Social Science & Medicine 128 (2015) 36–42

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Ethnic discrimination predicts poor self-rated health and cortisol in pregnancy: Insights from New Zealand

Zaneta M. Thayer [a, *], Christopher W. Kuzawa [b]

[a] Department of Anthropology, University of Colorado Denver, Denver, CO, USA
[b] Department of Anthropology, Northwestern University, Evanston, IL, USA

ARTICLE INFO

Article history:
Available online 6 January 2015

Keywords:
Racism
Intergenerational effects
Health disparities
Social gradient in health
DOHaD

ABSTRACT

Despite growing research emphasis on understanding the health effects of ethnic discrimination, little work has focused on how such exposures may influence a woman's biology and health during pregnancy. Understanding such effects is important given evidence that maternal stress experience in pregnancy can have long term effects on offspring health. Here we present data evaluating the relationship between perceived discrimination, self-rated health, and the stress hormone cortisol measured in late pregnancy among a diverse sample of women living in Auckland, New Zealand (N = 55). We also evaluated possible intergenerational impacts of maternal discrimination on stress reactivity in a subset of offspring (N = 19). Pregnant women were recruited from two antenatal care clinics in Auckland. Women were met in their homes between 34 and 36 weeks gestation, during which time a prenatal stress questionnaire was administered and saliva samples (morning and evening from two days) were obtained. Offspring cortisol reactivity was assessed at the standard six week postnatal vaccination visit. We found that 34% of women reported having experienced ethnic discrimination, with minority and immigrant women being more likely to report being angry or upset in response to discrimination experience compared with NZ-born women of European descent. Women reporting discrimination experience had worse self-rated health, higher evening cortisol and gave birth to infants with higher cortisol reactivity, all independent of ethnicity and material deprivation. These findings suggest that discrimination experience can have biological impacts in pregnancy and across generations, potentially contributing to the ethnic gradient in health.

1. Introduction

The consistent documentation of health disparities within and across societies has generated interest in exploring what factors contribute to these outcomes (Marmot and Wilkinson, 2009). Since genetic differences are unlikely causes of complex health outcomes such as low birth weight, cardiovascular disease and psychiatric disorders (David and Collins, 1997; Gravlee, 2009), research has instead focused on the importance of environmental factors, such as differential stress exposure, as key drivers of disparities in health (Lu and Halfon, 2003; Chapman and Berggren, 2005; Williams and Mohammed, 2009; Williams et al., 2010; Thayer and Kuzawa, 2011).

One important source of stress is ethnic discrimination, defined as unfair treatment that an individual perceives to be due to their ethnicity (Greene et al., 2006). Ethnic discrimination has been associated with a wide range of poor health outcomes, including hypertension, self-reported health, health risk behaviors and adverse birth outcomes (Collins et al., 2000; Dailey, 2009; Dole et al., 2003; Harris et al., 2006b; Pascoe and Smart Richman, 2009; Schulz et al., 2006). Cortisol, a hormone released following activation of the Hypothalamic Pituitary Adrenal (HPA)-axis, is modified in response to discrimination experience (Fuller-Rowell et al., 2012; Zeiders et al., 2012) and is hypothesized to contribute to the adverse health effects of discrimination through downstream impacts on other physiological systems (Williams and Mohammed, 2009).

Of the outcomes that have been previously associated with discrimination, adverse offspring birth outcomes are of particular relevance given evidence that being born small increases risk for developing cardiovascular disease, diabetes, and psychiatric

* Corresponding author. Campus Box 103, PO Box 173364, Denver, CO 80217, USA.
E-mail address: Zaneta.thayer@ucdenver.edu (Z.M. Thayer).

http://dx.doi.org/10.1016/j.socscimed.2015.01.003
0277-9536/

disorders in adulthood (Abel et al., 2010; Barker, 1994). These findings suggest that the experience of discrimination may not only impact risk for developing chronic disease in the present generation, but also in future generations (Goosby and Heidbrink, 2013; Kuzawa and Sweet, 2009; Wells, 2010). In support of this hypothesis, both elevated maternal cortisol outside of pregnancy, and ethnic discrimination experience, have been independently associated with the development of smaller birth size (Collins et al., 2000; Thayer et al., 2012). However, no study has evaluated whether the normal increase in cortisol during gestation (Wadhwa, 2005) is further elevated in response to discrimination experience.

Given this background we sought to investigate whether maternal cortisol and self-rated health are associated with reports of discrimination among an ethnically diverse sample of women living in Auckland, New Zealand (NZ). We hypothesized that: (1) women who reported ethnic discrimination would report poorer self-rated health, and (2) have cortisol levels in late pregnancy that were lower in the morning and higher in the evening, consistent with a pattern of chronic strain (Powell et al., 2002; Skinner et al., 2011). Based on prior research on the intergenerational effects of maternal stress, we also tested the hypothesis that women who experienced ethnic discrimination would (3) have offspring with altered cortisol reactivity in early infancy (Tollenaar et al., 2011).

2. Materials & methods

2.1. Study setting

Auckland is a diverse city with a population of approximately 1.5 million inhabitants, including major NZ European (59%), Asian (19%), non-Māori Pacific Islander (14%) and indigenous Māori (9%) sub-groups (Statistics New Zealand, 2013b). Auckland has the largest population of Polynesians in the world, and is home to approximately one quarter of all Māori in NZ (Statistics New Zealand, 2013a). Auckland is also notable for being a city with a large immigrant population. In the 2006 Census, 37% of Auckland's inhabitants were born overseas. Notably, this figure rises to 57% when one combines immigrants with their first generation, NZ born children (Spoonley and Meares, 2011). Immigration was historically difficult for individuals not coming from Britain or Polynesia (Ongley and Pearson, 1995). However economic privatization of many industries led to increased demand for skilled labor in the 1980s and 1990s, particularly from strengthening Asian economies (Ip and Pang, 2005). As a result, between 1986 and 1995 the percentage of immigrants to NZ coming from Asian countries increased from 17% to 59% (Spoonley and Bedford, 2008). While immigrants to NZ today have higher than average measurable skills than NZ-born workers, they are 17% less likely to be employed, which has been interpreted as an outcome of institutional racism against Asian immigrants (Spoonley and Bedford, 2008).

A recent analysis of data from the 2006/2007 NZ health survey found a reported lifetime discrimination prevalence of 35% among Asians, 29.5% among Māori, 23% among non-Māori Polynesians, and 13.5% among NZ Europeans (Harris et al., 2012). Māori and Asians completing this survey were also 10 times more likely to report experiencing multiple types of discrimination compared with Europeans, suggesting ethnic differences in chronicity of discrimination experience as well. The problem of ethnic discrimination in NZ has led to a growing interest in documenting and understanding its biological effects. Prior research utilizing several large, nationally representative samples has found that both adults and adolescents who report ethnic discrimination have worse self-rated health, with adults reporting discrimination also having poorer mental and physical functioning and higher rates of cardiovascular disease (Crengle et al., 2012; Harris et al., 2006a; Harris et al., 2012). However no study in NZ or elsewhere has evaluated ethnic discrimination in relation to stress physiology in pregnancy or offspring soon after birth.

2.2. Study sample

Pregnant women were recruited at two antenatal care clinics in Auckland (see Thayer and Kuzawa, 2014 for more details) (N = 64). Following recruitment, women were met by the study researcher in their homes during late pregnancy (34–36 weeks gestation) to retrieve saliva samples collected over two days and administered a structured questionnaire asking about discrimination and other potential covariates (described below). Ethnicity was recorded using self-report according to Statistics NZ standards for recording ethnicity (Ministry of Health, 2004). It is important to note that with the exception of Māori, all other major ethnic groupings in NZ (NZ European, Pacific and Asian) are aggregate groupings composed of multiple ethnic groups (Harris et al., 2012). Using major ethnic groupings as an index, the ethnic composition of the sample closely approximates that of Auckland as a whole (Table 1), reflecting high diversity. This study was conducted under conditions of written informed consent and was approved by the NZ Upper South B Health and Disability Ethics Committee and the Institutional Review Board of Northwestern University.

2.3. Saliva collection

Maternal saliva was collected in both the morning and evening to account for diurnal variation in cortisol levels. Women were sent four 2.0 ml saliva vials between 34 and 36 weeks gestation and instructed to fill them immediately upon waking and before going to sleep on two consecutive weekdays without eating, drinking or brushing their teeth for at least 30 min beforehand. Women

Table 1
Sample characteristics and comparison of women based on report of ethnic discrimination.

	Total sample (N = 64)	No ethnic discrimination (N = 41)	Experienced ethnic discrimination (N = 23)
Age (years)	30.8 (4.8)	31.4 (4.8)	29.5 (4.7)
Pre-pregnancy BMI (kg/m^2)	25.1 (7.1)	25.1 (8.0)	24.9 (5.7)
Ethnicity			
NZ European	53%	53%	54%
Pacific Islander/ Māori	27%	28%	25%
Asian	20%	20%	21%
Bachelors degree or greater	49%	55%	37%
Smoked before pregnancy	20%	17%	25%
Days/week exercise in 1st trimester	2	2.2	1.7
Diagnosed with depression	23%	15%	38%
Materially deprived (NZiDep $\geq$ 2)	19%	12%	29%
Morning cortisol (ng/ml)	3.2 (1.1)	3.1 (0.9)	3.4 (1.4)
Evening cortisol (ng/ml)	1.0 (0.2)	0.9 (0.3)	1.4 (1.1)
Weeks pregnant at delivery	39.2 (1.4)	39.3 (1.3)	39.2 (1.4)
Offspring birth weight (g)	3486.4 (530.9)	3484.1 (523.0)	3507.9 (579.4)
Male offspring	58%	62%	52%

Mean (SD) values reported for continuous variables, while percentages are presented for categorical variables.

recorded collection time and mood at time of collection. After collection women were instructed to store saliva samples in the freezer until they were retrieved during the prenatal interview the next day.

Since infants do not establish a diurnal cortisol rhythm until approximately three months after birth (Gunnar and Quevedo, 2007), infant cortisol was measured using a previously-published reactivity protocol (Tollenaar et al., 2011). Mothers and infants were met at a clinic during the infant's routine 6 week wellness check and vaccination. Infant saliva was collection before and 20–25 min after the vaccination (mean = 22.6 min, SD = 2.6 min) using two Salimetrics Infant Swabs which were placed into Salimetrics Swab Storage tubes. This protocol was designed to capture peak infant cortisol concentrations following stressor exposure. While sufficient saliva was collected for cortisol assessment in 48 infants at baseline and for 25 infants following vaccination, complete pre- and post-vaccination cortisol data were only available for 19 infants. The inability to obtain sufficient saliva, particularly for the post-vaccination measure, was attributed to infants having fallen asleep after the vaccination, being too fussy to retrieve saliva or because they did not salivate enough. There were no differences in maternal socioeconomic status, BMI, ethnicity or experience of discrimination between the mothers of infants for whom saliva samples were successfully collected and those with missing cortisol data (all $p > 0.24$). All saliva samples were taken to the Liggins Institute in Auckland, NZ and stored at −80 °C until analysis.

2.4. Health & health behavior measures

To assess self-rated health, women were asked, “In general would you say that your health is” and given the option of answering poor, fair, good or excellent. Following prior research in NZ (Crengle et al., 2012; Harris et al., 2012), these answers were dichotomized as either “excellent/good” or “fair/poor”. Prior diagnosis of maternal depression was assessed through self-report during both the pregnancy and postnatal interview.

We collected birth outcome information (birth weight, birth length, head circumference and gestation length) during the postnatal visit. Data were retrieved from children's Plunket books, which are infant health and wellness books owned by the mother where health information is recorded for their reference by a registered nurse.

2.5. Ethnic discrimination measures

Questions regarding ethnic discrimination were taken from the previously modified Everyday Discrimination Scale (Williams et al., 1997) and from the NZ 2006/2007 Health Survey. Women were asked whether they had ever been treated with less respect, had been harassed or called insulting names, had been ignored or not taken seriously or had been talked down to, based on their ethnicity. They were also asked whether they had ever been verbally or physically attacked based on their ethnicity. Answering “yes” to any of the above questions was scored as 1. Questions were summed to create an overall discrimination score, with scores ranging from 0 to 4. Cronbach's alpha in this sample was 0.73, which is in the acceptable range (Cortina, 1993).

Women were also asked how often they thought about their ethnicity, which was scored as less than or more than once a month. If a woman reported having experienced discrimination then she was asked if she responded to that experience by feeling angry, sad, or if they just ignored it (participants could select more than one response). These variables were each analyzed dichotomously (yes/no).

2.6. Covariates

Maternal height and weight were collected during the prenatal visit between 34 and 36 weeks gestation using standard approaches (Lohman et al., 1988). Maternal age, smoking status and pre-pregnancy weight were assessed through self-report. Socioeconomic status was evaluated using a recently validated measure of material deprivation in NZ, the individual NZ Deprivation Index (NZiDep) (Salmond et al., 2006). Scores ranged from 0 to 5, with higher scores indexing greater material deprivation.

2.7. Laboratory analysis

Cortisol samples were analyzed using triple quadrupole mass spectrometry at the Liggins Institute in Auckland, NZ. Samples were run in duplicate, with all samples from each participant run in the same assay. Cortisol was extracted using 1 mL of ethyl acetate (Merck KGaA Darnstadt, Germany) (Rumball et al., 2008). After removal of the organic supernatant, samples were dried by vacuum concentration (Savant SC250EXP, Thermo Scientific, Asheville, NC, USA), resuspended in 60 μL of mobile phase 72% methanol (Merck) and 28% water, and transferred to HPLC injector vials. Twelve μL was injected onto an HPLC mass spectrometer system consisting of an Accela MS pump and autosampler followed by an Ion Max APCI source on a Finnigan TSQ Quantum Ultra AM triple quadrapole mass spectrometer, all controlled by Finnigan Xcaliber software (Thermo Electron Corporation, San Jose, CA, USA) (Rumball et al., 2008). The mobile phase was isocratic, flowing at 250 μL min^{-1} through a Luna HST 2.6 μm C18(2) 100 × 3.0 mm column at 40 °C (Phenomenex, Auckland, NZ). Cortisol retention time was 3.1 min, ionization was in positive mode and Q2 had 1.2 mTorr of argon. The mass transitions followed were 363.2 Π 122.2 at 28 V. Coefficients of variation ranged from 3.4% to 12.1%.

2.8. Statistical analysis

All statistical analyses were conducted using Stata v.10.0 (College Station, Texas). Maternal morning and evening cortisol values were each averaged across the two days of collection. We began with a univariate analysis of all variables. Normality of all variables was assessed using the Shapiro–Wilk test. Evening cortisol and NZiDep were not normally distributed so were log transformed. All bivariate associations were calculated using two sided t-tests, unless otherwise stated. We began with an analysis of ethnic discrimination in relation to ethnicity within the full questionnaire sample, since prior research in NZ has found significant differences in discrimination experience by ethnicity (Crengle et al., 2012; Harris et al., 2012, 2006b). We then used logistic regression to predict poor self-rated health by ethnic discrimination measures within this sample, controlling for maternal ethnicity, age and socioeconomic status. Linear regression was then used to assess the relationship between discrimination and maternal cortisol, controlling for collection time, maternal age, pre-pregnancy BMI, maternal ethnicity and maternal medication use. The linear regression model analyzing offspring cortisol reactivity controlled for collection time, the baseline cortisol value, maternal ethnicity, maternal PTSD symptoms and offspring sex. We assessed the assumption of homoscedasticity for all regression models using the STATA estat hettest command. Conventional statistical thresholds were used ($p < 0.05$).

3. Results

Sample characteristics are presented in Table 1. Over one-third of sample participants reported having experienced any ethnic

discrimination during their lifetime (Table 2).

3.1. Ethnicity and discrimination experience

There were no significant differences in report of any experience of ethnic discrimination by ethnicity (ANOVA: $P = 0.34$). However immigrant NZ Europeans reported significantly more discrimination than native-born NZ Europeans ($P = 0.037$). Forty-six percent of women reported thinking about their ethnicity at least once a month, with significant differences based on a woman's ethnicity and immigration status. Immigrants, Asian, Māori and Pacific Islander women all thought about their ethnicity significantly more than women who had been born in NZ or who were NZ European (all $P < 0.017$). Asian, Pacific Islander and Māori women were significantly more likely to report getting angry when confronted with discrimination than NZ European women, while NZ European women were significantly more likely to ignore and not speak up about experiencing discrimination than other groups (all $P < 0.04$).

3.2. Discrimination experience and self-reported health

Women who reported being treated with less respect based on their ethnicity were significantly more likely to report poor self-rated health compared with women who did not feel like they were treated with less respect (odds ratio (OR) = 1.58, se = 0.72, $P = 0.028$, $R^2 = 0.06$). This relationship remained after controlling for maternal ethnicity, age and socioeconomic status (OR = 1.77, se = 0.78, $P = 0.024$, adj. $R^2 = 0.15$). Self-rated health was not related to any other measures of discrimination (data not shown; all $P > 0.28$).

3.3. Discrimination experience and cortisol

Ethnic discrimination was not significantly associated with cortisol decline across the day ($P = 0.68$) or morning cortisol ($P = 0.19$) (Table 3). However experience of ethnic discrimination was positively associated with evening cortisol in pregnancy ($P = 0.01$) (Fig. 1). Maternal use of medications to regulate depression, thyroid disorders and autoimmune disorders were significantly related to lower cortisol, resulting in a greater diurnal decline in cortisol across the day. Eliminating women who used these medications from the study sample (N = 10) did not significantly change the relationship between discrimination experience and maternal cortisol (data not shown).

Infants of women who experienced ethnic discrimination had significantly greater cortisol response to vaccination, measured as the difference in cortisol between baseline and 20–25 min after vaccination, after controlling for baseline value, maternal ethnicity, offspring sex, maternal medication use and maternal PTSD symptoms ($P = 0.03$) (Table 4) (Fig. 2).

Table 2
Report of ethnic discrimination (N = 64).

	Percent of total sample (N)	Percent of NZ European (N)	Percent of PI/Māori (N)	Percent of Asian (N)
Verbally attacked	11% (7)	9% (3)	6% (1)	23% (3)
Physically attacked	6% (4)	3% (1)	12% (2)	8% (1)
Treated with less respect	16% (10)	15% (5)	18% (3)	15% (2)
Harassed or called insulting names	19% (12)	18% (6)	12% (2)	31% (4)
Ignored or not taken seriously	14% (9)	9% (3)	18% (3)	23% (3)
Talked down to	14% (9)	6% (2)	24% (4)	23% (3)
Any discrimination	*34% (22)*	*38% (13)*	*35% (6)*	*38% (5)*
2+ experiences of discrimination	*16% (10)*	*8% (3)*	*25% (4)*	*23% (3)*

Table 3
Multivariate regression predicting maternal cortisol in late pregnancy.

	Beta	SE	t-statistic
Maternal diurnal cortisol decline			
AM collection time	0.0011	0.0016	0.75
Discrimination	−0.075	0.18	−0.42
PI/Māori	−1.04	0.52	−1.99[a]
Asian	−0.45	0.46	−0.99
Age	0.29	0.036	−0.77
Medication use	1.06	0.38	2.78[a]
Material deprivation	0.046	0.26	0.18
Model Adj. R^2	*0.20*		
Maternal waking cortisol			
AM collection time	0.00037	0.0014	0.26
Discrimination	0.22	0.16	1.32
PI/Māori	−0.69	0.48	−1.45
Asian	−0.31	0.42	−0.75
Age	−0.0036	0.036	−0.14
Medication use	0.53	0.35	1.50
Material deprivation	0.22	0.24	0.93
Model Adj. R^2	*0.08*		
Maternal evening cortisol			
PM collection time	−0.0003	0.0004	−0.79
Discrimination	0.18	0.07	2.60[a]
Māori	0.28	0.19	1.45
Asian	0.05	0.16	0.31
Age	0.02	0.02	1.00
Medication use	−0.41	0.15	−2.78[a]
Material deprivation	0.09	0.10	0.93
Model Adj. R^2	*0.32*		

[a] $= P < 0.05$.

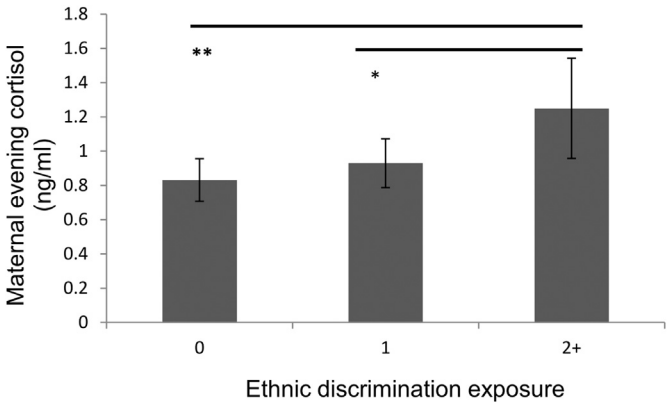

Fig. 1. Relationship between number of reported exposures to ethnic discrimination maternal evening cortisol in late pregnancy (figure presents mean and 95% CI) (** = $P < 0.001$; * = $P < 0.01$).

Table 4
Regression models predicting offspring cortisol response to vaccination (N = 19).

	Beta	SE	*t*-statistic
Baseline cortisol	0.82	0.30	2.71[a]
Discrimination	6.43	2.60	2.47[a]
PTSD	−5.92	2.79	−2.12
Pacific Islander/Māori	0.86	3.37	0.26
Asian	−1.92	2.71	−0.71
Female	3.59	2.35	1.52
Medication use	5.97	2.73	2.18[a]
Model Adj. R^2	*0.58*		

[a] $P \leq 0.05$.

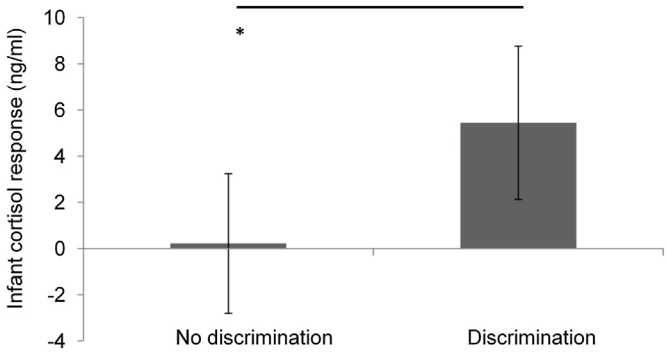

Fig. 2. Infant cortisol response to vaccination stratified by maternal exposure to ethnic discrimination (figure presents mean and 95% CI) (* = $P < 0.05$).

4. Discussion

In this diverse group from Auckland we found that women who reported experiencing ethnic discrimination had higher evening cortisol in late pregnancy and poorer self-rated health, independent of ethnicity. Interestingly, these women also gave birth to infants with higher stress reactivity at six weeks of age, suggesting that ethnic discrimination experienced by the mother has biological effects that can transcend the current generation, potentially operating directly during pregnancy or through maternal-offspring interactions during the first few weeks after birth. To our knowledge this is the first study to report an association between maternal ethnic discrimination and maternal stress physiology in pregnancy or with stress physiology in infancy.

Our finding that women reporting discrimination had higher evening but not morning cortisol is consistent with prior reports that evening cortisol is more strongly related and responsive to social influences (Dykens and Lambert, 2013). In addition, women with higher evening cortisol are more likely to experience adverse birth outcomes, such as reduced fetal growth (Goedhart et al., 2010; Thayer et al., 2012) and shorter length of gestation (Sandman et al., 2006). Notably, the relationship we report between perceived discrimination and evening cortisol remained after controlling for material deprivation, suggesting that these effects are independent of socioeconomic status in our sample.

The finding that offspring of women who experienced ethnic discrimination had greater cortisol reactivity in early infancy adds to growing evidence that a women's emotional, physical and mental well-being, during or around the time of pregnancy, can influence the biology of her child (Wadhwa, 2005; Worthman and Kuzara, 2005). Maternal experience of discrimination has elsewhere been associated with outcomes such as reduced offspring fetal growth, weight at 6 months and BMI at 4 years of age (Dixon et al., 2012). There is a rapidly growing literature demonstrating that maternal stress or depression in pregnancy predict offspring HPA-axis function in infancy (O'Connor et al., 2013; Oberlander et al., 2008; Tollenaar et al., 2011). Maternal HPA-axis function may program offspring HPA-axis function through multiple pathways, including changes in maternal diurnal cortisol rhythm at various stages of pregnancy or cortisol reactivity. Variation in placental activity, such as expression of 11-β-hydroxysteroid dehydrogenase, which was not assessed here, could also modify programming effects by regulating the amount of cortisol that reaches fetal circulation (Seckl and Meaney, 2004).

Experiences during the early postnatal period could also contribute to the offspring differences noted here. For instance, mothers who are stressed as a result of discrimination experiences may interact with their infants in a way that positively or negatively impacts their stress physiology (Albers et al., 2008; Haley and Stansbury, 2003; Murray et al., 1996). In addition, past studies show that hormones such as cortisol can be transferred through breast milk and further contribute to variation in offspring stress physiology (Beijers et al., 2013; Claessens et al., 2011; Glynn et al., 2007).

Although there are good empirical precedents suggesting that discrimination *per se* can lead to chronic activation of stress physiology and other biological pathways that influence health (Fuller-Rowell et al., 2012; Tomfohr et al., 2010; Zeiders et al., 2012), women who experience discrimination may vary in myriad other ways that can also impact these systems. For example, in a prior analysis of data collected in this sample we found a significant relationship between poverty, as indexed by material deprivation, and maternal and offspring cortisol (Thayer and Kuzawa, 2014). We therefore controlled for material deprivation in the present analyses, as well as other factors known to influence maternal and offspring cortisol, such as maternal age, smoking status and pre-pregnancy weight. Nonetheless, it is likely that the differences that we report here not only reflect the impacts of discrimination, but also the "cumulative vulnerabilities" related to racism and poverty more generally (Myers, 2009).

Prior research has found that individuals of Pacific Island, Māori and Asian descent report more discrimination in NZ (Statistics NZ, 2012). Surprisingly, within our sample there were no ethnic differences in reports of perceived discrimination, largely as a result of a larger proportion of NZ Europeans in our sample reporting having experienced ethnic discrimination compared with prior studies (Harris et al., 2006b; Statistics New Zealand, 2012). There are several features unique to our study sample that could be contributing to these findings. First is that the sample of NZ Europeans contains a disproportionate number of individuals of lower socioeconomic status. There was a significant relationship between socioeconomic status, as measured by material deprivation, and report of discrimination within the entire sample as well as within the NZ European women alone. This over-representation of poorer NZ European women may have contributed to higher reporting of discrimination in this group compared with previous samples (Crengle et al., 2012; Harris et al., 2012; Harris et al., 2006b; Statistics New Zealand, 2012).

A second factor stems from the fact that the ethnic categories used in the NZ census are an aggregation of individuals that vary in characteristics that could influence discrimination experience. For example, within the NZ European category 43% of women were immigrants, having been born in England, Australia, South Africa and Russia. While this is similar to the proportion of the Auckland population that is immigrant, it varies from the national average of 23% from which the previous discrimination study samples have been derived (Statistics New Zealand, 2013b). In our sample, these non-NZ born European women were significantly more likely to report at least two experiences of discrimination compared with NZ-born European women. Lastly, it is also notable that a prior study reported that 47% of New Zealanders heard racist remarks about immigrants "often" or "very often," with individuals from Auckland, from which this sample arises, being more likely to report hearing racist remarks than individuals from other parts of the country (Gendall et al., 2007).

It is also important to note that there were significant ethnic-based differences in response to discrimination experience. Pacific Islander, Māori and Asian women reported that they were more likely to get angry when confronted with discrimination, while NZ European women were significantly more likely than other groups to ignore discrimination experiences. Prior studies have noted that racial identity can affect responses to discrimination experience (Sellers et al., 2003), which in turn can moderate

the biological response to such experiences. For example, ethnic discrimination has been associated with different patterns of diurnal cortisol decline among African Americans and whites in the US, and this has been attributed to differences in psychological processing of discrimination events among these groups (Fuller-Rowell et al., 2012).

An important limitation of this analysis was the small sample size of mothers and especially their offspring. A range of issues, some related to the lower SES of study participants, made scheduling of appointments difficult. For example, many women had difficulties arranging transportation to their clinic visits, or had minimal telephone access, which made coordination difficult. In addition, many infants were upset, and some fell asleep, after their vaccinations, which limited the sample available for the post-vaccine cortisol reactivity analysis. Despite small sample sizes we were still able to detect clear and significant relationships between discrimination experience and maternal and offspring cortisol, suggesting that such exposures have substantial biological effects. However, given the limitations above, we emphasize that these findings will require replication.

There are also notable difficulties in measuring discrimination that warrant discussion. For one, although we only asked about discrimination on the basis of ethnicity, this is not the only form of discrimination that women experience. In the present study, several participants reported facing discrimination at work and at home that they attributed to their gender, which should be addressed in future work. Data on perceived discrimination are also inherently subjective and sensitive to individual interpretation of events (Harris et al., 2012). Further, the prevalence estimates of discrimination reported in our study were likely biased by our sample composition, and therefore are not meant to be generalized to NZ as a whole. It is important to note that the purpose of this study was not to measure the prevalence of discrimination, as has been recently done for the population from which this sample derives (Statistics New Zealand, 2012), but rather to evaluate the physiological correlates of perceived discrimination among pregnant women and their children.

5. Conclusions

Ethnic discrimination is an important issue within NZ and has been previously associated with poor mental and physical health outcomes in both adolescents and adults (Crengle et al., 2012; Harris et al., 2012, 2006b). In the present study we build upon this research and show that women who reported experiencing ethnic discrimination had poorer self-rated health and higher evening cortisol while pregnant. In addition, these women gave birth to offspring with heightened cortisol response to vaccination at six weeks of age. The fact that the associations between discrimination and maternal and offspring cortisol were independent of ethnicity suggests that these relationships are unlikely to be confounded by population-specific genetic factors. These findings suggest that reducing exposure to ethnic discrimination experience may not only improve health outcomes among exposed individuals, but also in future generations.

Acknowledgments

ZMT was supported by a NSF Graduate Research Fellowship and Northwestern University Presidential Fellowship during the study duration. Special thanks to the study participants, SAMCL, Greenlane Medical Clinic and Whariki Health Research Group. Dr. Elizabeth Rowe, Dr. Christopher Lynn, Dr. Hannah Wilson, Dr. Michaela Howells, and three anonymous reviewers provided helpful feedback on an earlier version of this manuscript. This work was supported by the NSF under grant # 7285514; Wenner Gren under grant # 8334.

References

Abel, Kathryn M., et al., 2010. Birth weight, schizophrenia, and adult mental disorder: is risk confined to the smallest babies? Archives General Psychiatry 67 (9), 923.
Albers, Esther M., et al., 2008. Maternal behavior predicts infant cortisol recovery from a mild everyday stressor. J. Child Psychol. Psychiatry 49 (1), 97–103.
Barker, D.J.P., 1994. The fetal origins of adult disease. Fetal Maternal Med. Rev. 6 (02), 71–80.
Beijers, R., Riksen-Walraven, J.M., de Weerth, C., 2013. Cortisol regulation in 12-month-old human infants: associations with the infants' early history of breastfeeding and co-sleeping. Stress 16 (3), 267–277.
Chapman, R.R., Berggren, J.R., 2005. Radical contextualization: contributions to an anthropology of racial/ethnic health disparities. Health (London) 9, 145–167.
Claessens, Sanne E.F., et al., 2011. Development of individual differences in stress responsiveness: an overview of factors mediating the outcome of early life experiences. Psychopharmacology 214 (1), 141–154.
Collins Jr., J.W., et al., 2000. Low-income African-American mothers' perception of exposure to racial discrimination and infant birth weight. Epidemiology 11 (3), 337–339.
Cortina, Jose M., 1993. What is coefficient alpha? An examination of theory and applications. J. Appl. Psychol. 78 (1), 98.
Crengle, Sue, et al., 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 (1), 45.
Dailey, D.E., 2009. Social stressors and strengths as predictors of infant birth weight in low-income African American women. Nurs. Res. 58 (5), 340–347.
David, R.J., Collins Jr., J.W., 1997. Differing birth weight among infants of U.S.-born blacks, African-born blacks, and U.S.-born whites. N. Engl. J. Med 337, 1209–1214.
Dixon, B., et al., 2012. Maternal experiences of racial discrimination and child weight status in the first 3 years of life. J. Dev. Orig. Health Dis. 3 (06), 433–441.
Dole, N., et al., 2003. Maternal stress and preterm birth. Am. J. Epidemiol. 157 (1), 14–24.
Dykens, Elisabeth M., Lambert, Warren, 2013. Trajectories of diurnal cortisol in mothers of children with autism and other developmental disabilities: relations to health and mental health. J. Autism Dev. Disord. 1–9.
Fuller-Rowell, Thomas E., Doan, Stacey N., Eccles, Jacquelynne S., 2012. Differential effects of perceived discrimination on the diurnal cortisol rhythm of African Americans and Whites. Psychoneuroendocrinology 37 (1), 107–118.
Gendall, Philip John, Spoonley, Paul, Trlin, Andrew Drago, 2007. The Attitudes of New Zealanders to Immigrants and Immigration: 2003 and 2006 Compared. New Settlers Programme, Massey University.
Glynn, Laura M., et al., 2007. Ethnic differences in adrenocorticotropic hormone, cortisol and corticotropin-releasing hormone during pregnancy. Peptides 28 (6), 1155–1161.
Goedhart, Geertje, et al., 2010. Maternal cortisol and offspring birthweight: results from a large prospective cohort study. Psychoneuroendocrinology 35 (5), 644–652.
Goosby, Bridget J., Heidbrink, Chelsea, 2013. The transgenerational consequences of discrimination on African-American health outcomes. Sociol. Compass 7 (8), 630–643.
Gravlee, Clarence, 2009. How race becomes biology: embodiment of social inequality. Am. J. Phys. Anthropol 139, 47–57.
Greene, M.L., Way, N., Pahl, K., 2006. Trajectories of perceived adult and peer discrimination among Black, Latino, and Asian American adolescents: patterns and psychological correlates. Dev. Psychol. 42, 218–236.
Gunnar, Megan, Quevedo, Karina, 2007. The neurobiology of stress and development. Annu. Rev. Psychol. 58, 145–173.
Haley, David W., Stansbury, Kathy, 2003. Infant stress and parent responsiveness: regulation of physiology and behavior during still-face and reunion. Child. Dev. 74 (5), 1534–1546.
Harris, R., et al., 2006a. Effects of self-reported racial discrimination and deprivation on Maori health and inequalities in New Zealand: cross-sectional study. Lancet 367, 2005–2009.
Harris, Ricci, et al., 2012. The pervasive effects of racism: experiences of racial discrimination in New Zealand over time and associations with multiple health domains. Soc. Sci. Med. 74 (3), 408–415.
Harris, Ricci, et al., 2006b. Racism and health: the relationship between experience of racial discrimination and health in New Zealand. Soc. Sci. Med. 63 (6), 1428–1441.
Ip, Manying, Pang, David, 2005. New Zealand Chinese Identity: Sojourners, Model Minority and Multiple Identities. In: New Zealand identities: Departures and Destinations, pp. 174–190.
Kuzawa, Christopher W., Sweet, Elizabeth, 2009. Epigenetics and the embodiment of race: developmental origins of US racial disparities in cardiovascular health. Am. J. Hum. Biol. 21 (1), 2–15.
Lohman, G.T., Roche, A.F., Martorell, Reynaldo, 1988. Skinfold thicknesses and measurement technique. In: Anthropometric Standardization Reference Manual. Human Kinetics Books, Champaign, IL, pp. 55–70.

Lu, Michael C., Halfon, Neal, 2003. Racial and ethnic disparities in birth outcomes: a life-course perspective. Matern. Child Health J 7, 13.
Marmot, M., Wilkinson, R., 2009. Social Determinants of Health. Oxford University Press.
Ministry of Health, 2004. Ethnicity Data Protocols for the Health and Disability Sector. In Book Ethnicity Data Protocols for the Health and Disability Sector.
Murray, Lynne, et al., 1996. The impact of postnatal depression and associated adversity on early mother-infant interactions and later infant outcome. Child Dev. 67 (5), 2512–2526.
Myers, Hector F., 2009. Ethnicity- and socio-economic status-related stresses in context: an integrative review and conceptual model. J. Behav. Med. 32 (1), 9–19.
O'Connor, Thomas G., et al., 2013. Prenatal cortisol exposure predicts infant cortisol response to acute stress. Dev. Psychobiol. 55 (2), 145–155.
Oberlander, Tim, et al., 2008. Prenatal exposure to maternal depression, neonatal methylation of human glucocorticoid receptor gene (NR2C1) and infant cortisol stress responses. Epigenetics 3 (2), 97–106.
Ongley, Patrick, Pearson, David, 1995. Post-1945 international migration: New Zealand, Australia and Canada compared. Int. Migr. Rev. 765–793.
Pascoe, E.A., Smart Richman, L., 2009. Perceived discrimination and health: a meta-analytic review. Psychol. Bull. 135, 531–554.
Powell, Lynda H., et al., 2002. Physiologic markers of chronic stress in premenopausal, middle-aged women. Psychosom. Med. 64 (3), 502–509.
Rumball, C.W.H., et al., 2008. Effects of twinning and periconceptional undernutrition on late-gestation hypothalamic-pituitary-adrenal axis function in ovine pregnancy. Endocrinology 149 (3), 1163–1172.
Salmond, Clare, et al., 2006. NZiDep: a New Zealand index of socioeconomic deprivation for individuals. Soc. Sci. Med. 62 (6), 1474–1485.
Sandman, Curt A., et al., 2006. Elevated maternal cortisol early in pregnancy predicts third trimester levels of placental corticotropin releasing hormone (CRH): priming the placental clock. Peptides 27 (6), 1457–1463.
Schulz, Amy J., et al., 2006. Discrimination, symptoms of depression, and self-rated health among African American women in Detroit: results from a longitudinal analysis. Am. J. Public Health 96 (7), 1265–1270.
Seckl, J.R., Meaney, Michael J., 2004. Glucocorticoid Programming. Annals of the New York Academy of Sciences 1032 (Biobehavioral Stress Response: Protective and Damaging Effects), pp. 63–84.
Sellers, Robert M., et al., 2003. Racial identity, racial discrimination, perceived stress, and psychological distress among African American young adults. J. Health Soc. Behav. 44 (3), 302–317.
Skinner, Martie L., et al., 2011. Allostasis model facilitates understanding race differences in the diurnal cortisol rhythm. Dev. Psychopathol. 23 (4), 1167.
Spoonley, Paul, Bedford, Richard, 2008. Responding to regional labour demand: international migration and labour markets in New Zealand's regions. J. Int. Migr. Integr./Rev. l'integr. Migr. Int. 9 (2), 203–223.
Spoonley, Paul, Meares, Carina L., 2011. Laissez-faire multiculturalism and relational embeddedness: ethnic precincts in Auckland. Cosmopolitan Civ. Soc. Interdiscip. J. 3 (1), 42–64.
Statistics New Zealand, 2012. Working Together: Racial Discrimination in New Zealand. www.stats.govt.nz.
Statistics New Zealand, 2013a. 2013 Census Quickstats about Maori. www.stats.govt.nz.
Statistics New Zealand, 2013b. QuickStats about Auckland Region. http://www.stats.govt.nz/Census/2006CensusHomePage/QuickStats/AboutAPlace/SnapShot.aspx?type=region&ParentID=1000002&tab=Culturaldiversity&id=1000002.
Thayer, Zaneta M., Kuzawa, Christopher W., 2011. Biological memories of past environments: epigenetic pathways to health disparities. Epigenetics 6, 798–803.
Thayer, Zaneta M., Feranil, Alan B., Kuzawa, Christopher W., 2012. Maternal cortisol disproportionately impacts fetal growth in male offspring: evidence from the Philippines. Am. J. Hum. Biol. 24 (1), 1–4.
Thayer, Zaneta M., Kuzawa, Christopher 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. Am. J. Hum. Bio 26, 723–730.
Tollenaar, M.S., et al., 2011. Maternal prenatal stress and cortisol reactivity to stressors in human infants. Stress 14 (1), 53–65.
Tomfohr, Lianne, et al., 2010. Everyday discrimination and nocturnal blood pressure dipping in Black and White Americans. Psychosom. Med. 72 (3), 266–272.
Wadhwa, Pathik D., 2005. Psychoneuroendocrine processes in human pregnancy influence fetal development and health. Psychoneuroendocrinology 30 (8), 724–743.
Wells, J.C., 2010. Maternal capital and the metabolic ghetto: an evolutionary perspective on the transgenerational basis of health inequalities. Am. J. Hum. Biol. 22 (1), 1–17.
Williams, David, Mohammed, Selina, 2009. Discrimination and racial disparities in health: evidence and needed research. J. Behav. Med. 32 (1), 20–47.
Williams, David R., Mohammed, Selina A., Leavell, Jacinta, Collins, Chiquita, 2010. Race, socioeconomic status, and health: complexities, ongoing challenges, and research opportunities. Ann. N. Y. Acad. Sci. 1186, 69–101.
Williams, David R., et al., 1997. Racial differences in physical and mental health socio-economic status, stress and discrimination. J. Health Psychol. 2 (3), 335–351.
Worthman, Carol, Kuzara, Jennifer, 2005. Life history and the early origins of health differentials. Am. J. Hum. Biol. 17 (1), 95–112.
Zeiders, Katharine H., Doane, Leah D., Roosa, Mark W., 2012. Perceived discrimination and diurnal cortisol: examining relations among Mexican American adolescents. Hormones Behav. 61 (4), 541–548.