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Trends in Hypertension Control and Management Disparities in U.S. Adults: A NHANES Analysis from 1999-2020

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Abstract: This study utilizes NHANES data from 1999-2020 to investigate trends in stage 2 hypertension management among U.S. adults. We examined the prevalence, awareness, and medication use associated with hypertension, incorporating demographic and comorbidity variables as covariates in logistic regression models. Our findings indicate a persistent treatment gap, with a concerning decline in awareness and medication use in recent years. The study highlights demographic factors, particularly race and BMI, as influential in hypertension control. Methodologically, we employed multiple imputation for missing data and adjusted weights for survey cycles. Our results underscore the need for targeted public health strategies to address identified disparities and improve hypertension management across the population. Limitations include potential self-reporting inaccuracies and changes in diagnostic criteria over time.

Key words: Hypertension Management, Stage 2 Hypertension, NHANES, Blood Pressure Awareness, Antihypertensive Medication Use, Health Disparities, Demographic Factors, Comorbid Conditions, Logistic Regression, Multiple Imputation

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1. Introduction

Hypertension, or high blood pressure, is a leading risk factor for cardiovascular diseases and a major public health challenge worldwide. In the United States, managing hypertension effectively has been a critical focus of public health initiatives. This study seeks to explore the trends and disparities in stage 2 hypertension control, awareness, and medication use among U.S. adults from 1999 to 2020, with a focus on the influence of demographic factors and comorbid conditions.

Recent study indicates a concerning trend in hypertension management. According to a study analyzing cross-sectional surveys from 1999 to 2018, there was an initial increase in controlled blood pressure among US adults with hypertension from 1999-2000 to 2007-2008. However, this trend did not continue significantly from 2007-2008 through 2013-2014 and then showed a decrease after 2013-2014 (Muntner P, et al., 2020). This decline signals potential challenges in hypertension management strategies and public health policies.

Our study aims to delve deeper into these trends, hypothesizing that significant disparities exist in stage 2 hypertension control, awareness, and medication use, influenced by demographic factors such as age, race, and BMI, as well as comorbid conditions like diabetes and cardiovascular disease. This hypothesis is grounded in the understanding that hypertension management is complex and multifaceted, often influenced by a range of demographic and health-related factors.

By analyzing data from the National Health and Nutrition Examination Survey (NHANES) spanning 1999 to 2020, this study will provide insights into the effectiveness of hypertension management strategies in the U.S. and identify areas needing improvement. The findings will be crucial for guiding future public health policies and clinical practices aimed at improving hypertension control and reducing the burden of cardiovascular diseases in the U.S. population.

2. Methods

2.1 *Data sources*

The dataset for our study is sourced from the National Health and Nutrition Examination Survey (NHANES), spanning the years 1999 to 2020, and it specifically includes data pertaining to 10,923 individuals who have been diagnosed with hypertension. In our analysis, we define stage 2 hypertension using the threshold of systolic blood pressure at or above 140 and diastolic blood pressure at or above 90. We initially focus on the relationship between various factors and the prevalence of stage 2 hypertension within the blood pressure and hypertension subpopulations. Subsequently, we investigate hypertension awareness within the subgroup of individuals with uncontrolled stage 2 hypertension. Finally, we examine the use of medication within the subset of individuals who are aware of their hypertension status. Demographic variables such as age, race, and gender, along with comorbidity indicators like BMI, diabetes, chronic kidney disease, and cardiovascular history, serve as covariates in our study.

2.2 *Weighting and multiple-year adjustment*

The NHANES dataset utilizes two-year cycle weights, with a special adjustment for the 2017-2020 cycle. Weights are adjusted for selection probability, non-response, and post-stratification to match U.S. population figures. When analyzing data across cycles, the weights are recalibrated to maintain accuracy over the multi-year span (CDC). For the 1999-2002 cycles, a unique four-year weight is applied, while the extended 2017-2020 cycle receives a proportional adjustment (CDC). To obtain a valid statistical inference, we conducted a domain analysis for the hypertension subpopulation by using the subset function in the survey package in R.

2.3 *Multiple imputation to handle missing covariates*

To handle missing data in our NHANES dataset, we utilize Multiple Imputation (MI) to

generate multiple datasets by imputing missing values. This method retains the advantages of single imputation, such as the application of complete data analysis methods, while also accurately reflecting uncertainty and accounting for imputation error. We implemented it using the MICE (Multivariate Imputation by Chained Equations) package in R, which allows for flexible and efficient imputation of missing values. Here we generated 5 imputations.

2.4 *Data Analysis*

Descriptive statistical analyses are performed for all covariates within each specific subgroup. Given the binary outcomes, we chose logistic regression as our statistical model. Suppose there are n covariates Xi, i = 1, ... n, the logistic model (Dobson, 2008) can be expressed as:

$$\log(\frac{\pi}{1-\pi}) = X\beta = \beta_0 + \beta_1 X_1 + ... + \beta_n X_n$$

- π is the risk
- $\frac{\pi}{1-\pi}$ is the odds
- β_0 is the log odds for $X_i's = 0$
- β_i is the log odds ratio per unit change of X_i, holding all other covariates fixed

In our logistic regression analysis for survey data, we have integrated multiple imputation and complex survey design in NHANES. Each imputed dataset was then individually analyzed with logistic regression models, incorporating essential survey design elements like stratification and weights via the `survey` package. Lastly, these results are aggregated to derive final estimates using Rubin's multiple imputation combining rule (Rubin, 2018).

3. Results

3.1 *Descriptive Statistics*

Table 1 outlines characteristics and comorbidities associated with uncontrolled stage 2 hypertension among U.S. adults between 1999 and 2020. It reveals that while 19% have stage 2 hypertension, only 63% of these are aware, and even fewer, 77% of the aware group, are

on medication. This indicates a treatment gap, as less than half (49%) of those with stage 2 hypertension are being medicated. The median age for each category slightly increases from the hypertension group to the medication use group. Racial and ethnic distributions are relatively consistent across groups. Gender distribution indicates that females are more likely to be aware and use medication. BMI categories show that a higher BMI is associated with higher rates of hypertension. There is a notable percentage of participants with diabetes and chronic kidney disease, and a history of cardiovascular disease (CVD) is present in 18% to 26% of participants across groups.

3.2 *Regression Analysis Results*

Figure 1 displays trends in stage 2 hypertension control, awareness, and medication use from 2001 to 2020 compared to 1999-2000. The prevalence of uncontrolled hypertension has generally decreased since 1999-2000, with particularly low odds ratios observed in 2009-2010 and 2013-2014. Post-2013, there's a slight uptick in prevalence. Awareness has mostly increased, peaking in 2013-2014, but shows a decrease in 2017-2020, reaching levels similar to 1999-2000 at a 5% significance level. Medication use among those aware of their hypertension has fluctuated, with a significant peak in 2009-2010 and a subsequent decline. The levels of awareness and medication use for hypertension among U.S. adults have not shown significant improvement from the baseline set in 1999-2000. This stagnation signals a challenge in the efforts to control hypertension nationwide.

In **Table 2**, age and non-Hispanic Black race are associated with higher odds of hypertension, related awareness, and medication use in all models. Females are less likely to have uncontrolled hypertension and more likely to be aware and use medication compared to males. Increased BMI is a significant predictor of uncontrolled hypertension and awareness, with the greatest odds in individuals with a BMI over 30. Comorbidities like chronic kidney disease and a history of CVD are strongly associated with all three outcomes, indicating

a high burden of disease but also a high awareness and treatment rate among those with hypertension. Diabetes shows a significant association with awareness and medication use but not directly with stage 2 hypertension.

4. Conclusion

Our study analyze NHANES data (1999-2020) on U.S. adults with hypertension to examine the effectiveness of U.S. hypertension management in relation to demographic factors such as age, race, and BMI, as well as comorbid conditions like diabetes and cardiovascular disease from 1999-2020. Descriptive statistics and logistic regression were used to explore the relationships between hypertension prevalence, awareness, and medication use. The analysis was weighted for survey design and adjusted for multiple years. Multiple Imputation handled missing data, and demographic and comorbidity variables served as covariates. The analysis shows a gap in hypertension treatment, with a significant proportion of those with stage 2 hypertension either unaware or untreated. While awareness and medication use have increased overall since 1999, recent years show a concerning decline. Demographic analysis indicates age, race, and BMI as key factors in hypertension prevalence, awareness, and treatment, with comorbid conditions like diabetes and chronic kidney disease playing a significant role. Efforts to improve hypertension control must address these gaps and demographic influences.

The limitations of the study may include factors such as potential inaccuracies in self-reported data, the exclusion of certain populations in NHANES, possible changes in diagnostic criteria over time, and the use of medication that may not fully capture adherence or effectiveness. The retrospective nature of the data might also limit causal inferences. Additionally, the study might not account for all confounding variables that could influence hypertension management outcomes.

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Appendix Tables and Figures

Table 1: Participant Characteristics and Comorbidity Status of Uncontrolled Stage 2 Hypertension, Awareness, and Medication Use in US Adults, 1999-2020

Characteristic	**Stage 2 Hypertension N = 56,017** [1]	**Awareness N = 10,923**[2]	**Medication Use N = 6,891**[3]
Age	64 (52, 74)	65 (54, 75)	68 (59, 77)
Race/Ethnicity			
Non-Hispanic White	4,627 (42%)	2,841 (41%)	2,223 (42%)
Hispanic/Asian/Other	3,221 (29%)	1,909 (28%)	1,406 (27%)
Non-Hispanic Black	3,075 (28%)	2,141 (31%)	1,664 (31%)
Gender			
Male	5,510 (50%)	3,249 (47%)	2,338 (44%)
Female	5,413 (50%)	3,642 (53%)	2,955 (56%)
BMI			
<25	2,584 (24%)	1,423 (21%)	1,067 (21%)
25 to 30	3,604 (34%)	2,202 (33%)	1,700 (33%)
30+	4,408 (42%)	3,057 (46%)	2,359 (46%)
Unknown	327	209	167
Diabetes	2,410 (22%)	1,867 (27%)	1,661 (31%)
Chronic Kidney Disease	3,653 (33%)	2,702 (39%)	2,272 (43%)
History of CVD	1,920 (18%)	1,588 (23%)	1,395 (26%)

[1] Stage 2 Hypertension Prevalence: Among the 56,017 participants, 10,923 (19%) have stage 2 hypertension.

[2] Awareness Among Those with Stage 2 Hypertension: 6,891 (63%) of them are aware of their condition.

[3] Medication Usage Among Aware Participants: 5,293 (77%) of them are taking medication .

Table 2: Odds Ratios and 95% CI of Uncontrolled Stage 2 Hypertension, Awareness, and Medication Use in US Adults, 1999-2020

	Model 1: Stage 2 Hypertension		**Model 2: Awareness**		**Model 3: Medication Use**	
	N = 56,017		**N = 10,923**		**N = 6,891**	
Characteristic	**OR (95% CI)**	**P-value**	**OR (95% CI)**	**P-value**	**OR (95% CI)**	**P-value**
Age	1.06 (1.06, 1.06)	< 0.0001	1.02 (1.01, 1.02)	< 0.0001	1.06 (1.05, 1.07)	< 0.0001
Race/Ethnicity						
Non-Hispanic White	Ref	Ref	Ref	Ref		
Hispanic/Asian/Other	1.23 (1.14, 1.33)	< 0.0001	0.98 (0.86, 1.13)	< 0.0001	0.93 (0.76, 1.15)	0.0517
Non-Hispanic Black	2.09 (1.94, 2.24)	< 0.0001	1.49 (1.32, 1.70)	< 0.0001	1.38 (1.15, 1.66)	< 0.0001
Gender						
Male	Ref	Ref	Ref	Ref		
Female	0.83 (0.78, 0.89)	< 0.0001	1.24 (1.10, 1.40)	< 0.0001	1.39 (1.17, 1.65)	< 0.0001
BMI						
< 25	Ref	Ref	Ref	Ref		
25 to 30	1.16 (1.06, 1.26)	< 0.0001	1.41 (1.21, 1.64)	< 0.0001	1.26 (1.00, 1.65)	0.0050
30+	1.57 (1.44, 1.70)	< 0.0001	2.26 (1.93, 2.64)	< 0.0001	1.62 (1.28, 2.03)	< 0.0001
Diabetes	1.02 (0.93, 1.12)	0.0652	1.68 (1.42, 1.98)	< 0.0001	2.10 (1.63, 2.70)	< 0.0001
Chronic Kidney Disease	1.72 (1.59, 1.87)	< 0.0001	1.56 (1.36, 1.77)	< 0.0001	1.10 (0.91, 1.34)	0.0335
History of CVD	0.84 (0.76, 0.92)	< 0.0001	2.79 (2.33, 3.36)	< 0.0001	1.61 (1.26, 2.05)	< 0.0001

SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure.

Stage 1 Hypertension: SBP $\geqslant$ 130 mm Hg or DBP $\geqslant$ 80 mm Hg.

Stage 2 Hypertension: SBP $\geqslant$ 140 mm Hg or DBP $\geqslant$ 90 mm Hg.

[Figure 1 about here.]

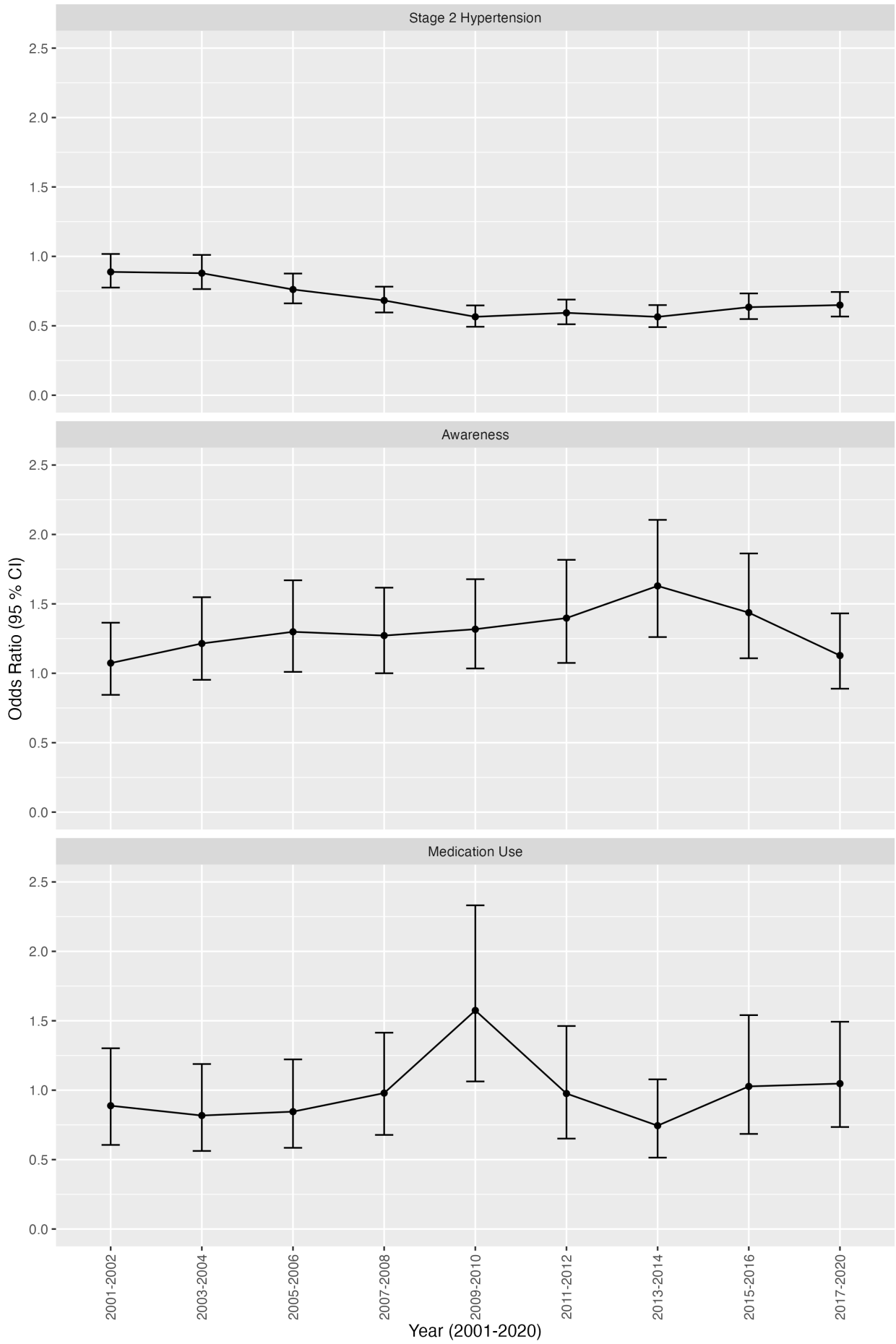

Figure 1. Odds Ratios and 95% CI of Uncontrolled Stage 2 Hypertension, Awareness, and Self-reported Antihypertensive Medication Use in US Adults by Year