THE ASSOCIATION BETWEEN MISCARRIAGE AND ALLOSTATIC LOAD WITH TRUAMATIC PREGNANCY EXPERIENCE AS A MODERATOR:

A Longitudinal Study for Women with Histories in Foster Care and Juvenile Justice

by

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A THESIS

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Title: The Association Between Miscarriage and Allostatic Load with Traumatic Pregnancy Experience as a Moderator: A Longitudinal Study for Women with Histories in Foster Care and Juvenile Justice

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Miscarriage is a common physical experience defined by the loss of a fetus before 20 weeks gestation. Miscarriage is frequently described as a traumatic experience yet is often studied as an outcome of stress rather than a contributor to stress accumulation. This study seeks to understand the link between miscarriage on allostatic load in individuals who have been involved in the American juvenile justice system. Allostatic load (AL) is the wear and tear on the body due to stress accumulation over an individual's lifetime. Contributors to a high AL may include socioeconomic disadvantages, mental and physical health disorders, and traumatic pregnancy experiences. In the Turning Points for Women study, participants' AL was quantified by five biomarkers. The biomarkers were a set of biological indicators assessed to determine typical or atypical functioning. Cardiovascular biomarkers included systolic blood pressure (SBP), diastolic blood pressure (DBP), and peak expiratory flow (PEF). Metabolic biomarkers consisted of participants' body mass index (BMI) and waist-to-hip ratio (WHR). Analysis of these data will help us understand how individuals with histories in juvenile justice and foster

care are impacted by adverse events such as miscarriage. Preliminary analysis of SBP, DBP, PEF, BMI and WHR show no evidence that miscarriage is linked with AL. Traumatic pregnancy was not shown to moderate this relationship. However, blood spot analysis of proteins and lipids are yet to be included for a full picture of AL. Further research is required to understand linkages between AL and experiences that are common for women in juvenile justice**.**

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Biomarker Type	Biomarker	Normal range	Score
Cardiovascular	SBP	< 129 mm Hg	1
	DBP	< 80 mm Hg	1
	PEF	320-470 L/min	1
Metabolic	BMI	18.5–24.9	1
	WHR	< 0.8	1
	HDL cholesterol	< 100 mg/dL	1
	LDL cholesterol	> 40 mg/dL	1
	Triglycerides	< 150 mg/dL	1
	A1c	< 5.7%	1
Immune function	CRP	< 10 mg/L	1
	IL-6	< 43.5 pg/ml	1
	EBV	< 17.9 U/mL	1
		AL Score	12

List of Biomarkers and the Normal Ranges for Allostatic Load.

Table 1: Participants' allostatic load (AL) was quantified out of 12 biomarkers. Cardiovascular biomarkers included systolic blood pressure (SBP), diastolic blood pressure (DBP), and peak expiratory flow (PEF). Metabolic biomarkers consisted of participants' body mass index (BMI) and waist-to-hip ratio (WHR), as well as levels of HDL and LDL cholesterol, triglycerides, and A1c. Biomarkers of immune function included Epstein-Barr virus levels and indicators of inflammation measured by CRP and IL-6.

	Mean	Median
Age of first pregnancy	16.8±3.23	15.00
Total miscarriages	0.855±0.108	1.00
Allostatic load	3.06±1.12	3.00
Self-reported health	3.08±0.853	3.00

Comparison of Descriptives of All Participants

Table 2: Descriptives table of age of first pregnancy, total miscarriages experienced by a participant, allostatic load, and self-reported health. Allostatic load was reported 1 to 5, with 5 representing worse health. Self-reported health was reported out of a score of 5, with 5 representing worse perceived health. Mean values reported with ±standard deviation. Total sample size was 117.

	Miscarriage – Yes		Miscarriage – No	
	Mean	Median	Mean	Median
Age of first pregnancy	15.3±3.22	15.00	18.6±2.20	18.00
Total miscarriages	1.69±0.951	1.00	0±0	0
Allostatic load	2.97±1.16	3.00	3.17±1.09	3.00
Self-reported health	2.97±0.816	3.00	3.19±0.89	3.00

Comparison of Descriptives Between Participants With and Without Miscarriage History

Table 3: Descriptives table of age of first pregnancy, total miscarriages experienced by a participant, allostatic load, and self-reported health. Allostatic load was reported 1 to 5, with 5 representing worse health. Self-reported health was reported out of a score of 5, with 5 representing worse perceived health. Mean values reported with ±standard deviation, split between participants who reported ever having a miscarriage (Miscarriage – Yes) and participants who reported never having a miscarriage (Miscarriage – No). Total sample size was 117.

	Miscarriage – Yes		Miscarriage – No	
Variable	Mean (SD)	Number of participants in clinical range	Mean (SD)	Number of participants in clinical range
SBP	119 ±12.5	12	121 ±15.1	13
DBP	77.7 ±11.0	23	82.6 ±11.4	36
BMI	30.8 ±8.37	47	30.9 ±7.53	46
WHR	0.897±0.0955	55	0.930 ±0.0854	54

PEF 284 ±110 38 269 ±117 35

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Allostatic Load Predictor	Estimate	Standard Error	t-statistic	p-value
Whether participants experienced a miscarriage	-0.320	0.239	-01.34	0.184
Age of first pregnancy	0.00559	0.0389	-1.3382	0.184
Foster care treatment	-0.00483	0.2184	-0.0221	0.982
Age at baseline	0.0240	0.0944	0.254	0.800
Whether the participant smokes cigarettes	0.1535	0.216	0.489	0.626
Whether the participant consumes caffeine	-1.23	0.381	-3.23	0.002
Whether the participant has ever been diagnosed with alcohol or drug abuse	-0.187	0.226	-0.828	0.410
Whether the participant took any NSAIDS	0.683	0.214	1.20	0.002

Linear Regression Analysis of Miscarriage Experiences and Covariates as Predictors of Allostatic Load

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Allostatic Load Predictor (Covariates)	Estimate	Standard Error	t-statistic	p-value
Total number of miscarriages	-0.128	0.109	-1.18	0.240
Age of first pregnancy	0.0125	0.0366	0.343	0.733
Foster care treatment	-0.0166	0.218	-0.0762	0.939
Age at baseline	0.130	0.215	0.603	0.548
Whether the participant smokes cigarettes	-1.29	0.384	-3.37	0.001
Whether the participant consumes caffeine	-1.29	0.384	-3.37	0.001
Whether the participant has ever been diagnosed with alcohol or drug abuse	-0.220	0.220	-0.970	0.334
Whether the participant took any NSAIDS	0.662	0.211	3.13	0.002

Linear Regression Analysis of Total Number of Miscarriage Experiences and Covariates as Predictors of Allostatic Load

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Allostatic Load Predictor	Estimate	Standard Error	t-statistic	p-value
Self-reported health	0.287	0.120	2.39	0.018

Linear Regression Analysis of Self-Reported Health as Predictors of Allostatic Load

Table 7: Linear regression analysis of self-reported health as a predictor for allostatic load. Self-reported health was reported out of a score of 5, with 5 representing worse perceived health.

Allostatic Load Predictor	Estimate	Standard Error	z-statistic	p-value
Whether participants experienced a miscarriage	-0.0803	0.104	-0.0775	0.434
Whether participants reported a traumatic pregnancy experience	-0.00752	0.242	-0.0311	0.975
Whether participants experienced a miscarriage × Whether participants reported a traumatic pregnancy experience	-0.125	0.220	-0.569	0.569

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Allostatic Load Predictor	Estimate	Standard Error	t-statistic	p-value
Total number of miscarriages	-0.350	0.229	-1.53	0.127
Whether participants reported a traumatic pregnancy experience	-0.00701	0.239	-0.0293	0.977
Total number of miscarriages × Whether participants reported a traumatic pregnancy experience	0.392	0.478	0.820	0.412

Moderation Estimate of Miscarriage Experience and Traumatic Pregnancy Experience as Predictors of Allostatic Load

Table 9: Allostatic load was reported out of a score of 5, with 5 representing worse health. Whether participants reported a traumatic pregnancy experience was measured yes = 1 or no = 0.

Variable	t Statistic	df	p value
SBP	1.01	115	0.317
DBP	2.38	115	0.019
BMI	0.08	115	0.936
WHR	1.92	114	0.057
PEF	-0.707	114	0.481
AL	0.99	115	0.324
Self-reported health	1.42	114	0.16
Age of first pregnancy	6.19	109	<0.001

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INTRODUCTION

Miscarriage is a common experience; of all pregnancies worldwide; 10.8% of the birthing population have experienced a miscarriage, totaling 23 million miscarriages every year (Quenby et al., 2021). The experience of miscarriage is emotionally and physically stressful for many people. Miscarriage is associated with a 1.5-fold increase in anxiety, depression, and adjustment disorder (Jacob et al., 2017). The stress associated with miscarriage potentially contributes to a higher allostatic load, defined as the wear and tear on the body due to accumulated stress. It is important to understand how miscarriage interacts with physiological health to expand treatment options for pregnant populations more likely to have a higher allostatic load.

The first purpose of the present study was to investigate the relationship between miscarriage and allostatic load in women who have histories in juvenile justice, with the hypothesis that women who experience miscarriage will have a higher allostatic load in adulthood. The second purpose addressed was whether a traumatic pregnancy experience moderates the relationship between miscarriage and allostatic load. I hypothesized that a traumatic pregnancy experience will exacerbate the relationship such that women who experience traumatic pregnancy and miscarriage have elevations in allostatic load.

This study used the data collected from the Turning Points Study, a longitudinal study following a population of women with histories in juvenile justice during adolescence. Many participants had foster care experiences in childhood and adolescence, had high adverse childhood experiences (ACE), were neglected or maltreated as children, and had experienced elevations in substance use. Miscarriage and adolescent pregnancy were also common experiences in this sample (Cioffi et al., 2022).

Research on how miscarriage is associated with the allostatic load in this underserved population is essential for the design of policies and interventions that prevent disease development in children in foster care and juvenile justice.

LITERATURE REVIEW

Miscarriage

Miscarriage, defined as the loss of a fetus prior to 20 weeks of gestation, is a widely stigmatized and misunderstood experience. For example, patients of miscarriage have reported a lack of empathy from doctors that has prevented them from processing the experience, leading to worse feelings of grief and guilt (Cecil, 1994). Individuals are more likely to have a prolonged experience of distress, grief, and anxiety when they had previous experiences of pregnancy loss, when the miscarriage was unexpected, if they lacked a support system, or if they had an underdeveloped ability to cope (Brier, 1999). Miscarriage is known to be associated with post-traumatic stress, moderate/severe anxiety, and moderate/severe depression even months after the pregnancy loss (Farren et al., 2020). Recurrent miscarriages are associated with increased likelihood of requiring emergency care due to complications during future pregnancies (Bicking Kinsey et al., 2015). For many, miscarriage is associated with a prolonged experience of stress. Understanding the impact of miscarriage on an individual's emotional and physiological health is imperative to normalizing the experience and protecting vulnerable birthing persons who experience a miscarriage.

Allostatic Load Model

Allostatic load (AL) is the physiological manifestation of stress across multiple physiological systems. The term originates from allostasis, or the body's ability to maintain homeostasis while under stress (McEwen & Wingfield, 2003). Throughout life, a person will experience their day-to-day stressors, life and environmental changes, and changes driven by behavior and decisions, all of which accumulate into fight or flight responses that physiological

systems have evolved to handle (Guidi et al., 2021). Although stress is a common human experience, chronic and extreme heightening of the stress response (often during experiences of trauma) has the potential to overload the body's system and can therefore produce quantifiable changes to the physiology of an individual. The body may be in a continuously stressed state and present with the development of an AL.

In 1993, McEwen and Stellar formulated the AL model, demonstrating how individual differences in the perception of the stressor and behavioral responses contribute to the physiological response (McEwen & Stellar, 1993). The physiological response to stress is measured as AL. AL acts as the moderator between allostasis and the resulting adaptation. The physiological response is measured with biomarkers that indicate clinically elevated or depressed levels of any given bio health indicator or, in extreme cases, the symptoms of AL overload (Guidi et al., 2021). I planned to quantify AL with a standard of 12 biomarkers reflecting the cardiovascular, metabolic, and immune functioning of each participant.

High AL has been studied in previous literature and found to be associated with implicated cardiovascular health (Evans, 2003), preterm birth (Olson et al., 2015), altered neural pathways and inhibition of the brain's ability to cope with stress (McEwen, 2000), and age-related disease (Danese & McEwen, 2012). Other health risks associated with chronic stress include cognitive decline in patients with cognitive impairment (Peavy et al., 2009), chronic fatigue (Maloney et al., 2006), metabolic syndrome (Chandola et al., 2006), and all-cause mortality (Parker et al., 2022). While most studies have described the health-related consequences of a high AL, our study will add insight to how miscarriage affects AL longitudinally, thereby reversing the order in which the AL-miscarriage association has been

studied previously. Research in this area therefore emphasizes the importance of mental wellbeing after a potentially traumatic event such as miscarriage that may contribute to disease.

Underserved populations are especially vulnerable to developing high AL due to systemic stressors. For example, prior research has documented that adolescents who reside in neighborhoods with increasing poverty rates showed significantly elevated AL (Brody et al., 2014). Middle-school children who experienced psychosocial and physical challenges such as violence, poverty, family turmoil, and substandard housing were also shown to have a greater AL (Evans et al., 2007). African Americans in the rural south of the US were shown to have links between high socioeconomic status-related stress, high AL, and low emotional and behavioral functioning (Brody et al., 2013).

Extant research on the link between miscarriage and AL is limited. One prior study has documented that pregnancies ending in miscarriages, induced abortions, and stillbirths were directly linked with higher AL in Indonesian women (Leone et al., 2023). A secondary data analysis found that high baseline AL was significantly associated with preterm birth and pre-eclampsia in women undergoing ovarian stimulation (Barrett et al., 2018). A high baseline AL was not, however, associated with miscarriage in the sample (Barrett et al., 2018). Another study found that both Black and white women in high-risk AL classes were not shown to have associated worse birth outcomes compared with low-risk AL classes (Barry et al., 2022). The mixed results in the literature suggest the need for further study on the link between miscarriage and AL. Certain populations have shown an association between miscarriage and AL, while other populations did not. It is possible that the AL is not as strong of a predictor of miscarriage (e.g., Barr et al., 2022) but instead may be a downstream consequence, something that no prior studies, to my knowledge, have explored. Further, it is important to determine which

populations are more likely to develop high AL after experiencing miscarriage in order to guide health care providers in identifying risk factors and customizing preventative treatments.

The present study is unique because it collects longitudinal data from participants' childhood, adolescence, and adulthood, thereby permitting us to explore the longitudinal associations between experiences of miscarriage on subsequent AL. With data collected from previous waves of the study, miscarriage reports were collected prospectively and contextualized through other life events and stressors described by the participant. Conversely, AL was collected only at the final wave of data collection, when participants were in adulthood. Past literature has not shown how miscarriage affects AL in the long term for a population with histories in juvenile justice. It is also unclear from previous studies how traumatic pregnancy experience moderates the relationship between miscarriage and AL.

Biomarkers for Allostatic Load

Multiple physiological systems interact and are involved in the stress response. In fight-or-flight situations, the cardiovascular system elevates blood pressure due to the release of the hormones norepinephrine and epinephrine (Zhang & Anderson, 2014). Hypertension, a condition of chronic high blood pressure, puts the body at risk for cardiomyopathy (Tackling & Borhade, 2022). Stress-induced cardiomyopathy is a disease acquired from a prolonged stress response (Golbidi et al., 2015). In cardiomyopathy, the muscles of the heart have thickened due to intense and sustained overuse to the degree that blood is no longer effectively pumped through the body (Tackling & Borhade, 2022). The present study evaluates systolic blood pressure, diastolic pressure, and peak expiratory flow to measure cardiovascular function in the context of AL.

Dysregulation of the immune system during emotional stress triggers an inflammatory response. The occurrence of inflammation when the body is not physically injured or ill is known as sterile inflammation (Hori & Kim, 2019). During stress, the hypothalamic–pituitary–adrenal (HPA) axis is activated, starting when the hypothalamus in the brain releases corticotropin-releasing hormone and arginine vasopressin (Hori & Kim, 2019). Vasopressin is involved in increasing blood pressure. Corticotropin-releasing hormone plays a role in the production of norepinephrine. Norepinephrine increases the production of IL-6 to promote inflammation. Interleukin-6 (IL-6) is one of the most integral proteins in inducing inflammation and also promotes the production of C-reactive protein (CRP) (Del Giudice & Gangestad, 2018). Both IL-6 and CRP are known as proinflammatory cytokines and are commonly measured to determine whether a person is experiencing sterile inflammation. A state of consistent, low-grade inflammation will cause tissue damage, age-related disease, and other long-term health effects if

not treated (Del Giudice & Gangestad, 2018). The present study intends to use levels of IL-6 and CRP in participants to analyze immune function and to measure AL.

Atypical metabolic function has been documented in studies that have shown an association between insomnia, stress, anxiety, and elevated triglyceride and reduced HDL cholesterol levels (Hsu & Chang, 2022). Dysregulation of the HPA axis due to stress may cause an abnormally high release of cortisol (Hannibal & Bishop, 2014), a hormone that increases the circulation of fat and glucose in the blood to provide energy to cells. Sustained release of cortisol leads to elevated levels of fatty acids such as triglycerides and cholesterol, as well as the deposit of circulating fat into the abdomen (Hewagalamulage et al., 2016). This increases the likelihood of developing obesity (Ren et al., 2021) and cardiovascular disease (Toker et al., 2012). The present study measured basal metabolic index (BMI), waist-to-hip ratio (WHR), and intended to include high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides, and hemoglobin A1c to determine participants' metabolic function.

Covariates considered in the study included treatment foster care, cigarette smoking, alcohol use, and caffeine intake. Participants in the initial waves of the Turning Points for Women Study were assigned in randomized control trial to either group care (treatment as usual) or Multidimensional Treatment Foster Care (MTFC) (Kerr et al., 2009). Participants who received MTFC experienced significantly fewer adolescent pregnancies compared to counterparts receiving group care (Kerr et al., 2009). MTFC is designed to enhance resiliency of children and adolescents who have experienced adversity (Leve et al., 2009), and receivers of MTFC may be more equipped to adjust to stressful events. Therefore, I included group assignment as a covariate in the present study.

Smoking is known to have a weak association with high AL (Petrovic et al., 2016). In individuals with HIV, smoking has been shown not to mediate the relationship between ACEs and AL (M. Wallace et al., 2020). Tobacco, caffeine, alcohol, and drug use have been shown not to alter the relationship between PTSD and AL in mothers (Glover, 2006). Caffeine use is also known to be associated with stress and frequent use of OTC analgesics (Skarstein et al., 2014). Therefore, these covariates were included in my main analyses.

The purpose of my study was to explore how miscarriage experiences through life contribute to allostatic load outcomes in women with histories in juvenile justice. I had two hypotheses. My first hypothesis was that miscarriage experiences would be positively correlated to a higher allostatic load. My second hypothesis was that traumatic pregnancy would moderate this relationship, such that the link between miscarriage and AL would be stronger in the presence of traumatic pregnancy.

METHODS

Sample

The subject pool consisted of 166 women initially recruited in the 1990 to 2008 waves of the Turning Points for Women Study. All participants self-identified as women, and their ages at the time of the current study ranged from 27–40 years. All participants were involved in foster care and the juvenile justice system during childhood and adolescence. The sample had experienced high levels of maltreatment: 86% of participants experienced child maltreatment or neglect and were involved in child welfare. Racially, 68% of participants identified as non-Hispanic white, 11% as Hispanic, 2% as Black, 1% as Native American, 1% as Asian, and 17% as mixed ethnic heritage. All women reported on their pregnancy and childhood history.

Procedures

All procedures were approved by the University of Oregon's Institutional Review Board in May 2021. Pregnancy data from the 2021–2023 wave of the Turning Points for Women study was used in the present study as well as data collected in all 15 prior waves. Data collection included two components. Part 1 was a three-hour phone interview which included questions about pregnancy history and pregnancy and childbirth experiences, and other psychosocial and health experiences. Part 2 was an in-person or remote bio assessment used to collect data on allostatic load and covariates.

The telephone interview and self-report were conducted remotely and evaluated participants' life outcomes and life stressors, following up from previous waves of the study. Self-report health surveys were recorded via interview during the bio assessment. Refer to the 36-Item Short Form Survey Instrument in Appendix 1 for the survey items.

Miscarriage

Data was used from previously reported pregnancy experiences and pregnancy losses collected in every wave of the Turning Points for Women Study. In all prior waves of the study, the participants (and their caregivers during the first two adolescent waves) were asked to report if they had been pregnant and the outcome of the pregnancy; non-confidential questions were reported by the assessor, while confidential questions, including pregnancy history, were self-reported on a computer by the participant. Data from caregiver reports in the first two waves of the study were used if the participant reports were unavailable (Cioffi et al., 2022). Questions on number of pregnancies and participant age at pregnancy were asked in every wave in the same way. Miscarriage was scored yes = 1 and no = 0. No value was input if participant declined to answer. Responses ranged from 0–1. Number of miscarriages was also reported as a separate data entry.

Pregnancy and Childbirth Trauma Questionnaire

The telephone interview included the Pregnancy and Childbirth Trauma Questionnaire adapted from Saxbe et al.'s Birth Experiences Questionnaire (Saxbe et al., 2018). Refer to the Telephone Interview Guide in Appendix 2 for the survey items. The 2021–2023 wave of the study was the first wave where the participants were asked about pregnancy trauma, including questions on whether they considered any prior pregnancy or childbirth experiences to be stressful or difficult. For each question, participants were asked which pregnancy they had the experience with and how old they were at the time. Pregnancy trauma was scored as yes = 1 and no = 0. No value was input if participant declined to answer. Responses ranged from 0–1.

Allostatic Load

The bio assessment was performed either in the lab, at the participant's place of residence, in a publicly available private meeting space, or remotely over Zoom, depending on the participant's location and preference. The bio assessment collected blood pressure, height and weight, waist and hip circumference, peak expiratory flow, and dried blood spot samples from which 6 biomarkers will be assayed. Sitting blood pressure was measured twice using an adult blood pressure cuff machine; once in the beginning of the assessment and again at the end. Peak expiratory flow was measured three times with a spirometer. Participants were instructed to stand, wear a nose clip, inhale to maximum capacity, and fully exhale as hard and fast as possible. Values coded for peak expiratory flow were in units of liters per minute and averaged across the three trials. Height and weight were measured with a standard scale and stadiometer and then used to calculate BMI. Waist circumference was measured transversely at the iliac crest. Hip circumference was measured transversely at the widest part of the gluteus maximus. Measurements were reported by a bio assessor on a Qualtrics survey form. Participant blood spots were collected from the finger with a disposable lancet. Five individual drops were collected on five points of a blood spot card. The blood spot card was allowed to dry for 24 hours before being stored in a freezer at −80°C.

Blood spot samples will be processed through high-sensitivity enzyme-linked immunosorbent assays (ELISA) to evaluate metabolic and immune function biomarkers. A 3.2-mm-diameter hole punch will be taken from the dried blood spot (DBS) card and washed in a 250 ml assay buffer overnight. The ELISA technique uses antigens to detect the presence of a specific antibody linked to an enzyme. The binding of an enzyme substrate dye displays a color that corresponded to the concentration of the protein of interest. ELISA will be used to evaluate

levels of the following: high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides, hemoglobin A1c, C-Reactive protein (CRP) level, Interleukin 6 (IL-6), and Epstein-Barr Virus (EBV) antibodies. Due to administrative delays, the DBS were not included in this current study as they are not yet processed.

In sum, together the above-described AL biomarkers measure the wear and tear on the body due to accumulated stress. The present study used a similar approach to Seeman et al.'s allostatic load model designed to evaluate disease risk in the atypical functioning of different biological systems (Seeman et al., 2002). Cardiovascular biomarkers included systolic blood pressure (SBP), diastolic blood pressure (DPB) and peak expiratory flow (PEF). Metabolic biomarkers were quantified by participants' body mass index (BMI), waist-to-hip ratio (WHR), high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides, and A1c. Biomarkers of immune function consisted of participants' indicators of inflammation measured by CRP, IL-6, and EBV levels. AL was determined by a score of 0 to 12. If one biomarker, such as SBP, was at or above clinical levels of atypical functioning, the participant's AL was increased by one point, as outlined in Table 1. Ranges of AL therefore were from 0-12 with higher values indicating greater AL (e.g., more wear and tear on the immune, cardiovascular, and metabolic systems). For this preliminary analysis, and due to the unavailability of DBS biomarkers, measures included SBP, DBP, PEF, BMI and WHR, and AL scores ranged from 0 to 5.

Statistical Analysis

Statistical analyses were produced with jamovi. A linear regression analysis was used to test the significance of whether the participant experienced a miscarriage, age of first pregnancy, and covariates as predictors of AL. A second linear regression analysis was used to test the

significance of the total number of miscarriages, age of first pregnancy, and covariates as predictors of AL. Group differences between participants who had a miscarriage experience and those who had no history of miscarriage on the key variables were tested with independent samples t-tests.

Biomarker Type	**Biomarker**	**Normal range**	**Score**
Cardiovascular	SBP	< 129 mm Hg	1
	DBP	< 80 mm Hg	1
	PEF	320-470 L/min	1
Metabolic	BMI	18.5–24.9	1
	WHR	< 0.8	1
	HDL cholesterol	< 100 mg/dL	1
	LDL cholesterol	> 40 mg/dL	1
	Triglycerides	< 150 mg/dL	1
	A1c	< 5.7%	1
Immune function	CRP	< 10 mg/L	1
	IL-6	< 43.5 pg/ml	1
	EBV	< 17.9 U/mL	1
		AL Score	12

List of Biomarkers and the Normal Ranges for Allostatic Load.

Table 1: Participants' allostatic load (AL) was quantified out of 12 biomarkers. Cardiovascular biomarkers included systolic blood pressure (SBP), diastolic blood pressure (DBP), and peak expiratory flow (PEF). Metabolic biomarkers consisted of participants' body mass index (BMI) and waist-to-hip ratio (WHR), as well as levels of HDL and LDL cholesterol, triglycerides, and A1c. Biomarkers of immune function included Epstein-Barr virus levels and indicators of inflammation measured by CRP and IL-6.

RESULTS

Data from 117 participants were included in this study, selected because they completed the most recent wave of data collection that included the measure of AL and traumatic pregnancy. The mean age of the participants at the most recent wave was 34.41 ±2.81. The mean age at baseline was 15.3 ±1.16. The mean age of first pregnancy was 16.8 ±3.23. AL was measured out of 5 biomarkers, with a score of 5 indicating worse health. Mean AL of the sample was 3.06 ±1.12. Self-reported health was reported out of a score of 5, with 5 representing worse perceived health. Mean self-reported health score was 3.08 ±0.853. Mean total miscarriages experienced was 0.855 ±1.08, with 59 out of 117 (50%) participants having reported experiencing at least one miscarriage in their lifetime. Descriptives are shown in **Table 2, Table 3** and **Table 4.**

	Mean	Median
Age of first pregnancy	16.8±3.23	15.00
Total miscarriages	0.855±0.108	1.00
Allostatic load	3.06±1.12	3.00
Self-reported health	3.08±0.853	3.00

Comparison of Descriptives of All Participants

Table 2: Descriptives table of age of first pregnancy, total miscarriages experienced by a participant, allostatic load, and self-reported health. Allostatic load was reported 1 to 5, with 5 representing worse health. Self-reported health was reported out of a score of 5, with 5 representing worse perceived health. Mean values reported with ±standard deviation. Total sample size was 117.

	Miscarriage – Yes		Miscarriage – No	
	Mean	Median	Mean	Median
Age of first pregnancy	15.3±3.22	15.00	18.6±2.20	18.00
Total miscarriages	1.69±0.951	1.00	0±0	0
Allostatic load	2.97±1.16	3.00	3.17±1.09	3.00
Self-reported health	2.97±0.816	3.00	3.19±0.89	3.00

Comparison of Descriptives Between Participants With and Without Miscarriage History

Table 3: Descriptives table of age of first pregnancy, total miscarriages experienced by a participant, allostatic load, and self-reported health. Allostatic load was reported 1 to 5, with 5 representing worse health. Self-reported health was reported out of a score of 5, with 5 representing worse perceived health. Mean values reported with ±standard deviation, split between participants who reported ever having a miscarriage (Miscarriage – Yes) and participants who reported never having a miscarriage (Miscarriage – No). Total sample size was 117.

	Miscarriage – Yes		Miscarriage – No	
Variable	Mean (SD)	Number of participants in clinical range	Mean (SD)	Number of participants in clinical range
SBP	119 ±12.5	12	121 ±15.1	13
DBP	77.7 ±11.0	23	82.6 ±11.4	36
BMI	30.8 ±8.37	47	30.9 ±7.53	46
WHR	0.897±0.0955	55	0.930 ±0.0854	54
PEF	284 ±110	38	269 ±117	35

Comparison of Allostatic Load Biomarkers Between Participants With and Without Miscarriage History

Table 4: Comparison of mean values of allostatic load biomarkers ±standard deviation between participants who reported ever having a miscarriage (Miscarriage – Yes) and participants who reported never having a miscarriage (Miscarriage – No). Biomarkers included systolic blood pressure (SBP), diastolic blood pressure (DBP), basal metabolic index (BMI), waist to hip ratio (WHR), peak expiratory flow (PEF). Total sample size was 117.

A linear regression was calculated to predict AL from a dichotomous variable assessing whether or not participants experienced a miscarriage and covariates. Results indicated that there was a significant association between AL, miscarriage experience, and covariates, $F(8,102) = 2.89$, $p = .008$ with an R^2 of .180. Miscarriage experience was not shown to be a significant predictor of AL, $t(102) = -1.34$, $p = .184$). Results for the linear regression are shown in **Table 5.**

A linear regression was calculated to predict AL from the total number of miscarriages experienced by a participant. Results indicated a significant association between AL, total number of miscarriages and covariates, $F(7,103) = 3.15$, $p = .005$ with an R^2 of .176. Miscarriage

experience was not shown to be a significant predictor of AL $t(103) = -1.18$, $p = .240$. Results for the linear regression are shown in **Table 6.**

In a follow-up exploratory analysis, self-reported health was shown to be a significant predictor of AL, with an estimate of 0.287 ($r = .217$, $p = .018$). Worse self-reported health suggested greater allostatic load. Linear regression results of self-reported health as a predictor of AL are shown on **Table 7.**

Allostatic Load Predictor	Estimate	Standard Error	t-statistic	p-value
Whether participants experienced a miscarriage	-0.320	0.239	-01.34	0.184
Age of first pregnancy	0.00559	0.0389	-1.3382	0.184
Foster care treatment	-0.00483	0.2184	-0.0221	0.982
Age at baseline	0.0240	0.0944	0.254	0.800
Whether the participant smokes cigarettes	0.1535	0.216	0.489	0.626
Whether the participant consumes caffeine	-1.23	0.381	-3.23	0.002
Whether the participant has ever been diagnosed with alcohol or drug abuse	-0.187	0.226	-0.828	0.410
Whether the participant took any NSAIDS	0.683	0.214	1.20	0.002

Linear Regression Analysis of Miscarriage Experiences and Covariates as Predictors of Allostatic Load

Table 5: Linear regression model of whether participants experienced a miscarriage as predictor of allostatic load. Covariates included age of first pregnancy, treatment foster care, age at baseline, whether the participant reported smoking cigarettes, whether they consume caffeine, whether the participant reported ever having been diagnosed with alcohol or drug abuse, and whether they took any NSAIDs, such as ibuprofen or aspirin.

Allostatic Load Predictor (Covariates)	Estimate	Standard Error	t-statistic	p-value
Total number of miscarriages	-0.128	0.109	-1.18	0.240
Age of first pregnancy	0.0125	0.0366	0.343	0.733
Foster care treatment	-0.0166	0.218	-0.0762	0.939
Age at baseline	0.130	0.215	0.603	0.548
Whether the participant smokes cigarettes	-1.29	0.384	-3.37	0.001
Whether the participant consumes caffeine	-1.29	0.384	-3.37	0.001
Whether the participant has ever been diagnosed with alcohol or drug abuse	-0.220	0.220	-0.970	0.334
Whether the participant took any NSAIDS	0.662	0.211	3.13	0.002

Linear Regression Analysis of Total Number of Miscarriage Experiences and Covariates as Predictors of Allostatic Load

Table 6: Linear regression model of total number of miscarriages participants experienced as predictor of allostatic load. Covariates included age of first pregnancy, treatment foster care, age at baseline, whether the participant reported smoking cigarettes, whether they consume caffeine, whether the participant reported ever having been diagnosed with alcohol or drug abuse, and whether they took any NSAIDs, such as ibuprofen or aspirin.

Allostatic Load Predictor	Estimate	Standard Error	t-statistic	p-value
Self-reported health	0.287	0.120	2.39	0.018

Linear Regression Analysis of Self-Reported Health as Predictors of Allostatic Load

Table 7: Linear regression analysis of self-reported health as a predictor for allostatic load. Self-reported health was reported out of a score of 5, with 5 representing worse perceived health.

A moderation analysis was performed using linear regression to test traumatic pregnancy experience as a moderator on the relationship between miscarriage and allostatic load. Of the sample, 63.4% reported a traumatic pregnancy experience. Results showed no evidence of a significant association between AL, miscarriage experience, and traumatic pregnancy experience B = -0.820, $\boldsymbol{p}$ = 0.412 (**Table 8**). Results did not indicate a significant association between AL, number of miscarriages, and traumatic pregnancy experience B -0.569, p = 0.569 (**Table 9**).

Allostatic Load Predictor	Estimate	Standard Error	z-statistic	p-value
Whether participants experienced a miscarriage	-0.0803	0.104	-0.0775	0.434
Whether participants reported a traumatic pregnancy experience	-0.00752	0.242	-0.0311	0.975
Whether participants experienced a miscarriage × Whether participants reported a traumatic pregnancy experience	-0.125	0.220	-0.569	0.569

Moderation Estimate of Miscarriage Experience and Traumatic Pregnancy Experience as Predictors of Allostatic Load

Table 8: Moderation estimate of traumatic pregnancy on the relationship between allostatic load and miscarriage experience. Allostatic load was reported out of a score of 5, with 5 representing worse health. Whether participants reported a miscarriage experience was measured yes = 1 or no = 0. Whether participants reported a traumatic pregnancy experience was measured yes = 1 or no = 0.

Allostatic Load Predictor	Estimate	Standard Error	t-statistic	p-value

Total number of miscarriages	-0.350	0.229	-1.53	0.127
Whether participants reported a traumatic pregnancy experience	-0.00701	0.239	-0.0293	0.977
Total number of miscarriages × Whether participants reported a traumatic pregnancy experience	0.392	0.478	0.820	0.412

Moderation Estimate of Miscarriage Experience and Traumatic Pregnancy Experience as Predictors of Allostatic Load

Table 9: Allostatic load was reported out of a score of 5, with 5 representing worse health. Whether participants reported a traumatic pregnancy experience was measured yes = 1 or no = 0.

Independent samples t-tests were performed to compare SBP, DBP, BMI, AL, self-reported health, and age of first pregnancy of the participants who experienced a miscarriage with those who have not. There was not a significant difference in SBP of the participants who had experienced a miscarriage (M = 119, SD = 12.5) and SBP in the participants who have not (M = 121, SD = 15.1); $t(115) = 1.01$, $p = .317$). There was a significant difference in DBP of the participants who had experienced a miscarriage (M = 77.7, SD = 11.0) and DBP in the participants who have not (M = 83.6, SD = 11.4); $t(115) = 2.38$, $p = .019$). There was not a significant difference in BMI of the participants who had experienced a miscarriage (M = 30.8, SD = 8.39) and BMI in the participants who have not (M = 30.9, SD = 7.53); $t(115) = 0.08$, $p = .936$). There was not a significant difference in AL for the participants who had experienced a miscarriage (M = 2.97, SD = 1.16) and AL of the participants who have not (M = 3.17, SD = 1.09); $t(115) = .99$, $p = .324$). There was not a significant difference in self-reported health of the participants who had experienced a miscarriage (M = 2.97, SD = 0.816) and self-reported health of women who have not (M = 3.19, SD = .888); $t(114) = 1.42$, $p = .160$). There was a significant difference in age of first pregnancy of the participants who had experienced a miscarriage (M =

15.3, SD = 3.22) and age of first pregnancy of the participants who have not (M = 18.6, SD = 2.20); $t(109) = 6.19$, $p < .001$). **Table 10.** compares results of t-tests. See **Figure 1** in Appendix 3 compares frequencies of age of first pregnancy.

Variable	t Statistic	df	p value
SBP	1.01	115	0.317
DBP	2.38	115	0.019
BMI	0.08	115	0.936
WHR	1.92	114	0.057
PEF	-0.707	114	0.481
AL	0.99	115	0.324
Self-reported health	1.42	114	0.16
Age of first pregnancy	6.19	109	<0.001

T-test Analysis Comparing SBP, DBP, BMI, AL, Self-Reported Health and Age of First Pregnancy of the Participants who Experienced a Miscarriage with those who have not.

Table 10: Results of independent samples t-tests comparing systolic blood pressure (SBP), diastolic blood pressure (DBP), basal metabolic index (BMI), waist to hip ratio (WHR), peak expiratory flow (PEF), allostatic load (AL), self-reported health and age of first pregnancy of participants who reported ever having a miscarriage and participants who reported never having a miscarriage. Total sample size was 117.

DISCUSSION

This study was a longitudinal investigation of how miscarriage impacts AL in women with histories in foster care and juvenile justice. Miscarriage data was collected from early adolescence to adulthood. I explored the relationship between miscarriage and AL with the hypothesis that miscarriage experience would be associated with a higher AL score. Contrary to my hypothesis, neither miscarriage nor number of miscarriages were shown to be a significant predictor of AL score. I also addressed the question of whether a traumatic pregnancy experience moderated the relationship between miscarriage and AL, hypothesizing that a traumatic pregnancy experience would exacerbate the relationship. The hypothesis was not supported, as traumatic pregnancy was not shown to be a significant moderator of miscarriage and AL. Other exploratory findings in my study showed that self-reported health was a significant negative predictor of AL. Additionally, comparative analysis of biomarkers showed women who had experienced a miscarriage in their lifetime had a significantly lower age of first pregnancy and DBP than the women who had never experienced a miscarriage.

Foster Care

According to the U.S. Department of Health and Human Services, there are 391,098 children in foster care as of 2021. Placement in foster care is associated with increased exposure to maltreatment, developmental delays, and mental health problems in children (Oswald et al., 2010). There is sparse research on the association between foster care and life outcomes in adulthood. The Turning Points for Women Study is unique as the longest ongoing study on women with histories in foster care and chronic involvement in juvenile justice due to delinquency. Longitudinal research on this population is essential to minimize the health risks associated with high AL. These data have potential to provide evidence for different and better

foster care that addresses the contributors to high AL, as well as better programs supporting youth transitioning out of foster care, specifically for youth who may become pregnant.

Miscarriage

The present study is unique because miscarriage is more commonly studied as a result of high AL as opposed to a psychologically and physiologically stressful experience that may be a contributor to high AL. Studying life experiences as contributors to long-term stress positions systemic inequalities as points of treatment for preventing high AL and the associated health risks. In this study, I specifically evaluated the potential outcomes associated with miscarriage as one stressful experience. Miscarriage experiences during adolescence have been shown to be a predictor of suicide attempts later in life in women who had been in foster care (Cioffi et al., 2022). Increasing physical and emotional ACEs have been shown to be significantly associated with miscarriage in adulthood (Kerkar et al., 2021). This literature demonstrate the importance of support and consideration of trauma in girls in foster care and juvenile justice. A study on a small sample of Latina women showed that the women who had a miscarriage in adolescence experienced a range of responses, from initial grief and subsequent sense of renewal, to deep, long-lasting grief, emphasizing the importance of grief assessments in health care (Sefton, 2007). The women who experienced their miscarriage as an adverse change also experienced a prolonged sense of grief and depression years after the loss (Sefton, 2007), demonstrating that miscarriage may represent a stressor potentially exuberating the risk of developing high AL. Mexican Americans have also been shown to have more intense grief responses to loss and death compared to their Anglo counterparts, showing a significant difference of main effect of ethnicity on a clinical scale (Oltjenbruns, 1998) and emphasizing the need for cultural consideration in care. My study is limited in that 68% of our sample were non-Hispanic whites.

However, these previous studies demonstrate the importance of holistic considerations of culture, ethnic, and trauma-related experiences in health care, particularly for pregnant persons. Although I did not find evidence that miscarriage, either number of miscarriages or the experience itself, predicts AL, it could be that next step studies find evidence of such a relationship with more robust measures of AL.

Traumatic Pregnancy

A traumatic pregnancy experience may be a result of exposure to physical or emotional trauma during pregnancy, which may cause implications to the pregnant individual and the fetus. 63.4% of the sample reported a traumatic pregnancy experience, which is much greater than the general population of 6% to 7% of pregnancies that are complicated by trauma (Hill & Pickinpaugh, 2008). The most common traumatic experiences during pregnancy are minor injuries, including car accidents, falls, and intimate partner violence (Murphy & Center, 2014). Physical trauma during pregnancy is known to be associated with miscarriage, among other prenatal complications (Schiff et al., 2002). One study found that while fetal outcomes depended on the type and severity of trauma experienced by the mother during the pregnancy, members of the group under 28 weeks of pregnancy were most likely to experience fetal loss following the traumatic event (El Kady et al., 2004). The study also reported that the members of the group over 28 weeks of pregnancy were more likely to have a stillbirth, hypothesizing that the pregnant mother's physiological stress may have affected the health of the fetus (El Kady et al., 2004). Finally, the study also identified young maternal age (under 20) and advanced maternal age (35-41) as the two groups most likely to have pregnancy complications following prenatal traumatic injury (El Kady et al., 2004). It is important to consider traumatic pregnancy in women who are at risk for high AL because traumatic pregnancy experience is highly elevated in our sample.

Miscarriage is known to be associated with physical trauma during pregnancy (Schiff et al., 2002), and physiological dysfunction is known to affect fetal health and outcomes (Fatima et al., 2017). Determining if traumatic pregnancy is a moderator for the relationship between miscarriage and AL is important for identifying contributors that may exuberate the relationship and heighten AL.

Maternal mental health is known to be an understudied subject compared with maternal physical health. Physicians are trained to monitor signs of implicated physical health and less so the mental state of perinatal patients (Rodríguez-Almagro et al., 2019). A systematic review and meta-analysis has shown the mean prevalence rate of PTSD is 3.3% in pregnant women in community samples (Yildiz et al., 2017). Lack of social support during pregnancy has been shown to be associated with PTSD diagnosis after birth (El Founti Khsim et al., 2022). This is especially relevant for individuals in the juvenile justice and foster care systems, as they have been shown to be in need of social support due to social network disruption during placement (Cudjoe et al., 2022; Johnson et al., 2011). Understanding how trauma and the responses to trauma affects foster care girls' ability to cope with pregnancy loss and the resulting health outcomes of associated stress may be key to designing support programs that fulfill their psychosocial needs during pregnancy. Psychological trauma during pregnancy is under-represented in research and has potential interactions with experiences of isolation and other types of traumatic events. Understanding the roles of physicians and social support networks is important for juvenile justice and foster care populations, especially for women who have been underserved by providers in the past. A study interviewing a sample of women from parent support groups and social media highlighted the importance of a supportive and empathetic physician, with the majority of participants reporting feeling disrespected, unsupported, and ill-

informed during their traumatic birthing process (Rodríguez-Almagro et al., 2019). Keeping patients informed of potential pregnancy complications and maintaining the dignity of patients have been emphasized as important parts of preventing worse mental health outcomes and traumatic experiences (Ertan et al., 2021; Rodríguez-Almagro et al., 2019). This may be extended to other healthcare and hospital settings, such as patients experiencing miscarriage, pregnant adolescents, and youth in juvenile justice. Although I did not find support for my hypothesis that traumatic pregnancy moderates the relationship between miscarriage and AL, it could be that other traumatic experiences in the sample were more predictive of elevations in AL (e.g., ACEs).

Juvenile Justice

It is known that adolescents in the juvenile justice system have a greater prevalence of mental health problems (Snehil & Sagar, 2020) and high rates of trauma exposure (Duron et al., 2022). From 1980 –2010, the rates of adolescent girls being admitted into juvenile justice facilities have increased, while the rates of arrest of adolescent boys has decreased (Parrish, 2020). This demonstrates the systemic disparities in female justice-system involvement and also the need for support and treatments tailored to the unique needs of incarcerated girls in a field that is dominated by male-centered research.

Incarcerated adolescent girls have unique potential contributors to allostatic load as a result of their childhood experiences. It has been found that incarcerated adolescents have greater rates of adolescent pregnancy than the general population (Committee on Adolescence et al., 2011). One study found that of their sample of 150 pregnant adolescents in juvenile justice, 25% had alcohol-exposed pregnancies compared to the general population risk of 3.4% (Cannon et al., 2015; Parrish et al., 2019). These pregnancy exposures may contribute to incidences of

miscarriage or other pregnancy-related health issues (Sundermann et al., 2019). Girls who are placed in juvenile justice systems are more likely to have trauma than their male counterparts, and have higher rates of physical, sexual, and emotional abuse and related mental health problems (Duron et al., 2022). All participants in our sample had been placed in the juvenile justice system during childhood and adolescence. It is important to study the life outcomes of women who have been in juvenile justice to better understand their needs and protect them from preventable diseases and disorders. Again, it could be that some of these other adversities were more significant contributors to elevated AL in adulthood.

Adolescent Pregnancy and Miscarriage

Our sample has a high prevalence of adolescent pregnancy, and my results show that participants who experienced miscarriage had significantly lower ages of first pregnancy than participants who had never experienced miscarriage. These results were supported in studies showing that young maternal age is associated with pregnancy loss in women who experienced physical trauma during pregnancy (El Kady et al., 2004). There is also research suggesting that gynecological immaturity may play a role in adolescent miscarriage (J. Wallace et al., 2006).

Miscarriage prevalence has been shown to be associated with increasing maternal ages ranging from 20 to 45 in the general population (Li & Marren, 2018). In our sample, however, early maternal age was shown to be associated with miscarriage. The mean age of first pregnancy in our sample was 16.8 ±3.23, ranging from 7 to 30 years. Previous studies have shown greatest risk for spontaneous miscarriage is at ages 13 to 15 due to gynecological immaturity (J. Wallace et al., 2006). It is also known that adolescent pregnancy is associated with foster care placement (Bilchik & Wilson-Simmons, 2010; Matta Oshima et al., 2013). Participants in our sample likely were predisposed to experiencing adolescent pregnancy and

thus miscarriage due to placement in foster care and juvenile justice. First pregnancy at the age of 19 and under had an incidence rate of 0.86 in our sample. Miscarriage in our sample had an incidence rate of 0.5.

Research on the health of foster care youth is particularly important because youth who are in foster care or juvenile justice have greater rates of adolescent pregnancies (Bilchik & Wilson-Simmons, 2010), substance use challenges (47%) (Vaughn et al., 2007), and poor mental health (Turney & Wildeman, 2016) relative to youth who have not spent time in foster care. The amount of support for youth who age out of foster care is also of concern, as girls in this population have been shown to be more likely to have been pregnant (50%) (Lee & Morgan, 2017) and parenting as an adolescent (Matta Oshima et al., 2013). Our sample demonstrates the importance of support during and following pregnancy for girls in foster care, with an average age of first pregnancy of 16.8 ±3.23 that was correlated with a higher rate of miscarriage. My findings on the association between adolescent pregnancy and miscarriage highlight the need for more support during and following pregnancy, particularly if it occurs in adolescence.

Biomarkers

The mean AL score of our sample was 3.06, indicating that, on average, participants had 3.06 of 5 biomarkers in clinical range. There was not a significant difference in the AL scores of participants who experienced a miscarriage and participants who had no miscarriage experience, likely due to our limited AL measure. There may also have been more salient contributors to the high AL. The biomarkers evaluated in this preliminary analysis included SBS, DBS, PEF, BMI and WHR. In the following paragraphs, I present research that may explain other potential predictors of AL in this unique sample due to early experiences of adversity (ACEs).

Blood pressure is an often modifiable risk factor for cardiovascular disease, and stress management is known as an important reducer of high blood pressure (Samadian et al., 2016). Psychosocial stress has been associated with development of cardiovascular disease (Markel et al., 2007). Our sample have experienced high adversity in childhood, which is known to be associated with high blood pressure (Kapur et al., 2022). Elevated DBP and SBP have been shown to be associated with high BMI in a sample of Black American children, likely due to alteration of the HPA axis (Kapur et al., 2022). The same sample of Black American adolescents were also shown to exhibit elevated SBP associated with childhood exposure to community violence (Kapur et al., 2022). While our sample was 68% non-Hispanic white, these studies show how systemic inequalities may impact cardiovascular functioning. Another study found that while ACE score did not show an effect on high blood pressure, elevated ACEs did show a faster rise in blood pressure in adulthood (Su et al., 2015), suggesting that childhood is an important period for developing hypertension, and these altered pathways may manifest in adulthood. ACEs are elevated in our sample. This literature suggests that our population of women with high ACEs are at risk for developing high blood pressure. Elevated BMI has also been shown to be associated with elevations in blood pressure in the general pediatric population (Flynn, 2013), likely due to overactivity of the HPA axis. In early life, stress pathways undergo development and reinforcement because of ACEs, resulting in enduring hyperactive stress responses across multiple systems (Danese & McEwen, 2012). High ACEs are associated with hyperactivation of the HPA axis and elevated inflammation in adulthood (Danese & McEwen, 2012). The link between the cardiovascular and metabolic pathways in stress may explain why our participants exhibited multiple dysfunctional indicators on average.

High depressive symptoms have been shown to be significantly associated with impaired pulmonary function and lower levels of forced expiratory volume (FEV) and forced vital capacity (FVC) in a sample of men who smoked regularly (Ochs-Balcom et al., 2013). This decline in pulmonary function was not shown to be associated with depressive symptoms in non-smokers and women, which may suggest that smoking plays a role in the relationship between depressive symptoms and pulmonary function (Ochs-Balcom et al., 2013). This may be relevant to our sample, as 60.8% of participants reported smoking cigarettes. Smoking is known to be a coping mechanism of stress and depressive symptoms (Horton & Loukas, 2013) and a contributor to worse pulmonary functioning (Lugg et al., 2022). While smoking cigarettes was not accessed as a predictor of high AL, smoking has been shown to be associated with atypical cardiovascular function as well as elevated inflammation, and oxidation of LDL cholesterol, which promotes build-up of cholesterol in arterial walls (Ambrose & Barua, 2004). While smoking cigarettes was not shown to be a significant covariate predictor of AL in this preliminary analysis, it is possible that cigarette smoking will be shown to interact with multiple cardiovascular and immune biomarkers for the AL of our participants in future analysis of DBS. In another study, changes in PEF were not shown to be associated with work stress (Loerbroks et al., 2017). This may suggest that on its own, PEF is not a sufficient indicator of AL and a fuller picture of multiple systems is needed.

Psychosocial stressors during puberty are known to be associated with higher BMI in previously institutionalized and nonadopted youth, demonstrating the impact that displacement-related adversity has on early development and(?) on health (Zhong et al., 2022). Childhood neglect has been shown to also be associated with obesity in adolescence, likely due to depressive symptoms and compulsive eating as a coping mechanism for stress (Shin & Miller,

2012). Childhood neglect and physical abuse have been shown to be associated with higher BMI (Shin & Miller, 2012). Previous literature demonstrates that most of our sample would be at risk for high BMI due to high ACEs. The HPA axis, a predominant mediator of the stress response, develops under social regulation during childhood (Tarullo & Gunnar, 2006). Hyperactivity of the HPA axis and elevated basal cortisol levels are exhibited in adulthood in people with histories of childhood maltreatment (Tarullo & Gunnar, 2006). This literature suggests that our population is at risk for developing clinically elevated BMI and WHR due to atypical development of their HPA axes and histories of ACEs. Stress-induced cortisol has been shown to be linked to increased abdominal diameter, visceral obesity, and heart disease (Tchernof & Després, 2013). Abdominal adipose deposits are likely contributors to increased WHRs and BMI. While it is undetermined if ACEs are causes of clinically elevated WHRs and BMIs in our sample, ACEs are known to play a role in metabolic-related manifestations of stress and high AL.

Study Limitations

Preliminary analyses show no evidence that miscarriage is linked with allostatic load. However, there were limitations to the study. First, not all allostatic load biomarkers were analyzed. Blood spots were not evaluated, resulting in an exclusion of half the metabolic biomarkers and all indicators of immune function. More robust measures of multiple indicators, including cardiometabolic, metabolic, and immune function indicators are necessary for a more complete picture of AL. Additionally, there are many other sources of stress in this sample that explain elevated AL, such as substance use, family trauma, maltreatment, or other, possibly more salient predictors of AL.

My study was limited in that most of the sample was white cis women. It is known that perceived experiences of racial discrimination are negatively associated with heightened stress, potentially impacting mental and physical health (Pascoe & Smart Richman, 2009). Previous literature has associated racism-related vigilance with increased allostatic load in a sample of Black women in the San Francisco Bay Area and Ordinary Least Squares (Daniels, 2020). There was also shown to be an association between proximity to publicized acts of racism in the form of police shootings and preterm birth and low birthweight in a sample of Black mothers from St Louis County (Daniels, 2020). My study is not capable of addressing how racial inequality intersects with miscarriage and AL in women with juvenile justice histories. AL has also not been shown to be associated with non-heterosexuality (Oi & Pollitt, 2023), though research in that area is limited. Sexuality and gender were not controlled in this study. Disability status was also not controlled in this study. These represent limitations of the current study.

While I evaluated data on miscarriage in this study, I only included spontaneous miscarriages and did not include abortions. There is potential for future studies on other pregnancy-related experiences that may be associated with greater allostatic load, such as teen pregnancies, abortion, stillbirth, or early infant loss in this population.

It is undeterminable from our study whether foster care, juvenile justice, or maltreatment predicts high AL because maltreatment data was not analyzed separately from foster care and juvenile justice experiences. Placements into foster care and juvenile justice are both known to be associated with maltreatment (Oswald et al., 2010; Parrish, 2020; Vidal et al., 2017). In our sample, maltreatment had higher prevalence than foster care placement, but all participants have experienced out-of-home placement and spent time in juvenile justice. While the association between foster care and maltreatment was not addressed in our study, 86% of our sample has

reported experiences of maltreatment in childhood; thus, it is likely there is limited variability in these experiences to examine associations with AL. Children in foster care are known to be exposed to high rates of various forms of maltreatment (Oswald et al., 2010). Girls in foster care are known to have higher rates of internalizing symptoms such as clinical levels of social and generalized anxiety that are associated with experiences of maltreatment (Moussavi et al., 2022). This evidence demonstrates that there are many salient potential contributors to high AL due to the unique stressors in this population, which may explain the null results. The interaction between these unique risk factors and AL are not well understood, so more research is necessary to identify and minimize these risk factors.

Next Steps for Research

Analysis on the blood spot biomarkers is still in progress. There is a possibility that a relationship between miscarriage and allostatic load will be found if I expand the allostatic load model to include more biological systems and a more robust measure of AL. Our current allostatic load model included three biomarkers of cardiovascular function and two biomarkers of metabolic function. There are four metabolic biomarkers that have yet to be assessed in the preliminary model, including the three biomarkers of immune functioning that were not assessed in this preliminary analysis.

Further research is needed on interactions between AL and experiences that are common for women in juvenile justice. Substance abuse, adolescent pregnancy, maltreatment, and ACEs are all common experiences in our sample. Additionally, more research is needed to understand the neurohormonal pathways involved in AL.

Appendix 1

Rand Health Questionnaire

HEALTH

RAND > RAND Health > Surveys > RAND Medical Outcomes Study > 36-Item Short Form Survey (SF-36) >

36-Item Short Form Survey Instrument (SF-36)

RAND 36-Item Health Survey 1.0 Questionnaire Items

Choose one option for each questionnaire item.

1. In general, would you say your health is:

- 1 - Excellent
- 2 - Very good
- 3 - Good
- 4 - Fair
- 5 - Poor

2. **Compared to one year ago**, how would you rate your health in general **now**?

- 1 - Much better now than one year ago
- 2 - Somewhat better now than one year ago

- 3 - About the same
- 4 - Somewhat worse now than one year ago
- 5 - Much worse now than one year ago

The following items are about activities you might do during a typical day. Does **your health now limit you** in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
3. **Vigorous activities**, such as running, lifting heavy objects, participating in strenuous sports	○ 1	○ 2	○ 3
4. **Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	○ 1	○ 2	○ 3
5. Lifting or carrying groceries	○ 1	○ 2	○ 3
6. Climbing **several** flights of stairs	○ 1	○ 2	○ 3
7. Climbing **one** flight of stairs	○ 1	○ 2	○ 3
8. Bending, kneeling, or stooping	○ 1	○ 2	○ 3
9. Walking **more than a mile**	○ 1	○ 2	○ 3
10. Walking **several blocks**	○ 1	○ 2	○ 3
11. Walking **one block**	○ 1	○ 2	○ 3
12. Bathing or dressing yourself	○ 1	○ 2	○ 3

During the **past 4 weeks**, have you had any of the following problems with your work or other regular daily activities **as a result of your physical health**?

	Yes	No
13. Cut down the **amount of time** you spent on work or other activities	○ 1	○ 2
14. **Accomplished less** than you would like	○ 1	○ 2
15. Were limited in the **kind** of work or other activities	○ 1	○ 2
16. Had **difficulty** performing the work or other activities (for example, it took extra effort)	○ 1	○ 2

During the **past 4 weeks**, have you had any of the following problems with your work or other regular daily activities **as a result of any emotional problems** (such as feeling depressed or anxious)?

	Yes	No
17. Cut down the **amount of time** you spent on work or other activities	○ 1	○ 2
18. **Accomplished less** than you would like	○ 1	○ 2
19. Didn't do work or other activities as **carefully** as usual	○ 1	○ 2

20. During the **past 4 weeks**, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

○ 1 - Not at all

- 2 - Slightly
- 3 - Moderately
- 4 - Quite a bit
- 5 - Extremely

21. How much **bodily** pain have you had during the **past 4 weeks**?

- 1 - None
- 2 - Very mild
- 3 - Mild
- 4 - Moderate
- 5 - Severe
- 6 - Very severe

---

22. During the **past 4 weeks**, how much did **pain** interfere with your normal work (including both work outside the home and housework)?

- 1 - Not at all
- 2 - A little bit
- 3 - Moderately
- 4 - Quite a bit
- 5 - Extremely

These questions are about how you feel and how things have been with you **during the past 4 weeks**. For each question, please give the one answer that comes closest to the way you have been feeling.

How much of the time during the **past 4 weeks**...

	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
23. Did you feel full of pep?	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6
24. Have you been a very nervous person?	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6
25. Have you felt so down in the dumps that nothing could cheer you up?	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6
26. Have you felt calm and peaceful?	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6
27. Did you have a lot of energy?	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6
28. Have you felt downhearted and blue?	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6
29. Did you feel worn out?	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6
30. Have you been a happy person?	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6
31. Did you feel tired?	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6

32. During the **past 4 weeks**, how much of the time has **your physical health or emotional problems** interfered with your social activities (like visiting with friends, relatives, etc.)?

- 1 - All of the time
- 2 - Most of the time
- 3 - Some of the time
- 4 - A little of the time
- 5 - None of the time

How TRUE or FALSE is **each** of the following statements for you.

	Definitely true	Mostly true	Don't know	Mostly false	Definitely false
33. I seem to get sick a little easier than other people	1	2	3	4	5
34. I am as healthy as anybody I know	1	2	3	4	5
35. I expect my health to get worse	1	2	3	4	5
36. My health is excellent	1	2	3	4	5

Appendix 2

Pregnancy and Childbirth Trauma Questionnaire

1. [text for assessor]
Read: "We know that pregnancy loss and trauma is a much more common experience than is often acknowledged. In this study, we are interested in better understanding any experience that has contributed stress to women's lives, so we are going to ask a few follow-up questions about your experiences in pregnancy and childbirth. Remember, you do not have to answer any question that you do not want to answer."
2. [text for assessor which requires referencing SPUD]
First, you have reported [total number if pregnancies and childbirth experiences from SPUD]. Assessor, add in if SPUD indicates a pregnancy loss [and you have reported [[number]] of pregnancy loss experiences to us previously].
Question 1: Do you consider any of your prior pregnancy or childbirth experiences to be stressful or difficult.
Options:
Yes
No (move on to biological children section)
Declined to answer (move on to biological children section)

IF YES
Question 2: During pregnancy …

a. were there serious complications that lead you to fear for your baby's life or health?

b. were there serious complications that lead you to fear for your own life or health?

c. Was your health seriously harmed?

d. Was your baby's health seriously harmed?

e. Program so that if yes is answered to any one or more of questions 2a-2d, we ask which pregnancy(pregnancies) (we have to decide on answer options)

Question 3: During childbirth …

a. were there serious complications that lead you to fear for your baby's life or health?

b. were there serious complications that lead you to fear for your own life or health?

c. Was your health seriously harmed?

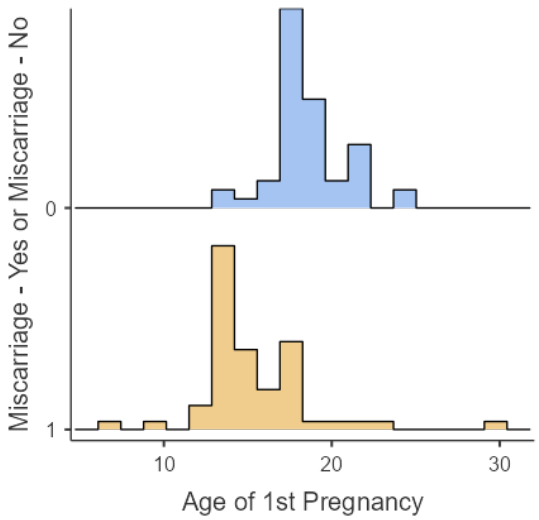
d. Was your baby's health seriously harmed?

e. Program so that if yes is answered to any one or more of questions 3a – 3d. we ask which childbirth/childbirth experiences (we have to decide on answer options)

* for all questions 2 a- d and 3a-d options are "yes" "no" and "decline to answer"

Appendix 3

Figure 1.



Comparison of Age of 1st Pregnancy Between Participants who Reported Yes or No to Having a Miscarriage

Figure 1: Comparison of age of 1st pregnancy between participants who reported ever having a miscarriage (Miscarriage – Yes) and participants who reported never having a miscarriage (Miscarriage – No).

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