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Associations among Maternal Perinatal Stress, Maternal-Infant Touch, and Infant Gross Motor Outcomes

by

Hillary Erin Swann

A dissertation

submitted in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy in the Department of Psychology

Idaho State University

Summer 2019

To the Graduate Faculty:

The members of the committee appointed to examine the dissertation of Hillary Erin Swann find it satisfactory and recommend that it be accepted.

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February 13, 2015

Nicki Aubuchon-Endsley, PhD
Stop 8112
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RE: Your application dated 2/2/2015 regarding study number 4191: Infant Development and Healthy Outcomes in Mothers (Idaho Mom Study)

Dear Dr. Aubuchon-Endsley:

Thank you for your response to requests from a prior review of your application for the new study listed above. Your study is eligible for expedited review under FDA and DHHS (OHRP) designation.

This is to confirm that your application is now fully approved. The protocol is approved through 2/13/2016.

You are granted permission to conduct your study as most recently described effective immediately. The study is subject to continuing review on or before 2/13/2016, unless closed before that date.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; fax 208-282-4723; email: humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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Study 4191: Infant Development and Healthy Outcomes in Mothers (Idaho Mom Study)

1 message

humsubj@isu.edu <humsubj@isu.edu> Tue, Jan 29, 2019 at 2:16 PM
To: aubunick@isu.edu
Cc: humsubj@isu.edu

January 29, 2019

Nicki Aubuchon-Endsley, PhD
Stop 8112
Psychology
Pocatello, ID 83209

RE: Your application dated 1/29/2019 regarding study number 4191: Infant Development and Healthy Outcomes in Mothers (Idaho Mom Study)

Dear Dr. Aubuchon-Endsley:

You are granted permission to continue your study as described effective immediately. The study is next subject to continuing review on or before 2/9/2020, unless closed before that date.

As with the initial approval, changes to the study must be promptly reported and approved. Contact Tom Bailey (208-282-2179, humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

This dissertation is dedicated to George T. Hutchinson. Papa, I did it!

Acknowledgements

I would like to thank my advisor and mentor, Dr. Michele R. Brumley, for her encouragement, dedication and support. Thank you for being an inspiration to not only me, but so many young aspiring scientists. Thank you for reminding that hard work and sacrifice always pays off as long as you continue to strive for success and never quit. I would also like to thank Dr. Nicki Aubuchon-Endsley. Not every graduate student is lucky enough to have not one, but two, amazing mentors. Thank you for teaching me patience and the importance of positive reframing. I would like to thank my other dissertation committee members, Dr. Bryan Gee, Dr. Robert Rieske, and Dr. Maria Wong, for their contributions and feedback throughout this process.

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Lastly, I would like to thank my family, particularly my son, Trent, and my husband, Ryan. Thank you for your love and support throughout this journey. I am so thankful to have you both by my side as my biggest fans.

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Dissertation Abstract-Idaho State University (2019)

Approximately 25% of women experience mental health problems during the perinatal period. Maternal stress and distress during pregnancy and postnatally can impact infant developmental outcomes, including gross motor development. Cortisol, a steroid hormone and output of the HPA axis, is often attributed as the mediating mechanisms between maternal perceived stress and infant outcomes. However, there is a lack of evidence supporting cortisol as a mediator between maternal subjective stress and infant gross motor development. The current study sought to explore potential behavioral factors that might mediate the relationship between maternal perinatal stress, including perceived stress and cortisol, and infant gross motor outcomes. It was hypothesized that maternal-infant physical touch at 6 months postnatally would mediate the relationship between maternal perinatal stress indices and infant gross motor outcomes at 14 months. Additionally, we examined the associations among maternal stress indices across the perinatal period. Participants were pregnant females recruited from a community sample in their third trimester (33-37 weeks gestation). Mothers returned to the lab with their infants at 6 months and 14 months for a behavioral observation session. Maternal-infant touch behavior was coded during a brief free-play session. Data was analyzed using a series of Pearson's correlations, simple linear regression, and Hayes' PROCESS macro for mediation analyses. Analyses revealed that maternal-infant touch did not significantly mediate the relationship between maternal perinatal stress indices and infant gross motor outcomes. Notably, we did find that maternal-infant touch negatively predicted infant gross motor outcomes, such that higher frequency of maternal-infant touch resulted in decreased infant gross

motor scores. These findings suggest that restrictive maternal touch captured during free-play session might influence infant motor development, independently of maternal mental health status.

Key Words: subjective stress, AUC, CAR, motor development, maternal-infant reciprocity

Associations among Maternal Perinatal Stress, Maternal-Infant Touch, and Infant Gross Motor Outcomes

During the perinatal period, approximately 25% of women experience mental health problems, such as anxiety, depression, and stress (Kingston, McDonald, Austin, & Tough, 2015). In Idaho, 21.7% of women endorsed high levels of stress, as defined by experiencing three or more stressful events in the 12 months prior to delivery (PRATS, 2018). Additionally, 20.3% of mothers in Idaho reported moderate to severe levels of postpartum depression in three months after pregnancy, with prevalence of depression significantly higher in women who had endorsed experiencing high levels of prenatal stress (PRATS, 2018). Maternal stress during the perinatal period can have cascading effects on infant outcomes, including both physiological and psychosocial development. Increased maternal cortisol levels, as a function of HPA axis activation, is often attributed as a mediator between maternal psychological stress and infant outcomes.

However, the relationship between psychological stress and cortisol, as a biological marker of stress, has not been fully elucidated, particularly within the perinatal population. It is probable that other factors mediate the relationship between stress, both psychological and physiological, and infant outcomes by influencing maternal-infant interactions, such as physical touch. For instance, maternal-infant interactions have been shown to influence infant growth and development, including psychomotor development. Thus, the current study examined the relationships between maternal perceived stress during the prenatal and postnatal period, maternal prenatal salivary cortisol, maternal-infant physical touch, and infant motor development to further our understanding of how maternal perinatal health influences infant development outcomes.

Generalized Stress

Stress is a well-studied phenomenon pervasive throughout populations affecting individuals across cultures, genders, and socioeconomic status with impacts on physical and psychosocial health. However, there is still a lack of a consistent operational definition across stress research. Hans Selye (1955) first established the term "stress" to refer to "the non-specific response of the body to a demand" and stressors as events that produce stress, or induce the body's response to a demand. Recently, definitions have attempted to capture that stress is a process, involving both the stressor and the stress response, both physiological and behavioral responses, as well as how an individual evaluates the event and their resources to adapt or cope to the demand (Lester, Nebel, & Baum, 1994). Similarly, Cohen and colleagues (1997) posit that stress can be assessed from an environmental perspective (the stressor), psychological perspective (the evaluation), and biological perspective (the physiological response). Thus, the current study approaches stress as a process, examining the physiological changes in response to stressors, as well as the individual's evaluation of stressors in their environment.

Stress and the HPA Axis. When an event is perceived as stressful, a series of processes are stimulated to restore or maintain homeostasis (i.e., physiological equilibrium). Although many systems and structures are involved, the hypothalamic-pituitary-adrenal (HPA) axis is perhaps the most studied system activated during the stress response. When a stressor occurs and is perceived as a demand on the body, the hypothalamus, specifically neural cells within the paraventricular nucleus of the hypothalamus, produce corticotrophin-releasing hormone (CRH), also referred to as corticotrophin-releasing factor (CRF), through blood vessels to the pituitary gland (Stephens & Wand, 2012; Smith & Vale, 2006). As CRH travels to the anterior pituitary gland and binds to receptors, this stimulates the pituitary gland to produce and secrete

adrenocorticotropic hormone (ACTH), which in turns stimulates the adrenal glands to produce glucocorticoid (Stephens & Wand, 2012; Smith & Vale, 2006). In humans, the glucocorticoid produced by the cortex of the adrenal glands is the steroid hormone, cortisol. As cortisol levels increase, ACTH and CRH production is suppressed, which in turn results in a decrease in cortisol secretion. This negative feedback regulates the HPA axis, as well as secretion of hormones and chemical messengers involved in the stress response, restoring the body to homeostasis (Stephens & Wand, 2012; Smith & Vale, 2006).

Cortisol follows a circadian rhythm, rising to a peak shortly after awakening and then falling throughout the day until it reaches its lowest point at night, but has a pulsatile release rhythm as well (see Figure 1, Chung et al., 2011; Herman et al., 2005). The release of cortisol influences behavior, as well as immune system functioning, cardiovascular and metabolic processes throughout the day (Smith & Vale, 2006). Release of cortisol triggered outside of the diurnal pattern, impacting physiological functioning, is considered to be in response to stressors (Herman et al., 2005). Protracted and severe stress responses result in cortisol production remaining high, negatively impacting the individual because of the important roles cortisol has in metabolic and immune functioning, thus, leading to impacted physical and mental health (Stephens & Wand, 2012).

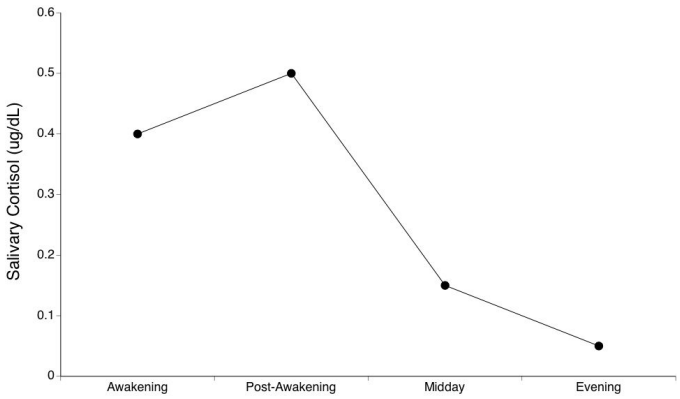

Figure 1. Representation of diurnal cortisol patterns (numbers do not reflect actual data).

Stress During the Perinatal Period. The perinatal period marks a significant time of change to optimize the growth and development of the fetus, including changes with the neuroendocrine system, and specifically the HPA axis. As previously discussed, cortisol production is regulated by a negative feedback loop. However, during pregnancy, regulation of cortisol secretion in the pregnant woman is altered.

During gestation, increased estrogen secretion stimulates production of corticosteroid-binding globulin (CBG), which stimulates the production of cortisol, increasing cortisol levels (Lindsay & Nieman, 2005). CBG increases cortisol levels by slowing the breakdown of cortisol molecules, increasing the half-life of cortisol (Mastorakos & Illias, 2003). Additionally, the placenta produces CRH, which is released into the maternal bloodstream in the second and third trimesters of pregnancy. CRH levels are increased threefold during pregnancy compared to pre-implantation CRH levels (Mastorakos & Ilias, 2003). The production of CRH in turn results in ACTH secretion in the pituitary gland—while these levels do not rise above normal ranges, the increased secretion results in increased cortisol production from the adrenal cortex (Lindsay & Neiman, 2005; Mastorakos & Illias, 2003). Given that the HPA axis relies on a negative feedback loop, increased cortisol levels stimulate further production of CRH, including placental CRH, thus, creating essentially a "positive feed-forward drive" with increasingly higher cortisol levels (Duthie & Reynolds, 2013). As such, cortisol levels peak during the third trimester of pregnancy at two to three times higher than non-pregnancy levels, resulting in pregnancy becoming a period of hypercortisolism (Mastorakos & Illias, 2003).

Following parturition, cortisol, CRH and ACTH levels begin to decline, returning to normal levels. While cortisol levels appear to return to normal quickly after delivery, due to adrenal gland atrophy and increased CBG levels, ACTH and CRH levels appear to be suppressed

during the postpartum period, taking longer to return to pre-pregnancy functioning at approximately 12 weeks postpartum (Mastorakos & Illias, 2003). In postpartum women, HPA axis functioning demonstrates a diminished response to administration of corticosteroids through the first five postpartum weeks (Owens et al., 1987). A diminished response to corticosteroid administration would suggest that the negative feedback loop of the HPA axis has not yet returned to a pre-pregnancy state, as cortisol production is not suppressed following administration of the corticosteroid. Furthermore, recovery of CRH production does not appear to fully return to the pre-pregnant state until the twelfth week postpartum (Magiakou et al., 1996).

Additionally, alterations in stress responses are seen following exposure to physical and psychosocial stressors during the perinatal period. During late pregnancy, women exposed to a physical stressor, via a cold hand stress test, did not show a significant increase in cortisol levels from baseline salivary cortisol measured prior to the stressor (Kammerer et al., 2002). Non-pregnant control subjects did show significant increases in cortisol levels following the stressor (Kammerer et al., 2002). Similar responses are seen when pregnant women experience a psychosocial stressor, such as the Trier Social Stress Test (TSST). The TSST is a laboratory test used to reliably induce psychosocial stress in individuals, resulting in changes in salivary cortisol and ACTH levels (Kirschbaum, Pirke, & Hellhammer, 1993). When administered to pregnant women during the second and third trimester of pregnancy, Entringer and colleagues (2010) found that women in the third trimester showed decreased responses to the TSST compared to women in their second trimester of pregnancy. Additionally, they also found that psychological distress responses (i.e., a Likert scale response to how distressed they were after the TSST) were dampened during pregnancy, with greater decreases in distress responses towards the third

trimester of pregnancy. Distress, as compared to stress, is often a composite of depressive symptoms/measures, anxiety, and stress, and thus, encompasses a broader range of symptomology. These results are in line with previous findings showing that pregnancy is associated with decreased responses regarding perceived stress (Glynn et al., 2001, 2008). It has been suggested that decreased stress responses to physical and psychosocial stressors might provide a protective effect for the fetus from maternal stress responses, such as increased maternal cortisol and ACTH levels (Kammerer et al., 2002).

During the postpartum period, continued diminished responses to physical stress occur, particularly in breastfeeding women. For instance, following a physical stressor, such as exercising on a treadmill, lactating women had lower ACTH and cortisol levels, even as far out as eighteen months postpartum, whereas non-lactating counterparts in the study did not demonstrate the same diminished response to physical stress (Altemus et al., 1995). However, it is less clear how the body responds to psychosocial stress during the postpartum period as conflicting findings have been reported for psychosocial stress in both human and non-human animal models. Previous research with lactating rats, as well as sheep, has found that stressors such as noise and social stress do not evoke the same response in non-lactating animals. However, studies with mice and humans generally do not find differences in response to psychosocial stressors across lactating and non-lactating females, suggesting that there might be species typical differences (for review see Brunton et al., 2008). Altemus and colleagues (2001) administered the TSST to lactating, as well as non-lactating, women and found that ACTH and cortisol levels significantly increased in response to the TSST across both groups, suggesting that there is not an attenuated response to psychosocial stress during the postpartum period. However, Heinrichs and colleagues (2001) found that women who breastfed their baby shortly before the

TSST had reduced ACTH and cortisol levels compared to lactating women who simply held their babies prior to the TSST, suggesting that postpartum women might have a more attenuated response to psychosocial stressors, but only when breastfeeding has occurred in a short period of time before the stressor occurs. Notably, it does appear that responses to stressors are attenuated during the perinatal period, for physical stress, and to some degree, psychosocial stress. Continued breastfeeding appears to bolster the attenuated response in the postpartum period. Importantly, attenuated HPA axis functioning and stress responses may allow for conservation of energy to facilitate milk production, as well as enhanced immune functioning and decreased anxiety and arousal to stressors, allowing mothers to adapt to the demands of their infants (Altemus et al., 1995).

Measuring Stress in Humans

Despite the large amount of extant literature on stress, the lack of consistent conceptualization of stress and the stress response has resulted in measurement problems that influence the comparability of findings across studies. Improved measurement approaches and assessments, as well as improved research designs, can facilitate elucidation of the role of stress on individuals. To this end, it is recommended that stress be approached and measured from multiple levels that encompass physiological, behavioral, and environmental components of stress and stress pathogenesis. According to Lester, Nebel, and Baum (1994), these elements are most commonly captured through self-report assessment, overtly observable behaviors, and physiological or biochemical changes. As such, our discussion on measuring stress in humans will focus on how we can measure stress at multiple levels and highlight exemplars of assessment and measurements approaches across these levels, specifically at the physiological and self-report measurement levels.

Physiological Measurements. Given the importance of cortisol in HPA axis activity and regulation, changes in cortisol levels are often used as an indicator for the physiological or biochemical response to stressors. As such, researchers measure cortisol levels, often through saliva, and use indices of cortisol measurement to examine associations between cortisol levels and behavior and health changes in individuals. Frequently used indices of cortisol levels include area under the curve (AUC), cortisol awakening response (CAR), maximum cortisol increase, diurnal cortisol slope, minimum cortisol value, reactivity and peak reactivity, regression intercept and slope, and percent change (Khoury et al., 2015). The most commonly used measurements are AUC and CAR, thus, our discussion will focus on these two indices of cortisol levels as a physiological indicator of the body's stress response. Prior to discussing indices of cortisol levels, we will discuss the methodologies that can be utilized to collect cortisol in human participants.

Cortisol Collection Methodology. Cortisol can be examined using assays for blood, saliva, urine, hair, and even nails, in human participants. Importantly, measuring cortisol in different biological samples influences the information gained regarding cortisol production, but also acute versus chronic stress/HPA axis activation. Acute stress and HPA axis activation is best examined using blood, saliva, or urine specimens, while assaying hair and nail specimens most accurately represents chronic stress and HPA axis activation. As such, it is important for researchers to carefully consider their research questions and study design when selecting cortisol collection methodology.

When cortisol is released, it circulates in the blood binding to CBG; however, approximately 5% to 10% remains unbound, or active. Some researchers have reported a wider range of 1% to 15% of active cortisol in the blood, suggesting some variability (Clements, 2012;

Aardal & Holm, 1995; Vining et al., 1983). Due to the passive nature in which cortisol is diffused into saliva, there is less active cortisol than in blood, however, the majority of cortisol that is diffused into saliva is active and unbound cortisol (Aardal & Holm, 1995; Vining et al., 1983). Both saliva and blood specimens allow researchers to examine the diurnal rhythm of cortisol, as well pulsatile releases of cortisol, and peaks and troughs of cortisol levels throughout the day (Aardal & Holm, 1995). Thus, indices of cortisol such as AUC and CAR can be calculated from both blood and saliva. However, the collection of blood can be time-consuming, expensive, and painful experiences for participants (Levine et al., 2007a).

As a result, studies using blood specimens to assay cortisol have decreased since researchers developed effective assays for salivary cortisol in the early 1980s, such as Campbell and colleagues (1982). In comparison to blood collection procedures, saliva collection methods are non-invasive, pain-free, and less stressful (Vining et al., 1983; Clements, 2012). Salivary cortisol is also advantageous as elevated CBG levels do not impact assays and more accurately reflect active cortisol levels (Vining et al., 1983). Given the positive correlations between salivary cortisol levels and serum (blood) cortisol levels, the advantages of collecting saliva to assay cortisol have led to increasing use of salivary cortisol, particularly in developmental studies (Levine et al., 2007a).

Lastly, urinary cortisol also serves as an indicator of acute stress. Primarily, urinary cortisol is obtained after a 24-hour collection period, resulting in estimation of total unbound cortisol production rather than the diurnal rhythm of cortisol (Nicolson, 2008). Urine samples can also be sampled throughout the day to examine cortisol's diurnal rhythm (Jerjes et al., 2006). However, urinary cortisol is a less popular collection method in human participants due to the demands placed on the participants to collect, store, and return urine samples, as well as the

burden of storing and transporting urine samples to be assayed (Nicolson, 2008). Furthermore, assays for urinary cortisol often results in artificially high cortisol values and are problematic due to low specificity and precision, potentially resulting in inflated significant findings as a result of falsely high cortisol estimates (Murphy, 2002; Fink et al., 2002).

According to Russell and colleagues (2012), these biological specimens—blood, urine, and saliva—most accurately indicate acute, rather than chronic, HPA axis activation and stress. Although repeated measures can be taken as a proxy for chronic stress, and commonly are with salivary cortisol, repeated collection of urine and blood can be painful and burdensome to participants, as well as costly and time-consuming for researchers (Wright, Hickman, & Laudenslager, 2015). Thus, other biological specimens might be better suited for evaluating chronic stress, such as hair and nail samples.

By using hair samples, researchers presumably are able to estimate chronic stress based on the rate of hair growth. It is assumed that hair grows an average of one centimeter per month, thus a 6-cm hair sample would be representative of cortisol production over the past 6 months (Liu & Doan, 2019; Wright, Hickman, & Laudenslager, 2015; Sauvé et al., 2007). The ability to reliably calculate total cortisol production in hair samples has been validated in adults, as well as infants and children (for review, see Liu & Doan, 2019). Short and colleagues (2016) assert that cortisol concentration in hair was a more reliable indicator of overall cortisol production than indices associated, primarily, with salivary cortisol. Notably, if salivary cortisol is being used to assess acute stress, then it would be reasonable to posit that salivary cortisol indices are not calculating total cortisol production, but HPA axis activation at that present time. It seems straightforward that biological specimens such as hair would better assess total cortisol production than salivary cortisol indices.

A relatively newer approach to estimating cortisol as a function of chronic stress is to use fingernail clippings. Previously, nail clippings have been used to detect toxic substances (Jenkins, 1979 as cited in Liu & Doan, 2019) and more recently has been demonstrated as a useful collection procedure to quantify cortisol production (for review, see Liu & Doan, 2019). While there is less validity data available for nail cortisol, early studies have found that nail cortisol has similar concentrations levels as found in hair (Hubmann et al., 2016) and also has been found to be positively correlated with salivary cortisol, specifically AUC (Izawa et al., 2015). Importantly, the relationship between nail cortisol concentration and psychosocial stress has not been fully elucidated. Some studies have found positive associations between nail cortisol and perceived stress (Wu et al., 2018) or stressful life events (Izawa et al., 2017), but these studies have small sample sizes. Particularly relevant to the current study, as far as we are aware, studies have not examined nail cortisol concentration and perceived stress in the perinatal population as an indicator of chronic stress prior, during, and after pregnancy.

In order to fully understand how these different collection approaches influence our understanding of HPA axis activation, it is important to continue examining biological markers of acute and chronic stress. Careful selection of collection specimens is important for accurately addressing research questions, i.e., acute versus chronic stress. Furthermore, validation in the study sample would also strengthen the use and findings based on the biological specimen selected. For the purposes of the current study, our focus is to examine prenatal and postnatal maternal stress during a relatively short period of time, i.e., the third trimester of pregnancy. As such, sampling salivary cortisol to calculate AUC and CAR work within the design of the study and the research questions posed by the current study.

Area Under the Curve (AUC). Measuring area under the curve allows researchers to

examine cortisol production and changes in cortisol production over repeated measurements; thus, it is a frequently used cortisol index. Previous research has demonstrated that stress is associated with alterations in the magnitude, as well as diurnal rhythm, of cortisol levels, which can result in changes in the magnitude and direction (positive or negative) of AUC. Importantly, AUC can be calculated in two different ways: AUC_G, which is the area under the curve with respect to *ground*, or AUC_I, which is area under the curve with respect to *increase*. Studies have found that individuals experiencing chronic stress have higher AUC_G values (Miller, Chen, & Zhou, 2007), whereas AUC_I is negatively correlated with distress (Vedhara et al., 2003). Pruessner and colleagues (2003) emphasize that these two calculations in AUC capture unique aspects of HPA physiology, which might account for directional differences in correlations with stress measures.

AUC_G allows researchers to capture total cortisol production by summing a series of trapezoids that reflect repeated measurements of cortisol (see Figure 2). However, AUC_G does not necessarily take into account the diurnal rhythm of cortisol production, but overall production of cortisol across the measurement period (Pruessner et al., 2003).

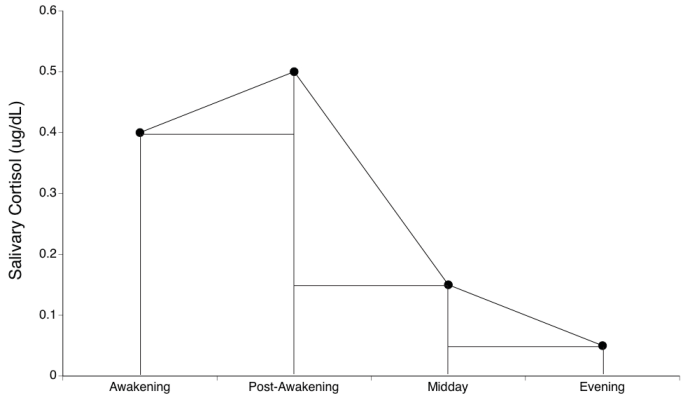

Figure 2. Representation of AUC *with respect to ground*. The summation of the trapezoids are equal to AUC_G.

Conversely, AUC_I highlights the change in cortisol over time by eliminating the "distance from

zero for all measurements" (see Figure 3, Pruessner et al., 2003, p. 919). As such, AUC_I values where there is a decrease over time, such as with diurnal cortisol patterns, can be negative (Pruessner et al., 2003).

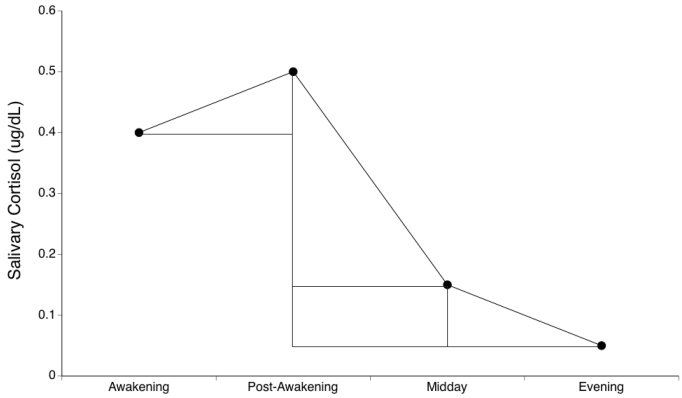

Figure 3. Representation of AUC *with respect to increase*. The summation of the trapezoids are equal to AUC_I and notably do not include the area from the ground to the first measurement.

In a principal component analysis (PCA), Fekedulegn and colleagues (2007) found that AUC_G and AUC_I captured different aspects of the stress response: AUC_G most effectively captured the magnitude of the response and AUC_I most effectively captured the pattern, or rate of change, over the repeated measurement, thus providing support that these two calculations capture different aspects of HPA axis activation and stress response. Similarly, Khoury and colleagues (2015) conducted a PCA using AUC_G and AUC_I to define latent variables and found that additional cortisol measurements, such as maximum cortisol increase, diurnal cortisol slope, minimum cortisol value, reactivity and peak reactivity, regression intercept and slope, and percent change, either reflected cortisol production or change in cortisol over time. Thus, without evidence to suggest that these additional cortisol measurements are actually representative of different components of the stress response not already captured by AUC_G and AUC_I, their inclusion in research studies with AUC indices seems redundant.

Cortisol Awakening Response (CAR). Researchers examining patterns of cortisol

discovered that cortisol levels increased quickly after awakening and this steep awakening response could be indicative of activity within the adrenal glands (Spath-Schwalbe et al., 1992; Linkowski et al., 1993; Van Cauter et al., 1994). Within 30 to 45 minutes after awakening, cortisol levels increase by approximately 50% and remain elevated for approximately one hour (see Figure 1: Awakening to Post-Awakening, Pruessner et al., 1997; Wust et al., 2000). Furthermore, individual CAR levels demonstrated high intra-individual, as well as inter-individual reliability, remaining consistent across days and present in the majority of individuals. Thus, CAR became a useful index for measuring cortisol level and HPA axis functioning (Pruessner et al., 1997; Pruessner, Hellhammer, & Kirschbuam, 1999; Clow et al., 2004). CAR is robust to factors such as sleeping time, awakening in the night, age, contraceptive use in women, smoking, and time of awakening (Wust et al., 2000). Increased or decreased CAR has been associated with physical and psychosocial health risks, such as chronic stress, obesity, and neuropsychiatric disorders, including depression (for review, see Clow, Thorn, Evans, and Hucklebridge, 2004), suggesting that CAR values might reveal an individual's ability to respond to and cope with stressors, as well as the capacity of the adrenal cortex's response to stress (Pruessner et al., 1997; Golden et al., 2013).

As previously discussed, studies have suggested redundancy across cortisol measures, yet CAR is often considered to measure a distinctive component of HPA axis function. However, previous studies have reported mixed findings on the associations between CAR and other cortisol indices. For example, Pruessner and colleagues (1997) found that CAR was significantly and reliably correlated with total cortisol production (i.e., AUC_G), and others have found similar results (Wust et al., 2000; Edwards et al., 2001). However, Golden and colleagues (2013) reported that CAR was poorly correlated with other cortisol measures, specifically AUC.

Importantly, Golden and colleagues suggest that CAR is not related to total cortisol production based on their use of AUC as total cortisol production measurement, but appear to use AUC_I rather than AUC_G, which would more accurately capture total cortisol production. Their use of AUC_I suggests that rather than CAR not being related to total cortisol production, it is not strongly associated with cortisol production across time, which given that it captures the steep awakening response, seems logical. Despite these inconsistencies, CAR provides information about HPA axis activity and function not captured by other measures. Therefore, Clow and colleagues (2010) implore researchers to continue using CAR, but to report the first waking sample and rate of increase, to overcome potential limitations.

Given the complexity of using cortisol indices to accurately assess stress and implications for physical and psychosocial health, continued use of validated and reliable measurements, such as AUC, as well as CAR, within a single study, would provide the most information on how these variables are associated with each other, as well as dependent variables within studies, thus, warranting the use of multiple measurements.

Self-Report Measurements. Psychometric tools, such as self-report questionnaires, allow for evaluation of subjective stress experiences. Quantifying subjective stress allows researchers and clinicians to examine how individuals perceive situations and events as stressful, as well as how an individual's subjective assessment of their stress can influence stress pathogenesis (Vallejo et al., 2018; Kopp et al., 2010). Thus, these assessments are often used to quantify stressful events, such as life events or daily hassles, and capture appraisal of stressors independently of neuroendocrine activity. Additionally, self-report measures are frequently used to evaluate perceived stress because these assessments are inexpensive and easy to administer compared to physiological measures or clinician interviews (Lester et al., 1994; Kopp et al.,

2010). Self-report instruments can capture different elements of perceived stress, including the frequency of life events, how an individual attempts to adapt to events, evaluation of the threat level of a stressor, as well as how distressed an individual becomes in response to events (Lester et al., 1994). However, it is important to ensure that the measurement selected is validated within the population of interest to ensure that the results are meaningful and applicable.

Within the perinatal population, Nast and colleagues (2013) in a systematic review found over 40 assessments that had been utilized in 118 studies evaluating stress during the perinatal period. Primarily, these measures evaluated constructs that aligned with seven categories: anxiety, depression, psychological symptomology not restricted to anxiety or depression, environmental stressors, life events, daily hassles, and lastly, pregnancy and parenting specific stress (Nast et al., 2013). Importantly, not all measures have been validated and found to be reliable in the perinatal population, and given that this period is a time of complex relationships with stress responses, validation within this population is critical. Additionally, while anxiety, depression, and other mental health disorders share overlap with stress, they are separate constructs and individuals can experience mental health disorders and symptomology and stress simultaneously (for review, see Chen, George, & Liberzon, 2017 and Hammen, 2015). Thus, anxiety- and depression-specific measures are assessing *distress* rather than stress, regardless of the validation and reliability within perinatal women. As such, our discussion will be limited to measures validated in the perinatal population that serve to capture stress, rather than distress, specifically focusing on the Perceived Stress Scale (PSS) and its relevance for perinatal populations.

The PSS is perhaps the most commonly disseminated approach for assessing subjective stress experiences (Vallejo et al., 2018). Cohen and colleagues (1983) established the PSS

originally as a 14-item self-report questionnaire designed to assess an individual's level of perceived stress, or the appraisal of stressors in their environment. Evaluating the appraisal of stressors, and how stressful an individual perceives their self to be, again, emphasizes that stressors often precipitate physiological effects of stress—the pathological and physical illnesses that are often associated with continued chronic stress (Cohen et al., 1983). The PSS asks general questions, such as, "In the last month, how often have you been upset because of something that happened unexpectedly?" This allows the individual to appraise the events in their life without necessarily identifying specific events or hassles, which promotes use across genders and life situations (i.e., pregnant versus non-pregnant women). The PSS has been validated across a variety of populations, including college students and a community sample within the United States, as well as samples in Great Britain, France, and Spain (Cohen et al., 1983; Vallejo et al., 2018). Importantly, the PSS is designed for use in community samples and is not designed to be a diagnostic tool within clinical populations; a higher score on the PSS simply means a higher level of perceived stress for the individual. Nast and colleagues (2013) advance the PSS as the best measure that is currently available to assess daily hassles in perinatal populations due to the number of studies conducted with high reliability in pregnant women, as well as the high validity in non-pregnant populations.

There has been some debate as to whether self-report measures that are pregnancy-specific are better at examining the effects of stress during pregnancy than general stressors. DiPietro and colleagues (2002, 2004) developed a measure of assessing stress that is pregnancy-specific and suggest that this pregnancy-specific measure better predicts the contributions of stress to outcomes than non-pregnancy specific stress. Similarly, Lobel and colleagues (2008) found that pregnancy-specific stress measures might better elucidate contributions of stress to

later outcomes than general stress. However, Solivan and colleagues (2015) assessed perceived stress in pregnant women using a pregnancy-specific instrument, the Prenatal Psychosocial Profile, and the PSS. In their study, they did not find differences in perceived stress levels and found that the two measures were significantly positive correlated, suggesting that the PSS accurately assesses perceived stress levels in pregnant women. Notably, DiPietro and colleagues (2002, 2004) utilized a measure, Daily Stress Inventory (DSI) to assess non-pregnancy specific stress, which captures daily hassles rather than stress appraisal, which might contribute to why the pregnancy-specific instrument had a stronger relationship with infant outcomes than the DSI. However, Lobel and colleagues (2008) utilized the PSS-4, an abbreviated version of the PSS scale, which has been shown to have good validity within perinatal populations (Lee, 2012), so it is less clear why Lobel et al. (2008) and Solivan et al. (2015) might have found different results for the PSS. However, it is important note that Solivan et al. (2015) do not specify the trimester of pregnancy and evaluates stress within women who were pregnant during Hurricane Katrina, which is a specific stressful event, and thus, might explain the differences in findings.

It is important to recognize that the perinatal period presents unique stressors, including physical changes, concerns regarding parenting, fear about labor and delivery, as well as concerns or fears for the baby's health. However, utilizing a non-clinical instrument to assess stress in a perinatal community population allows researchers to use the same measure to assess stress during the prenatal and postnatal periods. Limited literature is available that has examined the relationship between prenatal and postnatal subjective stress measures. Duffy and colleagues (2018) found that hair cortisol levels during pregnancy were not significantly correlated with postnatal perceived stress. Their results suggest that the relationship between physiological indicators of stress and subjective stress may continue to be muddled postpartum. As far as we

are aware, research has not examined how PSS scores specifically are correlated across the prenatal and postnatal periods. Thus, this study aims to further elucidate how non-pregnancy specific perceived stress measures are associated with physiological indicators of the stress response during the perinatal period.

Associations between Cortisol and Subjective Stress. The use of multilevel assessments of stress is important for elucidating the role of stress in health and behavioral outcomes. However, there are inconsistent findings on associations between subjective stress and physiological indicators of stress, particularly within the perinatal population. It is possible that conflicting findings are a result of the cortisol indices used or the measure of stress, or well-being, used, as well as the trimester of pregnancy in which cortisol and stress and well-being are measured.

For instance, Kalra and colleagues (2007) measured hair cortisol and stress using the PSS-10 during the late first or early second trimester and found PSS scores and hair cortisol levels were significantly, albeit moderately, positively correlated. Similarly, Harville and colleagues (2009) found moderate positive correlations between salivary cortisol and PSS in the first trimester and CRH and PSS in the late second trimester. However, other measures of anxiety, depression, life events, and pregnancy-specific stress measures were not correlated with cortisol or CRH levels. Relatedly, when examining salivary cortisol in pregnant women during the third trimester of pregnancy, Kivlighan and colleagues (2010) found that diurnal cortisol rhythms were not associated with maternal self-report of stress levels assessed via the PSS-10, as well as a pregnancy-specific measure of stress and hassles. Similar findings of non-significant correlations can be found throughout the literature examining perinatal stress and subjective stress, or psychological well-being (Voegtline et al., 2013; Davis & Sandman, 2010; Braig et al.,

2016; Rothenberger et al., 2011). Notably, measures of perceived stress, depression, and anxiety in these studies are often positively correlated (Harville et al., 2009).

These inconsistencies are indicative of the difficulties present with quantifying stress, as well as the differences that exist between subjective evaluations of stress, such as daily hassles and stress appraisal, and neuroendocrine activity, such as cortisol levels, and highlight the need for multiple measures of stress in research studies. They also emphasize that the relationship between subjective stress and cortisol as an explanation for outcomes in mothers and infants needs to be further explored. As we will discuss, cortisol is often an explanation for negative infant and fetal outcomes, but a lack of significant associations between perceived stress and cortisol suggests that other causal pathways and mechanisms should be explored as potential mediators or moderators of the relationship between stress and infant outcomes.

The Impact of Maternal Perinatal Stress on Infant Outcomes

The perinatal period is an important time for growth and development for the fetus. Fetal experiences can influence later outcomes during infancy and even into adulthood; similarly early postnatal experiences can continue to influence later outcomes. Environmental experiences, such as maternal prenatal stress, have important implications for behavioral and health outcomes. These changes in risks and developmental outcome are often considered to be the result of fetal programming, which involves fetal adaptations to experiences that shape physiological systems (Gluckman & Hanson, 2004; Morely, Blair, Dwyer, & Owens, 2002).

Research in human and non-human animal studies suggests that exposure to glucocorticoids during prenatal development is necessary for typical brain development, and can even be beneficial, suggesting that exposure to cortisol is not solely associated with increased health and behavioral risks and negative infant outcomes, but is important and necessary for fetal

physiological development (for review, see DiPietro, 2004; Matthews, 2000; Trejo, Cuchillo, Machin, & Rua, 2000; Welberg & Seckl, 2001). However, continued exposure to excessive glucocorticoid levels during the prenatal period could have adverse impacts on development and growth, such as preterm delivery, low birth weight, and aberrant development across psychological domains, such as cognition and motor domains (Wadhwa et al., 2004; Bolten et al., 2011; Davis & Sandman, 2010). The extant literature has primarily focused on associations between *prenatal* maternal stress and later infant outcomes and risks as a result of fetal exposure to high levels of glucocorticoids, or unusually attenuated stress responses, while less research has examined how *postnatal* maternal stress may impact the same outcomes and health risks, and which mechanisms might influence infant development and outcomes.

Further complicating the relationship between maternal cortisol and infant outcomes is the role of subjective stress on infant outcomes. Previous research has suggested that the relationship between subjective stress and cortisol are often mixed or negative; however, cortisol continues to be attributed as the primary mechanism linking maternal psychosocial stress and infant outcomes. Published studies have often examined these variables in isolation, measuring either cortisol or perceived stress, in relation to infant health and behavioral outcomes (Lobel et al., 2008; Sable & Wilkinson, 2010; Laplante et al., 2004, Simcock et al., 2016). Additionally, research has not always examined both the prenatal and postnatal period for stress and resulting outcomes; thus, it is critical to closely examine how stress, as measured both by cortisol and subjective stress measures, might influence later health and developmental outcomes, particularly given the complexity of stress and its effects on both mother and offspring.

Maternal Prenatal Stress and Infant Health. Research has examined infant health outcomes associated with maternal prenatal stress, particularly birth weight and gestational age

at delivery. For instance, Sable and Wilkinson (2000) found that maternal perceived stress during pregnancy was significantly predictive of low birth weight, such that mothers who indicated that they "almost always" felt stressed during pregnancy were more likely to have infants with low birth weight. Similarly, Wadhwa and colleagues (1993) found that number of life events during pregnancy were significantly associated with infant birth weight, such that more prenatal life events were associated with a decrease in infant birth weight (Wadhwa et al., 1993). However, Lobel and colleagues (2008) did not find that pregnancy-specific anxiety or perceived stress were significant predictors for birth weight. A number of studies have also reported not finding significant relationships between maternal distress, or stress, and infant birth weight, and often found that other confounding variables explained the variance in birth weight, such as smoking (for extensive review, see Graignic-Phillipe et al., 2014).

While Lobel and colleagues (2008) did not find significant correlations between birth weight and distress, they did report that pregnancy-specific anxiety was a significant predictor for gestational age, such that mothers who reported higher levels of anxiety were more likely to deliver preterm compared to mothers with lower levels of pregnancy-specific anxiety. Notably, perceived stress, as measured via the PSS-4, did not significantly predict gestational age—nor did it predict birth weight as mentioned above, suggesting that maternal distress, or at least pregnancy-specific distress, might have a greater impact on infant outcomes, as has been previously suggested (Lobel et al., 2008). However, other studies have reported that higher maternal report of distress, and *stress,* during pregnancy was associated with preterm delivery (Gunter, 1963; Schwartz, 1979; Sable & Wilkinson, 2000; Glynn et al, 2001; for review, see Graignic-Phillipe et al., 2014). Interestingly, Phelan and colleagues (2015) studied how psychosocial stress during pregnancy, specifically first pregnancies, might impact infant health

during the first postpartum year. They found that maternal report of infant sickness, i.e., urgent care and emergency room visits, were higher in infants whose mothers indicated higher prenatal stress. Overall, these findings suggest that maternal prenatal stress and distress are associated with infant health outcomes at birth such as birth weight, gestational age, but also physical illnesses during infancy.

While the bulk of research has focused on maternal subjective assessment of distress, a few studies have examined neuroendocrine activity during pregnancy and infant birth outcomes. Wadhwa and colleagues (2004) measured maternal plasma CRH levels during the third trimester of pregnancy and found that elevated CRH levels were significantly associated with increased risk for preterm delivery, as well as fetal growth restriction. Interestingly, women who delivered postterm had significantly lower levels of CRH than women who delivered at term (Wadhwa et al., 2004). Relatedly, Bolten and colleagues (2011) also examined neuroendocrine activity during gestation, specifically salivary CAR, and found that mothers with increased CAR delivered infants with lower birth weights. Taken together, these findings suggest that HPA axis activity is an important component of timing in pregnancy and overexposure to stress-related hormones could result in premature delivery of infants, as well increase risk of low birth weight or fetal growth restriction.

Maternal Prenatal Stress and Infant Psychological Development. In addition to infant health and growth outcomes, maternal prenatal stress also has been associated with infant development across psychological domains, such as cognition and motor skills. Interestingly, the timing and measurement of stress, i.e., cortisol or subjective stress, influenced the findings across psychological domains. This is suggestive of the muddled findings regarding associations between maternal cortisol and maternal subjective stress assessment, and again, highlights the

importance of not examining cortisol as an indicator of stress or subjective stress assessment in isolation, but in conjunction with other measures, to best understand the relationship between maternal prenatal stress and infant psychological development.

Davis and Sandman (2010) examined the relationship between maternal prenatal stress during early and late gestation and infant mental development, using both cortisol and maternal report of pregnancy-specific anxiety and perceived stress. Infant mental development was assessed using the Bayley Scale of Infant Development (BSID) at 3, 6, and 12 months to determine if maternal prenatal stress was predictive of infant mental development, using the Mental Development Index (MDI) scale on the BSID. It was found that cortisol, at both early and late gestation sampling points, was predictive of infant mental development at 12 months (Davis and Sandman, 2010). The MDI at 12 months includes behaviors such as placing one cube in a cup, responding to verbal requests, and placing a single puzzle piece. Interestingly, lower maternal cortisol during the first trimester predicted a steeper rate of mental development across the first postnatal year with higher MDI scores at 12 months, but so did *higher* maternal cortisol during the third trimester. Comparatively, infants with higher cortisol exposure during the first trimester had lower MDI scores (Davis & Sandman, 2010). Consequently, these findings support the assertion that exposure to glucocorticoids can have both facilitatory and adverse impacts on infant development dependent upon the timing of cortisol exposure. During early gestation, the fetus is protected from overexposure to increasing cortisol level; however, during the third trimester, exposure to glucocorticoids becomes important for fetal growth and development (Davis & Sandman, 2010).

In the study conducted by Davis and Sandman (2010), pregnancy-specific anxiety, but not perceived stress, was predictive of infant mental development, such that higher pregnancy-

specific anxiety during early gestation predicted lower MDI scores at 12 months of age. However, Laplante and colleagues (2004) found that MDI scores at 2 years of age were associated with maternal prenatal stress. Following a natural disaster, women that were pregnant during the event were asked to evaluate their experience with the stressor, assessing threat, loss, scope (exposure to event), and change that was a result of the disaster. Prenatal stress exposure was a significant predictor of toddler MDI scores, such that high levels of perceived stress resulted in lower MDI scores (Laplante et al., 2004). Furthermore, this association was strengthened in mothers who were earlier in their pregnancy when the disaster occurred, which corroborates the findings reported by Davis and Sandman (2010).

In addition to infant cognitive development, maternal prenatal stress might also have implications for infant motor development. Similar to the study conducted by Laplante et al. (2004), Simcock and colleagues (2016) examined the relationship between maternal prenatal stress following exposure to a natural disaster and infant developmental outcomes, specifically infant gross and fine motor development. Maternal objective assessment of the disaster, (i.e., number of days without power, loss of personal income, physically hurt, number of times residence changed), was used to evaluate the severity of the disaster exposure during pregnancy, as well as subjective stress assessment and distress (Simcock et al., 2016). Evaluation of objective assessment allowed the researchers to control for these disaster-specific events and evaluate maternal appraisal of their stress levels (i.e., intrusive thoughts, feelings of helplessness, avoidance). Simcock et al. (2016) reported positive associations with motor development at two months, such that higher prenatal maternal stress was correlated with higher motor scores; however, at later ages, specifically 6 and 16 months, prenatal maternal stress and motor development were *negatively* correlated. This was particularly the case for infants whose

mothers experienced the disaster later in gestation and mothers that endorsed a more negative evaluation of the disaster (Simcock et al., 2016). This is contradictory to previous findings with cognitive development in that higher stress in late gestation was associated with accelerated cognitive development. Additional studies corroborate that prenatal maternal stress during late gestation is associated with deficits in motor skills in infancy, as well as into childhood and adolescence (Cao et al., 2104; Grace et al., 2016; Moss et al., 2017). Simcock and colleagues (2016) hypothesize that late gestation maternal stress might adversely impact the development of the cerebellum and impact an individual's motor control and coordination abilities.

Collectively, these findings highlight the importance of severity, as well as timing, of maternal prenatal stress on infant cognitive and motor outcomes. Exposure to increased stress, through high cortisol concentration or high levels of maternal stress and distress, during early gestation appears to have adverse outcomes on infant cognitive abilities during infancy and toddlerhood, while late gestation maternal stress appears to have the greatest adverse impact on infant motor development. Furthermore, these associations between maternal prenatal stress and infant developmental outcomes continue beyond infancy into childhood and even adolescence. As such, it is important to contemplate how continued exposure to maternal postnatal stress might impact continued infant development, thus, posing the question, does postnatal stress exposure have further detrimental effects on infant development?

Maternal Postpartum Stress and Infant Development. As has been discussed, the timing of stress exposure appears to play a pivotal role on infant outcomes; however, most studies have focused on the prenatal period or have examined maternal distress rather than stress. In fact, we were only able to find two studies that utilized a stress measure rather than distress measures, emphasizing the need for studies examining postpartum maternal stress. As such, the

discussion will focus on studies examining both maternal stress and distress in the postpartum period on infant outcomes.

With regards to maternal stress, Keim and colleagues (2011) examined postpartum maternal stress using the PSS-10 and infant cognitive and motor abilities (Mullen Early Learning Scale) and found that PSS scores were positively correlated with cognitive and language abilities. Postpartum perceived stress was not predictive of negative cognitive outcomes (Keim et al., 2011). Interestingly, they found that PSS scores were associated with gross motor ability, such that infants who were at the lowest and highest levels of maternal perceived stress demonstrated slightly advanced motor skills compared to infants whose mothers fell into the median range of PSS scores (Keim et al., 2011). This is contradictory to the findings reported by DiPietro and colleagues (2006) who found that moderate, but not high, exposure to maternal distress prenatally resulted in advanced development in offspring, but does corroborate the findings of Davis and Sandman (2010) who found that high levels of stress in late gestation was predictive of advanced cognitive development. However, it is important to note that the DiPietro et al. (2006) and Davis and Sandman (2010) studies were examining prenatal stress and distress rather than postpartum stress and thus different mechanisms could, and likely, influence these findings. Karam et al. (2016) also reported that postpartum maternal stress was negatively associated with gross motor ability, replicating the findings of Keim et al. (2011).

Additional studies have examined maternal distress and found significant relationships with infant motor development. For instance, Piallini and colleagues (2016) examined how maternal subclinical symptoms of depression influenced motor development during the first postnatal year. By examining aspects of mental health that do not reach diagnosis criteria, findings from these types of studies can begin to elucidate how maternal health at a subclinical

level impacts infant outcomes (Piallini et al., 2016). They found that aspects of maternal distress, such as depression, hostility, and psychological distress status, were predictive of infant motor abilities, particularly gross motor ability. In sum, it appears that infant motor development is significantly associated with maternal postpartum stress, as well as subclinical mental health symptomology, (i.e., subclinical depression), suggesting that it is important to examine the relationship between maternal stress/subclinical symptoms and infant developmental outcomes rather than focusing on the prenatal period only, or symptomology that reaches a diagnostic level.

Researchers have more reliably found associations between maternal postpartum distress, such as postpartum depression and anxiety, with infant socioemotional development, and to a lesser extent cognitive development. For example, maternal postnatal distress has been shown to be associated with infant sociability, including social engagement and fear of strangers, throughout the first year after birth (Albertsson-Karlgren et al., 2000; Feldman et al., 2009; Matthey et al., 2005). Murray (1992) found that mothers who had more severe postpartum depression (PPD) had infants with poorer performance on cognitive tasks than infants whose mothers had lower depression scores. As previously mentioned, Keim and colleagues (2011) did find significant correlations between cognitive and language abilities and postpartum stress; however, other researchers have not found associations with maternal postpartum distress and infant cognitive development. For instance, Cornish and colleagues (2005) examined PPD and language development at 12 months and did not find significant correlations between the variables. Similarly, Kaspers et al. (2009) reported non-significant findings between postpartum psychological symptoms and infant mental development at 12 months.

It is important to note that across these studies, infants are often assessed at different

developmental time points and with different instruments, which could contribute to mixed findings across studies. Additionally, given the limited number of studies that have examined postpartum rather than prenatal maternal distress and stress, these cited studies are across a variety of populations, including different cultural samples and high-risk samples. While these aspects muddle our understanding of how maternal postpartum stress might influence infant outcomes, it also highlights the need for future studies that examine postpartum maternal stress and infant outcomes rather than maternal distress or stress during the prenatal period. Of significance, adverse impacts on infant psychological development as a result of maternal postpartum stress suggests that a mediating or moderating variable might be influencing these associations—perhaps maternal responsiveness or infant attachment—and is an important aspect to explore in future studies.

Early Motor Outcomes: A Window into Infant Psychological Development

Thus far, evidence has been presented on the relationship between maternal perinatal stress and infant psychological development, including gross motor abilities. Research has found that maternal perinatal mental health may influence infant motor behavior, as well as cognitive abilities. While there is existing literature on these relationships, this study seeks to further examine the relationship between maternal perinatal stress and infant motor behavior, due to the importance of early motor development. Infant motor behavior provides an overt means of examining developmental change. Infant motor milestone achievement timescales have been well established based on decades of research that provide norms for transitions in motor behavior (for review, see Adolph, Rachwani, & Hoch, 2018). Studying motor behavior provides an advantage over other psychological domains, such as cognition, as these are often inferred from other behavioral measures, and thus, are changing covertly, contrary to motor behavior

(Adolph, Hoch, & Cole, 2018).

Significantly, changes in motor abilities occur simultaneously with changes in other psychological domains, including cognition and social skills (Clearfield, Osborne, & Mullen, 2008; Iverson, 2010). The transition to crawling allows infants to explore their environment, and interact with objects as well as their caregivers (Campos et al., 2000). Independent locomotion alters the experiences that the infant has, and through those experiences changes in other domains are facilitated, and perhaps instigated, as posited by Adolph and colleagues (2019). Thus, achievement of independent locomotion has a cascading effect on development and as such delays in motor milestone achievement may result in delays in social skills, cognition, as well as language acquisition (Clearfield, 2011; Clearfield, Osborne, & Mullen, 2008). Of utmost importance, motor development does not occur in an isolated bubble, but is subject to physiological processes and changes, environmental variables, as well as cultural practices and social contexts. Therefore, infant motor development provides a series of behavioral changes that are observable, allowing researchers to examine how risk factors, such as maternal perinatal health or maternal behavior, may impact motor development with implications across infant psychological domains.

Maternal-Infant Physical Touch

Sensory experiences allow the infant to interact with their environment and gain information about their surroundings, but it also promotes communication and bonding with caregivers. Additionally, research has suggested that these early experiences support development of cognition, self-regulation, as well as motor behavior (Feldman et al., 2002; Feldman et al., 2003; Feldman, Singer, & Zagoory, 2010). Infants gain one type of sensory experience through touch—both maternal-initiated and infant-initiated touch.

The Importance of Early Tactile Stimulation. Early sensory stimulation, such as touch, is important for the development and growth of the infant. Early sensory deprivation could have negative impacts on growth and development of offspring, both human and non-human. Gonzalez and colleagues (2001) manipulated maternal care in postnatal rat pups by leaving some to be reared by their dam while others were removed and reared, isolated, in cups. Isolation-reared pups weighed less at weaning than dam-reared pups, despite controlling for nutritional intake. Additionally, as adults, isolation-reared pups engaged in less maternal behavior, such as licking and grooming, implicating transgenerational effects of early sensory deprivation. While the effects of isolation rearing on later maternal behavior could be ameliorated to some degree if pups received tactile stimulation, maternal behavior was still reduced compared to pups reared by their dam that received licking and grooming. According to Ferber and colleagues (2008), licking and grooming behavior in rodents is comparable to affectionate touch in humans, thus, highlighting the importance of this early deprivation. Licking and grooming in rat pups also serves other purposes, such as stimulating the pup to urinate and defecate.

In humans, much of the evidence linking touch and tactile stimulation to negative developmental outcomes is the result of studies examining early deprivation in children, such as children in institutional orphanages, as well as studies examining cross-cultural differences in rearing practice that either promote or restrict tactile stimulation. In Central and Eastern Europe, it has been estimated that over one million children are placed in institutional orphanages that are understaffed and rely on poorly trained staff to provide care to the children placed in their care (Nelson, 2007). As a result, sensory stimulation, particularly affectionate tactile stimulation, is minimal. Children raised in these institutions exhibit delays in physical growth, as well as their cognitive and socioemotional development (Carlson & Earls, 1997). In an attempt to study early

deprivation, as well as establish an intervention project for these institutions, Zeanah and colleagues (2003) removed some children from these institutions and placed them in foster care and compared their later outcomes with children who remained in institutional care, as well as children raised by their biological parents. Findings from this intervention project suggest that placing children in foster care over institutional orphanages boosts physical growth, as well as psychological development, such as cognitive and language skills (Nelson et al., 2007).

Comparably, studies examining cross-cultural rearing practices have found that early tactile stimulation influences the onset of motor skills. In regions of Africa, including West Africa, rearing practices promote tactile stimulation through the bouncing, shaking, and rubbing of limbs, and as a result infants typically have an earlier onset of motor behavior, including independent walking (Bril & Sabatier, 1986; Hopkins & Westra, 1988). Conversely, in some regions of China, infants are placed on their back in sandbags, restricting their movement as well as reducing tactile stimulation, until they are toilet trained, resulting in delays of motor skills (Mei, 1994). Importantly, rearing practices that promote tactile stimulation are not necessarily seen in Western cultures. Thus, Lobo and Galloway (2012) had caregivers in the United States provide infants with increased handling and positioning, similar to that provided by mothers in some Eastern cultures. At time of recruitment, infants were two months of age and received three weeks of increased tactile stimulation. They found that after three weeks of increased experience with handling and positioning, infant posture advanced with improved control of the head, limbs, and trunk (Lobo & Galloway, 2012). Furthermore, infants that experienced increased tactile stimulation showed earlier onset of crawling and walking behavior than the control group. These findings suggest that increased tactile stimulation can facilitate the development of infant motor development, resulting in improved motor control at earlier ages, but also earlier onset of

locomotion (Lobo & Galloway, 2012). Understanding the importance of touch during development allows us to examine how variations in tactile stimulation might impact infant outcomes, as well as to study risk factors (i.e., maternal health) that might impact early tactile stimulation.

Development and Classification of Maternal-Infant Touch. According to Stack and Muir (1990), maternal touch occurs in the majority of maternal-infant interactions, specifically face-to-face interactions. Thus, the ways that mothers touch their infants is an important aspect of building future interactions. Touch during the early postnatal period encompasses many different types of tactile stimulation, including massage, breastfeeding, and skin-to-skin contact. Maternal touch has also been further classified based on the assumed intent or purpose of maternal touch, such as affectionate or stimulating touch. Affectionate touch includes behaviors such as caressing, holding, and light stroking whereas as stimulating touch refers to firm patting and stroking, massages, or touches that adjust or change the infant's body positioning (Ferber, Feldman, & Makhoul, 2008). During the first 6 months, mothers engage in high frequencies of affectionate and stimulating touch with affectionate touch dominating interactions. Affectionate and stimulating touch begin to significantly decrease after 6 months postpartum (Ferber, Feldman, & Makhoul, 2008; Feldman, 2011). Previous research has found that breastfeeding mothers engage in increased maternal touch during free-play sessions, suggesting that rates of maternal touch are influenced by maternal feeding practices (Kuzela, Stifter, and Worobey, 1990). Furthermore, breastfeeding rates begin to decline after six months postpartum, with less than 25% of women continuing to exclusively breastfeed (Breastfeeding Report Card, 2018); thus, this change in feeding practice could also contribute to changes in rates of maternal touch particularly after 6 months postpartum. Maternal touch can also be intrusive, i.e., rough handling

of the infant, or insensitivity to infant cues (Feldman, 2011). Factors such as premature birth or maternal postpartum depression are often associated with changes in maternal touch from affectionate to intrusive (Feldman, 2011).

During bouts of maternal-infant interactions, infant-initiated touch is occurring 85% of the time (Moszkowski & Stack, 2007). However, the majority of literature that examines how mother-infant dyads interact focuses not on infant-initiated touch during maternal-infant interactions, but other infant behavior, such as gaze and affect. Given that infant-initiated touch is prominent in these dyadic interactions, it is important to further classify infant-initiated touch during development, as well as touch within maternal-infant interactions, as infant-initiated touch may also play an important role in influencing future maternal-infant interactions.

Previous studies examining infant touch have done so using the still face (SF) paradigm (i.e., Moszkowski & Stack, 2007). The SF paradigm consists of two face-to-face interactions where the infant and mother are able to interact naturally. These periods of natural interaction are separated by a period where the mother is instructed to maintain a neutral face and refrain from interacting with their infant, including through touch. Primarily, these studies have examined how infants are touching—self-regulatory touches, touching items such as clothing or seat, or touching their mothers (Moszkowski & Stack, 2007). Moszkowski and Stack (2007) found that during times of the still face, infants engaged in greater self-touch when mothers were not available for interactions. Infants also spent a large part of the natural interaction periods touching their mothers, both before and after the still face. The findings suggest that infants attempt to adjust their touching behavior across interactions, notably switching to self-touch, when they are not able touch their mothers (Moszkowski & Stack, 2007). This seems to indicate that infants are responsive to changes in maternal communication cues.

Thus far, research has not examined how infant touch occurs in settings outside of the SF paradigm, nor has it examined how infant-initiated touch changes during development. In an unpublished study conducted in our laboratory, we examined the development of infant touch at 8, 12, and 16 months during free-play sessions. Infant-initiated touch was categorized based on changes in posture or locomotor behavior. Active touch was coded when infants utilized the caregiver to change posture or motor behavior. For example, if the infant used the leg of the caregiver to transition from a sitting posture to a standing posture. Passive touch was coded when the infant touched a caregiver in a non-supporting manner. For instance, if the infant touched the caregiver as they crawled to reach a toy. Preliminary findings from this study suggest that infants engage primarily in passive touch during these free-play sessions, with subtle decreases in the duration of passive touch from 8 to16 months. This decrease seems intuitive as infants are becoming more mobile and are able to explore their environment. Thus, interactions with caregivers, such as mothers, may switch from touch to other behavior and modalities (i.e., gaze and shared attention).

Overall, these studies suggest that how mothers and infants touch is important and also is a very malleable behavior that undergoes developmental changes, as infants become more independent explorers of their surroundings. While there is limited research available on infant-initiated touch behavior, the infant is an active participant in maternal-infant interactions, thus, it is crucial to further explore how infant touch develops and changes, but also the overlap in touch behavior during maternal-infant interactions.

The Synchrony of Maternal-Infant Physical Touch. Notably, few studies have examined the synchrony and overlap of maternal-infant touch. Mantis and colleagues (2014) were the first to examine bidirectional touch in maternal-infant dyads in typically developing

infants at five and half months of age, as well as in preterm and low birth weight infants, using the SF paradigm. Touch interactions were classified as one-sided touch, one-sided touch with movement, or mutual touch. In one-sided touch, one individual within the dyad touched the other, either actively or passively, without a response from the other. In one-sided with movement, the initial touch evoked a response, such as movement, but not necessarily a reciprocating touch. Lastly, mutual touch was coded when both members of the dyad engaged in active and reciprocal touch behavior (Mantis et al., 2014). Both typically-developing and low birth weight/premature infants predominantly engaged in mutual touch and one-sided touch with movement, however preterm and low birth weight infants had reduced durations of mutual touch following the perturbation period of the SF paradigm (Mantis et al., 2014). This may be indicative of differences in self-regulation in preterm versus term infants (Mantis et al., 2014). These findings also suggest that maternal-infant synchrony, with regards to touch, is better captured when quantifying both maternal and infant touch behavior rather than examining these variables separately. By understanding how maternal-infant dyads engage in mutual touch, we can begin to explore how risk factors, such as maternal perinatal mental health, can impact and alter touch patterns in these dyadic relationships.

Maternal-Infant Physical Touch and Infant Gross Motor Outcomes

Developmental processes across all domains, but particularly for motor development, do not occur in isolation. Rather the development of motor behavior reflects refinement in neural and muscle activity, but also is the result of mechanical stimulation of bones and muscles, as well as input from environmental factors during both the prenatal and postnatal period, such as maternal perinatal health. However, environmental experiences are not limited strictly to health factors, but also opportunities presented to infants to explore and interact with their

surroundings, including the caregiver.

One form of environmental experience and opportunity is tactile stimulation, including maternal-infant touch. As discussed previously, cultural rearing practices can facilitate or hinder motor development. Active touch behavior, such as facilitating an upright posture, provides infant with practice and experience with standing. Infants that are provided with daily stepping practice begin to walk earlier than infants who were provided with non-stepping exercises (Zelazo, 1983; Zelazo, Zelazo, & Kolb, 1972). As caregivers provide experience and opportunity to engage in new behaviors that serve to scaffold later motor behavior, infant developmental trajectories are influenced. Experiences that occur during early development, as well as current experiences, can influence developmental outcomes, therefore, it is important to examine both early and current influences on infant developmental trajectories.

The importance of early touch experience is persistent and long lasting. Studies have found that when preterm infants were provided with increased tactile stimulation for a ten-day period, infants demonstrated improved developmental and growth outcomes following the ten-day period, but also at follow-ups one year after the tactile stimulation intervention occurred, including performance on the Bayley motor assessment (Field et al., 1986; Scafidi et al., 1986). The current literature has not yet examined how early touch experiences in maternal-infant dyadic interactions might impact motor development. However, previous research suggests the importance of touch for motor outcomes. Thus, this study aimed to further understanding of how early touch influences motor development. In particular, we propose that examining touch at 6 months postnatally allows us to capture a time when touch interactions, chiefly maternal touch, are likely to be higher than at other times during development. In turn, this would allow us to examine how these early experiences might have lasting impacts on infant's developmental

trajectories.

The Effects of Maternal Perinatal Stress on Maternal-Infant Physical Touch

The maternal-infant relationship is perhaps one of the most important relationships for an infant, particularly during the perinatal period. According to Ainsworth and Marvin (1995), infants rely on their mothers to provide a level of security, or a safe base, to promote infant exploration. Maternal-infant dyadic relationships can be impacted by maternal mental health, including psychopathology and stress, resulting in adverse and persistent outcomes in offspring. As previously discussed, maternal-infant touch is an important behavior found in interactions between the mother and infant. Both mother and infant are sensitive to cues exhibited by responses and adjust their future interactions based on those cues. If mothers are exhibiting psychological symptoms of depression, anxiety, stress, or other mental health issues, this could impact maternal-infant touch behavior.

Research in humans has primarily focused on the role of maternal psychopathology, such as depression and anxiety; however, non-human animal models shed light on how maternal-infant touch is associated with stress measures, such as cortisol. In non-human animal studies, it has been demonstrated that exposure to stressors can result in reduced maternal behavior (Fride & Weinstock, 1988; Andrews, Sunderland, & Rosenblum, 1993; von Holst, 1974). For instance, Bahr and colleagues (1998) found that ventro-ventral contact in gorillas—the gorilla analogy of skin-to-skin contact—was reduced in females that had higher levels of cortisol postpartum. As maternal postpartum stress levels increased, as measured through urinary cortisol, body contact and ventro-ventral contact were decreased. In females with extremely high cortisol levels, maternal behavior was drastically reduced with almost no body contact, which resulted in the death of the infant in one maternal-infant dyad (Bahr et al., 1998). These findings implicate

postpartum maternal stress as a factor that can adversely impact maternal touch behavior in non-human primates. In humans, skin-to-skin contact (SSC) has been associated with decreased salivary cortisol levels. Bigelow and colleagues (2012) found that in maternal SSC intervention groups, increased SSC resulted in a larger reduction in salivary cortisol in the first postpartum month compared to mothers in the control group. In parallel to the findings of Bahr et al. (1998), these findings highlight that SSC is associated with postpartum maternal stress and that increased SSC might have beneficial effects.

While Bahr and colleagues (1998) highlight the adverse outcomes on maternal behavior, Bigelow et al. (2012) emphasize the benefits of SSC on mothers, which could translate into changes in maternal behavior. Wolf and colleagues (2018) found differences in maternal-infant interactions during the SF paradigm in mothers with high versus low psychosocial stress (composite score of negative life events and self-report of social support), but not perceived stress (measured by perceived stress and distress measures). Maternal-infant dyads with higher psychosocial prenatal stress had increased positive maternal-infant interactions, consisting of play and positive engagement, during the first SF interaction compared to low prenatal psychosocial stress dyads. In maternal-infant dyads where the mother had increased diurnal cortisol prenatally, as well as a steeper decline in cortisol, interactions were more negative, (i.e., intrusive maternal behavior), in the second SF interaction following the perturbation (Wolf et al., 2018). However, an earlier study conducted by Denham and Moser (1994) found that stress impacted infant attachment with higher stress resulting in less attached infants; however, higher maternal stress did not impact maternal behaviors, such as imitation of the infant, acknowledgement of infant's interest, and verbally discussing infant's emotions. It is possible that design differences might contribute to these varying results. Denham and Moser (1994)

utilized a free-play session, whereas Wolf et al. (2018) utilized the SF paradigm, which introduces a perturbation in maternal-infant interactions that could influence changes in maternal-infant behavior within brief interactions.

Outstandingly, there are a limited number of published studies examining maternal perinatal stress on maternal-infant touch and of the studies discussed here, those studies focus almost exclusively on maternal behavior rather than infant behavior, nor are there studies examining synchronous maternal-infant mutual touch. Given that these maternal-infant dyads exhibit mutual bidirectional interactions, it is crucial to begin examining mutual maternal-infant touch and maternal perinatal stress to better understand how maternal mental health, (i.e., stress) affects offspring developmental trajectories.

Purpose of the Current Study

The purpose of the current study was to investigate the relationship between maternal perinatal stress and infant motor outcomes, as well as if maternal-physical touch influenced this relationship. The extant literature has examined associations between maternal perinatal stress and infant developmental outcomes, including gross motor behavior, as well as how maternal perinatal stress is related to maternal-infant interactions. Across these studies, stress, whether through cortisol exposure during gestation or subjective stress of the mother across the perinatal period, is often attributed as the underlying mechanism in changes to infant developmental outcomes. The current study posits that changes in infant motor outcomes might not be the direct result of subjective stress during the prenatal or postpartum period or due to exposure to cortisol during gestation, but that this relationship is mediated by changes in maternal-infant physical touch.

Thus, the current study used a longitudinal design to measure maternal stress, through

salivary cortisol and the PSS-14, during the third trimester of pregnancy and at 6 months postpartum. We also examined maternal-infant physical touch at 6 months of age. The six-month postnatal session was selected as our time point for maternal-infant physical touch for three reasons: 1.) to coincide with the last measure of maternal stress, 2.) to capture high frequencies of maternal touch, which might change after 6 months due to decreased breastfeeding rates, as well as changes in how mothers interact with their infants, and 3.) given that previous findings suggest that maternal-infant physical touch begins to decrease after 8 months of age during free-play sessions (unpublished findings). Lastly, we examined infant gross motor milestone achievement at 13 to 14 months of age, given that studies have suggested that associations between maternal perinatal stress and infant developmental outcomes are persistent through infancy and into childhood and adolescence. As such, we would expect that early exposure to maternal perinatal stress and changes in maternal-infant physical touch, would have persistent effects on infant motor milestone achievement in the current study. Additionally, measuring motor outcomes at or around 14 months should allow us to see the most variability in infant motor behavior, with infants demonstrating cruising, standing, and walking based on established development norms for 14 months of age.

The current study sought to address four separate research objectives. The first objective was to examine the association (i.e., correlations) between maternal perceived stress during the prenatal and postnatal periods, as well as the association between maternal perceived stress and maternal cortisol levels (see Figure 4). This objective has three distinct hypotheses:

Hypothesis 1A: There would be a positive correlation between perceived stress during the prenatal period and perceived stress during the postnatal period.

Hypothesis 1B: There would not be a significant correlation between perceived stress

during the prenatal period and prenatal cortisol levels.

Hypothesis 1C: There would not be a significant correlation between prenatal cortisol levels and perceived stress during the postnatal period.

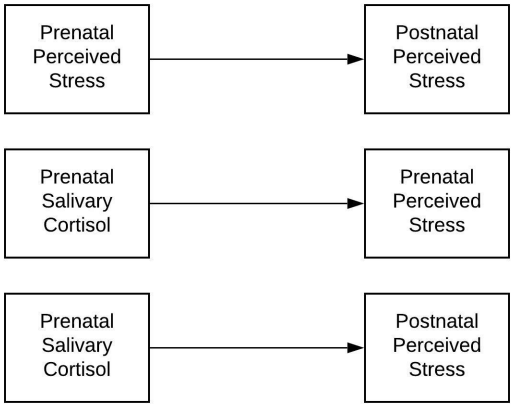

Figure 4. *The association between maternal perinatal stress during the prenatal and postnatal periods.*

The second objective of this study sought to examine the relationship (i.e., linear regression) between maternal perinatal stress and maternal infant-physical touch at six months postpartum (see Figure 5). This question also has three distinct hypotheses:

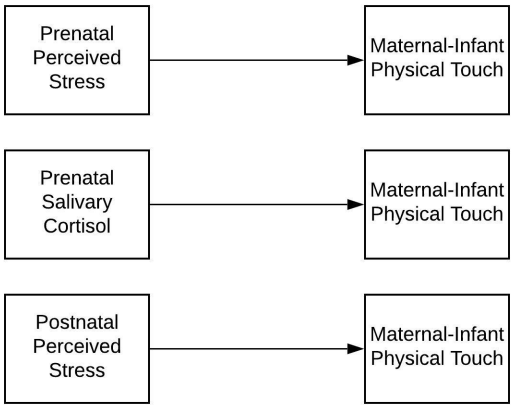

Figure 5. *The relationship between maternal perinatal stress and maternal-infant physical touch.*

Hypothesis 2A: Participants that report higher perceived stress during pregnancy would

have lower duration of maternal-infant physical touch at 6 months postnatal.

Hypothesis 2B: Participants with higher prenatal cortisol levels would have lower durations of maternal-infant physical touch at 6 months postnatal.

Hypothesis 2C: Participants that report higher perceived stress postnatally would have lower duration of physical touch postnatally.

The third research objective examined the relationship (i.e., linear regression) between maternal perinatal stress and infant motor milestone achievement (see Figure 6). This research question has three hypotheses:

Hypothesis 3A: Participants who report higher prenatal perceived stress would have infants with lower motor scores at 14 months of age.

Hypothesis 3B: Participants who had higher prenatal cortisol levels would have infant with lower motor scores at 14 months of age.

Hypothesis 3C: Participants who report higher perceived stress 6 months postpartum would have infants with lower motor scores at 14 months of age.

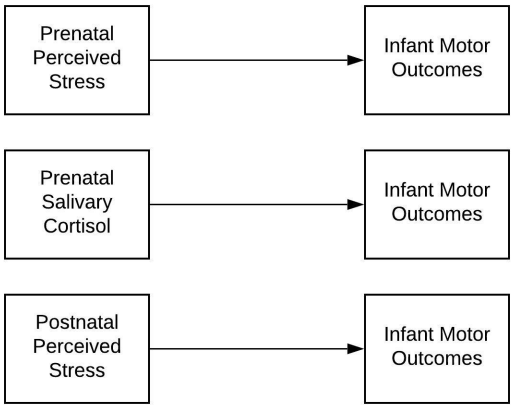

Figure 6. *The relationship between maternal perinatal stress and infant motor outcomes.*

Lastly, the fourth research objective examined the hypothesis that maternal-infant physical touch mediates the relationship between maternal perinatal stress and infant motor

milestone achievement, such that mothers who reported higher perceived stress during the prenatal or postnatal period, or who had higher prenatal cortisol levels, would engage in lower physical touch with their infants at 6 months postnatally, resulting in lower infant gross motor milestone scores at 14 months of age (see Figure 7).

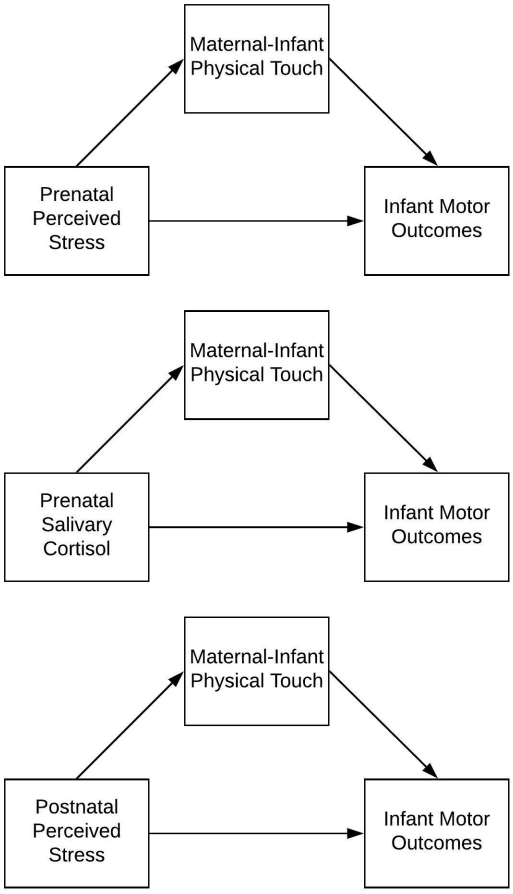

Figure 7. *A mediation model of maternal perinatal stress, infant motor outcome, and maternal-infant physical touch.*

Methods

The data included in the current study was collected as part of the larger Infant Development and Healthy Outcomes in Mothers (IDAHO Mom) and Long-Term Follow-Up (LTFU) studies conducted at Idaho State University. For the larger study, data was collected during the third trimester of pregnancy and at 6 months, 10 months, 13 to 14 months, and 18 months postnatally. Data collection began in April 2015 and was completed in July 2018. For the

purposes of the current study, data from the prenatal session, 6-month postnatal session, and 13 to 14-month postnatal session was used.

Participants

A total of 125 participants completed the prenatal session during the third trimester of pregnancy, 96 completed their 6-month postnatal session, and 53 completed their 14-month postnatal session. Demographic information was collected at the prenatal session, including age, ethnicity, martial status, employment and household income, and education level. Religious affiliation was collected at the 6-month postnatal session.

Procedures

Recruitment. Pregnant females were recruited through advertisement materials distributed to local services for women and children (i.e., Department of Health and Welfare, local WIC offices, and doctor offices). Participants also were recruited through ISU's weekly email distributions to student and faculty mailing lists, as well as through the university's research participation management web-based system (SONA). Lastly, participants were recruited via advertisements on social media websites, specifically Facebook. A total of 506 individuals were contacted regarding participating in the study. Interested individuals were contacted and asked to briefly answer a screening questionnaire to determine their eligibility (see **Inclusion and Exclusion Criteria** below) in participating in the study. If a participant was eligible for the study, they were scheduled for their prenatal session, which took place in the laboratory.

Inclusion and Exclusion Criteria. To be considered for participation, individuals needed to be pregnant females between 18 and 35 years of age, who were between 33 to 37 weeks gestation, and fluent in English. If participants were not yet in their 33rd week of gestation,

a follow-up call was scheduled to screen and schedule their session closer to the 33rd-37th week of gestation. Participants were not considered for participation if they had multiple births (i.e., twins) or maternal or infant conditions that impacted endocrine functioning. Individuals who endorsed a diagnosis of severe mental or physical illness, recreational substance usage or excessive alcohol consumption, or medications with documented negative fetal effects were deemed ineligible for participation. Infants were not excluded from the study if they had a developmental disorder, however, our sample did not have any developmental disorder diagnoses reported during the study.

Prenatal Session. During the third trimester of pregnancy, participants were asked to come into the laboratory where they met with trained research assistants (RAs) who went over the study consent form for participation. A copy of the informed consent form was provided to participants for their records. As part of the informed consent procedure, privacy and confidentiality protocols for all sessions were described to the participant. All identifying information, including contact information, was disassociated from their documents and securely stored and locked. All electronic documents containing participant information are secured using password protected electronic documents and saved on a computer that is password protected.

Once the participant agreed to participate and signed the consent form, a RA collected anthropometric measurements, including height, weight, and waist circumference. Additionally, participants were asked a series of questions regarding mental health history, pregnancy and health history, and demographics, including ethnicity, household income, and education level. Participants were then asked to complete several self-report measures, including mental health history, diet, risk-taking behavior, maternal sensitivity and maternal responsiveness. For the current study, only a few of these measures were selected and will be discussed in detail in a

later section. Following completion of the interview and self-report portion of the session, participants were provided with a saliva sample collection kit and the sampling procedure was explained to them. The RA scheduled a time to collect the samples from the participants following the 3-day sampling period. Participants received cash compensation for participation in the prenatal session, as well as for the saliva samples.

Saliva Collection Procedures. Participants were provided with a 3-day saliva sample collection kit, which contained 12 2-mL cryovials, plastic straws approximately 55 mm in length, and instructions on how to use the cryovials and straw to collect saliva via passive drooling. Participants were provided with a worksheet that indicated time of samples with entries for the participants to record the actual time that the sample was collected for each day and sample time. Participants were asked to avoid eating, drinking fluids besides water, or smoking immediately prior to the sample time, to avoid contamination. Additionally, participants were asked to store their samples in the freezer until collected at the end of the sampling period. Participants were instructed to collect saliva samples immediately after awakening, 30 minutes after awakening, one hour post-awakening, and immediately prior to bedtime for the 3-day sampling period. In order to maintain consistency, it was requested that participants select a 3-day sampling period that most accurately reflect their typical schedule. After the sampling period, samples were gathered from the participant and stored in a freezer until they were delivered to the ISU Molecular Core Research Facility for analyses (see **Salivary Cortisol Assays**).

6-Month Postnatal Session. Participants that completed their prenatal session were contacted one-month post-delivery date to confirm the infant's date of birth and adjust the postnatal session date as needed. Additional reminder calls were conducted one month, one week, and one day prior to the session to confirm the date and time with the participant. On the

day of the postnatal session, participants returned to the laboratory where they were met by 2 trained RAs. The participant and their infant were led to the behavioral observation room for a 20-minute behavioral observation, which included a caregiving task, where participants were asked to change their infant into gender neutral clothing, a quasi free-play task, a block task, and lastly, an arm restraint task. For the current study, only the quasi free-play task portion of the behavioral observation was utilized. During the 7-minute quasi free-play task, participants were invited to play with their infants using a set of toys provided by the laboratory. Notably, participants were asked to complete a maternal report of infant health during the free-play task. Thus, while the task allows for naturalistic play, it also introduced a structured task and thus is not a true free-play task (hence quasi free-play). For ease of communication, future references to this task will be referred to as the free-play task. Recording of the behavioral observation was done with 3 to 5 AXIS cameras mounted to either the ceiling (3 angles) or the wall (2 angles) and was stored in the AXIS camera management software until exported at the completion of the postnatal session. A microphone fed into one of the AXIS cameras and camera management software captured audio from the session.

Following the behavioral observation portion of the session, participants returned to the laboratory and anthropometric measurements were collected from both mother and infant, including height/length, weight, and waist circumference. Participants were then asked to complete a series of questionnaires administered by the RA, as well as self-report measures, similar to those completed during the prenatal session. In addition, participants also provided information on their labor and delivery, as well as infant's health since birth, infant behavior, and infant diet and breastfeeding. After completing the postnatal session, participants were provided with cash compensation, in the amount of $30, for their participation.

Long-Term Follow-Up Sessions. Participants that completed the prenatal session or the prenatal and postnatal session were contacted regarding participating in a follow-up study on their infant's development. Participants were asked to return to the lab when the infant was 10 months, 13 to 14 months, and 18 months of age. Similar procedures as previously described were followed for contacting and scheduling participants. On the day of the sessions, the same behavioral observation tasks were recorded and anthropometry of the infant was collected. Maternal report of infant development, including diet, health, sleep, language development, motor development, sensory processing, and infant equipment use, was collected. After completing the session or returning the mail packet, participants were compensated for their participation. After completing the session, participants were provided with cash compensation ($30) for their participation.

Mail Packet Procedures. To reduce attrition across sessions, participants were provided the option of completing postnatal sessions and long-term follow-up sessions via a mail packet. Participants were sent a packet that included all measures from the appropriate session for completion, as well as a stamped envelope to return the packet in once they had finished. This allowed participants to continue their participation without requiring them to physically return to the lab. Notably, this meant the loss of behavioral observation sessions for the individuals/dyads, which reduced the sample size for some analyses in the current study (see Table 1). Compensation was the same as for in-person sessions and was mailed to the participant upon receiving their completed mail packet.

Primary Variables of Interest

Variables of interest in the current study included self-report of maternal prenatal and postnatal perceived stress, maternal prenatal salivary cortisol measurements, maternal-infant

physical touch interactions from the behavioral observation free-play task, and maternal report of infant gross motor development. Each primary variable of interest included in the proposed models will be discussed in greater detail.

Table 1
Participant Counts across Postnatal and Long-Term Follow-Up Sessions

	6-Month Postnatal Session	10-Month Long-Term Follow-Up Session	13/14-Month Long-Term Follow-Up Session	18-Month Long-Term Follow-Up Session
In-Person	95*	37	45*	43
Mail Packet	1	7	8	11

**Sessions used for current study*

Primary Variables of Interest

Variables of interest in the current study included self-report of maternal prenatal and postnatal perceived stress, maternal prenatal salivary cortisol measurements, maternal-infant physical touch interactions from the behavioral observation free-play task, and maternal report of infant gross motor development. Each primary variable of interest included in the proposed models will be discussed in greater detail.

Maternal Perceived Stress. To evaluate maternal perceived stress, responses on the Perceived Stress Scale Feelings Questionnaire (PSS-FQ) were used. The PSS-14 is a 14-item self-report questionnaire that is designed to evaluate how an individual perceives events as stressful (see Appendix A; Cohen, Kamarck, & Mermelstein, 1983). Each item is rated on a five point Likert scale (0 = Never to 4 = Very often). Positive items (4-7, 9, 10, and 13) are reversed coded and then a total score is computed from the sum of all 14 items using the 7 reversed coded items. Individuals can score from 0 to 56, with higher scores indicating higher endorsement of perceived stress by the individual.

In multiple college student samples, as well as a community smoking cessation sample,

the PSS-FQ demonstrated sufficient reliability (Cronbach's α=0.84, 0.85, 0.86), and was found to be a more accurate predictor of health outcomes than life event scores, as assessed by the College Student Life-Event Schedule (CSLES, Cohen et al., 1983). While the PSS-14 (the PSS-FQ version used in the current study) has not been validated in pregnant women, adaptations of the PSS-14, specifically the PSS-10 (α=0.74) and PSS-4 (α=0.79), have been validated in pregnant samples (Lee, 2012). Additionally, the PSS-14 demonstrated sufficient reliability (Cronbach's *a*=0.80 and 0.78, respectively) in the current sample at both the prenatal and 6-month postnatal session, as demonstrated by Riedstra and colleagues (unpublished).

Maternal Salivary Cortisol. The ISU Molecular Core Research Facility analyzed participant saliva samples for cortisol using salivary cortisol ELISA assay kits purchased from Salimetrics. Assays were conducted in duplicate for each sample such that each participant had a total of 24 samples analyzed. The specificity for the ELISA assay kit for cortisol is less than 0.007 ug/dL and has the ability to detect cortisol concentration values ranging between 0.012-3.00 ug/dL. Once the ELISA assays were completed, a coefficient of variation (CV%) was calculated to determine the intra-replicate variation. Sample concentrations were eliminated if the CV% between the replicates exceeded 15% and the concentration values differed by 0.007 ug/dL. Cortisol concentrations greater than 4 ug/dL were eliminated, as they are unlikely to be physiologically plausible. From the cortisol concentration values, three separate cortisol response values were calculated and used for analyses purposes: the cortisol awakening response (CAR), area under the curve with respect to ground (AUC_G) and area under the curve with respect to increase (AUC_I). Values from the 3-day sampling were averaged to create average CAR and AUC values for each participant.

As far as we are aware, established normative ranges for cortisol have not been

published; however, previous studies using salivary cortisol in pregnant woman have reported averages of 0.36 to 0.41 ug/dL during the 33rd through 40th week of gestation (Allolio et al., 1990) and 0.25 to 0.48 ug/dL during the 36th week of gestation (Kivlighan et al., 2008). Thus, we anticipated similar cortisol concentration ranges in the current sample. For CAR values, it has been suggested that a cortisol response occurs when an individual's post-awakening sample demonstrates an increase by 0.09 ug/dL from their baseline (Weitzman et al., 1971;Wust et al., 2000). Wust and colleagues (2000) reported increases from awakening to 30 minutes post-awakening values ranging from -0.01 to 0.56 ug/dL in non-pregnant populations. Thus, we anticipated similar CAR values in our sample. Notably, larger increases reflect a steeper slope, which is indicative of a more rapid increase in cortisol levels after awakening. Higher CAR values have been associated with persistent pain and chronic stress (Geiss et al., 1997; Pruessner et al., 1999).

It is less straightforward to provide typical ranges for AUC values given that these require calculations based on the number of measurements and time intervals within each individual sample. For instance, our study collected four samples at specific times, however, other studies might collect five samples at 30-minute intervals. Thus, the changes and total cortisol production within those time intervals would differ, making parallel interpretation difficult. Interpretations of AUC are restricted to the shape of the curve, thus individuals with higher cortisol production would have a greater area under the curve when assessed by AUC_G and values would be continuous, although not negative given that zero is always included as a reference point. Conversely, AUC_I might result in negative values if there was a steeper decrease over time than increase, as is typically seen with diurnal cortisol patterns (Pruessner et al., 2003). Thus, given that our study examined diurnal patterns of cortisol production, we anticipated

negative AUC_I values in our range.

Maternal-Infant Physical Touch. The 7-minute free-play session during the 6-month postnatal session was scored during video playback at normal speed using an event recorder program, Mangold INTERACT, which records the onset/offset and frequency of behavior. During video playback, physical touch between the mother and infant was coded for frequency and duration of touch. Physical touch behavior consists of interactions where the infant and mother interact through physical contact. These interactions of physical touch behavior were categorized as either maternal-initiated or infant-initiated touch. Maternal-initiated touch was further classified as active, passive, or restrictive. Infant-initiated touch was further classified as active or passive. Active touch was defined as touch that directly results in the transitioning of the infant's body, head, or limbs, positioning, posture or locomotor behavior. For example, if the infant used the mother to push their self up from a sitting position to a standing position. Similarly, if a mother lifted the infant from a sitting position to a standing position, this was classified as active touch. Active touch was coded until the initiator ended physical contact, at which point either no behavior was actively coded or the next bout of behavior began. Passive touch was defined as any touch, between mother and infant, which did not result in a transition of the infant's posture or motor behavior. Passive touch was coded until the initiator ended the touch or engaged in a new touch bout. Lastly, restrictive touch was a touch behavior that results in preventing the infant from transitioning their posture or motor behavior. For instance, if the mother grabbed the child by their leg to prevent them from crawling away, this was classified as restrictive touch. The inter- and intra-rater reliability for touch behavioral coding for maternal-infant dyads from 6 to 18 months was $\kappa = 0.89$ and 0.90, respectively. Due to low occurrence of touch behavior, maternal-infant physical touch behavior was collapsed and summed for a total

duration and frequency of maternal-infant touch for the current study. Future follow-up studies, outside of the current study, may examine types of touch behavior separately.

Infant Gross Motor Behavior. To evaluate infant gross motor behavior, we used the Gross Motor scale from the Infant Development Inventory (IDI). The IDI assesses infant development across five domains: social, self-help, gross motor, fine motor, and language (see Appendix B, Ireton, 2005). The IDI is derived from the Minnesota Child Development Inventories and maps on well to the Bayley scales of Infant Development; in particular, the MCDI was positively correlated with the gross motor score on the Bayley (r=0.58*,* Creighton & Sauvé, 1988). The IDI consists of 78 items divided across five domains that describe behaviors infants may or may not engage in, starting at birth and ending at 21 months of age. The mother indicates behaviors that their infant demonstrates regularly by using a check mark and behaviors that the infant is just beginning to demonstrate by a "B". Behaviors that the infant has not yet begun to demonstrate are not marked at all.

Typically, to score the IDI, the infant's development is compared to the infant's age. An "age line" is drawn at the infant's actual age and a 70% line is drawn at 70% of the infant's age. For example, if the infant is 18 months, then the 70% age line is drawn in at 12.5 months. If the infant's behavior, as indicated by check marks, is above 80% of their age, they are classified as typically developing, at 70-79%, borderline, and below 70% of their age is classified as delayed. Since the current study was not expecting to see borderline or delayed development, we scored the IDI by summing the behaviors that the infant showed from 7 months of age, the age where mothers are instructed to begin for the 14 month session, through the end of the IDI at 21 months of age. Entries left blank by the mother were assigned a zero, as were entries marked with a "B" as beginning since the infant was only beginning to show these behaviors and was not

demonstrating them regularly or well at the time. Entries marked with a checkmark were assigned a one value. The total IDI score provided a continuous variable that indicated the number of age-typical motor milestones that an infant demonstrated at 14 months; thus, lower scores indicated less motor milestone achievement and higher scores indicated normative, or advanced, motor milestone achievement.

Gross Motor Milestones Assessed by the IDI. As mentioned above, for the 14-month session, gross motor behavior from 7 months through 21 months was indicated as present, beginning, or absent. The behaviors indicated on the IDI have been established as motor behavior norms for infants and thus a summed total provided an estimation of motor milestone achievement. However, it is important to understand the behaviors that have been established as norms based on how the infant is developing across this timescale. As such, we will briefly review infant gross motor development as assessed by the IDI from 7 months through 21 months.

At 7 months of age, infants typically are able to sit alone and steady. This ability to sit independently without propping demonstrates that the infants have gained postural control of not only their trunk, but their head and extremities as well. This postural control also demonstrates that infants are adapting to, and overcoming, gravity. This progression of control is a rostral-caudal process, with the head and trunk gaining control first, followed by the neck, shoulders, waist, and lastly, hips (Hopkins & Ronnqvist, 2002; Saavedra, van Donkelaar, & Woollacott, 2012). At 8 months through 9 months, infants typically are beginning to develop early crawling behavior, such as moving forward on their stomachs, as well as beginning to crawl on their hands and knees with stomachs off the ground. As infants are gaining control of their limbs and trunks, they can now begin to balance, resting on their stomachs, lifting their arms or head, and can begin to use their bellies to propel themselves (for review, see Adolph & Franchak, 2016). As

infants continue to gain balance, they can then begin to lift their bellies, followed by their knees and arms, to crawl on their hands and knees rather than belly crawling. From about 9 months through 12 months of age, infants develop increased stability in their balance and postural control of the trunk, and as such, begin to stand. At first, infants typically can stand by holding onto objects and even begin cruising behavior, where they are "walking" by holding onto objects or individuals to support themselves, but later begin to standing alone, unsupported by objects or individuals, steadily. Again, these transitions from sitting to standing with support to standing alone demonstrate how the infant is continuing to gain postural control and stability in their balance. At 13 months of age through 15 months of age, infants are typically independent walkers—walking without help and soon beginning to run. This change in their gait and abilities requires the development of not only posture and balance as previously discussed, but also muscle strength as walking requires that the infant is strong enough to be able to fully support the body on one leg as the other leg takes a step (McGraw, 1945; Hallemans, De Clercq, & Aerts, 2006). From 15 through 21 months and beyond, infants and toddlers typically are skillful walkers that are now beginning to run and manipulate objects with their feet (i.e., kicking a ball), in addition to their hands. Continued balance and coordination emerge as the child continues to grow and develop, gaining experience, strength, and stability.

Covariates

Potential covariates in the current study included maternal age, infant gestational age, parity, and breastfeeding duration. Each potential covariate will be discussed in greater detail.

Maternal Age. Maternal age was calculated at the prenatal session by the participant's reported birth date, which was measured by the Prenatal Session Screener. Notably, maternal age was restricted in the current sample to 18 through 35 years of age at the time of the prenatal

session.

Parity. Parity was measured as the number of live births that the participant had endorsed at the prenatal session. Participants were asked to note the number of live births on the Pregnancy Context questionnaire.

Gestational Age. Gestational age (in weeks) at birth was calculated based on infant's delivery date and mother's last menstrual period. Last menstrual period was established via the Pregnancy Context measure and infant's delivery date was reported on the 6-Month Postnatal Session Screener.

Breastfeeding Duration. Breastfeeding duration was determined using an open ended item on the Infant Dietary Questionnaire which asked the participants for how many months, weeks, and days they breastfed their infants at the 14 month session. Although participants reported duration in this format, for analysis purposes, duration was calculated as the number of days that a participant engaged in breastfeeding.

Data Analysis

Data analysis was performed using SPSS statistical software. Descriptive statistics for demographics, primary study variables, as well as potential covariates, are provided. Correlation, regression, and mediation analyses were conducted to examine associations among maternal perinatal stress, maternal-infant physical touch, and infant gross motor behavior. A significance level of $p < .05$ was adopted for all tests. All tests are two-tailed tests and all variables used in the current study were continuous variables.

Prior to running analyses, statistical test assumptions were checked and detailed in the results section. As needed, transformed variable(s) was used for analyses. First, correlations between maternal perceived stress and maternal cortisol levels were examined (see Figure 4). For

these analyses, data were analyzed using Pearson's correlations to examine the association between prenatal and postnatal perceived stress (as measured by the PSS-14), prenatal perceived stress and prenatal cortisol (CAR, AUC_G, and AUC_I), and prenatal cortisol and postnatal perceived stress. Next, the relationship between maternal perinatal stress and maternal-infant physical touch was examined (see Figure 5). Instances of maternal-initiated and infant-initiated touch were summed together for a total duration and total frequency of maternal-infant touch at 6 months. Regression analyses were conducted to examine the relationship between prenatal perceived stress and total maternal-infant physical touch at 6 months, prenatal cortisol and total maternal-infant physical touch at 6 months, and postnatal perceived stress and total maternal-infant physical touch at 6 months. For these analyses, maternal perinatal stress was the predictor variable and maternal-infant physical touch was the outcome variable. For the next series of analyses, linear regression was used to examine the relationship between maternal perinatal stress indices (predictor variable) and total infant IDI gross motor scores at 14 months (outcome variable), as seen in Figure 6.

A mediation model was proposed to examine maternal perinatal stress on infant gross motor scores as mediated by maternal-infant physical touch (see Figure 7). An *a priori* power analysis showed that a sample size of 68 participants is necessary for sufficient power in the final mediation model with a medium effect size and power of 0.80. Due to missing data and attrition, the sample size for the most complex model was below the recommended sample size according to the power analyses (n=51). The proposed mediation model was performed using Hayes' (2017) PROCESS macro, specifically model 4, which tests for mediation of the direct effect between maternal perinatal stress and infant gross motor outcomes by maternal-infant physical touch. The PROCESS macro uses bootstrapping, which uses sampling with replacement, to

create a bootstrap sample that is the same size as the original sample. This was repeated 5000 times to create a sampling distribution and results in bias-corrected 95% confidence intervals. These confidence intervals are used to determine whether the indirect effect, or mediated effect, is significant. The range of the confidence intervals determines significance; if the confidence intervals include 0 then there is not a significant indirect effect.

Results

Descriptive Statistics

Descriptive statistics showed that on average participants were 27 years of age when they first enrolled in the study. The majority of participants were Caucasian, married, and identified their religious affiliation as the Church of Jesus Christ of Latter-Day Saints (see Table 2 in Appendix C). Additionally, the largest percentage of mothers had a total household income of $50,000-$74,999 (25%) and had received a college or university degree (i.e., bachelor's degree; 37%). Thirty-seven percent of women enrolled in the study were pregnant for the first time and 30% of women had given birth to one other child prior to participating in the study (see Table 2 in Appendix C). Gestational age for infants ranged from 37.3 weeks to 42.3 weeks with 46% of women delivering between 39 to 40 weeks.

The average prenatal perceived stress level as measured by the PSS-14 was 19.9 out of 56 possible points (*SD* = 6.55). The average prenatal maternal cortisol value ranged from 0.21 ug/dL (*SD* = 0.18) to 0.62 ug/dL (*SD* = 0.28). The average prenatal value for maternal cortisol as measured by AUC_G was 340.23 ug/dL (*SD* = 110) with values ranging from 118.16 ug/dL to 681.55 ug/Dl. The average value for prenatal maternal cortisol as measured by AUC_I was -50.68 ug/dL (*SD* = 127) with values ranging from -367.55 ug/dL to 379.74 ug/dL. The average value for maternal prenatal cortisol as measured by CAR was 0.13 ug/dL (*SD* = .18) with values

ranging from -0.62 ug/dL to 0.70 ug/dL. Lastly, the average postnatal PSS-14 score was 20.2 (*SD* = 5.95, see Table 3).

Table 3
Maternal Perinatal Stress Indices Averages

Measure	Mean (SD)	*n*
Prenatal PSS score	19.9 (6.55)	125
Prenatal cortisol sample 1 (awakening)	0.49 (0.23)	95
Prenatal cortisol sample 2 (30m after awakening)	0.62 (0.28)	95
Prenatal cortisol sample 3 (1hr after awakening)	0.60 (0.26)	95
Prenatal cortisol sample 4 (immediately prior to bedtime)	0.21 (0.18)	95
Prenatal AUC_G	340.23 (110.31)	77
Prenatal AUC_I	-50.68 (127.02)	78
Prenatal CAR	0.13 (0.18)	95
Postnatal PSS scores	20.16(5.95)	96

**Prenatal Cortisol Sample values represent the average cortisol value for that sample across the 3-day sampling period, all cortisol values are reported in ug/dL units.*

During the 6-month postnatal session, there was an average duration of total maternal-infant physical touch of 62.42 seconds (*SD* = 83.16) and an average frequency of 10 touches (*SD* = 8) during the 7-minute free-play session. (see Table 4) At 14 months, infants demonstrated an average score of 8 points (*SD* = 2) on the gross motor scale of the IDI out of a possible 10 points. At the 14-month LTFU session, 34% of mothers were still currently breastfeeding their infants. The average duration of breastfeeding was 271.28 days, or approximately 9 months (see Table 4).

Table 4
Maternal and Infant Variables

Measure	Mean (SD)
Duration of maternal-infant physical touch (seconds)	62.42 (83.16)
Frequency of maternal-infant physical touch	10 (8)
IDI gross motor summed score	8 (2)
Breastfeeding duration at 14 months (days)	271.28 (160.06)

Hypothesis 1: Associations Among Maternal Stress Indices in the Perinatal Period

Correlation Assumptions. Prior to conducting correlational analyses for relationships among maternal perinatal stress variables, specifically maternal prenatal PSS-14 scores, maternal

postnatal PSS-14 scores, maternal AUC_G, AUC_I, and CAR, correlation assumptions were assessed. Preliminary analyses showed that the relationship among these variables was linear and normally distributed as assessed by Shapiro-Wilk's test ($p > .05$), with the exception of AUC_G ($p < .05$). There were two outliers (±3 *SD*) detected for maternal cortisol concentration values, one for AUC_G and one for CAR. Given that the outlier for CAR did not affect the variable's linear relationship or distribution, it was not removed to avoid restricting range or removal of stressed participants. However, given the severity of the outlier for AUC_G, it was removed from analyses. Once the outlier was removed, the AUC_G variable no longer violated the assumption of normality.

Primary Analyses. A Pearson's product-moment correlation was run to assess the relationship between maternal prenatal perceived stress and maternal postnatal perceived stress at 6 months postpartum. There was a significant positive correlation between prenatal PSS-14 scores and postnatal PSS-14 scores, $r(96) = .58$, $p = .001$, such that mothers who reported higher prenatal perceived stress reported higher postnatal perceived stress (see Table 5). Next, a series of Pearson's product-moment correlations were run to assess the relationship between maternal prenatal cortisol levels, including AUC_G, AUC_I, and CAR, and maternal prenatal perceived stress. There were no statistically significant correlations between maternal prenatal cortisol (AUC_G $p = .49$, AUC_I $p = .68$, CAR $p = .15$) and maternal prenatal PSS-14 scores (see Table 5). Lastly, a series of Pearson's product-moment correlations were run to assess the relationship between maternal prenatal cortisol levels and maternal postnatal perceived stress. There were no statistically significant correlations between maternal prenatal cortisol and maternal postnatal perceived stress as measured by the PSS-14 (AUC_G $p = .93$, AUC_I $p = .25$, CAR $p = .33$; see Table 5).

Table 5
Pearson's Correlation Coefficients for Maternal Perinatal Stress Indices

	Maternal Postnatal Perceived Stress	**Maternal Prenatal AUC_G**	**Maternal Prenatal AUC_I**	**Maternal Prenatal CAR**
Maternal Prenatal Perceived Stress	**.58****	.08	-.05	.15
Maternal Postnatal Perceived Stress	1	-.01	-.15	.12

**Correlation is significant at the $p < .01$ level

Hypothesis 2: The Relationship between Maternal Perinatal Stress and Maternal-Infant Physical Touch

Regression Assumptions. Prior to examining the relationship between maternal perinatal stress indices and maternal-infant physical touch, regression assumptions were assessed. Previous analyses (Hypothesis 1) identified two outliers for AUC_G and CAR and were addressed above. An additional three outliers were identified for total maternal-infant physical touch duration; however, these outliers were not deleted due to the importance of variability in touch behavior. Furthermore, total maternal-infant touch duration was substantially positively skewed and was transformed using a logarithmic transformation, which brought the skewness to an acceptable value. Following transformation of the variable, no outliers were identified in casewise diagnostics. Similarly, an outlier was identified for total maternal-infant touch frequency. Total maternal-infant touch frequency was moderately positively skewed and was transformed using a square root transformation, which brought skewness to acceptable levels. The transformed variables for duration and frequency were used for all analyses. To assess linearity, scatterplots and residual plots for each independent variable, maternal stress indices,

with each transformed dependent variable, touch duration and frequency, were plotted. Visual inspection of these plots indicated linear relationships across the variables. Additionally, there was homoscedasticity and normality of residuals. Lastly, Durbin-Watson statistics were examined to ensure independence of observations. All regression analyses had acceptable Durbin-Watson statistics at approximately 2.

Primary Analyses: Maternal Perinatal Stress and Maternal-Infant Physical Touch Duration. A simple linear regression was conducted to examine the relationship between maternal prenatal perceived stress and total maternal-infant physical touch duration at 6 months. There was not a significant relationship between maternal prenatal PSS-14 scores and total touch duration at 6 months ($F(1,87) = 2.02$, p =.16, see Table 6). Next, a series of simple linear regression were run to examine the relationship between prenatal AUC_G, AUC_I, and CAR, and maternal-infant physical touch duration. Maternal prenatal AUC_G was not a significant predictor of touch duration ($F(1,54) = 1.42$, $p = .24$), nor was maternal prenatal AUC_I ($F(1,54) = 0.02$, $p = .90$) or maternal prenatal CAR ($F(1,66) = 0.62$, $p = .43$, see Table 6). Lastly, a simple linear regression was conducted to examine the relationship between maternal postnatal perceived stress and physical touch duration. There was not a significant relationship between maternal postnatal PSS-14 scores and physical touch duration ($F(1,87) = 1.29$, $p = .26$, see Table 6).

Table 6

Regression Analyses for Maternal Perinatal Stress and Maternal-Infant Physical Touch Duration

	B	**SE(B)**	**β**	***t***	R^2
Prenatal PSS	-.01	.01	-.15	-1.42	.01
Prenatal AUC_G	.001	.001	.16	1.19	.01
Prenatal AUC_I	.00007	.001	.02	0.001	0
Prenatal CAR	-.305	.39	-.10	-0.79	-.01
Postnatal PSS	-.012	.01	-.12	-1.14	.02

PSS=Perceived Stress Scale AUC_G=Area under the curve with respect to ground AUC_I=Area under the cure with respect to increase CAR=Cortisol Awakening Response

Primary Analyses: Maternal Perinatal Stress and Maternal-Infant Physical Touch Frequency. A series of simple linear regressions were conducted to examine the relationship between maternal perinatal stress and maternal-infant physical touch frequency. Maternal prenatal PSS-14 scores did not significantly predict total maternal-infant physical touch frequency at 6 months ($F(1,88)=0.87$, $p=.35$, see Table 7). Linear regression analyses did not find that maternal prenatal AUC_G ($F(1,55)=.01$, $p=.94$), AUC_I ($F(1,55)=0.05$, $p=.83$), and CAR ($F(1,67)=1.05$, $p=.31$) significantly predicted total maternal-infant physical touch frequency (see Table 7). Lastly, there was not a significant relationship between postnatal PSS-14 scores and physical touch frequency ($F(1,88)= 0.01$, $p=.92$, see Table 6).

Table 7
Regression Analyses for Maternal Perinatal Stress and Maternal-Infant Physical Touch Frequency

	B	SE(B)	β	*t*	R^2
Prenatal PSS	-.02	.02	-.10	-.93	.01
Prenatal AUC_G	0	.002	.01	4.93	0
Prenatal AUC_I	0	.001	-.03	-.22	.001
Prenatal CAR	-.89	.87	-.12	-1.03	.02
Postnatal PSS	-.002	.02	-.01	-.10	0

PSS=Perceived Stress Scale AUC_G=Area under the curve with respect to ground AUC_I=Area under the cure with respect to increase CAR=Cortisol Awakening Response

Hypothesis 3: The Relationship between Maternal Perinatal Stress and Infant Gross Motor Outcomes

Regression Assumptions. Prior to examining the relationship between maternal perinatal stress and infant gross motor outcomes, regression assumptions were assessed. As previously described, outliers in maternal stress indices variables were identified and addressed as needed. An additional two outliers were identified for infant gross motor outcomes at 14 months; however, outliers were not removed to avoid removal of developmentally delayed infants, as well as range restriction. The IDI gross motor summed score was substantially negatively

skewed and thus was first reflected and then transformed using a logarithmic transformation that brought the skewness value to acceptable levels. Following transformation of the variable, no outliers were identified in casewise diagnostics. The transformed variable was used for all analyses.

To assess linearity, scatterplots and residual plots were generated for each independent variable (maternal prenatal PSS-14 scores, maternal postnatal PSS-14 scores, maternal prenatal AUC_G, maternal prenatal AUC_I, and maternal prenatal CAR) with the transformed dependent variable (infant IDI summered scores). Visual inspection of these plots indicated linear relationships across the variables. Durbin-Watson statistics were examined to ensure independence of observations. All regression analyses had acceptable Durbin-Watson statistics at approximately 2. Additionally, there was homoscedasticity and normality of residuals.

Primary Analyses. To examine the relationship between maternal perinatal stress indices and infant gross motor outcomes at 14 months, a series of linear regressions were conducted. A linear regression for maternal prenatal perceived stress and infant IDI gross motor summed scores at 14 months did not find that prenatal PSS-14 scores significantly predicted infant gross motor outcomes at 14 months ($F(1,49)=0.76$, $p = .39$). Linear regression analyses did not find that maternal prenatal AUC_G ($F(1,31) =.06$, $p =.80$), AUC_I ($F(1,31) =0.05$, $p =.83$), and CAR ($F(1,35) =0.06$, $p =.81$) was predictive of infant IDI gross motor scores at 14 months. Lastly, there was not a significant relationship between postnatal PSS-14 scores infant gross motor IDI scores ($F(1,49)=0.65$, $p=0.42$, see Table 8).

Table 8
Regression Analyses for Maternal Perinatal Stress and Infant Gross Motor Outcomes

	B	SE(B)	β	*t*	R^2
Prenatal PSS	.01	.01	.12	.87	.02
Prenatal AUC_G	0	.001	-.05	-.25	.002
Prenatal AUC_I	0	0	.04	.21	.001
Prenatal CAR	-.05	.21	-.04	-.25	.002
Postnatal PSS	.01	.01	.12	.81	.01

PSS=Perceived Stress Scale AUC_G=Area under the curve with respect to ground AUC_I=Area under the cure with respect to increase CAR=Cortisol Awakening Response

Hypothesis 4: Mediation of the Relationship between Maternal Perinatal Stress and Infant Gross Motor Outcomes by Maternal-Infant Physical Touch

Preliminary Analyses. Prior to conducting mediation analyses proposed for this hypothesis, preliminary analyses examining univariate correlations across potential covariates (maternal age, parity, gestational age, and breastfeeding duration), the independent variable (maternal stress indices), and the dependent variable (infant gross motor outcomes) were conducted. Correlation analyses revealed that maternal age was negatively correlated with maternal prenatal PSS-14 scores ($r(125)= -.22$, $p = .01$) and maternal postnatal PSS-14 scores ($r(125)= -.24$, $p=.02$). Additionally, gestational age was negatively correlated with maternal prenatal CAR ($r(72)= -.27$, $p=.02$). There were not significant correlations across the majority of variables as shown in Table 9. Additionally, it was not found that any covariates were correlated with both predictor and outcome variables, and thus were not included in the analyses.

Table 9
Univariate Correlations Across Potential Covariates and Primary Study Variables

	Prenatal PSS	**Postnatal PSS**	**Prenatal AUC_G**	**Prenatal AUC_I**	**Prenatal CAR**	**IDI Gross Motor**
Maternal Age	**-.22***	**-.24***	.08	-.14	-.05	-.16
Parity	-.12	-.11	.18	.04	.15	-.18
Gestational Age	.01	.12	-.16	-.19	**-.27***	-.15
BF Duration	-.23	-.23	.25	.14	.19	-.04

*Correlation is significant at the $p < .05$ level
PSS=Perceived Stress Scale AUC_G=Area under the curve with respect to ground AUC_I=Area

under the cure with respect to increase CAR=Cortisol Awakening Response IDI=Infant Development Inventory BF=Breastfeeding

Primary Analyses: Mediation of Maternal Perinatal Perceived Stress and Infant Gross Motor Outcomes by Maternal-Infant Physical Touch. A mediation model examining if maternal-infant physical touch duration mediates the relationship between maternal prenatal perceived stress and infant gross motor outcomes was conducted and found to be not statistically significant (F (2,45) = 1.92, R^2 = 0.08, p = 0.16, see Table 10). It was found that prenatal perceived stress did not significantly predict total touch duration at 6 months (i.e., the a path, b = -0.01, t(46) = -1.09, p = 0.28), total touch duration did not significantly predict infant gross motor outcomes at 14 months (i.e., the b path, b=0.11, t(45)=1.82, p=0.07), and prenatal perceived stress did not significantly predict infant gross motor outcomes (i.e., the direct effect, b=0.005, t(45)=0.99, p=0.32). Touch duration did not significantly mediate the relationship between maternal prenatal perceived stress and 14-month infant gross motor outcomes as indicated by the indirect effect confidence intervals (*CI*[-0.006, 0.001]).

A mediation model examining if maternal-infant physical touch frequency mediates the relationship between maternal prenatal perceived stress and infant gross motor outcomes was run and found to not be statistically significant (F(2,45)=3.17, R^2=0.12, p = 0.051). Prenatal perceived stress did not predict total touch frequency (i.e., the a path, b=-0.02, t(46)=-0.65, p = 0.52) or infant gross motor outcomes (i.e., the direct effect, b=0.005, t(45)=0.96, p=0.34). Although the overall model was not statistically significant, frequency of maternal-infant physical touch did significantly predict infant gross motor outcomes (i.e., the b path, b=0.07, t(45)=2.41, p =.02, see Table 10). Total touch frequency did not significantly mediate the relationship between maternal prenatal perceived stress and total touch frequency as indicated by the indirect effect confidence intervals (*CI*[-0.006, 0.002]).

Table 10
Maternal Prenatal Perceived Stress Mediation Findings

	F	R^2	Stress → Touch	Touch → Motor	Stress → Motor
			b/SE	*b/SE*	*b/SE*
Duration	1.92	0.08	-0.01/0.01	0.11/0.06	0.005/0.005
Frequency	3.17	0.12	-.02/.03	**.07/.03***	.005/.005

**p <.05*

Maternal-infant physical touch duration did not significantly mediate the relationship between maternal postnatal perceived stress and infant gross motor outcomes at 14 months ($F(2,45)=1.57$, $R^2=0.07$, $p=0.22$, see Table 11). Specifically, postnatal PSS-14 scores did not significantly predict total maternal-infant touch duration at 6 months (i.e., the a path, $b=-0.02$ $t(46)=-1.45$, $p=0.15$), total touch duration did not significantly predict infant gross motor outcomes at 14 months (i.e., the b path, $b=0.10$, $t(45)=1.76$, $p=0.08$), and prenatal stress did not significantly predict infant gross motor outcomes (i.e., the direct effect, $b=0.003$, $t(45)=0.59$, $p=0.56$). Total touch duration did not significantly mediate the relationship between postnatal perceived stress and infant gross motor outcomes as indicated by the indirect effect confidence intervals (*CI*[-0.007, 0.001]).

Lastly, a mediation model examining if maternal-infant touch frequency mediated the relationship between maternal postnatal perceived stress and infant gross motor outcomes was not statistically significant ($F(2,45=2.71$, $R^2=0.11$, $p=0.08$, see Table 11). It was found that postnatal perceived stress did not significantly predict total touch frequency at 6 months (i.e., the a path, $b=-0.01$, $t(46)=-0.27$, $p=0.79$) or infant gross motor outcomes at 14 months (i.e., the direct effect, $b=-0.002$, $t(45)=0.32$, $p=0.75$). Although the overall model was not significant, total maternal-infant touch frequency did significantly predict infant gross motor outcomes at 14 months (i.e., the b path, $b=0.06$, $t(45)=2.32$, $p=.03$). Total touch frequency did not significantly mediate the relationship between maternal postnatal perceived stress and 14-month infant gross

motor outcomes as indicated by the indirect effect confidence intervals (*CI*[-0.005,0.003]).

Table 11
Maternal Postnatal Perceived Stress Mediation Findings

	F	R^2	Stress → Touch	Touch → Motor	Stress → Motor
			b/SE	*b/SE*	*b/SE*
Duration	1.57	.07	-0.02/0.01	0.10/0.06	0.003/0.006
Frequency	2.71	.11	-.01/.03	**.06/.03***	.002/.001

**p <.05*

Primary Analyses: Mediation of Maternal Prenatal Cortisol and Infant Gross Motor Outcomes by Maternal-Infant Physical Touch. A mediation model examining if total maternal-infant physical touch duration mediates the relationship between maternal prenatal AUC_G and infant gross motor outcomes at 14 months was found to explain a significant amount of variance in 14-month infant gross motor outcomes ($F(2,29)=4.28$, $R^2=0.23$, $p=.02$), see Table 12). Approximately 23% of variance in 14-month infant gross motor outcomes is explained in the current model. Specifically, it was found that while prenatal AUC_G did not significantly predict total maternal-infant touch at 6 months (i.e., the a path, $b=0.002$, $t(30)=1.66$, $p=0.11$) or infant gross motor outcomes at 14 months (i.e., the direct effect, $b=-0.001$, $t(29)=-1.047$, $p=0.30$), total maternal-infant touch duration at 6 months did significantly predict infant gross motor outcomes at 14 months (i.e., the b path, $b=0.20$, $t(29)=2.92$, $p=.01$). Touch duration did not significantly mediate the relationship between maternal AUC_G and infant gross motor outcomes as indicated by the indirect effect 95% confidence intervals, which contain 0 (*CI*[-0.0001,0.001]).

There was not a significant mediation by total maternal-infant physical touch frequency at 6 months when examining maternal prenatal AUC_G and infant gross motor outcomes at 14 months ($F(2,29)=2.76$, $R^2=0.16$, $p=0.08$, see Table 12). Prenatal AUC_G did not significantly predict total maternal-infant touch at 6 months (i.e., the a path, $b=0.003$, $t(30)=0.945$, $p=0.35$) or

infant gross motor outcomes at 14 months (i.e., the direct effect, b=-0.003, t(29)=-0.60, p=0.56). Although the overall model was not significant, total maternal-infant touch frequency at 6 months did significantly predict infant gross motor outcomes at 14 months (i.e., the b path, b=0.08, t(29)=2.34, p=.03). Touch frequency did not significantly mediate the relationship between maternal AUC_G and infant gross motor outcomes as indicated by the indirect effect (*CI*[-0.0002, 0.001]).

Table 12

Maternal Prenatal Cortisol (AUC_G) Mediation Findings

	F	R^2	Stress → Touch	Touch → Motor	Stress → Motor
			b/SE	*b/SE*	*b/SE*
Duration	**4.28***	0.23	.002/.001	**.20/.07***	-.001/.001
Frequency	2.76	.16	.003/.003	**.08/.03***	-.0003/.001

**p <.05*

A mediation model examining maternal prenatal $\underline{AUC_I}$, total maternal-infant touch duration, and infant gross motor outcomes was found to explain a significant amount of variance (F(2,29)=3.60, R^2=0.20, p=.04, see Table 13). The current model explained approximately 20% of the variance in 14-month infant gross motor outcomes. Specifically, it was found that prenatal AUC_I did not significantly predict total maternal-infant touch duration at six months (i.e., the a path, b=0.001, t(30)=0.68, p = 0.50) or significantly predict infant gross motor outcomes at 14 months (i.e., the direct effect, b=0, t(29)=-0.12, p =0.90). However, maternal-infant touch duration did significantly predict infant gross motor outcomes at 14 months (i.e., the b path, b=0.18, t(29)=2.68, p=.01; see Table 13). Touch duration did not significantly mediate the relationship between maternal AUC_I and infant gross motor outcomes at 14 months, as indicated by the indirect effect confidence intervals (*CI*[-0.0002, 0.001]).

Maternal-infant touch frequency at 6 months did not mediate the relationship between maternal prenatal $\underline{AUC_I}$ and infant gross motor outcomes at 14 months (F(2,29)=2.55, R^2=0.15,

p=0.10). It was found that maternal AUC_I was not predictive of total maternal-infant physical touch frequency (i.e., the a path, *b*=0.001, *t*(30)=0.38, *p* = 0.70) or infant gross motor outcomes (i.e., the direct effect, *b*=0, *t*(29)=0.04, *p* = 0.97). Maternal-infant touch frequency was predictive of infant gross motor outcomes (i.e., the b path, *b*=0.07, *t*(29)=2.25, *p*=.03; see Table 13). Touch frequency did not significantly mediate the relationship between maternal AUC_I and infant gross motor outcomes at 14 months, as indicated by the indirect confidence intervals [*CI*(-0.0002, 0.0004)].

Table 13

Maternal Prenatal Cortisol (AUC_I) Mediation Findings

	F	R^2	Stress → Touch	Touch → Motor	Stress → Motor
			b/SE	*b/SE*	*b/SE*
Duration	**3.60***	0.20	.001/.001	**.18/.07****	0/.0004
Frequency	2.55	.15	.001/.002	**.07/.03***	0/.0004

**p <.05*

***p < 0.01*

A mediation model examining the relationship between maternal prenatal CAR, infant gross motor outcomes, and maternal-infant touch duration did not explain a significant amount of variance in 14-month infant gross motor outcomes (*F*(2,33)=2.97, R^2=0.15, *p* = 0.06). Specifically, it was found that prenatal CAR was not predictive of maternal-infant touch duration (i.e., the a path, *b*=-0.41, *t*(34)=-0.77, *p*=0.44) or infant gross motor outcomes (i.e., the direct effect, *b*=0.02, *t*(33)=0.08, *p*=0.93). However, touch duration was predictive of infant gross motor outcomes (i.e., the b path, *b*=0.16, *t*(33)=2.43, *p*=.02; see Table 14). Touch duration did not significantly mediate the relationship between maternal CAR and infant gross motor outcomes, as indicated by the indirect confidence intervals (*CI*[-0.262,0.165]).

A similar model examining maternal-infant touch frequency was also found to not be statistically significant (*F*(2,33)=1.61, R^2=0.09, *p*=0.22, see Table 14). Maternal prenatal CAR was not predictive of maternal-infant touch frequency (i.e., the a path, *b*=-1.42, *t*(34)=-1.24,

p=0.23) or infant gross motor scores (i.e., the direct path, *b*=0.03, *t*(33)=0.15, *p*=0.89). Maternal-infant touch frequency was not predictive of infant gross motor outcomes (i.e., the b path, *b*=0.06, *t*(33)=1.78, *p*=0.08). Touch frequency did not significantly mediate the relationship between maternal prenatal CAR and infant gross motor outcomes as determined by the indirect confidence intervals (*CI*[-0.31, 0.04]).

Table 14
Maternal Prenatal Cortisol (CAR) Mediation Findings

	F	R^2	Stress → Touch	Touch → Motor	Stress → Motor
			b/SE	*b/SE*	*b/SE*
Duration	2.97	.15	-.41/.53	**.16/.07***	.02/.20
Frequency	1.61	0.09	-1.42/1.15	0.06/0.03	0.03/0.21

**p <.05*

Follow-Up Analyses: The Relationship between Maternal-Infant Touch and Infant Gross Motor Outcomes

Given the statistically significant findings reported in the mediation models regarding the relationship between maternal-infant touch at 6 months and infant gross motor scores at 14 months, additional analyses were conducted, including correlations and linear regression models. Correlations for total maternal-infant touch duration and frequency with infant gross motor scores were conducted. Linear regression models were run separately for duration and frequency and infant gross motor outcomes, based on significant correlation values. As assumptions have been checked previously for these variables, they are not reported again here. Both the transformed duration and frequency variables for touch were used, as well as the transformed variable of IDI gross motor summed scores.

A series of Pearson's product-moment correlations revealed that only maternal-infant touch frequency at 6 months was significantly correlated with infant gross motor outcomes at 14 months (*r*=0.33, *p*=.02). A simple linear regression revealed that total maternal-infant physical

touch frequency at 6 months was significantly predictive of infant gross motor scores at 14 months ($F(1,46)=5.43$, $p < .05$, see Table 15). The direction of effects was consistent with previously reported findings in the mediation models (see Table 14).

Table 15
Regression Analyses for Maternal-Infant Physical Touch Frequency and Infant Gross Motor Outcomes

	B	**SE(B)**	**β**	***t***	***R^2***
Transformed	.06	.09	.33	2.33	.11

SE= standard error

Descriptive statistics were conducted to more closely examine touch behavior by initiator and type of touch. While infants initiated only passive touch behavior, mothers initiated both active and passive touch during the free-play session. However, there was higher duration and frequency of maternal-initiated passive touch compared to maternal-initiated active touch (see Table 16).

Table 16
Descriptive Statistics for Maternal-Infant Touch by Initiator and Type

	Mean	SD
MIA Duration (seconds)	10.71	14.49
MIA Frequency	2.87	2.72
MIP Duration (seconds)	45.87	73.85
MIP Frequency	6.11	6.12
IIP Duration (seconds)	5.65	14.04
IIP Frequency	1.31	2.74

MIA = maternal-initiated active; MIP = maternal-initiated passive; IIP = infant-initiated passive

Additionally, univariate correlations were conducted to examine the associations across maternal-initiated and infant-initiated, by type of touch, in an attempt to further elucidate the findings regarding touch and infant motor outcomes. Maternal-initiated restrictive touch, as well as infant-initiated active touch, were not included in these analyses as the frequency and duration

of these touch behaviors was 0. Prior to running Pearson's product-moment correlations, assumptions were checked. Maternal-initiated passive and active touch duration, as well infant-initiated passive touch duration were highly positively skewed and thus were transformed using a logarithmic transformation. Maternal-initiated active and infant-initiated passive touch frequency were substantially positively skewed and also were transformed using a logarithmic transformation. Maternal-initiated passive touch was only moderately positively skewed and was transformed using a square transformation. For analysis purposes, transformed variables were used. As reported with total touch variables, some outliers were present in the current sample; however, these were not eliminated to avoid restriction of range and to accurately capture variability in touch behavior within maternal-infant dyads.

A series of Pearson's product-moment correlations revealed several significant correlations across touch behaviors, as well as in relation to infant gross motor outcomes, as shown in Table 17. Interestingly, only maternal-initiated active touch duration and frequency were significantly correlated with infant gross motor outcomes (r=0.39, p =.01; r=0.41, p=.01). Additionally, significant correlations were found across maternal-initiated touch types. For instance, maternal-initiated active touch duration was correlated with maternal-initiated passive touch duration (see Table 17). Lastly, it was found that infant-initiated passive touch duration was correlated with maternal-initiated passive touch duration (r=0.28, p=.01).

Table 17
Pearson's Correlation Coefficients for Maternal-Infant Touch and Infant Gross Motor Outcomes

	Infant IDI	MIA Dur	MIA Freq	MIP Dur	MIP Freq	IIP Dur	IIP Freq
MIA Dur	**.39***	1					
MIA Freq	**.41****	**.85****	1				
MIP Dur	.22	**.37****	**.40****	1			
MIP Freq	.20	**.43****	**.44****	**.79****	1		
IIP Dur	.09	.15	.12	**.28****	.16	1	
IIP Freq	.10	.14	.13	.19	.19	**.88****	1

MIA = maternal-initiated active; MIP = maternal-initiated passive; IIP = infant-initiated passive; Dur = Duration; Freq = Frequency
**Correlation is significant at the $p < .01$ level

Discussion

This study utilized a longitudinal design to examine associations among maternal perinatal stress, maternal-infant physical touch, and infant gross motor outcomes. The purpose of the current study was to further our understanding of how maternal subjective stress and maternal cortisol may influence maternal-infant dyadic relationships and later infant developmental outcomes. Notably, we found novel associations among maternal perinatal subjective stress measures, specifically the PSS-14, as well as novel relationships between maternal-infant physical touch at 6 months and infant gross motor behavior at 14 months.

Study Limitations

The current study has certain limitations that should be discussed. Due to attrition after the 6-month postnatal session, our sample size was small and as a result some of our analyses were underpowered. Thus, it is possible that we were unable to detect some real effects within the current study. Additionally, reduced power also lowers the likelihood that our statistically

significant findings that are reported here reflect real effects. Therefore, we remain cautious in interpreting both our null and significant findings.

By recruiting a non-clinical community sample, we anticipated that participants would express varying rates of perceived stress. However, participants in the current study indicated low perceived stress across the prenatal and postnatal periods. Unfortunately, due to inconsistences across previous studies using various versions of the PSS (i.e., PSS-4 vs. PSS-10 vs. PSS-14), we are not able to draw direct parallels between the means in our sample versus other samples. Additionally, although it was a community sample, our sample was fairly homogenous regarding maternal demographic and socioeconomic characteristics. If we had a more diverse sample with increased variability and range of scores, it is possible that we might have detected different associations across study variables.

Furthermore, although we coded free-play sessions for touch by initiator and type of touch, these variables were collapsed for analyses purposes due to the low occurrence and variability in touch type. It is possible that the age we selected was not the ideal age for capturing infant-initiated touch, despite literature supporting higher rates of touch at 6 months. Additionally, it is possible that we inadvertently introduced a perturbation in the form of the questionnaire that participants were asked to complete during the brief free-play session. Thus, we might have observed a higher amount of both maternal and infant touch if we had a longer free-play session without the introduction of a questionnaire.

Finally, we used the Infant Development Inventory (IDI) to measure infant gross motor outcomes. The IDI is designed to create cutoffs for typical, borderline, and delayed infant development across all developmental domains queried on the IDI rather than individual domains, such as gross motor. The IDI also does not provide a continuous score of gross motor

development. Furthermore, as the IDI serves as a diagnostic tool, it is not sensitive to more subtle transitions in posture and motor development. Increased sensitivity to the coordination of an infants' walking, for example, could increase the range and variability in infant development compared to simply measuring milestone achievement. As a result, the current study did not use the IDI in its intended format, but rather used it in an exploratory way to capture a broader scale of infant motor development rather than as a diagnostic tool for delayed development in infants. It is possible that by using the inventory in this unintended manner, infant gross motor development was not accurately recorded/reflected. Although our mean IDI summed score did place infants at the 14-month gross motor milestone achievement level, an infant development scale, such as the Bayley Scales of Infant Development, might be a more valid and reliable measure of infant gross motor development.

Maternal Perceived Stress is Positively Correlated Across the Perinatal Period

Consistent with our hypothesis, we found that maternal prenatal and postnatal PSS-14 scores were positively correlated. This finding represents a novel contribution to the literature regarding the stability of maternal subjective stress across the prenatal and postpartum period. Previously, Bush and colleagues (2017) reported that maternal prenatal and postnatal PSS-10 scores were positively correlated. Notably, Bush and colleagues (2017) measured prenatal stress during the first and second trimester, whereas the current study measured prenatal perceived stress during the third trimester. Furthermore, the study conducted by Bush et al. (2017) recruited from a diverse and low-income sample, whereas the current sample was fairly homogenous with a higher average income. Thus, it appears that later correlations with maternal prenatal perceived stress generally are stable throughout the gestation and are consistent across socioeconomic status. Additionally, while the PSS-10 has been validated in pregnant samples (Lee, 2012), the

PSS-14 has not. The consistency in direction and effect size (r=0.66 in Bush et al., 2017) provide support that the PSS-14 is accurately measuring perceived stress in pregnant women. This stability for maternal perceived stress across the perinatal period highlights the importance of examining maternal mental health across pregnancy and the postpartum period.

Maternal perinatal stress is often linked to infant growth and developmental outcomes, and potential mechanisms that mediate these relationships may differ across the prenatal and postnatal periods. For example, continued exposure to stressors during both the prenatal and postnatal period could further intensify changes in maternal behavior or infant behavior and/or development. Previous research in rodent models have found that gestational stress alters maternal behavior, as well as neural substrates involved in maternal behavior, such as oxytocin receptors (Champagne & Meaney, 2006). A recent study conducted by Boero and colleagues (2018) found that when maternal prenatal stress is followed by continued negative experiences, maternal behavior is further impacted, independent from HPA axis activity. Previous studies have suggested that increased HPA axis activity is a mediating mechanism in decreased maternal behavior following prenatal stress (Brummelte & Galea, 2010; Carini & Nephew, 2013); however, Boero et al. (2018) did not find that HPA axis activation was a mediator in their study. Collectively, these findings suggest that although gestational stress may influence maternal behavior through alterations of the HPA axis, as well as other neural substrates, continued exposure to postnatal stressors further reduces maternal behavior, which could potentially further influence offspring behavior.

Conversely, changes during prenatal development as a result of maternal prenatal stress might be ameliorated by postnatal experiences. Likewise, the effects of maternal postnatal stress might be buffered by maternal and/or fetal experiences during prenatal development. As

mentioned previously, research with rodents have found that the effects of gestational stress are transgenerational, often impacting maternal behavior of the offspring born to stressed dams (Del Cerro et al., 2010). Del Cerro and colleagues (2010) examined how increased maternal care impacted offspring maternal behavior and found that when female offspring were cross-fostered by a non-stressed dam, they did not show reduced maternal behavior. Non-stressed dams demonstrated increased maternal licking and physical contact, thus altering the postnatal experiences of the stress-exposed offspring (Del Cerro et al., 2010). Thus, it appears that while prenatal stress impacts offspring behavior, postnatal experiences can play a significant role in shaping offspring trajectories.

Although the studies described above use non-human animal models, studies examining maternal mental health in humans also have highlighted developmental effects on offspring. Pearson and colleagues (2013) posited that the pathways for increased risk in offspring are independent and different for prenatal and postnatal depression. Prenatal depression, independent of postnatal depression, predicted risk for offspring depression. Additionally, low maternal education increased risk for maternal postnatal depression. Collectively these findings suggest that treating depression prenatally has important implications for offspring outcomes, but also that postnatally, treatment and intervention towards mothers with lower education or other SES factors could improve not only maternal mental health, but also future outcomes for their offspring (Pearson et al., 2013). Importantly, there are some maternal and infant characteristics that are associated with increased offspring resiliency to maternal postnatal depressive symptoms, such as self-report of maternal positive feelings towards parenting and infants' non-verbal communication (Savage-McGlynn et al., 2015). Notably, few studies have specifically examined potential factors that mitigate the effects of maternal perinatal stress, but rather have

examined maternal depression or depressive symptoms; however, there is likely overlap in factors influencing infant outcomes from maternal stress and maternal depression.

Pregnancy represents a time for not only physiological changes, but psychological and social changes as well. During pregnancy, women are more vulnerable to physical and mental health problems. Importantly, the postpartum period continues to be a period of transition with continued susceptibility to physical health complications and mental health problems. Mental health problems throughout the perinatal period have important implications for infant outcomes and the risk mechanisms and influences differ dependent upon the timing of the exposure. Thus, it is important for researchers to continue to examine maternal stress, and distress, across the perinatal period rather than isolating observations to the prenatal or postnatal period.

Maternal Prenatal Cortisol is Not Correlated with Maternal Perinatal Perceived Stress

As hypothesized, maternal prenatal cortisol was not significantly correlated with maternal prenatal or postnatal perceived stress. These findings are consistent with previous studies that have found either non-significant or weak correlations between maternal cortisol and psychological distress across cortisol measurement approaches (i.e., salivary versus serum cortisol), throughout gestation, and across heterogeneous study samples (Gutteling et al., 2006; Petraglia et al., 2001; Wadhwa et al., 1996; Kivlighan et al., 2010; Voegtline et al., 2013; Davis & Sandman, 2010; Braig et al., 2016; Rothenberger et al., 2011). HPA axis functioning is a complex physiological process that is significantly altered during pregnancy and the early postpartum period. These alterations likely contribute to the lack of significant associations between cortisol and maternal perinatal distress (Mastorakos & Illias, 2003; Lindsay & Neiman, 2005; Duthie & Reynolds, 2013). Although the hypothalamus is involved in stress responses, elevated CRH and cortisol levels during pregnancy occur independently of environmental

stressors, which could contribute to the lack of associations between cortisol levels and maternal stress (Petraglia et al., 2001; DiPietro, 2012). Thus, it is necessary to distinguish between the influence of prenatal cortisol exposure on fetal development versus the influence of maternal perinatal stress and distress during early development. Furthermore, while the current study did not examine postnatal maternal cortisol, continued high exposure of cortisol postnatally, through breastfeeding for instance, may continue to influence infant developmental trajectories in mechanisms that are independent of environmental stressors and maternal subjective stress.

Maternal Perinatal Stress is not Predictive of Maternal-Infant Physical Touch

Based on previous research suggesting that maternal care is influenced by maternal perinatal distress, it was hypothesized that maternal perinatal stress, as measured by subjective stress and cortisol, would predict maternal-infant physical touch at 6 months. We did not find this to be the case. The current study proposed to examine maternal-infant touch in a novel way, focusing on the reciprocal nature of maternal-initiated and infant-initiated touch. However, the rates of infant-initiated touch at 6 months during the free-play session were extremely low; as such, we primarily observed maternal-initiated touch rather than bidirectional dyadic touch interactions. Taking this into consideration, we would still have expected that maternal perinatal stress would influence maternal-initiated touch. Therefore, it may be that there are mediating variables that influence the relationship between maternal perinatal stress and maternal-infant touch interactions, which were not captured in the current study, such as other hormones and environmental factors.

Although previous studies have indicated the influence of cortisol on maternal behavior, oxytocin also plays an important role in maternal-infant bonding and maternal care behavior (Kendrick et al., 1987; Holman et al., 1995; Maestripieri et al., 2009; Feldman et al., 2010;

Kohlhoff et al., 2017; Levine et al., 2007b). Sensitive caregiving behavior was found to be associated with higher oxytocin levels in mothers at 3-4 month postpartum, suggesting that oxytocin may also influence how mothers interact with their infants (Kohlhoff et al., 2017). However, the directionality of these effects in humans is not clear, as research has also found that maternal-infant touch increases oxytocin levels (Francis, Champagne, & Meaney, 2002). Investigating how maternal subjective stress and cortisol interact with oxytocin levels and maternal-infant touch could be important in further understanding mechanisms that promote healthy infant outcomes.

Additional environmental factors are associated with maternal-infant interactions, including paternal support and maternal education, such that positive maternal interactions were increased in mothers with higher paternal support, as well as in mothers with higher education (Lee, Holditch-Davis, & Miles, 2007). Interestingly, higher paternal support was only associated with more positive involvement in mothers who did not indicate higher depressive symptomology, suggesting that other environmental and physiological factors might influence maternal interactions in mothers who endorse depression or other mental health problems (Lee et al., 2007). Gondwe and colleagues (2017) found that other maternal, SES, and infant characteristics such as maternal age, race, infant gender and medical complications, differentially influenced maternal-infant interactions in preterm infant dyads. Lastly, Frith and colleagues (2009) found that iron and folic acid supplements improved maternal-infant interactions, independent of supplementation effects on maternal distress, suggesting that nutrient status could also influence maternal-infant interactions.

Contradictory to our hypothesis, Wolf and colleagues (2018) suggest that increased maternal cortisol and psychosocial stress, but not perceived stress, may provide a beneficial, and

protective buffer that may facilitate maternal-infant interactions. The authors found, using the SF paradigm, that mothers with higher psychosocial stress engaged in increased positive behavior with their infants before the SF perturbation; however, mothers with higher AUC_G engaged in more positive behavior after the SF perturbation (Wolf et al., 2018). Although we did not find differences in maternal-infant interactions/touch in the current study, differences in experimental design with the Wolf et al. (2018) study (i.e., SF paradigm vs. a brief free-play session), might explain why we did not see altered patterns of maternal behavior. Hence, future studies should consider that perinatal stress might facilitate rather than dampen maternal-infant interactions.

Collectively, the findings from previous literature and the current study suggest that while maternal cortisol may influence maternal-infant interactions, other factors, such as physiological and environmental variables, also play a significant role in the development of maternal behavior. Notably, there is limited research that examines how maternal subjective stress, rather than maternal distress, specifically depression and anxiety symptomology, might influence maternal behavior. Current (albeit mixed) literature exists for the role of cortisol in maternal behavior, but not subjective stress in humans. Also, maternal-infant touch represents one form of dyadic interactions. Continued research on how maternal perinatal perceived stress impacts other forms of maternal behavior and maternal-infant reciprocity could elucidate potential relationships and mechanisms of maternal behavior and infant development.

Maternal Perinatal Stress is not Predictive of Infant Gross Motor Milestone Achievement

We hypothesized that maternal perinatal stress would predict infant gross motor outcomes. Conversely to our hypothesis, we did not find that maternal perinatal stress was predictive of infant gross motor outcomes at 14 months. Previous studies found that maternal prenatal and postnatal stress influenced infant motor development. However, we failed to

replicate those findings in the current study. Maternal perceived stress scores were relatively low in our sample; thus, a study sample with a broader range of subjective stress scores might yield different results. At 14 months of age, the infants in our study had an average IDI summed score of 8 out of 10, which maps directly onto motor milestone achievement typically seen at 14 months of age. This indicates that our cohort of infants, on average, demonstrated typical motor milestone achievement.

Although maternal prenatal subjective stress, particularly during late gestation, has been associated with differences in infant motor development (Simcock et al., 2016; Cao et al., 2014; Grace et al., 2016; Moss et al., 2017), maternal prenatal cortisol has not been associated with infant gross motor skills (Davis & Sandman, 2010). We have consistently suggested that continuing to attribute maternal perinatal cortisol as the mediating variable between maternal perinatal perceived stress and infant outcomes is not a parsimonious approach and that examining other physiological and behavioral mechanisms is important. For example, one mechanism that may mediate the relationship between maternal prenatal stress and infant gross motor development is maternal nutrient intake. Research has found that maternal stress is associated with other factors such as socioeconomic status, food availability, and nutritional status, including decreased folate intake (for review, see Monk, Georgieff, & Osterholm, 2013). While the direction of these effects is likely bidirectional, Beijers and colleagues (2014) argue that maternal stress alters health behaviors, including diet, sleep, and exercise, which could further influence maternal nutrient status. Nutrient deficiency, such as iron deficiency, has been associated with adverse outcomes from maternal mental health, but has also been associated with delayed infant gross motor development (Beard et al., 2005; Corwin et al., 2003; Santos et al., 2018). Maternal iron stores impact fetal iron stores resulting in iron-deficient infants postnatally.

This continued deficiency of nutrients continues to negatively impact postnatal motor development (Lozoff 2007; Lozoff et al., 1991). Iron supplementation has been shown to reduce maternal distress (Beard et al., 2005), as well as improve maternal-infant dyadic behavior (Frith et al., 2009; Perez et al., 2005). Collectively, these findings suggest that future research should examine multiple maternal health variables simultaneously to elucidate how maternal stress and maternal nutrient intake may overlap to influence infant developmental trajectories.

It also has been proposed that while environmental stressors and subjective stress may not be directly associated with maternal cortisol levels during pregnancy, they still may impact sensitivity and transfer of glucocorticoids to the fetus. For instance, low SES has been associated with alterations in genes related to glucocorticoid metabolism that might increase sensitivity to glucocorticoids (Räikkönen et al., 2014) and high levels of maternal anxiety have been associated with elevated cortisol levels in amniotic fluid (Glover et al., 2009; Baibazarova et al., 2013 Alterations in fetal exposure and sensitivity to glucocorticoids may increase risk of physical and mental health problems in the infant, thus, it may be that these changes to glucocorticoid metabolism and levels as a by-product of maternal characteristics or mental health status influence infant developmental outcomes. Additionally, as these changes to glucocorticoids occurs independently of maternal cortisol levels, these other mechanisms may help to explain why maternal cortisol during pregnancy is not associated with infant motor outcomes, but maternal prenatal perceived stress is associated with delayed motor abilities.

Interestingly, Bleker and colleagues (2017) argue that maternal cortisol is impacted by biological and environmental, but not psychosocial, factors during pregnancy. This is consistent with previously discussed literature, however, rather than suggest that there is another mediating variable between maternal perceived stress and infant development, Bleker and colleagues

(2017) suggest that subjective stress might still influence infant outcomes through cortisol, but in instances of severe stress only. Maternal history of distress and trauma exposure has been found to be differentially associated with cortisol during pregnancy. Endorsement of trauma history has been associated with increased CAR during pregnancy (Bublitz & Stroud, 2012), whereas self-report of prolonged stressful life events has been associated with a lower cortisol peak after awakening (Obel et al., 2005). Lastly, decreased cortisol levels during pregnancy have been correlated with a higher number of positive life events (Pluess et al., 2012). Thus, it could be that current maternal stress is not an accurate indicator for maternal prenatal cortisol, but that researchers should also incorporate measures of chronic distress and trauma exposure to better understand cortisol patterns during pregnancy, and how those patterns may influence infant developmental outcomes. Additionally, studies examining maternal prenatal cortisol and perceived stress in high stress or clinical populations might discover findings that are more in-line the hypothesis presented by Bleker and colleagues (2017).

Continued exposure to maternal subjective stress during the postnatal period may also have important implications for infant development and mechanisms that influence developmental trajectories. Although the current study did not find a significant relationship between maternal postnatal perceived stress and infant gross motor outcomes, previous research has reported that infant motor outcomes are differentially affected by maternal postpartum stress and distress. Keim and colleagues (2011) reported that infants demonstrated advanced motor skills when their mothers reported postnatal perceived stress at the lowest and highest levels, but not necessarily that moderate stress resulted in delayed motor development. Some researchers have suggested that the relationship between maternal postpartum stress and infant gross motor outcomes may be due to differences in maternal caregiving practices, particularly in mothers

who endorse higher levels of stress (Karam et al., 2016). Although Karam and colleagues (2016) reported negative correlations between maternal postpartum stress and infant gross motor outcomes, rather than positive associations, differences in caregiving behavior may still help to explain differences in infant developmental trajectories across differing levels of maternal postpartum stress.

For the current study, we hypothesized that higher levels of maternal perinatal stress would predict lower motor score outcomes. This is contradictory to the findings reported by DiPietro et al. (2006) and Davis and Sandman (2010) that found maternal prenatal stress and distress was positively correlated to infant motor development. Similarly, Keim and colleagues (2011) also found that higher maternal postnatal stress was associated with advanced motor skills. Thus, it is necessary to reconsider that maternal perinatal stress is strictly an insult for fetal development and later infant outcomes. Hartman and colleagues (2018) suggest that stress is both a risk factor for negative outcomes, but may also represent an opportunity. They argue that stress may alter behavioral and physiological reactivity in ways that increase an offspring's susceptibility to both positive and negative experiences in the postnatal environment. Reclassifying stress exposure from a strictly detrimental event to an event that might facilitate increased receptiveness to experiences provides a possible explanation for why directions of associations between stress and infant motor outcomes vary across studies, time points, and severity.

Maternal-Infant Touch is Predictive of Infant Gross Motor Outcomes

It was hypothesized that maternal perinatal stress would alter maternal-infant touch interactions and these changes in maternal-infant touch would mediate the relationship between maternal perinatal stress and infant gross motor outcomes. We did not find that maternal-infant

physical touch mediated the relationship between maternal perinatal stress and infant gross motor outcomes. As discussed previously, these relationships also were not significant in the simple linear regression analyses prior to the mediation models. However, the mediation model analyses did reveal that total maternal-infant physical touch was predictive of infant gross motor outcomes.

We found that total maternal-infant touch, specifically frequency of maternal-infant touch, negatively predicted motor outcomes. Anecdotally, we observed that touch bouts were often quick interactions to adjust infant's posture before mothers reoriented towards the questionnaire task, rather than more prolonged engagements with infants, which might explain why we saw higher frequency of touch, but not duration, and thus influence the significant associations across touch and motor variables in the current study. The current findings that physical touch negatively predicted infant motor outcomes contradicts previous research on the facilitative role of maternal-infant touch interactions on infant growth and development (Gonzalez et al., 2001; Bril & Sabatier, 1986; Hopkins & Westra, 1988; Lobo & Galloway, 2012). Furthermore, it is inconsistent with a systematic review conducted by Underdown and colleagues (2010) that suggest tactile stimulation in healthy infants, such as massage, does not result in harm to infant outcomes. Herrera and colleagues (2004) found that depressed mothers restrained the behavior of their infants by lifting them more than non-depressed mothers. Increased restriction of infant movement could reduce the opportunities that the infant has to engage in exploration and opportunities for posture and motor transitions; however, the authors did not examine the effects of these differences on infant development (Herrera, Reissland, & Shepard, 2004).

Notably, the current touch classification system differed from previous research that

examined touch as affectionate, stimulating, instrumental, or intrusive by centering touch in terms of transitions in body orientation, posture, and motor behavior. Although we recorded these types of body transition touches in our passive category, our active touch category might have inadvertently recorded restriction of movement rather than facilitation of increasingly complex posture and motor behavior. Active touch behavior did not necessarily require the mother or infant to complete a change to more complex behavior, but simply a change that would not have occurred without the initiation of the touch. Therefore, a mother could have moved the infant from a sitting posture to a prone or supine posture. This would not have been coded as restrictive touch because it did not prevent the infant from changing orientation, posture, or motor behavior. Although we saw active touch as an opportunity for experience with more complex stance, posture, or motor behavior, if we are capturing restriction of movement, this could explain why maternal-infant touch is negatively correlated with infant gross motor outcomes. Upon further analysis of touch behavior at the 6-month session, this seems the most parsimonious explanation to our findings. Due to the low occurrence of infant-initiated touch, our total maternal-infant touch variable is primarily maternal-initiated touch. Closer examination revealed that although maternal-initiated passive touch frequency and duration were the highest, only maternal-initiated active touch was significantly correlated with infant gross motor outcomes at 14 months.

Importantly, the current study only describes a small portion of maternal-infant dyadic interactions. Overall, there was low infant-initiated touch behavior and fairly low maternal-initiated touch behavior. By introducing a questionnaire, which ultimately distracted mothers from infants in some cases, in a brief free-play session, we have undeniably altered maternal-directed interactions. Thus, their touch behavior outside of the laboratory might differ

significantly. Furthermore, maternal-infant reciprocity consists of more than touch behavior, thus, other forms of reciprocity might influence maternal-infant dyadic interactions, as well infant developmental outcomes.

Clinical Implications and Future Research

The current study sought to further our understanding of how maternal perinatal health influences infant development. Understanding how physiological and environmental factors interact to impact maternal mental health and behavior, along with infant outcomes, could potentially have important clinical implications. However, given the lack of significant findings and the limitations mentioned previously, it is difficult to promote clinical implications at this time. We did find that maternal prenatal and postnatal perceived stress scores were positively correlated, emphasizing the need for healthcare providers to continue to work with women after childbirth to teach skills to improve mental health, such as self-care (e.g., proper diet and exercise, personal hygiene maintenance) and coping techniques (Fahey & Shenassa, 2013). Fahey and Shenassa (2013) explain that coping involves effortful management of demands that might be challenging by either focusing on the problem, appraisal of the demand, or emotional coping, such as through mediation. Maternal distress may result in maladaptive behavior, such as changes in diet, sleep, exercise, but also breastfeeding and touch behavior. Thus, screening and prevention across the perinatal period are important for both maternal and infant health and wellbeing.

Indirectly, this study highlights the need for behavioral observations over standardized assessments in regards to measuring developmental changes in motor behavior. While the IDI, and other standardized assessments, are valuable tools for establishing diagnostic criteria and cut-offs, researchers would measure and learn much more about subtle transitions in infant

developmental trajectories by making video recordings and developing clear and objective coding schemes. Increased measurement sensitivity for investigating developmental phenomena would provide a more accurate and realistic picture of infant behavior. While we recognize the increased time involvement required of behavioral coding through video observations, advances in technology allow for caregivers to capture behavior samples on video from smartphones, which can then be sent to clinicians. Additionally, partnerships with researchers and clinicians through interdisciplinary teams would allow for clinicians to also benefit from a more sensitive tool rather than standardized assessments.

Maternal-infant touch behavior continues to be an important factor in infant development. However, further research could improve and expand upon how maternal-infant touch behavior is examined and classified. Although the current study attempted to use a novel classification system, our findings highlight the need for better objective definitions to identify touch that restricts versus facilitates infant exploration. Also, follow-up studies could extend the free-play session length and exclude any additional tasks for mothers to complete, which would allow for a more naturalistic observation of maternal-initiated touch. Moreover, longitudinal studies examining how maternal-infant bidirectional touch changes across development might better describe how touch relates to infant development.

Conclusions

Infant developmental outcomes are influenced by experiences and factors during prenatal and postnatal development, including maternal perinatal health, prenatal cortisol exposure, and maternal behavior postnatally. The current study sought to examine if maternal-infant touch mediates the relationship between maternal perinatal stress and infant gross motor development. Importantly, we found that maternal prenatal and postnatal PSS-14 scores were correlated,

emphasizing the importance of examining maternal health across the perinatal period. Additionally, though maternal-infant touch did not mediate the relationship between maternal perinatal stress and infant gross motor outcomes, we did find that maternal-infant touch negatively predicted infant gross motor outcomes, potentially through restriction of movement by maternal-initiated touch. This study represents an important contribution towards moving beyond cortisol as an underlying mechanism between maternal subjective stress and infant outcomes by promoting exploration of other behavioral and physiological mechanisms that might contribute towards elucidating the complexity of the relationship between maternal perinatal stress and infant development.

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Appendix A

Subject #: _____Session #: _____ Date:_____

PSS- FEELING QUESTIONNAIRE

The questions in this scale ask you about your feelings and thoughts **DURING THE LAST MONTH.** In each case, you will be asked to indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer each question fairly quickly. That is, don't try to count up the number of times you felt a particular way, but rather indicate the alternative that seems like a reasonable estimate.

Be sure to circle just* ONE *number for each question.	**NEVER**	**ALMOST NEVER**	**SOMETIMES**	**FAIRLY OFTEN**	**VERY OFTEN**
1. In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
2. In the last month, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
3. In the last month, how often have you felt nervous and "stressed"?	0	1	2	3	4
4. In the last month, how often have you dealt successfully with irritating life hassles?	0	1	2	3	4
5. In the last month, how often have you felt that you were effectively coping with important changes that were occurring in your life?	0	1	2	3	4
6. In the last month, how often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
7. In the last month, how often have you felt things were going your way?	0	1	2	3	4
8. In the last month, how often have you found you could not cope with all the things that you had to do?	0	1	2	3	4
9. In the last month, how often have you been able to control irritations in your life?	0	1	2	3	4
10. In the last month, how often have you felt that you were on top of things?	0	1	2	3	4
11. In the last month, how often have you been angered because of things that happened that were outside of your control?	0	1	2	3	4
12. In the last month, how often have you found yourself thinking about things that you have to accomplish?	0	1	2	3	4
13. In the last month, how often have you been able to control the way you spend your time?	0	1	2	3	4
14. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

4/20/12

Appendix B

Child's Name: _____

Infant Development Chart - First 18 Months

Harold Ireton, Ph.D.

	Social	Self-Help	Gross Motor	Fine Motor	Language	
Birth	Quiets when fed and comforted. Makes eye contact.	Alert: interested in sights and sounds.	Wiggles and kicks. Thrusts arms and legs in play.	Looks at objects or faces.	Cries. Makes small throaty sounds.	Birth
1 mo.	Social smile.		Lifts head and chest when lying on stomach.	Follows moving objects with eyes.	Cries in a special way when hungry.	1 mo.
2 mos.	Recognizes mother.	Reacts to sight of bottle or breast.	Holds head steady when held sitting.	Holds objects put in hand.	Makes sounds–ah, eh, ugh.	2 mos.
3 mos.	Recognizes other familiar adults.	Increases activity when shown toy.	Makes crawling movements.	Holds up hand and looks at it.	Laughs out loud. Squeals.	3 mos.
4 mos.	Interested in his or her image in mirror, smiles, playful.	Reaches for objects.	Pivots around when lying on stomach.	Puts toys or other objects in mouth.	Makes sounds like "Ah-goo."	4 mos.
5 mos.	Reacts differently to strangers.	Comforts self with thumb or pacifier.	Rolls over from stomach to back.	Picks up objects with one hand.	Responds to voices: turns head toward a voice.	5 mos.
6 mos.	Reaches for familiar persons.	Looks for object after it disappears from sight–for example, looks for toy after it falls off tray.	Rolls over from back to stomach.	Transfers objects from one hand to the other.	Babbles. Responds to his/her name; turns and looks.	6 mos.
7 mos.	Gets upset and cries if left alone.	Feeds self cracker or cookie.	Sits alone, steady.	Holds two objects, one in each hand, at the same time.	Makes sounds like da, ba, ga, ka, ma.	7 mos.
8 mos.	Plays "peek-a-boo."	Picks up small cup with two hands.	Moves forward somehow while on stomach.	Uses two hands to pick up large objects.	Makes sounds like da-da, ma-ma, ba-ba.	8 mos.
9 mos.		Resists having a toy taken away.	Crawls on hands and knees. Pulls self to standing position.			9 mos.
10 mos.	Plays "patty-cake.	Picks up spoon by handle.	Walks around playpen or furniture while holding on.	Picks up small objects using precise thumb and finger grasp.	Imitates sounds that you make.	10 mos.
11 mos.	Waves "Bye-bye."		Stands alone briefly.	Puts small objects in cup or other container.	Understands phrases like "No No" and "All gone."	11 mos.
12 mos.		Helps a little when being dressed.	Stands alone, steady.	Turns pages of books a few at a time.	Says "Mama" or "Dada" for parent. Hands you a toy when asked.	12 mos.
13 mos.	Plays with other children.	Lifts cup to mouth and drinks.	Walks without help.	Builds tower of 2 or more blocks.	Points to things.	13 mos.
14 mos.	Gives kisses or hugs. Imitates simple acts such as hugging or loving a doll.	Insists on feeding self.	Climbs up on chairs or other furniture.	Marks with crayon or pencil.		14 mos.
15 mos.	Greets people with "Hi" or similar.	Feeds self with a spoon.	Runs.	Scribbles with crayon or pencil.	Says 2 or more words besides Mama or Dada.	15 mos.
18 mos.	Wants a doll, teddy bear or blanket in bed with him/her. Sometimes says "No" when interfered with.	Eats with a fork.	Kicks a ball forward. Good balance and coordination.	Builds tower of 4 or more blocks.	Uses at least ten words. Asks for a drink or food, using words or sounds.	18 mos.
21 mos.						21 mos.

Appendix C

Table 2
Participant Sociodemographic Characteristics

Race/Ethnicity	**N / %**
White/Caucasian	116 / 92.8
Black/African American	2 / 1.6
Native Hawaiian or other Pacific Islander	2 / 1.6
American Indian/Alaska Native	3 / 2.4
Hispanic/Latino	16/ 12.8
Asian	1 / 0.8
Other	8 / 6.4
Marital Status	**N / %**
Single/never married	10 / 8%
Married	99 / 79.2
Divorced	3 / 2.4
Committed relationship	9 / 7.2
Engaged	4 / 3.2
Religious Affiliation	**N / %**
Agnostic	3 / 3.1
Assembly of God	2 / 2.1
Atheist	2 / 2.1
Baptist	2 / 2.1
Catholic	5 / 5.2
Lutheran	2 / 2.1
Methodist	1 / 1
Church of Jesus Christ of Latter-Day Saints	60 / 62.5
Non-denominational	10 / 10.4
Pentecostal	1 / 1
Presbyterian	1 / 1
Other	12 / 12.5
Prefer not to say	9 / 9.4
Income	**N / %**
< $5,000	2 / 1.6
$5,000-9,999	3 / 2.4
$10,000-19,999	19 / 15.2
$20,000-29,999	24 / 19.2
$30,000-39,999	15 / 12
$40,000-49,999	12 / 9.6
$50,000-74,999	31 / 24.8
$75,000-99,999	9 / 7.2
>/= $100,000	10 / 8
Education	**N / %**
Junior high school	1 / 0.8
Partial high school	4 / 3.2
High school	18 / 14.4

Partial college	44/ 35.2
Standard college or university	46 / 36.8
Graduate training with a degree	12 / 9.6
First Pregnancy	**N / %**
Yes	46 / 36.8
No	79 / 63.2
Parity	**N / %**
No other child	53 / 42.4
One other child	38 / 30.4
Two other children	16 / 12.8
Three other children	6 / 4.8
Four other children	5 / 4
Five other children	5 / 4
More than 5 other children	2 / 1.6