	496 (32.0%)	458 (29.6%)
Never	381 (48.0%)	326 (41.1%)	801 (51.7%)	741 (47.8%)
Alcohol use, n (%)	145 (18.2%)	193 (19.7%)	157 (19.7%)	196 (20.0%)
Hypertension awareness, n (%)	564 (70.8%)	570 (58.2%)	580 (72.8%)	576 (58.8%)
BP medication use, n (%)	480 (60.2%)	464 (47.4%)	487 (61.1%)	462 (47.2%)
BP medication class, n (%)				
None	291 (36.5%)	464 (47.4%)	282 (35.4%)	469 (47.9%)
One	158 (19.8%)	255 (26.0%)	152 (19.1%)	248 (25.3%)
Two	195 (24.5%)	160 (16.3%)	193 (24.2%)	153 (15.6%)
Three	99 (12.4%)	67 (6.8%)	113 (14.2%)	77 (7.9%)
Four	54 (6.8%)	33 (3.4%)	57 (7.2%)	32 (3.3%)
History of diabetes, n (%)	241 (30.2%)	152 (15.5%)	232 (29.1%)	139 (14.2%)
History of chronic kidney diseases, n (%)	242 (30.4%)	220 (22.5%)	235 (29.5%)	224 (22.9%)
History of chronic cardiovascular diseases, n (%)	124 (15.6%)	145 (14.8%)	128 (16.1%)	147 (15.0%)

TABLE 2 Parameter estimates from the DID analyses

Outcome	Parameter	Estimates (standard error)		
		Overall model	With medication use	Without medication use
Adjusted Systolic Blood Pressure	β_0	136.63 (0.20)	137.16 (0.29)	136.33 (0.27)
	β_1	0.02 (0.24)	0.48 (0.35)	0.20 (0.40)
	β_2	-1.58 (0.28)*	1.89 (0.35)*	-1.45 (0.41)*
	β_3 *(DID)*	-0.01 (0.34)	0.53 (0.47)	-0.44 (0.51)
Adjusted Diastolic Blood Pressure	β_0	77.07 (0.21)	75.31 (0.18)	81.11 (0.19)
	β_1	-0.38 (0.26)	0.65 (0.31)*	0.19 (0.33)
	β_2	1.02 (0.29)*	-1.10 (0.60)*	-1.80 (0.26)*
	β_3 *(DID)*	0.03 (0.36)	0.99 (0.47)*	0.05 (0.44)

Reference level of β_1: 2011-2012. Reference level of β_2: non-obese group.
*: p-value < 0.05.