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Social, Racial, and Economic Disparities Affecting Outcomes of Hypertensive Adolescents

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ABSTRACT

Essential hypertension is one of the most common conditions managed in pediatric cardiology and can result in lasting deleterious effects on the cardiovascular system. Pediatric hypertension is so prevalent in the United States that it is often referred to as a public health challenge.

Social determinants of health (SDH) are the cultural, economic, educational, healthcare accessibility, and political influences in the environment in which an individual is born or lives, all of which can affect that individual's overall health. This study investigated the impact of social determinants such as rurality, food insecurity, transportation challenges, minority status, income, and race on cardiovascular outcomes in adolescent patients with essential hypertension.

This study utilizes multiple validated tools including those from the United States Census and the United States Department of Agriculture (USDA). Using these tools, the patients were scored on their social vulnerability based on home address. These scores were then compared with their echocardiographic data, focusing on measures of end-organ damage known to occur in the setting of hypertension, including but not limited to indexed left ventricular (LV) mass. LV mass is an independent risk factor for future adverse cardiovascular events.

In this study, more social vulnerability and low income were associated with a greater indexed LV mass ($r = 0.18$, $p = 0.008$). African American race was associated with a higher left atrial (LA) volume ($p = 0.03$). These findings substantiate that adolescents with essential hypertension are not only impacted by biological factors but also a combination of intersecting social constructs. The results of this study provide both a deeper understanding of the challenges these patients face and the opportunity to develop real-life interventions that can optimize clinical outcomes.

1 | Introduction

Social determinants of health (SDH) are the cultural, economic, educational, and healthcare accessibility-related conditions in which an individual is born or lives, all of which can affect that individual's overall health [1, 2]. Although the United States ranks among the richest countries in the world per capita, its citizens experience significant health disparities that are rooted in the political and economic value systems of their environment. The Centers for Disease Control reported that in the United States, place of birth is more strongly associated with life expectancy than race or genetics [3]. Studies show that investing in determinants such as housing, income support, nutrition support, care coordination, and community outreach can have a positive impact on health outcomes, health inequity, and even reduce healthcare spending [4].

The prevalence of essential hypertension has been increasing not only in adults but also among the pediatric population in the United States. Previous studies in adults note a correlation between elevated blood pressures and urbanization [5], income, and housing as well as behavioral factors such as poor diet, physical inactivity, cigarette usage, and alcohol consumption [6]. There is a paucity of studies looking at social vulnerability's impact on the pediatric population. Previous studies have evaluated the association between social vulnerability and adolescents' weight [7], the incidence of substance abuse, and mental health [8], as well as the incidence of adolescent pregnancy [9]. One study demonstrated that a higher socioeconomic status and better diet (less salt, fat, and processed foods) can have a positive impact on blood pressure [10] and a Polish study found that pediatric patients were more likely to develop prehypertension with lower maternal educational attainment, lower paternal employment status, and lower familial income [11]. To date, no study has investigated the socioeconomic impact on hypertensive end-organ damage in general nor on the development of left ventricular hypertrophy (LVH) specifically. This is particularly important because LVH is an independent risk factor for future adverse cardiovascular events. The aim of this study was to determine if socioeconomic factors are associated with cardiac end-organ dysfunction and LVH in pediatric adolescent patients with hypertension.

2 | Methods

This study was approved by the Louisiana State University Health Sciences Center—New Orleans's (LSUHSC-NO) Human Research Protection Program and Institutional Review Board (IRB) and Children's Hospital New Orleans (CHNO) Administrative Review Committee and was performed in accordance with their policies. Informed consent and Health Insurance Portability and Accountability Act (HIPPA) authorization were waived by the IRB.

2.1 | Patients

This project consisted of a retrospective chart review. Inclusion criteria consisted of adolescent patients (ages 11–19 years) with a diagnosis of essential hypertension who were seen in the pediatric cardiology clinic from January 1, 2015, to December 31, 2021. Patients were excluded if they did not have an echocardiogram or if they had hypertension due to secondary causes such as pulmonary hypertension, renal artery anomalies, lupus nephritis, other forms of kidney disease, history of transplant, congenital heart disease, cardiomyopathies, hyperthyroidism, and pheochromocytoma. Patients who were acutely ill at the time of their echocardiogram were excluded. These patients had acute processes including but limited to postoperative pain, sickle cell pain crisis, cardiac arrest, trauma, acute respiratory distress syndrome, myocarditis, COVID-19, and pulmonary embolism.

2.2 | Demographics and Clinical Data

For each patient, the following demographics were obtained: age, sex, race, ethnicity, current home address, distance from the hospital, and family history of a first-degree relative with diabetes or hypertension. The following clinical data were obtained: weight, height, body mass index (BMI), systolic and diastolic blood pressures obtained in the upper extremity, weight-for-age and stature-for-age percentiles based on CDC data, and current medications.

2.3 | Indices of Health Disparity

This study utilized multiple validated tools to evaluate patients' index of disadvantage based on their home address: the United States Department of Agriculture (USDA) Food Access Research Atlas [12], The social vulnerability index (SVI) [13], a database that uses United States Census data to determine the social vulnerability of every census tract across the United States, and the Index of Relative Rurality (IRR) [14].

To determine the scores for SDH, the patient's address was entered into the three tools described below:

1. The USDA Food Access Research Atlas <https://www.ers.usda.gov/data-products/food-access-research-atlas/>. Using the patients' street address, it was determined if the patient:
   a. Resides in an area with low income (defined as areas with a poverty rate of 20% or higher, or areas with a median family income less than 80% of the median family income for the state).
   b. Resides in an area with low income AND with poor access to nutritious food (defined as living more than 1 mile (for urban zip codes) or more than 10 miles (for rural zip codes) from the nearest supermarket).
   c. Has low vehicle access (defined as living in an area in which more than 10 households have no access to a vehicle and are more than ½ mile from the nearest supermarket, or a significant number of residents are > 20 miles from nearest supermarket).
   d. Lives in an area designated "high group quarters" (defined as an area wherein 67% or more of the population lives in group quarters).
2. The SVI, which allows us to give each patient a numerical score (0–1, 0 meaning less vulnerable, and 1 meaning more socially vulnerable) based on their street address, as well as a separate score for the following four themes:
   a. Socioeconomic status (below poverty, unemployed, income, no high school diploma).
   b. Household composition (aged 65 or older, aged 17 or younger, civilian with a disability, single-parent households).
   c. Race/ethnicity/language (minority, aged 5 or older who speaks English "less than well").
   d. Housing/transportation (multi-unit structures, mobile homes, crowding, no vehicle, group quarters).
3. The IRR, this score ranges between 0 (low level of rurality, i.e., urban) and 1 (most rural) based on the patient's parish of

residence. The index is based on four dimensions: population size, density, and percentage of urban residents.

2.4 | Cardiac Assessment

Two-dimensional, M-mode, and Doppler echocardiography were performed with the patient in a quiet, resting state. Measures of cardiac structure and function were obtained per the guidelines of the American Society of Echocardiography [15]. Left ventricular (LV) dimension, interventricular septal thickness, and LV posterior wall thickness were measured by 2-dimensionally directed M-mode echocardiography at end-diastole and end-systole.

2.5 | LV Mass

The LV mass was calculated from the LV end-diastolic dimension and posterior wall and septal thicknesses using the formula of Devereaux et al., the LV mass was indexed to height using an allometric power of 2.7 [16, 17].

2.6 | LV Systolic Function

LV systolic function was assessed by LV shortening fraction. This was calculated by the following equation:

$$\text{Fractionalshortening} = \text{LVIDd} - \text{LVIDs}/\text{LVIDd} \times 100\%$$

where, LVIDd = LV internal diameter at end-diastole and LVIDs = LV internal diameter at end-systole.

2.7 | LV Diastolic Function

LV diastolic function was assessed from mitral valve Doppler inflow velocities (E and A wave) as well as myocardial Doppler annular velocities (E' and A'). The E and A waves were derived by measuring the flow through the mitral valve using pulsed wave Doppler echocardiography ensuring that the sample volume was aligned parallel to the flow as demonstrated by color Doppler echocardiography. The E/A wave ratio was calculated. The E' and A' waves were derived by tissue Doppler echocardiographic assessment of both the lateral (E' and A' lateral) and septal (E' and A' septal) annular velocities. These were obtained with the sample volume-oriented parallel to mitral annular motion. The E'/A' lateral and E'/A' septal ratios were calculated. In addition, the E/E' lateral and the E/E' septal ratios were calculated and served as a non-invasive estimate of LV end-diastolic pressure [18].

2.8 | Left Atrial (LA) Volume

LA volume was measured from the apical view at end-systole just before the mitral valve opened. It was measured in a 4-chambered view as well as a 2-chambered view, in order to obtain orthogonal measurements [12].

2.9 | Inter- and Intraobserver Variability

Echocardiographic metrics were collected and measured by a single investigator (KS) on three consecutive cardiac cycles in order to ensure measurement consistency. To further substantiate the accuracy of these measurements, interobserver variability, or the difference in measurements between two researchers, and intraobserver variability, or the difference in repeated measurements by the same researcher were obtained on a small randomized group of patients. The interobserver correlations were high (average correlation of 0.88). The intraobserver correlations were also high (average correlation of 0.86).

2.10 | Statistical Analysis

Descriptive statistics were used to describe the characteristics of the patients in the study cohort. Categorical variables were summarized as frequencies and percentages, and continuous variables were summarized using means and standard deviations or medians and ranges, as appropriate. Comparisons were made between groups utilizing ANOVA analysis. A linear regression model was used to evaluate the relationship between SVI, as well as the four themes of SVI, and LV mass, while adjusting for both clinical and social determinant factors. The clinical factors adjusted for include whether the patients have a concurrent diagnosis of Type II Diabetes and whether they are being treated with medication for their hypertension or diabetes. The statistical significance level was set at 0.05. The Pearson correlation coefficient was utilized in this study. No multiple adjustments were performed. All analyses were performed using SAS (Windows version 9.4; SAS Institute, Cary, NC) and/or the statistical program R version 4.0.2.

3 | Results

3.1 | Patients

A total of 414 patients were identified between the ages of 11–19 with a diagnosis of essential hypertension and who had undergone an echocardiogram. After applying the exclusion criteria as detailed in our Methods section, a final number of 226 patients were included in this study. Demographic data are summarized in Table 1. The majority of the patients were African American (62.4%), and 29.2% of the patients were Caucasian. The category delineated "Other," which made up 5.3% of the patients included in this study, included individuals from the following designations: Asian, Native American, Hispanic, and Middle-Eastern. There was a preponderance of African American patients in both the "low access" and "low income" categories; however, the majority of African American patients did not belong to the "low vehicle access" category. The majority of the patients in this study had Medicaid insurance (60.6%). African American patients comprised the majority of the Medicaid patients and the patients with a family history of hypertension.

The majority (68.6%) of the patients were not on blood pressure medication. The population had a wide range of BMI

TABLE 1 | Demographic data.

	Mean (SD)		Range
Age (years)	14 (2)		7–18
Weight (kg)	93 (33)		37–201
Height (m)	1.68 (0.12)		1.17–1.95
BMI (kg/m^2)	33.1 (11.4)		17–75
Race	**Number**		**Percentage**
African American	141		62.4%
Caucasian	66		29.2%
Other	12		5.3%
Declined to respond	7		3.1%
	Number	**Percentage**	**African American**
Insurance			
Medicaid	137	60.6%	92 (65.2%)
Private	51	22.5%	24 (17%)
Uninsured	38	17%	25 (17.7%)
On blood pressure medication			
Yes	70	30.9%	41 (29%)
No	155	68.6%	100 (70.9%)
Unknown	1	0.44%	0
Family history of hypertension			
Yes	134	59.3%	92 (65.2%)
No	88	39%	47 (33.3%)
Adopted	2	0.88%	2 (1.4%)
Family history of diabetes			
Yes	34	15%	23 (16.3%)
No	190	84%	116 (82.2%)
Adopted	2	0.88%	2 (1.4%)

Abbreviations: BMI, body mass index; SD, standard deviation.

(17–75 kg/m^2) with a mean of 33.1 ± 11.4. The majority of patients had a family history of hypertension (59.3%) but did not have a family history of diabetes mellitus (16%). The average age of the patient was 14 ± 2.1 years.

3.2 | Socioeconomic Indices

Patients lived an average distance of 52.1 ± 61.1 miles (median of 31.9 miles, range 1.7–318) from the Children's Hospital of New Orleans. The socioeconomic data gathered from the USDA is summarized in Table 2. The majority of patients lived in an area of "low access," indicating poor access to nutritious foods. The mean, standard deviation, and range of the patients' social vulnerability scores are summarized in Table 2. The data exhibits the wide range of values of social vulnerability captured in this study. The mean values tended towards the more socially vulnerable.

3.3 | Echocardiographic Indices (Table 3)

3.3.1 | LV Structure

The mean indexed LV mass was 33.14 g/m$^{2.7}$ ± 9.8 (range 17.5–48.9) The mean relative wall thickness was 0.4 +/ 0.1.

3.3.2 | LV Systolic Function

The mean shortening fraction was 0.28 ± 1.2 which is within the normal range.

3.3.3 | LV Diastolic Function

The mean E/A ratio was 1.99 ± 1.33. The mean E/E' lateral was 6.29 ± 2.28. The mean E/E' septal was 8.29 ± 3.78. The mean indexed LA volume was 22.43 mL/m^2 ± 7.05.

TABLE 2 | Indices of social vulnerability.

	Category	Number (percentage)	African American
Low income	No	98 (43%)	43 (30.5%)
	Yes	128 (57%)	98 (69.5%)
Low access	No	60 (27%)	32 (22.7%)
	Yes	166 (73%)	109 (77.3%)
Low vehicle access	No	133 (59%)	80 (57.4%)
	Yes	93 (41%)	61 (42.6%)
	Mean (SD)	**African American**	**Range (for all races and ethnicities)**
Overall social vulnerability index score	0.60 (0.26)	0.664 (0.24)	0.01–0.98
Socioeconomic status	0.65 (0.26)	0.70 (0.25)	0.01–0.10
Household composition/disability	0.58 (0.27)	0.61 (0.28)	0.03–0.99
Minority status/language	0.45 (0.26)	0.77 (0.20)	0–0.99
Household type/transportation	0.65 (0.27)	0.46 (0.25)	0.00–0.99
Index of rurality	0.38 (0.09)	0.37 (0.06)	0.27–0.64

Abbreviation: SD, standard deviation.

TABLE 3 | Cardiac assessment.

Cardiac measures	Mean (SD)	Range
Indexed LV mass ($g/m^{2.7}$)	33 (10)	17.5–48.9
Relative wall thickness	0.4 (0.1)	0.4–0.8
Shortening fraction	0.3 (1.2)	0.2–0.6
Indexed LA volume (mL/m^2)	22.5 (7.1)	8.4–46.1
E/A	2.0 (1.3)	0.76–20.0
E/E' lateral	6.3 (2.3)	3.5–29.4
E/E' septal	8.3 (3.8)	0.5–55.8
E'/A' lateral	2.8 (1.0)	0.4–6.1
E'/A' septal	2.2 (2.7)	0.8–41.1

Abbreviations: LA, left atrial; LV, left ventricular; SD, standard deviation.

3.4 | Relationship of Cardiac Measures to Social Vulnerability (Table 4)

Univariate correlation analysis demonstrated that a higher LV Mass was associated with a higher overall social vulnerability score ($r = 0.18$, $p = 0.008$) and low-income designation ($p = 0.005$). African American race was associated with a higher LA volume ($p = 0.03$).

Similar to previous reports [19] we found a significant association between a greater indexed LV Mass and a higher BMI ($r = 0.46$, $p < 0.001$). A higher BMI, in turn, was also associated with higher scores in overall SVI ($r = 0.19$, $p = 0.004$), the SVI domain of Minority status ($r = 0.17$, $p = 0.004$), and Housing type/transportation ($r = 0.2$, $p = 0.002$) (Table 5).

Use of blood pressure medication was associated with a lower (which translates to less vulnerable) score for the social vulnerability domain of Household composition/disability ($R = -0.16$, $p = 0.013$).

Multivariate analysis was performed to build a model for the social determinants impacting LV mass (Table 6). BMI had a dominant influence on LV mass with this model. Therefore, multivariate analysis was performed to determine the social economic factors impacting BMI. The results demonstrate an association between a higher BMI and a higher score for the social vulnerability indices of minority status and Housing type/transportation.

4 | Discussion

The significant finding of this study is that some SDH are associated with LV mass. However, those socioeconomic factors also are associated with BMI. It is known that higher BMI is associated with higher LV mass. Therefore it is possible that the social determinants associated with LV mass may causally work through that of BMI. These findings are clinically significant because an elevated BMI is likely a consequence of a variety of complex factors intrinsic to being socially vulnerable. Given these associations, we speculate a causal mechanism between poorer SES and higher LV mass, either via a cumulative or intersecting effect between poorer SES resulting in higher BMI, resulting in higher LV mass.

TABLE 4 | Associations between SDH and cardiac measures (mean ± standard deviation).

		Mean indexed LV mass (g/m$^{2.7}$)	Mean indexed LA volume (mL/m^2)	Mean E/E' lateral	Mean E/E' septal	Mean BMI (kg/m^2)
Race	Caucasian	32 ± 11	20 ± 7	6 ± 3	9 ± 6	31 ± 9
	African American	34 ± 10	23 ± 7 **	6 ± 2	8 ± 2	34 ± 11
	Other	31 ± 6	23 ± 5	6 ± 1	9 ± 2	31 ± 9
Insurance	Medicaid	34 ± 9	23 ± 7	6 ± 2	8 ± 2	33 ± 11
	Private	32 ± 9	24 ± 8	6 ± 4	9 ± 7	33 ± 10
	Not insured	33 ± 12	21 ± 6	6 ± 2	8 ± 2	32 ± 10
USDA food Atlas	Low food access: Yes	33 ± 9	22 ± 7	6 ± 2	8 ± 4	33 ± 11
	Low food access: No	34 ± 11	22 ± 6	6 ± 2	8 ± 2	34 ± 11
	Low income: Yes	35 ± 10*	23 ± 7	6 ± 2	8 ± 2	34 ± 11
	Low income: No	31 ± 9	22 ± 8	6 ± 3	8 ± 5	32 ± 12
	Low vehicle access: Yes	34 ± 10	22 ± 6	6 ± 2	8 ± 2	34 ± 11
	Low vehicle access: No	32 ± 10	23 ± 8	6 ± 3	8 ± 5	33 ± 12

Abbreviations: BMI, body mass index; LA, left atrial; SDH, social determinants of health; USDA, United States Department of Agriculture.
*$p = 0.005$.
**$p = 0.03$.

TABLE 5 | Univariate correlation between SDH and cardiac measures.

	Indexed LV mass (g/m2.7)	Indexed left atrial volume (mL/m^2)	E/E' lateral	E/E' septal	BMI (kg/m^2)
Overall SVI	0.18 ($p = 0.008$)	0.11	0.05	0.1	0.19 ($p = 0.004$)
Socio-economic Status	0.13	0.09	−0.01	0.08	0.11 ($p = 0.09$)
Household composition	0.11	0.08	0.05	0.1	0.05
Household/transportation	0.11	0.11	0.07	0.05	0.2 ($p = 0.002$)
Race/ethnicity/language	0.12	0.08	−0.03	0.05	0.17 ($p = 0.004$)
Rurality	0.09	−0.02	0.07	0.12	0.08

Abbreviations: BMI, body mass index; SDH, social determinants of health; SVI, social vulnerability index.

TABLE 6 | Multiple variate correlation analysis of LV mass.

	Estimate	*p* value
Low income	1.67	0.27
Overall SVI score	7.34	0.11
Minority status	−1.87	0.56
Housing type	−4.74	0.19
Distance	0.01	0.22
BMI	0.47	< 0.001

Abbreviations: BMI, body mass index; SVI, social vulnerability index.

The SVI scoring system has been utilized in studies looking at morbidity and mortality in adult cardiac patients [18, 20]. There are fewer studies looking at SDH in the adolescent population. In the United States, a study found that both SDH and overall cardiovascular health were more favorable for non-Hispanic White adolescents as compared to non-Hispanic Black and Mexican American adolescents [21]. Another study based in the United States showed that high-level fast-food expenditures in the neighborhood were associated with higher blood pressure in adolescents [5]. However, this study goes one step further to investigate the link between a wide breadth of SDH and echocardiographic evidence of end-organ damage in hypertensive adolescents.

Essential hypertension is known to be a multifactorial disease. Adolescents belonging to low socioeconomic backgrounds or to minority groups face many barriers to healthy living, including food deserts, higher exposures to unhealthy foods, lack of access to recreational facilities, and lack of role models of healthy living [22, 23]. Even parental smoking [24] has been shown to adversely affect pediatric clinical outcomes. Food insecurity is associated with poorer quality diets, higher salt intake, and chronic stress, all of which could culminate in the development of hypertension. Living in a rural environment, for example, further from a large medical center, could translate into poor clinical follow-up, which in turn would likely translate into poor blood pressure control.

This study contributes to the previously published body of literature by suggesting exactly which of a large breadth of SDH most impact our adolescent patients with essential hypertension in Louisiana. By doing so, we aim to develop strategies to optimize these patients' outcomes.

4.1 | Race/Racism

This study inspired many points of discussion regarding race between the authors. Importantly, it should be acknowledged that belonging to a racial group must be considered within the context of the complex social construct that surrounds them. Namely, there are many race-specific social and cultural stressors that impact an individual's health that are difficult to define and measure.

4.2 | Strengths

The socioeconomic data presented in Table 2 demonstrate that our study was successful in capturing a wide distribution of hypertensive patients who live in areas that are considered very vulnerable as well as not vulnerable. This indicates that our study is truly reflective of the patient population we serve here in Louisiana.

4.3 | Limitations

One of the limitations of this study is that approximately 30.9% of the patients in this study were already on blood pressure medications at the time of their echocardiogram. Therefore, it is not known what their baseline cardiac size and function were as a hypertensive patient prior to the disease-altering medication.

Another limitation of this study is that only the most recent home addresses of the patients (home addresses in the chart are updated every clinic visit) were available. Therefore, the home address in their chart may not be the one at which the patients resided at the time of their initial presentation for echocardiogram and collection of clinical data. To evaluate how much this may have affected the data, we calculated the number of days between the day of the patient's latest clinic visit (and therefore the time their home address was most recently recorded) and the time of their echocardiogram. The mean difference was 473 days, with a standard deviation of 443 days. The maximum number of days between the latest clinic visit and the echocardiogram was 1540 days.

During the planning stages of this project, many indices of food access were evaluated for inclusion, including the modified retail food environment index. However, the most recent data for the modified retail food environment index was from 2011, and our USDA food access data was more recent (2019).

The demographics as delineated in Table 1 were not surprising, as the racial distribution is likely consistent with the racial distribution of the Children's Hospital of New Orleans in general. Most patients had a family history of hypertension, which may be attributed to similar lived exposures. The elevated mean BMI as detailed in Table 4 is also not surprising, as obesity can play a part in the development of hypertension. The results in Table 2 were interesting: although the majority of these hypertensive patients lived in an area with low access to nutritious foods, they did not live in an area with low vehicle access, which brings into question whether these patients truly did not purchase nutritious foods out of a lack of health fluency or if the healthy foods are cost-prohibitive. Being in a rural area may also mean a lack of access to public health facilities such as parks and gyms, but again, these patients did not seem for the most part to have poor access to transportation.

Finally, the data demonstrate associations only. Any conjecture regarding causality is speculative and would require a larger study and one with intervention associated with it.

5 | Clinical Implications

These findings substantiate that adolescents with essential hypertension are not only impacted by biological factors but also a combination of intersecting social determinants. The results of this study provide a deeper understanding of the challenges these patients face and the opportunity to develop real-life interventions that can optimize clinical outcomes via an intimate understanding of these patients' specific needs.

Conflicts of Interest

The authors declare no conflicts of interest.

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