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Chronic hypertension and risk of preterm delivery: National Longitudinal Study of Adolescents to Adult Health

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Abstract

Background: Chronic hypertension during pregnancy is associated with increased risk of adverse birth outcomes. In 2017, the American College of Cardiology and American Heart Association (ACC/AHA) lowered thresholds to classify hypertension in nonpregnant adults to SBP ≥ 130 mmHg and DBP ≥ 80 mmHg (i.e. stage I hypertension), resulting in an additional 4.5 million reproductive-aged women meeting criteria for hypertension. Little is known about effects of pre-pregnancy blood pressure (BP) in this range.

Objectives: To examine the effect of pre-pregnancy maternal BP on preterm delivery.

Methods: We analysed data from two waves of the National Longitudinal Study of Adolescent to Adult Health, including participants that had measured BP at Wave IV (2008-09) and a pregnancy that resulted in a singleton live birth between Waves IV and V (2016-18; n=2038). We categorised BP using ACC/AHA cutoffs: normal (SBP <120 mmHg and DBP < 80 mmHg), elevated (SBP 120-129 mmHg and DBP <80 mmHg), hypertension stage I (SBP 130-139 mmHg or DBP 80-89 mmHg), hypertension stage II (SBP ≥140 mmHg or DBP ≥90 mmHg). We estimated risk ratios (RR) with log-binomial regression adjusting for maternal demographics, anthropometrics, and medication use.

Results: The prevalence of preterm delivery was 12.6%. A standard deviation (SD) increment in SBP (SD = 12.2 mmHg) and DBP (SD = 9.3 mmHg) was associated with a 14% (95% confidence interval [CI] 2, 27) and 20% (95% CI 4, 37) higher risk of preterm delivery. Compared

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to normotensive controls, stage I (RR 1.33, 95% CI 1.01, 1.74) and stage II (RR 1.34, 95% CI 0.89, 2.00) hypertension were associated with increased risk.

Conclusions: We observed greater risk of preterm delivery among women with higher pre-pregnancy BP. Women with stage I hypertension during pregnancy may benefit from increased BP monitoring. Additional studies on the utility of fetal surveillance in this group are warranted.

Keywords

pre-pregnancy; chronic hypertension; blood pressure; preterm delivery

BACKGROUND

Approximately 10% of all US births are delivered preterm (i.e. <37 weeks' gestation).[1] Preterm newborns have increased risk of mortality due to inadequate *in utero* growth and immaturity of organs needed for survival. Also, they spend more time in the hospital resulting in greater financial and psychological stress for families.[2,3] Consequences of preterm delivery extend beyond the neonatal period as babies born preterm experience poorer neurodevelopmental, socioemotional, and behavioral outcomes across development.[2] The specific etiology of preterm delivery is unclear, but likely includes a complex interplay of obstetric, nutritional, environmental, and maternal factors.[2]

Pre-pregnancy maternal blood pressure plays a role in the development and vascular modeling of the placenta and is related to risk of preterm delivery. Chronic hypertension, defined as systolic blood pressure (SBP) ≥140 mmHg or diastolic blood pressure (DBP) ≥90 mmHg diagnosed before pregnancy or <20 weeks, is associated with two to three times increased risk of preterm delivery.[4–9] Placental pathology studies suggest this may be due to altered placentation, leading to reduced functional capacity of the placenta and impaired delivery of nutrients and oxygen to the fetus.[10,11] Thus, clinical recommendations suggest pregnant people with chronic hypertension receive increased surveillance of fetal growth and, potentially, antihypertensive medication.[12,13]

In 2017, the American College of Cardiology and American Heart Association (ACC/AHA) lowered thresholds to classify hypertension in nonpregnant adults to SBP ≥ 130 mmHg and DBP ≥80 mmHg (i.e. stage I hypertension).[14] Lowering these thresholds resulted in a doubling of the prevalence of hypertension among US reproductive-aged women with approximately 4.5 million additional women meeting criteria.[15–17] However, there is no clear clinical guidance on how to address stage I hypertension during pregnancy due to limited data.[6,12,17] The epidemiologic studies that have examined pre-pregnancy blood pressure in this range report mixed results, with risk estimates for the association between stage I hypertension and preterm delivery ranging from 1.05 to 3.8.[18–26] More research is needed to inform clinical decision making for this group.

In this paper, we leveraged data from a national cohort study of young adults to examine the effect of pre-pregnancy maternal BP on preterm delivery. First, we examined blood pressure according to the 2017 ACC/AHA categories and hypothesized that people with stage I and stage II hypertension prior to pregnancy would have greater risk of preterm delivery

compared to normotensive controls. Second, we examined linear associations between blood pressure and preterm delivery and hypothesized that greater SBP and greater DBP would be associated with increased risk of preterm delivery.

METHODS

Cohort selection

The National Longitudinal Study of Adolescent to Adult Health (Add Health) is an observational cohort study designed to examine health and risk behaviors across the transition from adolescence to young adulthood.[27] In 1994-1995, a sample of 80 high schools and 52 middle schools from across the US was selected using systematic random sampling. The core baseline sample included 20,745 adolescents from grades 7-12 who completed an in-school questionnaire. The study design is described in detail elsewhere.[27]

Including the baseline examination there have been five Add Health survey waves. Our analyses include data from Waves IV (2008-2009) and V (2016-2018) when participants were ages 24-32 and 32-42. We included non-pregnant women that participated in an in-home exam at Wave IV and reported a live singleton birth between Waves IV and V (n=2195). We excluded participants that reported conflicting or no information for gestational age (3.4%), were taking antihypertensive medication at Wave IV (3.1%), or had missing blood pressure data (3.0%), resulting in an analytic sample of 2038 women (Fig 1). A comparison between the women included in the analytic sample to all women enrolled in Add Health at the initial study baseline (Wave I) showed a slightly greater proportion of those in the analytic sample were white (66% vs 60%), were born in the US (95% vs 91%) and had parents with higher levels of education completed (34% vs 29% with college degree) (Supplemental table S1). A list of therapeutic classifications used to identify and exclude women with antihypertensive medication use at Wave IV is provided in supplemental table S2.

Exposure

At the Wave IV visit, field interviewers measured BP with a Microlife BP3MC1-PC-1B oscillometric BP monitor (MicroLife USA, Inc.; Dunedin, FL). Participants were in a seated position with both feet on the ground. Measurement of the right brachial blood pressure was repeated three times in 30-second intervals. SBP and DBP were computed as the average of the second and third readings.[28] We calculated mean arterial pressure (MAP, mmHg) as $\frac{SBP + (2 * DBP)}{3}$, which reflects the average arterial flow through one cardiac cycle. We created a four-level BP variable according to ACC/AHA guidelines: normal (SBP <120 mmHg and DBP <80 mmHg), elevated (SBP 120-129 mmHg and DBP <80 mmHg), hypertension stage I (SBP 130-139 mmHg or DBP 80-89 mmHg), or hypertension stage II (SBP ≥140 mmHg or DBP ≥90 mmHg).[14] Lastly, we also considered self-reported hypertension, which was measured with the questionnaire item, “has a doctor, nurse, or other health care provider ever told you that you have or had high BP or hypertension when you were not pregnant?”

Outcomes

At Wave V, information about live births were self-reported by participants. Preterm delivery was a binary variable determined from a questionnaire item, “A preterm delivery is one that occurs before 37 weeks in pregnancy (more than 3 weeks early). Was this baby born preterm?” For women reporting more than one live birth, only the first birth (most proximal to BP measurement) was considered because we were not able to obtain interpregnancy measurements of BP.

Covariates

Sociodemographic variables that may confound the relationship between pre-pregnancy BP and preterm delivery were selected based on literature review. These included Wave IV self-reported health insurance status (private, public, uninsured), highest education level completed (less than high school, high school to some college or vocational/technical training, bachelor’s degree or more), US region (Northeast, Midwest, South, West), gravidity, and self-reported race (White, Black, or African American, American Indian or Alaskan Native, Asian or Pacific Islander, other race). Responses for several items were collapsed into the categories indicated above due to sparse data. Using data collected at Wave V, we computed time between BP measurement and birth (in months) and maternal age at birth.

We also considered whether the associations under study were independent of pre-pregnancy maternal height and waist circumference, which were measured by trained team members at the Wave IV visit,[28] and maternal smoking status (self-reported at Wave IV: never, current or former). Waist circumference, rather than body mass index, was included as a covariate because the variables were strongly correlated (r=0.85), it was more strongly associated with SBP (r=0.36) and DBP (r=0.27), and is a better discriminator of cardiovascular risk.[29] We included several other variables to characterize the sample which were self-reported at Wave IV (language spoken in the home, US born, Hispanic or Latina/x ethnicity, family income (below $25k, $25k-$49k, $50k-$99k, $100k-$150k, or over $150k), engagement in health care (last routine health care visit ≤12 months ago, >12 months ago).

Statistical Analysis

We used multivariable log-binomial regression to estimate risk ratios (RR) for the associations between each BP variable and preterm delivery.[30] Models were adjusted for maternal age at delivery, months between maternal BP measurement and birth, self-reported race, US region, gravidity, smoking status, education, insurance status, pre-pregnancy waist circumference, and maternal height. We first estimated associations between ACC/AHA BP categories and preterm delivery. Then, we considered SBP, DBP and MAP as continuous variables and estimated risk associated per 10 mmHg unit increase in BP. We also present standardized estimates (interpreted as risk associated with one standard deviation increase in BP variable). In exploratory analyses, we examined the potential for non-linear relationships between BP and risk of preterm delivery using an unadjusted restricted cubic spline model with knots placed at the 25^{th}, 50^{th}, and 75^{th} percentiles.[31] We created plots of SBP and DBP (x-axis) and individual predicted risks of preterm delivery with 95% confidence intervals (y-axis) (Supplemental Figure S1. Lastly, we considered categorical variables for SBP (<120

mmHg [reference], 120-129 mmHg, 130-139 mmHg, ≥140mmHg) and DBP (<80 mmHg [reference], 80-89 mmHg, ≥90 mmHg).

We estimated associations between ACC/AHA BP categories and risk of preterm delivery stratified by maternal age (<30 years versus ≥30 years, cutoffs decided *a priori*) to improve comparability with other US cohorts[19,22,24,32,33] that have included samples of women younger than those included in our sample. We hypothesised that effect measure modification by maternal age may help explain heterogeneity in findings across studies. In addition to presenting stratified analyses, we estimated the relative excess risk due to interaction (RERI) using a linear relative risk model which included a product term between age category and each level of the chronic hypertension variable.[34]

Sensitivity analysis

First, we re-fit the multivariable regression models restricting the sample to births occurring within 3 years of the Wave IV blood pressure measurement to address potential misclassification of the exposure among participants with several years between blood pressure measurement and conception. Second, we re-fit the multivariable regression models including an additional 69 women who were taking antihypertensive medication at Wave IV. Third, we identified women who reported a pregnancy loss (self-reported miscarriage, ectopic (tubal) pregnancy, stillbirth, molar pregnancy or other pregnancy loss) between Wave IV and Wave V and were excluded from the analytic sample due to no live birth. We first assessed whether these women differed from those included and estimated inverse probability (IP) weights by modeling probability of inclusion into the analytic sample as a function of age, education, health care utilization, waist circumference, SBP, and DBP.[35] We repeated the multivariable regression models using the estimated IP weights as censoring weights to evaluate potential selection bias.

All data management and analyses were conducted using SAS version 9.4 (SAS Institute Inc, Cary, NC).

Missing Data

We used multiple imputation by chained equations to address missingness.[36] We used a fully conditional method to identify categorical variables, which uses a discriminant function to specify prior probabilities of group membership such that missing data are imputed as full integers.[36] Estimates for regression analyses are pooled regression results generated from 50 imputations. We included all independent variables from regression models in the multiple imputation process along with preterm delivery and a few auxiliary variables that may be associated with missingness or strongly correlated with values for a missing variable. The percentage of missingness for each variable ranged from 0% to 5% (Supplemental table S3).

Ethics Approval

We obtained Add Health data through a restricted contract with the University of North Carolina at Chapel Hill, Carolina Population Center. Secondary analyses of these data were deemed exempt from Institutional Review Board review by the UC San Diego Human Research Protections Program. Cross-tabulations resulting in fewer than five cases per cell

were omitted from the manuscript to avoid inadvertent disclosure of persons, families, or households.

RESULTS

The 2038 women included in the sample were, on average, 28.6 years at the Wave IV exam, and were living in all four US regions. Most were white or Black/African American, were US born citizens, and spoke English in the home. The median household income was between $50,000 and $100,000, almost all had at least a high school education, and the majority were privately insured (Table 1).

The prevalence of preterm delivery was 13%. The distributions of SBP, DBP, and MAP were normally distributed (supplemental figure S2). Of the 2038 participants, 8% met criteria for stage II hypertension at Wave IV, 26% met criteria for stage I hypertension, 15% had elevated blood pressure, and 52% were normotensive (Table 2).

Greater SBP, DBP, and MAP were associated with increased risk of preterm delivery with similar point estimates across variables (Table 2). A one standard deviation increase in SBP was associated with a 14% increased risk (95% CI 2, 27), a one standard deviation increase in DBP was associated with a 20% increased risk (95% CI 4, 37), and a one standard deviation increase in MAP was associated with a 10% (95% CI −7, 30) increased risk of preterm delivery (Table 2). For ACC/AHA BP category, stage I hypertension and stage II hypertension were associated with 1.33 (95% CI 1.01, 1.74) and 1.34 (95% CI 0.89, 2.00) times greater risk of preterm delivery compared to normal BP. Limited sample size in the stage II hypertension category resulted in wide confidence intervals. We found slightly larger risk ratios for stage I and stage II hypertension among participants aged 30 years or more compared to those with maternal age <30 years. However, there was no evidence of an additive interaction (Table 3).

Our study results did not meaningfully change after including women that were taking antihypertensive medications at Wave IV (Supplemental table S4) or after restricting to births that occurred within 3 years of blood pressure measurement (Supplemental table S5). We report small differences between women included in the analytic sample and those excluded from the analysis due to a pregnancy loss between Waves IV and V (Supplemental table S6). We found no meaningful differences in effect estimates after weighting the sample based on propensity to be included (Supplemental table S7).

COMMENT

Principal Findings

Using data from women enrolled in Add Health, we observed greater risk of preterm delivery among women with higher pre-pregnancy BP. The magnitude of associations between BP and preterm delivery were slightly stronger when comparing pre-pregnancy DBP (20% increase per SD) to MAP (10% increase per SD) and SBP (14% increase per SD). Additionally, we observed that women with pre-pregnancy stage I hypertension and stage II hypertension had similarly increased risk of preterm delivery compared to those with

normal blood pressure. These associations were independent of several sociodemographic factors and pre-pregnancy waist circumference and were robust to sensitivity analyses.

Strengths of the study

The study leveraged existing data from a well-characterized sample of women living in all four US regions. Importantly, the data included both participant self-report of hypertension diagnosis and measured BP prior to pregnancy. SBP and DBP were measured using standardized protocols by trained research staff in the participant's home.[28] This allowed for examination of SBP, DBP, and MAP as continuous variables, rather than limiting our analyses to the study of diagnosed hypertension or blood pressure categories. Lastly, the prospective design allowed for investigation of selection bias due to restriction on live birth because we were able to identify a subgroup of women that had pregnancies which did not end with a live birth during the study period.

Limitations of the data

Several limitations with the study design and variable measurement should be considered. Because blood pressure was measured at Wave IV (ages 24-32), we only analyzed data from births occurring after that assessment. As a result, the average maternal age at birth in our sample (32 years) is higher than the national average (27 years).[1] Also, we did not use Add Health sampling weights due to small cell sizes and unstable effect estimates. Thus, the descriptive statistics and prevalence estimates presented in this paper are not considered to be nationally representative estimates. The sample had a small proportion of Hispanic or Latina/x participants, was predominantly English speaking, US born, highly educated and with adequate prenatal care. These analyses must be replicated in samples with varying demographics to improve generalisability.

Additionally, the time between Wave IV blood pressure measurement and birth was about 3 years (interquartile range: 1.7 to 5.2 years). This could have resulted in misclassification of our independent variable if, for example, women moved from stage I to stage II hypertension by the time of conception. However, we conducted a sensitivity analysis restricting our sample to people with a blood pressure measurement within 3 years of birth and found little change in estimates. Additionally, prior literature found no change in SBP and only 1-2 unit increases in DBP in the five years prior to childbearing,[33] thus we expect the amount of misclassification in our sample to be low.

Although we ran sensitivity analyses assessing potential selection bias due to restriction on live births,[37,38] we were not able to assess potential selection bias due to women having difficulty getting pregnant because this information was not measured. If women with stage I or II hypertension had more difficulty getting pregnant, and thus were not included in our analytic sample, we would expect the presented effect estimates to be biased towards the null.

Finally, spontaneous preterm delivery versus clinician-initiated preterm deliveries have distinct aetiologies that we were not able to evaluate or disentangle due to no data on subtype. Research shows that increases in preterm delivery associated with chronic hypertension are ascribed to clinician-initiated, and not spontaneous, preterm deliveries.[39]

This appears to hold when examining associations between stage I hypertension and preterm delivery as well.[22] Further, preterm delivery was self-reported, so misclassification of the study outcome is possible, though maternal report of preterm delivery has good specificity and sensitivity.[40]

Interpretation

The findings for preterm delivery are mostly consistent with a growing body of literature examining the same associations. In the Young Finns study, standard deviation increases in SBP and DBP were associated with 28% and 19% increased risk of preterm delivery, respectively.[41] In a US cohort of women in Louisiana, Mississippi and Texas, the associations between pre-pregnancy BP and preterm delivery were similar in magnitude but imprecise.[32] A study from Shanghai, China analysed MAP continuously and reported a 11% increase per 10-mmHg unit change in MAP, which is like the estimate presented in our study.

Our findings relating SBP and DBP to preterm delivery were dissimilar to results from the CARDIA study,[33] a US cohort that reported no differences in trajectories of pre-pregnancy BP when comparing women with preterm versus term deliveries. The authors of that report suggested the null finding could relate to the relatively young age of participants included (mean age ~ 24 years), when “differences in metabolic and vascular function…might be too minimal to detect or have yet to appear.”[33] Notably, mean SBP and DBP in the CARDIA study were about 12 mmHg and 10 mmHg lower compared to our Add Health sample. In response to the possibility that differing maternal age may contribute to heterogeneity across studies, we conducted post hoc analyses stratified by maternal age at birth, finding slightly larger associations among women 30 years and older compared to those under 30 years at child’s birthdate. Age-specific associations should be investigated in future research.

Our finding that stage I hypertension is associated with increased risk of preterm delivery is consistent with what has been reported in other studies[18,20–23,25,26] In aggregate, these findings suggest that women falling in this category may benefit from increased BP monitoring. We note that current practice in pregnancy is to tolerate permissive mild hypertension to maintain adequate placental perfusion.[13] As such, questions about potential effects of BP lowering need to be tested in further studies. Clinical trials examining treatment of hypertension at lower thresholds are needed to answer questions surrounding potential benefits for maternal and perinatal outcomes.[15] Women who become normotensive by virtue of medication use may still incur identical risks of preeclampsia and indicated preterm delivery.[13,42–44] Additional studies assessing the relationship between stage I hypertension and utility of fetal surveillance could be warranted. Decisions to increase antenatal testing and ultrasound surveillance must consider potential harms of increased surveillance including costs and utilization of healthcare resources, in addition to potential benefits. Lastly, a change of thresholds used to classify hypertension will result in cases of gestational hypertension reclassified as chronic hypertension, affecting clinical decisions surrounding timing of delivery and induction.[45]

Conclusions

Data from this well-characterized sample of women, living in all four US census regions adds to the literature investigating the effects of pre-pregnancy BP on preterm delivery. Our data suggest that elevated pre-pregnancy BP below traditionally held clinical thresholds may confer higher risk for preterm delivery, and those women with stage I hypertension may benefit from increased BP monitoring throughout pregnancy. Optimizing women's health early in life is necessary for not only an individual's lifelong health, but for the health of the next generation.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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DATA AVAILABILITY

Persons interested in obtaining Data Files from Add Health should contact Add Health, The University of North Carolina at Chapel Hill, Carolina Population Center, Carolina Square, Suite 210, 123 W. Franklin Street, Chapel Hill, NC 27516 (addhealth_contracts@unc.edu).

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SYNOPSIS

Study question:

How does pre-pregnancy blood pressure (BP) relate to risk of preterm delivery?

What's already known:

Women with chronic hypertension, traditionally defined as systolic BP ≥140 mmHg or diastolic BP ≥90 mmHg diagnosed before pregnancy or before 20 weeks of gestation, have two to three times the risk of delivering preterm.

What this study adds:

We found associations between higher pre-pregnancy systolic and diastolic BP and greater risk of preterm delivery across the full spectrum of BP, suggesting increased risk at levels below traditional clinical cutoffs.

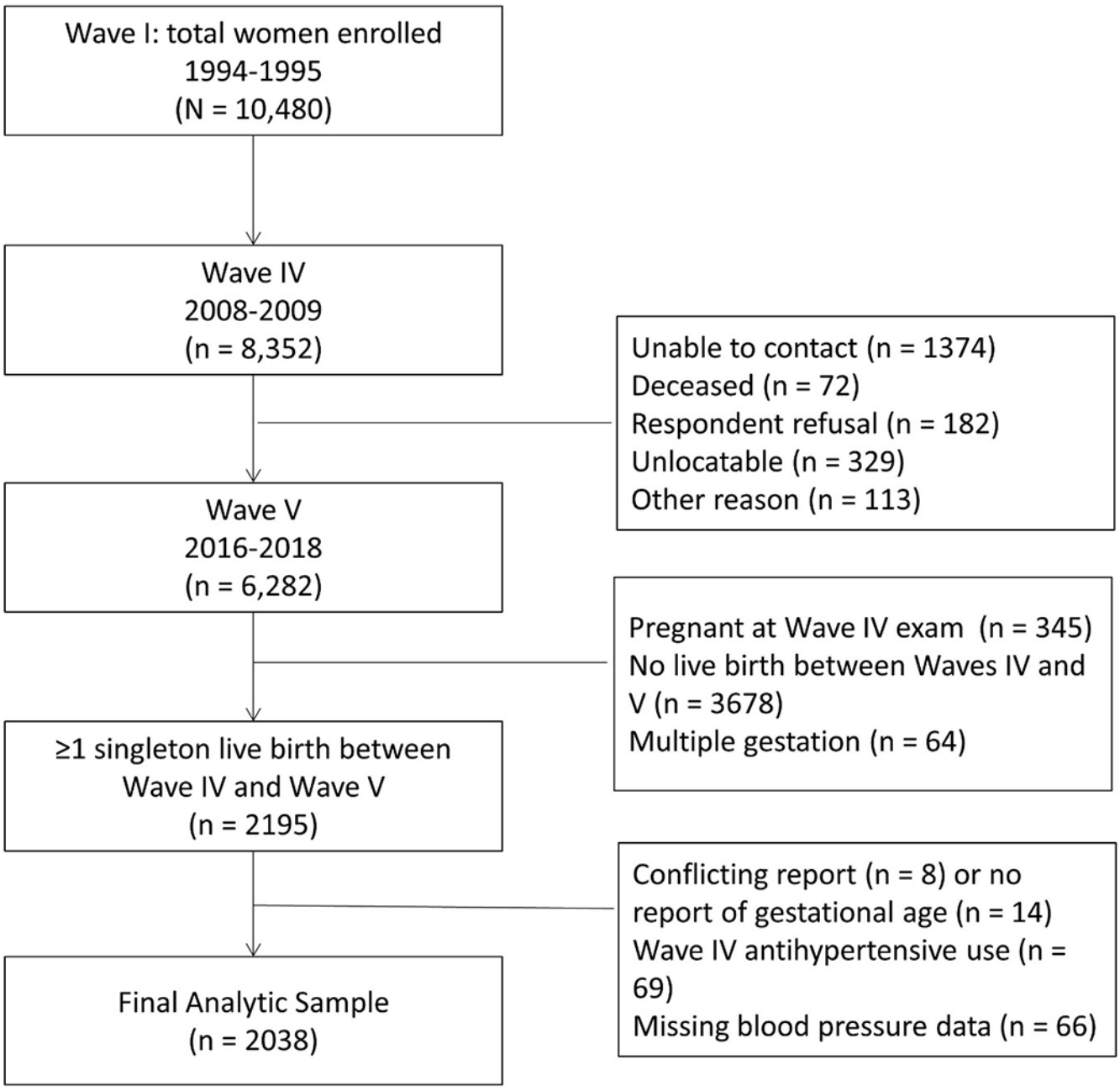

Figure 1.
Process of selecting the analytic sample from participants enrolled in the National Longitudinal Study of Adolescent to Adult Health (Add Health)

Table 1.

Summary statistics of demographic and socioeconomic characteristics at the Wave IV assessment described in the full sample and stratified by ACC/AHA blood pressure category, Add Health 2008-2009 (N = 2038)

	Full Sample	ACC / AHA Blood Pressure Category			
	N = 2038	Normal N = 1055	Elevated N = 295	Stage I HT N = 522	Stage II HT N = 166
Wave IV age, years	28.6 ± 1.7	28.5 ± 1.7	28.5 ± 1.7	28.6 ± 1.7	28.9 ± 1.6
Maternal age at birth, years	32.2 ± 2.7	32.1 ± 2.7	32.1 ± 2.6	32.3 ± 2.7	32.8 ± 3.0
Time from Wave IV to birth, years	3.1 (1.7, 5.2)	3.1 (1.7, 5.1)	3.4 (1.8, 5.2)	3.1 (1.8, 5.2)	3.5 (1.9, 5.7)
US Region					
Northeast	329 (16.1)	173 (16.4)	47 (15.9)	84 (16.1)	25 (15.1)
Midwest	479 (23.5)	231 (21.9)	79 (26.8)	127 (24.3)	42 (25.3)
South	723 (35.5)	370 (35.1)	90 (30.5)	195 (37.4)	68 (41.0)
West	507 (24.9)	281 (26.6)	79 (26.8)	116 (22.2)	31 (18.7)
Race					
White	1341 (65.8)	696 (66.0)	197 (66.8)	339 (64.9)	109 (65.7)
Black or African American	373 (18.3)	163 (15.5)	63 (21.4)	108 (20.7)	39 (23.5)
American Indian or Alaskan Nat.	44 (2.2)	24 (2.3)	5 (1.7)	12 (2.3)	**
Asian or Pacific Islander	130 (6.4)	75 (7.1)	16 (5.4)	33 (6.3)	6 (3.6)
Not listed above	147 (7.2)	94 (8.9)	14 (4.8)	30 (5.8)	9 (5.4)
Missing	3 (0.2)	**	**	**	**
Ethnicity					
Hispanic or Latina/x	293 (14.4)	178 (16.9)	35 (11.9)	63 (12.1)	17 (10.2)
Missing	4 (0.2)	**	**	**	**
Language spoken in home					
English	1867 (91.6)	949 (90.0)	276 (93.6)	486 (93.1)	156 (94.0)
Spanish	130 (6.4)	81 (7.7)	5.8 (17)	24 (4.5)	4.8 (8)
Other	41 (2.0)	25 (2.4)	**	12 (2.3)	**
US Born Citizen	1933 (94.9)	988 (93.7)	283 (95.9)	299 (95.6)	163 (98.2)
Household Annual income, $					
<25,000	255 (12.5)	118 (11.2)	28 (9.5)	79 (15.1)	30 (18.1)
25,000 – 50,000	464 (22.8)	254 (24.1)	71 (24.1)	99 (19.0)	40 (24.1)
50,000 – 100,000	840 (41.2)	436 (41.3)	118 (40.0)	222 (42.5)	64 (38.6)
100,000 – 150,000	255 (12.5)	140 (13.3)	35 (11.9)	63 (12.1)	17 (10.2)
>150,000	123 (6.0)	61 (5.8)	24 (8.1)	31 (5.9)	7 (4.2)
Missing	101 (5.0)	46 (4.4)	19 (6.4)	28 (5.4)	8 (4.8)
Highest education completed					
less than high school	67 (3.3)	35 (3.3)	8 (2.7)	16 (3.1)	8 (4.8)
high school to some college	975 (47.8)	476 (45.1)	166 (56.3)	254(48.7)	79 (47.6)
college or more	937 (46.0)	515 (48.8)	115 (39.0)	234 (44.8)	73 (44.0)
Missing	59 (2.9)	29 (2.8)	6 (2.0)	18 (3.5)	6 (3.6)
Insurance status					
Uninsured	280 (13.7)	142 (13.5)	44 (14.9)	67 (12.8)	27 (16.3)

	Full Sample	ACC / AHA Blood Pressure Category			
	N = 2038	Normal N = 1055	Elevated N = 295	Stage I HT N = 522	Stage II HT N = 166
Public Insurance	159 (7.8)	82 (7.8)	16 (5.4)	43 (8.2)	18 (10.8)
Private Insurance	1593 (78.2)	829 (78.6)	233 (79.0)	412 (78.9)	119 (71.7)
Missing	6 (0.3)	**	**	**	**
Last routine health care visit					
≤12 months ago	1494 (73.3)	774 (73.4)	226 (76.6)	383 (73.4)	111 (66.9)
Over 12 months ago	542 (26.6)	281 (26.6)	69 (23.4)	137 (26.3)	55 (33.1)
Missing	2 (0.1)	**	**	**	**
Never pregnant	1022 (50.2)	522 (49.5)	144 (48.8)	261 (50.0)	95 (57.2)
Never smoker	1193 (58.5)	627 (59.4)	171 (58.0)	313 (60.0)	82 (49.4)
Waist circumference, cm	88.3 ± 14.0	88.0 ± 13.6	98.3 ± 18.0	97.9 ± 17.3	100.5 ± 17.9
Maternal height, cm	163.5 ± 6.9	163.5 ± 6.9	165.1 ± 6.6	164.0 ± 6.6	164.3 ± 7.2

Alaskan Nat. = Alaskan native; ACC = American College of Cardiology; AHA = American Heart Association

For all categorical variables, we display column percentages as n (%). For years between Wave IV measurement and birth, we present median (Q1, Q3). For all other continuous variables, we present mean ± standard deviation.

** Data not shown because cell count < 5

Table 2.

Multivariable adjusted associations between categorical and continuous measures of pre-pregnancy maternal blood pressure with preterm delivery, Add Health (N=2038)

	Total Births Number (col %)	Preterm Delivery Number (row %)	Unadjusted Risk Ratio (95% CI)	Adjusted Risk Ratio (95% CI)
Chronic Hypertension				
Normal	1055 (51.8)	114 (10.8)	1.00 (Reference)	1.00 (Reference)
Elevated	295 (14.5)	37 (12.5)	1.16 (0.82, 1.64)	1.08 (0.76, 1.54)
Hypertension – Stage I	522 (25.6)	80 (15.3)	1.42 (1.09, 1.85)	1.33 (1.01, 1.74)
Hypertension – Stage II	166 (8.1)	26 (15.7)	1.45 (0.99, 2.15)	1.34 (0.89, 2.00)
Self-reported hypertension diagnosis				
No	1940 (95.2)	239 (12.3)	1.00 (Reference)	1.00 (Reference)
Yes	98 (4.8)	18 (18.4)	1.49 (0.97, 2.30)	1.32 (0.85, 2.03)
Systolic Blood Pressure				
Continuous, per 1 SD (12.2 mmHg)	---	---	1.19 (1.07, 1.31)	1.14 (1.02, 1.27)
Continuous, per 10 mmHg	---	---	1.15 (1.06, 1.26)	1.11 (1.02, 1.22)
Categorical				
< 120 mmHg	1154 (56.6)	129 (11.2)	1.00 (Reference)	1.00 (Reference)
120 - 129 mmHg	561 (27.5)	79 (14.1)	1.26 (0.97, 1.64)	1.19 (0.91, 1.56)
130 - 139 mmHg	231 (11.3)	35 (15.2)	1.36 (0.96, 1.92)	1.22 (0.85, 1.74)
≥ 140 mmHg	92 (4.5)	14 (15.2)	1.36 (0.82, 2.26)	1.28 (0.76, 2.15)
Diastolic Blood Pressure				
Continuous, per 1SD (9.3 mmHg)	---	---	1.25 (1.13, 1.39)	1.20 (1.04, 1.37)
Continuous, per 10 mmHg	---	---	1.27 (1.14, 1.42)	1.21 (1.05, 1.41)
Categorical				
< 80 mmHg	1446 (71.0)	166 (11.5)	1.00 (Reference)	1.00 (Reference)
80-89 mmHg	460 (22.6)	68 (14.8)	1.29 (0.99, 1.67)	1.26 (0.96, 1.64)
≥ 90 mmHg	132 (6.5)	23 (17.4)	1.52 (1.02, 2.26)	1.43 (0.96 2.13)
Mean Arterial Pressure				
Continuous, per 1SD (10 mmHg)	---	---	1.25 (1.12, 1.39)	1.10 (0.93, 1.30)

SD = standard deviation

Adjusted risk ratios were estimated from models that included months between exam and birth, maternal age, race, US region, gravidity, Wave IV smoking status, insurance status, pre-pregnancy waist circumference, and height

Table 3.

Risk ratios examining association between chronic hypertension and preterm delivery stratified by maternal age at birth, Add Health (N=2038)

	Full sample (n=2038)		Maternal age < 30 (n=462)		Maternal age ≥ 30 (n=1576)	
	Adj. Risk Ratio (95%CI)	**PTD/n**	**Adj. Risk Ratio (95% CI)**	**PTD/n**	**Adj. Risk Ratio (95%CI)**	**RERI (95% CI)**
Normal	1.00 (Reference)	29/256	1.00 (Reference)	85/799	1.00 (Reference)	
Elevated	1.08 (0.76, 1.54)	11/68	1.29 (0.61, 2.70)	26/227	1.01 (0.66, 1.55)	−0.40 (−1.62, 0.82)
Hypertension Stage I	1.33 (1.01, 1.74)	16/111	1.21 (0.63, 2.33)	64/411	1.38 (1.00, 1.89)	0.18 (−0.62, 0.98)
Hypertension Stage II	1.34 (0.89, 2.00)	4/27	1.24 (0.41, 3.73)	22/139	1.40 (0.90, 2.20)	0.17 (−1.35, 1.69)

PTD = Preterm Delivery; RERI = Relative Excess Risk Due to Interaction (reference group = maternal age <30); Adj. = Adjusted

Stratified adjusted risk ratios were estimated from models that included months between exam and birth, race, US region, gravidity, Wave IV smoking status, insurance status, pre-pregnancy waist circumference, and height