



ELSEVIER

Contents lists available at ScienceDirect

## SSM – Population Health

journal homepage: [www.elsevier.com/locate/ssmph](http://www.elsevier.com/locate/ssmph)

## Article

# Dark shadow of the long white cloud: Neighborhood safety is associated with self-rated health and cortisol during pregnancy in Auckland, Aotearoa/New Zealand



Zaneta M. Thayer

Department of Anthropology, Dartmouth College, 6047 Silsby Hall, Hanover, NH 03755, United States

## ARTICLE INFO

## Keywords:

Neighborhood quality  
Neighborhood safety  
Self-rated health  
Cortisol  
Pregnancy  
New Zealand

## ABSTRACT

Auckland, Aotearoa/New Zealand is a culturally and ethnically diverse city. Despite popular global conceptions regarding its utopian nature, the lived experience for many individuals in Auckland attests to the substantial social, economic, and health inequalities that exist there. In particular, rapidly rising home prices constrain housing decisions and force individuals to live in less desirable neighborhoods, with potential impacts on individual health. One of the pathways through which adverse neighborhood conditions could impact health is through alterations in the functioning of the hypothalamic pituitary adrenal (HPA)-axis, which regulates the physiological stress response. This paper evaluates the relationship between perceived neighborhood safety, self-rated health, and cortisol, an end product of HPA-axis activation, among women in late pregnancy. Pregnant women living in neighborhoods where they were concerned about safety of their property had poorer self-rated health and elevated morning cortisol, even after adjusting for maternal age, material deprivation, and ethnicity. However, fear of personal safety was unrelated to self-rated health and cortisol. These results suggest that maternal health in pregnancy is sensitive to perceptions regarding neighborhood safety. Such findings are important since higher cortisol levels in pregnancy could not only influence maternal health, but also the health and development of women's children.

*Shana is 24 years old. She is eight months pregnant with her first child. After serving five years in prison, she was released one month ago and now lives with her whanau (family) in a household of 14 people. Her father is a traditional Māori carver and tattooist, specializing in ta moko. We exchange stories about growing up and living in poverty. I make an offhand remark about how at least in poor neighborhoods in Auckland the chance of witnessing gunfire is relatively low. "Oh yea," she tells me, "I've only been caught in cross fire three times".*

## 1. Introduction

Shana's life experiences, while extreme, highlight the extent to which poverty and neighborhood violence impact the lives of individuals residing in poorer sections of Auckland, Aotearoa/New Zealand, a city undergoing an immensely rapid demographic transition. There is now a sizeable literature suggesting that neighborhood safety, which varies substantially in global cities like Auckland, has important

impacts on health. For example, perceived neighborhood safety has been associated with lower self-rated health (Baum, Ziersch, Zhang, & Osborne, 2009; Chandola, 2001; Ziersch, Baum, MacDougall, & Putland, 2005), even after adjusting for individual and household level socioeconomic factors.

In recent years there has been growing interest in not only understanding how neighborhoods might influence health in one generation, but also how they might influence health in subsequent generations (Cubbin, Heck, Powell, Marchi, & Braveman, 2015; Giurgescu et al., 2015; Metcalfe, Lail, Ghali, & Sauve, 2011; Ncube, Enquobahrie, Albert, Herrick, & Burke, 2016; Sealy-Jefferson, Giurgescu, Helmkamp, Misra, & Osypuk, 2015; Vos, Posthumus, Bonsel, Steegers, & Denktas, 2014). As an example of this type of work, researchers have found consistent associations between unsafe neighborhoods and risk for adverse birth outcomes (Kramer, Cooper, Drews-Botsch, Waller, & Hogue, 2010; Masi, Hawkey, Harry Piotrowski, & Pickett, 2007; Messer, Kaufman, Dole, Savitz, & Laraia, 2006; Morenoff, 2003). Since birth outcomes strongly predict health in adulthood (Barker, 2012; Lee, Fried, Thayer, & Kuzawa, 2014; Lu & Halfon, 2003), it is important to understand some of the inter-

E-mail address: [Zaneta.Thayer@Dartmouth.edu](mailto:Zaneta.Thayer@Dartmouth.edu).

<http://dx.doi.org/10.1016/j.ssmph.2016.11.004>

Received 26 May 2016; Received in revised form 4 November 2016; Accepted 21 November 2016

2352-8273/ © 2016 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

mediate mechanisms that may link maternal experience of neighborhood safety with offspring birth outcomes.

One pathway through which unsafe neighborhoods may influence birth outcomes is by contributing to over-activation of the Hypothalamic Pituitary Adrenal (HPA)-axis. The HPA-axis is a physiological system that regulates the stress response. Short term activation of the HPA-axis is considered healthy, but over-activation can lead to pathological impacts on the HPA-axis and downstream systems it affects, such as the brain, the immune system, and the cardiovascular system (McEwen, 2005). Cortisol, an end product of HPA-axis activation, is commonly measured as an index of HPA-axis function (Saxbe, 2008). Cortisol can be measured by evaluating diurnal rhythm across the day, or by measuring the magnitude of cortisol response to an acute stress exposure (de Weerth & Buitelaar, 2005). In general, higher cortisol levels across the day, as well as an elevated or blunted response to stress, are interpreted as less healthy (Miller, Chen, & Zhou, 2007).

Cortisol levels naturally increase across pregnancy, as cortisol is necessary for fetal maturation (Glynn et al., 2007). Perhaps because of this increase in basal levels, cortisol response to stress tends to become blunted as pregnancy proceeds (de Weerth & Buitelaar, 2005; Entringer et al., 2010). This makes diurnal cortisol levels a more commonly studied indicator of HPA-axis function in late pregnancy. To this end, higher diurnal cortisol levels in pregnancy have been associated with pathological impacts on fetal development (Constantinof, Moisiadis, & Matthews, 2016; Seckl & Meaney, 2006; Weinstock, 2008). As an example, diurnal cortisol measures have been associated with adverse birth outcomes in some (Giurgescu, 2009; Kivlighan, DiPietro, Costigan, & Laudenslager, 2008; Thayer, Feranil, & Kuzawa, 2012) but not all (Kramer et al., 2013) studies, and are also associated with a range of physiological and cognitive outcomes measured in childhood (Davis & Sandman, 2010; Erni, Shaqiri, La Marca, Zimmermann, & Ehlert, 2012; LeWinn et al., 2009). Since cortisol levels in pregnancy are associated with chronic stress exposure (Giesbrecht, Campbell, Letourneau, Kooistra, & Kaplan, 2012; Obel et al., 2005; Thayer & Kuzawa, 2014, 2015), it is possible that chronic stress resulting from living in unsafe neighborhoods could contribute to adverse birth outcomes via elevated diurnal cortisol rhythm. In support of this hypothesis, a meta-analysis found that morning cortisol levels were higher among non-pregnant individuals who experienced poor neighborhood quality (Hosseini, Adha, Zainol, Isahak, & Nemati, 2014). However, no prior research has evaluated whether neighborhood safety is associated with higher diurnal cortisol levels measured in late pregnancy.

In this paper, I evaluate whether variation in perceived neighborhood safety is associated with differences in self-rated health and diurnal cortisol among women in late pregnancy (34–36 weeks gestation) living in neighborhoods across Auckland. These analyses adjust for material deprivation in order to assess the associations between neighborhood safety, self-rated health, and cortisol, respectively, independent of socioeconomic status. In addition, qualitative information derived from interviews is used to provide examples of participant's actual neighborhood experiences.

### 1.1. Background and study context

While New Zealand or *Aotearoa*, Māori for “land of the long white cloud,” is well known for the All-Blacks rugby team, the kiwi bird, and Lord of the Rings, this is a political economic context that has been greatly shaped by imperialism, colonialism, and the Neoliberal agenda (Larner, 1997). A series of statistics reflect the consequences of these factors. For example, 24% of all New Zealand children live in poverty (Simpson et al., 2014). Between the 1980s and the mid-2000s, income inequality has increased in New Zealand at a faster rate than in any other developed country (OECD, 2011). There is a strong racial component to economic inequality, with Pacific Islanders and indigen-

ous Māori having higher rates of material deprivation compared with other ethnicities (Salmond, Crampton, King, & Waldegrave, 2006).

Auckland is the largest and most ethnically diverse city in New Zealand, with the majority of all immigrants to the country settling there. According to the 2013 Census, there were 1.4 million people in the Auckland region, with over 517,000 having been born overseas and over 220 different ethnicities being represented. Notably, one out of three residents of New Zealand live in Auckland, and one out of three in Auckland are foreign born. The diversity in languages spoken demonstrates the ethnic heterogeneity of the population; the six most common spoken languages in Auckland on the 2013 Census were English, Māori, Samoan, Hindi, Northern Chinese, and French, respectively (New Zealand Census 2013).

Auckland is now considered the fourth most expensive city globally. Auckland home prices largely drive this trend, with the median house price being eight times the median household income (<http://www.demographia.com/dhi2014.pdf>). Given the unaffordability of homes, families with little financial resources are forced to live in less desirable neighborhoods. Prior research in New Zealand has found that perceived neighborhood problems were associated with psychological and social quality of life indexes (Erin, Shepherd, Welch, Dirks, & McBride, 2012). In addition, area deprivation, an objective measure of neighborhood quality, has been strongly associated with poorer self-rated health among indigenous Māori (Bécares, Cormack, & Harris, 2013). Studies investigating the proximate mechanisms linking neighborhood quality to health in this context have primarily focused on the availability of resources important for health. For example, one study found that poorer neighborhoods were more likely to be located near fast-food and farther from grocery stores with fresh fruits and vegetables (Pearce, Blakely, Witten, & Bartie, 2007a). Seemingly counter-intuitively, another analysis found that individuals living in more deprived (lower socioeconomic status) areas had better access to community resources, such as recreational amenities, shopping facilities, educational facilities, health facilities and local *marae* (Māori meeting places) (Pearce, Witten, Hiscock, & Blakely, 2007b). While these studies are valuable for highlighting how factors such as resource access contribute to poor health within low income neighborhoods in New Zealand, additional research is needed to assess (1) the impacts of neighborhood safety on health in this context, and (2) the physiological pathways for neighborhood safety-associated stress to influence health, such as changes in cortisol.

## 2. Methods

This analysis reflects questionnaire, interview, and biomarker data from 64 women who were 34–36 weeks pregnant with singletons. A more detailed description of recruitment is found in Thayer and Kuzawa (2014). In brief, women were recruited while waiting for their routine prenatal care visits from one of two prenatal clinics in Auckland, New Zealand. One clinic, Greenlane, is a community health clinic located in Central Auckland that serves an ethnically and socioeconomically diverse patient population. The second clinic, SAMCL (Serious About Maternity Care, Limited) is a not-for-profit clinic in South Auckland that serves a primarily Māori/Pacific Islander/Asian patient population. Recruiting from these two clinics generated a multi-ethnic study sample with individuals from all five regions of Auckland. This study was approved by Northwestern University Ethics Review Board and New Zealand Health and Disability Ethics Review Board.

### 2.1. Semi-structured interviews

Participants were met in their homes and administered semi-structured interviews. Interviews lasted approximately one hour. The survey began with basic demographic questions before asking about neighborhood quality. Women were encouraged to elaborate on any of

**Table 1**  
Summary statistics of study sample.

	Full sample (N=64)	Low NZiDep (NZiDep < 2) (N=31)	High NZiDep (NZiDep ≥ 2) (N=24)	P-value
Age (years)	30.8 (4.8)	31.9 (4.6)	29.7 (4.7)	0.06
Ethnicity				0.01
NZ European	54%	62%	45%	
Pacific Islander/Māori	26%	12%	42%	
Asian	20%	27%	13%	
Partner (married or <i>de facto</i> )	97%	100%	94%	0.50
Immigrant	50%	55%	33%	0.22
Height (cm)	166.3 (7.1)	164.8 (6.4)	167.8 (7.5)	0.08
Pre-pregnancy weight (kg)	69.8 (20.8)	65.4 (21.2)	74.3 (19.8)	0.08
University degree	48%	56%	32%	< 0.001
Own home	47%	56%	37%	0.12
Amount of time lived in present home (years)	2.8 (1.9)	3.3 (2.1)	2.2 (1.5)	0.78
Number of moves in last 5 years	2.4 (1.6)	2.2 (1.7)	2.8 (1.6)	0.8
Household size	3.9 (2.3)	3.5 (1.4)	5.9 (4.0)	0.04
Feel personally unsafe in neighborhood	9%	6%	13%	0.33
Feel property is unsafe in neighborhood	17%	9%	26%	0.07
Poor self-rated health	29%	20%	38%	0.11
Morning cortisol (ng/ml)	3.2 (1.1)	3.2 (0.9)	3.3 (1.3)	0.54
Evening cortisol (ng/ml)	1.0 (0.7)	0.9 (0.6)	1.2 (0.9)	0.20

Mean (SD) values reported for continuous variables, while percentages are presented for categorical variables. Two-tailed t-tests (continuous variables) and Pearson chi-squared tests (categorical variables) were used to evaluate differences between individuals who are less materially deprived (NZiDep < 2) with those who are more materially deprived (NZiDep ≥ 2).

the questions asked in the questionnaire, which are described in greater depth below.

## 2.2. Neighborhood safety

Perceived neighborhood safety was measured by asking participants to strongly disagree, disagree, agree or strongly agree about whether they felt personally safe in their neighborhood and whether they felt their property was safe. These questions were taken from the Growing up in New Zealand Study (Morton et al. 2014). For analysis, questions were broken into dichotomous “strongly agree/agree” versus “strongly disagree/disagree” categories (hereafter referred to as “agree” and “disagree”). Each of these questions was analyzed separately in the analysis.

## 2.3. Self-rated health

Self-rated health was assessed through the following question: “Would you say that your health is: poor, fair, good, or excellent.” Answers were dichotomized as poor/fair versus good/excellent, consistent with prior research in New Zealand (Crengle, Robinson, Ameratunga, Clark, & Raphael, 2012).

## 2.4. Cortisol

Since cortisol demonstrates a diurnal rhythm (Kivlighan et al., 2008), women were asked to collect saliva samples at waking and before going to sleep on two consecutive weekdays between 34 and 36 weeks gestation. Of the 64 study participants, sufficient saliva for cortisol analysis for both times of day were available for 55 women. Samples were stored in the freezer until they were collected by the study researcher. Samples were analyzed using radioimmunoassay at Liggins Institute in Auckland. Detailed description of cortisol analysis can be found in Thayer and Kuzawa (2014).

## 2.5. Covariates

Women were also asked a series of questions about where they live. Data were recorded regarding how many times women had moved in the last five years, how many months they had lived at their current address, and whether or not they owned their home. Material deprivation, an index of individual socioeconomic status, was assessed through

the individual New Zealand deprivation index (NZiDep) (Salmond et al., 2006). Women were asked a total of six questions indexing material deprivation, including whether they had gone without a series of resources over the last 12 months, such as sufficient heating and fresh fruits or vegetables. Maternal ethnicity was also collected using self-report according to the Ethnicity Collection Protocols of the New Zealand Ministry of Health (Ministry of Health, 2004). Relationship status was recorded by asking women if they were single, partnered (married or *de facto*), separated, divorced, or widowed.

## 2.6. Statistical analysis

All analyses were conducted using STATA 10.0 (College Station, Texas). Initially a univariate analysis was conducted on all variables to assess normality. Material deprivation was not normally distributed so it was log-transformed. The relationship between neighborhood safety and self-rated health was evaluated using logistic regression. Separate models were used to evaluate the impacts of perceived safety of personal property and personal safety, respectively, on self-rated health. The relationship between neighborhood quality and morning and evening cortisol, respectively, were evaluated using linear regression. Once again, separate models were used to evaluate the associations between perceived safety of personal property and personal safety on cortisol. All analyses controlled for age, ethnicity, and material deprivation. The cortisol analyses also controlled for time of day of sample collection.

## 3. Results

Summary statistics of the sample are provided in Table 1. Overall 9% of the study sample reported feeling personally unsafe in their neighborhood, while 17% reported that they felt their property was unsafe in their neighborhood.

### 3.1. Neighborhood safety and self-rated health

Table 2 presents the relationship between neighborhood quality and self-rated health. Feeling personally unsafe in the neighborhood was not associated with significantly lower self-rated health (OR=3.56, 95% CI=[0.8, 15.8]). However, concern about safety of personal property was associated with significantly lower self-rated health (OR=2.87, 95% CI=[1.07, 7.68]).

**Table 2**  
Adjusted odds ratios and 95% confidence intervals (CI) for each independent variable of interest in relation to poor self-rated health (N=64).

	OR	95% CI	Pseudo R <sup>2</sup>
<b>Personal safety</b>	3.56	0.80, 15.8	0.04
Material deprivation	0.97	0.68, 1.40	
Age	1.00	0.99, 1.00	
NZ European	—	—	
Pacific Islander/Maori	2.77	0.98, 7.87	
Asian	1.26	0.47, 3.41	
<b>Safety of personal property</b>	2.87	1.07, 7.68	0.06
Material deprivation	0.97	0.68, 1.40	
Age	0.99	0.99, 1.00	
NZ European	—	—	
Pacific Islander/Maori	2.87	1.01, 8.13	
Asian	1.41	0.51, 3.89	

### 3.2. Neighborhood safety and cortisol

Table 3 presents the relationship between neighborhood quality and cortisol. There was no significant relationship between personal safety and either morning ( $\beta=-0.82$ ,  $SE=0.80$ ,  $P=0.31$ ) or evening ( $\beta=0.04$ ,  $SE=0.52$ ,  $P=0.93$ ) cortisol. However, women who said that their personal property was unsafe had elevated morning cortisol ( $\beta=1.17$ ,  $SE=0.56$ ,  $P=0.04$ ). Evening cortisol was unrelated to feelings about safety of property ( $\beta=0.03$ ,  $SE=0.37$ ,  $P=0.94$ ).

## 4. Discussion

This is the first study to evaluate the impacts of neighborhood safety on health among pregnant women in New Zealand. In addition, this is the first study to investigate the relationship between neighborhood safety and cortisol in pregnancy. Fear of personal safety was not associated with self-rated health or cortisol. However, perceived safety of personal property was significantly associated with poorer self-rated health and higher morning cortisol levels in this sample. This effect remained even after adjustment for material deprivation, an index of socioeconomic status.

The finding that morning cortisol, but not evening cortisol, was associated with fear of safety of personal property is consistent with prior research which reported higher morning cortisol levels in response to poor neighborhood quality among non-pregnant individuals (Hosseini et al., 2014), but is inconsistent with several other studies among pregnant individuals that have found stronger associations between stress exposure and evening cortisol (Obel et al., 2005; Thayer & Kuzawa, 2014, 2015). Notably, higher morning cortisol in pregnancy, when combined with a rapid decline over the morning, has been associated with reduced birth weight of offspring among primi-

para, while evening cortisol levels were unrelated to birth weight (Kivlighan et al., 2008). It has therefore possible that while evening cortisol levels are more commonly associated with the majority of stress exposures that morning cortisol levels actually have greater influences on fetal growth rate. This may be due to saturation of the enzyme that converts bioactive cortisol into inactive cortisone, 11 $\beta$ -Hydroxysteroid dehydrogenase type 2 (11 $\beta$ -HSD2), during peak morning cortisol values (Venihaki, Carrigan, Dikkes, & Majzoub, 2000). Regardless, additional studies of neighborhood safety and cortisol are needed to understand whether the influences of this stressor on HPA-axis function are actually different than other types of stress exposures, as well as the differential impacts of cortisol levels measured at various times of day on offspring outcomes.

As seen in Table 1, concern over safety of personal property was more prevalent than fear of personal safety. During interviews several participants mentioned that their homes had been burglarized. Notably, even participants in wealthier areas were not exempt. A participant living in a neighborhood with a deprivation score of 1 (least deprived) stated that her home had been broken into the week prior to the interview. Participants also described having clothes stolen off of their drying lines, having garages broken into, and having cars stolen from in front of their homes. The numerous personal experiences of burglary and theft could contribute to the relationship between safety of personal property, poorer self-rated health, and higher morning cortisol in this sample.

While less prevalent than fear of safety of property, some women did express concern regarding their personal safety. As an example, one participant said that recreation areas were available in her neighborhood but that she hadn't used them because she was "worried about taking [her] son to the playground outside of the garden area. The neighborhood can be pretty dangerous." Somewhat surprisingly, fear for personal safety was related to neither self-rated health nor cortisol. These results are consistent with a study of African American women in Chicago that found that concern of safety of property was associated with significantly increased odds of having very low birth weight offspring (<1500 g), while concern of personal safety was not (Collins et al., 1998). That said, other research has found that threats to personal safety, as indexed by living in high violence neighborhoods, can increase risk for pregnancy complications (Zapata, Rebolledo, Atalah, Newman, & King, 1992). Therefore, more research is needed to explore the relationships between neighborhood safety, cortisol, and self-rated health across cultural contexts to determine whether or how they compare to prior studies.

While this study exhibits several strengths, such as evaluating neighborhood safety in relation to self-rated health and cortisol while adjusting for individual material deprivation, there are also several limitations that warrant mentioning. One important limitation of this

**Table 3**  
Adjusted beta coefficients and standard error for each independent variable of interest in relation to maternal morning and evening cortisol, respectively (N=55).

	Morning cortisol				Evening cortisol			
	$\beta$	SE	P	Adjusted R <sup>2</sup>	$\beta$	SE	P	Adjusted R <sup>2</sup>
<b>Personal safety</b>	-0.82	0.80	0.31	0.04	0.04	0.52	0.93	0.17
Material deprivation	0.48	0.22	0.03*		0.26	0.14	0.06	
Age	-0.001	0.000001	0.42		0.00001	0.00006	0.08	
Pacific Islander/Maori	-0.73	0.48	0.14		0.21	0.30	0.49	
Asian	-0.30	0.40	0.46		0.38	0.24	0.12	
Time of sample collection	-0.0002	0.0014	0.88		-0.0001	0.0006	0.76	
<b>Safety of personal property</b>	1.17	0.56	0.04*	0.11	0.03	0.37	0.94	0.17
Material deprivation	0.38	0.21	0.08		0.26	0.14	0.06	
Age	-0.0001	0.0001	0.58		0.0001	0.0000	0.07	
Pacific Islander/Maori	-0.60	0.47	0.21		0.22	0.31	0.49	
Asian	-0.27	0.38	0.49		0.38	0.24	0.12	
Time of sample collection	0.0004	0.001	0.76		-0.0001	0.00006	0.76	

\*  $P < 0.05$ .

analysis is that it is a cross-sectional study. It is therefore possible that individuals who have poor health are more likely to rate their neighborhood negatively. A longitudinal study within this cultural context would be more effective at establishing causality. In addition, current neighborhood quality may not reflect long term exposure to neighborhood conditions, since individuals often live in multiple neighborhoods in their lifetime. Adding number of moves in the last five years and length of residence at current address to the study models, however, did not significantly change any of the results presented here (Supplementary Tables 1 and 2). Cortisol levels in pregnancy reflect a combination of both chronic stress exposures prior to pregnancy as well as stress experience during pregnancy (O'Connor et al., 2014; Obel et al., 2005; Suglia et al., 2010; Thayer & Kuzawa, 2015). It is therefore likely that neighborhood safety is only one of several potentially important influences on cortisol levels in pregnancy. Lastly, the small sample size may have limited statistical power for some of the relationships. In particular, the small number of women who reported feeling personally unsafe could have limited our ability to detect an effect if present. Future studies in larger samples are needed to replicate the results reported here.

Neighborhood quality likely influences maternal and child health through a complex combination of structural and psychosocial factors (Macintyre, Ellaway, & Cummins, 2002). Due to prior research that found consistent relationships between unsafe neighborhoods and adverse birth outcomes (Kramer et al., 2010; Masi et al., 2007; Messer et al., 2006; Morenoff, 2003), the measure of neighborhood quality discussed here was neighborhood safety. However other factors, including and not limited to access to resources, ability to exercise, social support, and cohesion, could also be important factors linking neighborhood quality with maternal and offspring health (Culhane & Elo, 2005; Evenson, Moos, Carrier, & Siega-Riz, 2009; Ma, Liu, Hardin, Zhao, & Liese, 2016; Metcalfe et al., 2011; Schempf, Strobino, & O'Campo, 2009). Additional research evaluating the relationship between other aspects of neighborhood quality and maternal health, particularly in larger samples, are needed.

## 5. Conclusion

Auckland is a rapidly growing city that is experiencing a housing crisis. Remarkably, the average sale price for a three-bedroom home in the neighborhood that the participant in the opening vignette grew up in has more than doubled in the last two years, highlighting economic pressures that shape and constrain individual decision making regarding where to live. In this sample of pregnant women living in Auckland, fear regarding safety of personal property was associated with poorer self-rated health and elevated morning cortisol, while concern over personal safety was unrelated to either measure. Additional research is needed to understand what additional aspects of neighborhood quality may influence maternal health in pregnancy.

## Acknowledgements

The author would like to thank comments provided by three anonymous reviewers and Joel Hattis. In addition, the author would like to acknowledge Elizabeth Howland and Aisling Galling for their assistance in data collection, as well as Chris Kuzawa, Whariki Health Research Group, SAMCL, and Greenlane Clinic for their assistance in this study. This study was supported by National Science Foundation Graduate Research Grant # 7285514 and Wenner Gren Dissertation Grant # 8334.

## Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ssmph.2016.11.004.

## References

- Barker, D. J. P. (2012). Developmental origins of chronic disease. *Public Health*, 126, 185–189.
- Baum, F. E., Ziersch, A. M., Zhang, G., & Osborne, K. (2009). Do perceived neighbourhood cohesion and safety contribute to neighbourhood differences in health? *Health place*, 15, 925–934.
- Bécares, L., Cormack, D., & Harris, R. (2013). Ethnic density and area deprivation: Neighbourhood effects on Māori health and racial discrimination in Aotearoa/New Zealand. *Social science medicine*, 88, 76–82.
- Chandola, T. (2001). The fear of crime and area differences in health. *Health place*, 7, 105–116.
- Collins, J. W., Jr., David, R. J., Symons, R., Handler, A., Wall, S., & Andes, S. (1998). African-American mothers' perception of their residential environment, stressful life events, and very low birthweight. *Epidemiology*, 9, 286–289.
- Constantinof, A., Moisiadis, V. G., & Matthews, S. G. (2016). Programming of stress pathways: A transgenerational perspective. *The Journal of steroid biochemistry and molecular biology*, 160, 175–180.
- Crengle, S., Robinson, E., Ameratunga, S., Clark, T., & Raphael, D. (2012). Ethnic discrimination prevalence and associations with health outcomes: Data from a nationally representative cross-sectional survey of secondary school students in New Zealand. *BMC Public Health*, 12, 45.
- Cubbin, C., Heck, K., Powell, T., Marchi, K., & Braveman, P. (2015). Racial/Ethnic disparities in depressive symptoms among pregnant women vary by income and neighborhood poverty. *AIMS Public Health*, 2, 411–425.
- Culhane, J. F., & Elo, I. T. (2005). Neighborhood context and reproductive health. *American journal of obstetrics and gynecology*, 192, S22–S29.
- Davis, E. P., & Sandman, C. A. (2010). The timing of prenatal exposure to maternal cortisol and psychosocial stress is associated with human infant cognitive development. *Child development*, 81, 131–148.
- Entringer, S., Buss, C., Shirtcliff, E. A., Cammack, A. L., Yim, I. S., Chic-DeMet, A. et al. (2010). Attenuation of maternal psychophysiological stress responses and the maternal cortisol awakening response over the course of human pregnancy. *Stress*, 13, 258–268.
- Erin, M. H., Shepherd, D., Welch, D., Dirks, K. N., & McBride, D. (2012). Perception of neighborhood problems and health-related quality of life. *Journal of Community Psychology*, 40, 814–827.
- Erni, K., Shaqiri, L., La Marca, R., Zimmermann, R., & Ehlert, U. (2012). Psychobiological effects of prenatal glucocorticoid exposure in 10-year old children. *Frontiers in Psychiatry*, 3.
- Evenson, K. R., Moos, M.-K., Carrier, K., & Siega-Riz, A. M. (2009). Perceived barriers to physical activity among pregnant women. *Maternal and Child Health Journal*, 13, 364–375.
- Giesbrecht, G. F., Campbell, T., Letourneau, N., Kooistra, L., & Kaplan, B. (2012). Psychological distress and salivary cortisol covary within persons during pregnancy. *Psychoneuroendocrinology*, 37, 270–279.
- Giurgescu, C. (2009). Are maternal cortisol levels related to preterm birth? *Journal of Obstetric, Gynecologic, Neonatal Nursing*, 38, 377–390.
- Giurgescu, C., Misra, D. P., Sealy-Jefferson, S., Caldwell, C. H., Templin, T. N., Slaughter-Acey, J. C. et al. (2015). The impact of neighborhood quality, perceived stress, and social support on depressive symptoms during pregnancy in African American women. *Social science medicine*, 130, 172–180.
- Hosseini, F., Adha, N., Zainol, R., Isahak, M., & Nemati, N. (2014). Neighborhood-level stress and circadian cortisol: A systematic review and meta-analysis. *Iranian Journal of Public Health*, 43, 1324–1334.
- Kivlighan, K. T., DiPietro, J. A., Costigan, K. A., & Laudenslager, M. L. (2008). Diurnal rhythm of cortisol during late pregnancy: Associations with maternal psychological well-being and fetal growth. *Psychoneuroendocrinology*, 33, 1225–1235.
- Kramer, M., Cooper, H. L., Drews-Botsch, C. D., Waller, L. A., & Hogue, C. R. (2010). Metropolitan isolation segregation and black–white disparities in very preterm birth: A test of mediating pathways and variance explained. *Social science medicine*, 71, 2108–2116.
- Kramer, M. S., Lydon, J., Goulet, L., Kahn, S., Dahhou, M., Platt, R. W. et al. (2013). Maternal stress/distress, hormonal pathways and spontaneous preterm birth. *Paediatric and Perinatal Epidemiology*, 27, 237–246.
- Larner, W. (1997). "A Means to an End": Neoliberalism and State processes in New Zealand. *Studies in Political Economy*, 52.
- Lee, J., Fried, R., Thayer, Z., & Kuzawa, C. W. (2014). Preterm delivery as a predictor of diurnal cortisol profiles in adulthood: Evidence from Cebu, Philippines. *American Journal of Human Biology*, 26, 598–602.
- LeWinn, K. Z., Stroud, L. R., Molnar, B. E., Ware, J. H., Koenen, K. C., & Buka, S. L. (2009). Elevated maternal cortisol levels during pregnancy are associated with reduced childhood IQ. *International Journal of Epidemiology*, 38, 1700–1710.
- Lu, M. C., & Halfon, N. (2003). Racial and ethnic disparities in birth outcomes: a life-course perspective. *Maternal Child Health Journal*, 7, 13.
- Ma, X., Liu, J., Hardin, J. W., Zhao, G., & Liese, A. D. (2016). Neighborhood food access and birth outcomes in South Carolina. *Maternal and Child Health Journal*, 20, 187–195.
- Macintyre, S., Ellaway, A., & Cummins, S. (2002). Place effects on health: How can we conceptualise, operationalise and measure them? *Social science medicine*, 55, 125–139.
- Masi, C. M., Hawkey, L. C., Harry Piotrowski, Z., & Pickett, K. E. (2007). Neighborhood economic disadvantage, violent crime, group density, and pregnancy outcomes in a diverse, urban population. *Social science medicine*, 65, 2440–2457.
- McEwen, B. S. (2005). Stressed or stressed out: What is the difference? *Journal of*

- Psychiatry and Neuroscience*, 30, 315.
- Messer, L. C., Kaufman, J. S., Dole, N., Savitz, D. A., & Laraia, B. A. (2006). Neighborhood crime, deprivation, and preterm birth. *Annals of Epidemiology*, 16, 455–462.
- Metcalf, A., Lail, P., Ghali, W. A., & Sauve, R. S. (2011). The association between neighbourhoods and adverse birth outcomes: A systematic review and meta-analysis of multi-level studies. *Paediatric and Perinatal Epidemiology*, 25, 236–245.
- Miller, G. E., Chen, E., & Zhou, E. S. (2007). If it goes up, must it come down? Chronic stress and the hypothalamic-pituitary-adrenocortical axis in humans. *Psychological bulletin*, 133, 25.
- Ministry of Health (2004). Ethnicity data protocols for the health and disability sector. Book Ethnicity Data Protocols for the Health and Disability Sector.
- Morenoff, J. D. (2003). Neighborhood mechanisms and the spatial dynamics of birth weight. *American Journal of Sociology*, 108, 976–1017.
- Ncube, C. N., Enquobahrie, D. A., Albert, S. M., Herrick, A. L., & Burke, J. G. (2016). Association of neighborhood context with offspring risk of preterm birth and low birthweight: A systematic review and meta-analysis of population-based studies. *Social science medicine*, 153, 156–164.
- Obel, C., Hedegaard, M., Henriksen, T. B., Secher, N. J., Olsen, J., & Levine, S. (2005). Stress and salivary cortisol during pregnancy. *Psychoneuroendocrinology*, 30, 647–656.
- O'Connor, T. G., Tang, W., Gilchrist, M. A., Moynihan, J. A., Pressman, E. K., & Blackmore, E. R. (2014). Diurnal cortisol patterns and psychiatric symptoms in pregnancy: Short-term longitudinal study. *Biological Psychology*, 96, 35–41.
- OECD (2011). Divided we stand—why inequality keeps rising. In OECD (Ed.), *An overview of growing income inequalities in OECD countries: Main findings*.
- Pearce, J., Blakely, T., Witten, K., & Bartie, P. (2007). Neighborhood deprivation and access to fast-food retailing: A National study. *American journal of preventive medicine*, 32, 375–382.
- Pearce, J., Witten, K., Hiscock, R., & Blakely, T. (2007). Are socially disadvantaged neighbourhoods deprived of health-related community resources? *International Journal of Epidemiology*, 36, 348–355.
- Salmond, C., Crampton, P., King, P., & Waldegrave, C. (2006). NZiDep: A New Zealand index of socioeconomic deprivation for individuals. *Social science medicine*, 62, 1474–1485.
- Saxbe, D. E. (2008). A field (researcher's) guide to cortisol: Tracking HPA axis functioning in everyday life. *Health psychology review*, 2, 163–190.
- Schempf, A., Strobino, D., & O'Campo, P. (2009). Neighborhood effects on birthweight: An exploration of psychosocial and behavioral pathways in Baltimore, 1995–1996. *Social science medicine*, 68, 100–110.
- Sealy-Jefferson, S., Giurgescu, C., Helmkamp, L., Misra, D. P., & Osypuk, T. L. (2015). Perceived physical and social residential environment and preterm delivery in African-American women. *American Journal of Epidemiology*, 182, 485–493.
- Seckl, J. R., & Meaney, M. J. (2006). Glucocorticoid “Programming” and PTSD Risk. *Annals of the New York Academy of Sciences*, 1071, 351–378.
- Simpson, J., Oben, G., Wicken, A., Adams, J., Reddington, A., & Duncanson, M. (2014). Child Poverty Monitor 2014 Technical Report. NZ Child & Youth Epidemiology Service, University of Otago, Dunedin.
- Suglia, S., Staudenmayer, J., Cohen, S., Enlow, M., Rich-Edwards, J., & Wright, R. (2010). Cumulative stress and cortisol disruption among Black and Hispanic pregnant women in an urban cohort. *Psychological Trauma*, 2, 326–334.
- Thayer, Z. M., & Kuzawa, C. W. (2014). Early origins of health disparities: Material deprivation predicts maternal evening cortisol in pregnancy and offspring cortisol reactivity in the first few weeks of life. *American Journal of Human Biology*, 26, 723–730.
- Thayer, Z. M., & Kuzawa, C. W. (2015). Ethnic discrimination predicts poor self-rated health and cortisol in pregnancy: Insights from New Zealand. *Social science medicine*, 128, 36–42.
- Thayer, Z. M., Feranil, A. B., & Kuzawa, C. W. (2012). Maternal cortisol disproportionately impacts fetal growth in male offspring: Evidence from the Philippines. *American Journal of Human Biology*, 24, 1–4.
- Venihaki, M., Carrigan, A., Dikkes, P., & Majzoub, J. A. (2000). Circadian rise in maternal glucocorticoid prevents pulmonary dysplasia in fetal mice with adrenal insufficiency. *Proceedings of the National Academy of Sciences of the United States of America*, 97, 7336–7341.
- Vos, A. A., Posthumus, A. G., Bonsel, G. J., Steegers, E. A. P., & Denktaş, S. (2014). Deprived neighborhoods and adverse perinatal outcome: A systematic review and meta-analysis. *Acta Obstetrica et Gynecologica Scandinavica*, 93, 727–740.
- de Weerth, C., & Buitelaar, J. K. (2005). Physiological stress reactivity in human pregnancy – a review. *Neuroscience Biobehavioral Reviews*, 29, 295–312.
- Weinstock, M. (2008). The long-term behavioural consequences of prenatal stress. *Neuroscience and Biobehavioral Reviews*, 32, 1073–1086.
- Zapata, B. C., Rebolledo, A., Atalah, E., Newman, B., & King, M.-C. (1992). The influence of social and political violence on the risk of pregnancy complications. *American Journal of Public Health*, 82, 685–690.
- Ziersch, A. M., Baum, F. E., MacDougall, C., & Putland, C. (2005). Neighbourhood life and social capital: The implications for health. *Social science medicine*, 60, 71–86.