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Associations of household and neighborhood contexts and hair cortisol among adolescents from low-income Mexican immigrant families

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Abstract

Although neighborhood contexts are upstream determinants of health, how neighborhood contexts "get under the skin" is unclear, especially among Mexican low-income immigrant youth who are disproportionally concentrated in highly disadvantaged yet coethnic neighborhoods. The current study examined associations between household and neighborhood socioeconomic status, neighborhood racial-ethnic and immigrant structuring and hair cortisol concentration (HCC) – a physiological index of chronic stress response - among Mexican-origin American adolescents from low-income immigrant families. **Methods.** 297 (54.20% female; M_{age} = 17.61, *SD* = .93) Mexican-origin adolescents' hair cortisol were collected and residential addresses were geocoded and merged with the American Community Survey. **Results.** Neighborhoods with higher Hispanic and foreign-born residents were associated with higher neighborhood disadvantage, whereas neighborhoods with higher white residents were associated with higher neighborhood affluence. Mexican-origin adolescents living in neighborhood with a higher proportion of Hispanic residents showed *lower* levels of HCC, consistent with the protective role of ethnic enclave. In contrast, adolescents living in more affluence neighborhoods showed *higher* levels of HCC, possibly reflecting a physiological toll. No association was found between household SES and HCC. **Conclusions.** Findings infer that relocating low-income racial-ethnic minorized families to more affluent neighborhoods without understanding its racial-ethnic structuring and providing socio-cultural support could backfire.

Keywords: neighborhood socioeconomic status, hair cortisol, immigrant, racial-ethnic concentration, adolescents, HPA axis, stress

Associations of household and neighborhood contexts and hair cortisol among adolescents from low-income Mexican immigrant families

Mexican immigrant families in the United States (US) often experience high rates of poverty (Lopez & Velasco, 2011) and are disproportionally concentrated in highly disadvantaged (more impoverished) neighborhoods, characterized by extreme poverty and unemployment (Massey, 1996; Reardon et al., 2015). Although neighborhood contexts are upstream social determinants of physical and mental health (Leventhal & Dupéré, 2019) that have been proposed to have downstream consequences by altering the hypothalamic-pituitary-adrenal (HPA) axis (Amaro et al., 2021), empirical studies, especially those among racial-ethnic minoritized (including Mexican-origin immigrant) adolescents, are lacking (Harnett, 2020). Understanding associations between neighborhood contexts and HPA axis among racial-ethnic minoritized adolescents represent a first step towards understanding the biological pathways of health disparities often borne by racial-ethnic minorities (Williams & Collins, 2001).

The current study aimed to address this gap in knowledge by examining associations between neighborhood socioeconomic status (SES), neighborhood racial-ethnic and immigrant structuring and hair cortisol concentration (HCC), which is a physiological index of chronic stress response of the HPA axis (Russell et al., 2012; Stalder et al., 2017), among Mexican-origin American adolescents from low-income immigrant families. We focused on this question because US housing intervention and policies (e.g., neighborhood revitalization and housing mobility) tend to focus on residential integration of low-income families into more affluent (often white) neighborhoods as a potential solution to remediate effects of disadvantaged neighborhoods (Leventhal & Dupéré, 2019). Yet, emerging evidence has suggested that living in more affluent neighborhood and/or with less coethnics (e.g., whiter) neighborhood can inhibit healthy development among Hispanic adolescents from low-income families (White et al., 2020;

White, Kho, et al., 2021). To date, it is unknown whether there is a physiological toll (or benefit) for Mexican-origin adolescents from low-income immigrant families living in more, as compared to less affluent and whiter neighborhood. By 2060, 1 in 3 youth in the US would be from Hispanic background. Of which, children of Mexican American immigrant families represent the largest and fastest growing Hispanic population (Pew Research Center). Hence, we argue it is necessary to a) characterize neighborhood contexts where Mexican-origin adolescents from low-income immigrant families reside, and b) understand how neighborhood contexts may associate with physiological index (i.e., HCC) of chronic stress response. Understanding how neighborhood contexts "get under the skin" can help to elucidate the impact of neighborhood on adolescents that may not be able to capture by subjective self-report measure (Chen et al., 2015) and have strong implication to inform housing intervention and policies.

Household and neighborhood socioeconomic status (SES)

While household SES has often been used as a proxy of social adversity in the neurobiology literature (Farah, 2017), it does not address adverse exposures further upstream at the macrosocial levels (i.e., neighborhood environment), nor does it reflect structural inequalities (e.g., racial-ethnic minoritized and immigrant families have lower income return even with the same education level as their white counterparts) that are deemed as the fundamental cause of racial-ethnic disparities (Acevedo-Garcia et al., 2013; Williams & Collins, 2001). Racial-ethnic residential segregation is a central feature in the United States (US)(Acevedo-Garcia et al., 2013; Williams & Collins, 2001). Influenced by racial-ethnic residential segregation, over three decades of research have documented that Hispanic and Black families are disproportionally concentrated in highly disadvantaged neighborhoods with high rates of poverty and unemployment, high exposure to environmental toxics (e.g., air quality and lead), and violent crime (Sampson et al., 2002). In contrast, white families are disproportionally concentrated in more affluent neighborhoods, characterized with larger proportion of high income, highly educated adults with professional occupations that attract health-promotive resources (Browning & Cagney, 2003). Indeed, while there is a decline in segregation among Black families, segregation of Hispanic families continued to remains high and stable (Bischoff & Reardon, 2014), which likely has multigenerational consequences on child developmental outcomes as residential segregation exacerbates inequality across neighborhood contexts (Sharkey, 2013). It is important to note that neighborhood disadvantage and affluence are two distinct constructs (i.e., affluence is not simply the absence of disadvantage; Clarke et al., 2014). This is because in addition to a lower likelihood of environmental toxics and crime exposure, affluent neighborhood are more likely to attract health-promotive resources (e.g., restaurants and groceries, gym, well-maintained buildings, and green space) and have higher social control that can facilitate health (Browning & Cagney, 2003). Indeed, neighborhood affluence has been found to be a better predictor of health than household and neighborhood disadvantage (Wen et al., 2003).

Prominent theories (e.g., social disorganization theory; Sampson & Groves, 1989) posited that neigborhood disadvantage adversely influence social relationship of the neigborhood, creating limited opportunities for residents to develop community cohesion to achieve shared norms of monitoring unacceptable behaviors within the community. Hence, youth growing up in more disadvantaged neighborhood may be associated with more behavioral problems given the environmental risk factors associated with neighborhood disadvantage (e.g., Sampson et al., 2002; Wodtke et al., 2011). However, recent review suggesting that the previously established association between neighborhood disadvantage and higher behavioral problems was not consistently replicated among Hispanic youth (see White et al., 2021 for a review). Rather, for Hispanic adolescents from low-income families, residing or relocating to a more affluent neighborhood may be associated with *higher l*evels of maladaptive outcomes (e.g., lower school performance, higher substance use; Fauth et al., 2007). This finding may be in part because living in an affluent environment as a low-income family could elicit stress resulting from higher financial burden (e.g., higher cost of living with limited job availability), lower social resources, and feeling of insecure regarding their place in the more affluent communities (Fauth et al., 2007). Despite this, it is unclear how neighborhood SES may associate with chronic physiological stress responses.

Neighborhood racial-ethnic and immigrant structure

Moreover, most studies of neighborhood tend to omit the substantial heterogeneity in racial-ethnic and immigrant structure within a neighborhood (i.e., proportion of people of non-Hispanic white, proportion of people of Hispanic origin and proportion of people who are foreign born) that Hispanic families reside, in addition to neighborhood SES (White et al., 2020). Yet, neighborhood racial-ethnic and immigrant structure is an important aspect of neighborhood context that can promote and inhibit adolescent healthy development (Rivas-Drake & Witherspoon, 2013; White et al., 2020). For example, neighborhoods with a higher proportion of Hispanic population was associated with better adjustment (e.g., lower behavioral and depressive problems) among Mexican American adolescents (see White et al., 2020 for a review). This suggests that exposure to neighborhood contexts with a higher proportion of coethnic (within-group) members can be a promoting factor for adolescents, consistent with theories suggesting the protective role of ethnic enclaves (Logan et al., 2002). Ethnic enclave theory posits that even though communities of immigrant consist of poor minority groups, they do not experience the same neighborhood problems, given their goal for migration may motivate them for entrepreneurship that provides flourishing communities that may act as a social/community buffer against living in disadvantaged neighborhood (Logan et al., 2002). Interestingly, Mexican American adolescents moving to a whiter neighborhood have been linked with *increased* externalizing symptom trajectories (White, Kho, et al., 2021). This finding may be explained by reductions in quality of living (e.g., higher discrimination and lower sense of belonging and social support) among Mexican American youth living in a whiter environment (White et al., 2020). Collectively, these findings highlight that neighborhood racial-ethnic and immigrant structure is an important aspect to Mexican-origin American adolescents' development. Despite this, to our knowledge, no study has examined whether variations in neighborhood racial-ethnic and immigrant structure are associated with biological or hormonal markers of health among Mexican American adolescents, such as youths' HCC levels.

Hair cortisol concentration (HCC) as chronic physiological stress response

Glucocorticoids (i.e., cortisol in humans), the end-product of HPA activation, are indicators of stress responses for modulation and preparative (e.g., adapting to chronic stressors) actions (Gunnar et al., 2010; Sapolsky et al., 2000). Unlike salivary or urine cortisol that is often used to inform acute stress response in a relatively short time frame (e.g., a few days), hair cortisol is the product of accumulation of unbound free (active) circulating cortisol that are incorporated into the growing hair over an extended period of time (e.g., 3 months; Russell et al., 2012; Stalder et al., 2017). Thus, hair cortisol concentration (HCC) has increasingly been recognized as a potential indicator that can retrospectively track the cumulative physiological stress response (Liu & Doan, 2019; Russell et al., 2012).

The role of household and neighborhood contexts on HCC

The associations between SES and HCC are equivocal (Bryson et al., 2021). Moreover, these studies have primarily focused on young children and from primarily middle-class and white backgrounds. To our knowledge, no study thus far has examined how adolescents' HCC may be influenced by different neighborhood contexts (SES racial-ethnic and immigrant structure), above and beyond the effect of household SES, especially among adolescents from low-income immigrant family background. This is a critical omission because first adolescence is a developmental period by which individuals are highly sensitive to environmental influence (Gee & Casey, 2015), and that neighborhood is a salient context of adolescent development, above and beyond effects of household socioeconomic SES (Rivas-Drake & Witherspoon, 2013; White, Witherspoon, et al., 2021). Second, Hispanic adolescents from low-income families are disproportionally living in more disadvantaged neighborhoods. Third, the utilization of HCC as a relatively non-invasive way to assess chronic stress response of the HPA axis has strong potentials to understand effects of neighborhood environments on adolescent development that may not be able to capture by subjective self-report measure (Chen et al., 2015).

Among existing studies that have linked HCC with household SES, lower parental education (Tarullo et al., 2020; Ursache et al., 2017; Vaghri et al., 2013) and household income (Rippe et al., 2016) was associated with higher HCC among typically developing preschool- and early school-aged children. Other studies have found no association between household SES (income and education) and HCC among children (see Bryson et al., 2021 for a review). Among studies that have linked HCC with neighborhood SES, higher housing problems (e.g., overcrowding, mold) was associated with *lower* HCC among 2-year-old children, even after controlling for household SES. Yet, low tenure housing (e.g., public rental) was associated with *higher* child HCC (Bryson et al., 2019).

Collectively, there seems to be some evidence (e.g., Bryson et al., 2019) suggesting that neighborhood contexts may be associated with HCC among children, above and beyond the impact of household SES, albeit the nature of the association is unclear and prior studies did not capture important neighborhood indices (i.e., neighborhood affluence and neighborhood racial-ethnic and immigrant structure). Moreover, prior studies of HCC have not focused on adolescents among Hispanic immigrant families, despite as a group these families often experience high rates of poverty (Lopez & Velasco, 2011) and are disproportionally concentrated in highly disadvantaged (more impoverished) neighborhoods. For this reason and to maximize power, we focused on using a relatively homogenous sample of Mexican-origin adolescents rather than using a heterogenous sample of youth from a diverse cultural background (i.e., race/ethnicity and household SES) and controlled for child sex and immigrant status. Indeed, HCC levels have been shown to be differed by race/ethnicity (Bryson et al., 2021; Rippe et al., 2016), further highlight the importance of using a homogenous sample to account for variation in family cultural background as a first step towards clarifying the role of household and neighborhood contexts on HCC. After which, we can examine whether this association is robust by examining the extent to which this finding may be generalized to youth from other cultural backgrounds.

The Current Study

The current study aims to investigate the associations between neighborhood socioeconomic status (SES), neighborhood racial-ethnic and immigrant structure and hair cortisol concentration (HCC) among Mexican-origin American adolescents from low-income immigrant families. To better contextualize the neighborhood environment in which our sample of Mexican-origin American adolescents from low-income immigrant families reside, we first examined the associations among neighborhood SES (i.e., neighborhood disadvantage and affluence) and neighborhood racial-ethnic and immigrant structure (i.e., proportion of non-Hispanic white residents, proportion of Hispanic origin residents, and proportion of foreign born residents) at the neighborhood level. Based on the effects of racial residential segregation (Acevedo-Garcia et al., 2008; Williams & Collins, 2001), we hypothesized that neighborhood with higher proportion of Hispanic origin or foreign born residents would be associated with higher neighborhood disadvantage and lower neighborhood affluence. In contrast, neighborhood with higher proportion of non-Hispanic white residents would be associated with higher neighborhood affluence and lower disadvantage.

Second, using a multilevel modelling approach to account for the nesting effect of household within a neighborhood, we examined association between household (i.e., parental education and income) and neighborhood SES (i.e., neighborhood disadvantage and affluence) and HCC among Mexican-origin adolescents. We expected that neighborhood disadvantage and affluence would be associated with HCC, above and beyond the effect of parental education and income, given that neighborhood is a salient aspect of adolescent development. However, we did not make any directionality hypotheses between the association of household and neighborhood SES and HCC due to insufficient and mixed evidence (Bryson et al., 2021). Covariates included child sex, age and nativity.

Third, using a multilevel modelling approach and the same covariates, we examined the associations among neighborhood racial-ethnic and immigrant structure (i.e., proportion of people of non-Hispanic white, proportion of people of Hispanic origin and proportion of people who are foreign born) within a neighborhood and HCC among Mexican-origin adolescents from low-income immigrant families, after accounting for household SES. While there is no direct study to guide the nature of the association, we expected that Mexican-origin adolescents living in neighborhood with higher (relative to lower) proportion of Hispanic origin residents and foreign-born residents would exhibit lower HCC, which is consistent with behavioral studies suggesting that neighborhood with higher coethnics group may promote healthy development (Rivas- Drake & Witherspoon, 2013; White et at al., 2020). In contrast, we expected for Mexican-origin adolescents living in neighborhood with higher (relative to lower) proportion of non-Hispanic white residents would exhibit higher HCC (White et al., 2021).

Method

Participants and Procedures

Data were drawn from a larger longitudinal study among low-income Mexican immigrant families recruited in central Texas from 2012 to 2020 through convenience sampling. Families were qualified for the larger study if at least one child in the family was in middle school and translating/interpreting for parents between Spanish and English. Data utilized in the current study include adolescents' and mothers' reports on the yearly interview at Wave 3 (N = 334, 2017 to 2020) and adolescents' hair cortisol data (N = 301) collected before or in the yearly interview. Adolescents with hair cortisol values below or above three standard deviations from the mean were considered outliers and removed from the analysis (n = 4) as recommended (Enlow et al., 2019). Overall, the current study included 297 adolescents (M_{age} = 17.61, *SD* = 0.93) and their mothers (N =292; M_{age} = 43.26, *SD* = 5.74). Adolescent participants included 161 females (54.20%) and 136 males (45.80%), and more than half of them were born in the U.S. (76.10%). Most mothers were born in Mexico (98.90%), and the average years of living permanently in the U.S. is 19.85. The median and mode of mothers' education level was middle school or junior high school. The median and mean household family income for participants was in the range of $30,001 to $40,000.

In the yearly interview, bilingual research assistants read questions aloud to participants in their preferred language (i.e., Spanish or English) and recorded their responses by writing down their answers on a laptop computer. All questions were prepared in both Spanish and English. Research assistants translated original English questions to Spanish and back-translated to English to check translation validity. Each family was compensated $90 for participating in the interview.

Hair samples were collected by trained research assistants during a home visit. Research assistants carefully cut adolescents' hair strands with sterilized scissors as close as possible to the scalp from a posterior vertex position. Research assistants were instructed to obtain approximately 100 strands of hair for at least 3 cm segment for each adolescent. Hair samples were placed on aluminum foils and the scalp-near end of the hair was marked for hair longer than 3 cm. Each family was compensated $20 for hair collection. Hair samples were stored in room temperature and analyzed in Kirschbaum Endocrine Laboratory at the Technical University Dresden, Germany.

Measures

Adolescent hair cortisol extraction

The hair strands were lined up and cut into a 3 cm segment in the laboratory, corresponding to hair cortisol in approximately the prior three months. For washing of hair and cortisol extraction, the protocol of Davenport et al., 2006 was employed. In brief, each hair segment was put into a 10 ml glass container, then 2.5 ml isopropanol was added, and the tube was gently mixed on an overhead rotator for three minutes. After decanting, the wash cycle was repeated twice. Then the hair samples were allowed to dry for at least 12 hours. Next, the hair segment was weighed, and 7.5 mg were transferred into a 2 ml cryovial. 1.5 ml of pure methanol was added, and the cortisol extraction was performed for 18 hours. Samples were then spun in a microcentrifuge at 10.000 rpm for 2 minutes, and 1 ml of the clear supernatant was transferred into a new 2 ml glass vial. The alcohol was evaporated at 50 degrees Celsius under a constant stream of nitrogen until the samples were completely dried. Finally, 0.4 ml of water was added, and the tube vortexed for 15 seconds. Fifty microliters were removed from the vial and used for cortisol determination with commercially available immunoassays with chemiluminescence detection (CLIA, IBL-Hamburg, Germany). The intraassay and interassay coefficients of variance of this assay are below 15% for hair cortisol levels above 1 pg/mg.

Household SES

Family income was measured by one item of annual family income (i.e., think of all the income from persons in your family who live in the same house with you. Consider all kinds of income including wages earned from jobs, alimony, unemployment compensation, and government assistance. What was your family's income from all?) Mothers answered this item on a scale from 0 *($10,000 or under $10,000*) to 11 (*$110,001 or more*).

Mother education was measured by one item of maternal highest education level (i.e., What is the highest level of education you have completed?). Mothers answered this item on a scale ranging from 1 (*no formal schooling*) to 11 (*finished graduate degree*).

Neighborhood Contexts:

We extracted theoretically-derived measures of neighborhood SES and neighborhood racial-ethnic and immigrant structure from the National Neighborhood Data Achieve (NaNDA)'s Socioeconomic Status and Demographic Characteristics of ZIP Code Tabulation Areas dataset (https://nanda.isr.umich.edu/). In which, neighborhood and demographic proportions per ZIP code tabulation areas (ZCTA) are from the US Census Bureau's American Community Survey (ACS) that represents socioeconomic status and demographics of each census tract for the years from 2013 – 2017. The 5-year estimates from the ACS is a standard way to capture neighbourhood characteristics given that the multiyear estimates increased statistical reliability of the data for less populated area and small population subgroups, and it is available for all geographies down to the ZCTA level (United States Census Bureau). Lane area from each ZCTA comes from the TIGER/Line shapefiles, released in 2019 (United States Census Bureau, 2019) to maintain consistency with other similar datasets from NaNDA (Melendez et al., 2020). We geocoded family's residential address based on family's ZIP code at Wave 2 and neighborhood indices were merged into our study using a ZIP code to ZCTA crosswalk.

Neighborhood SES

Neighborhood SES factors were derived from a principal factor analysis with an orthogonal varimax rotation of seven census indicators (log transformed to correct positive skew) (Morenoff et al., 2007). *Neighborhood disadvantage* is a factor score based on four census indicators: proportion of female headed families with children, proportion of households with public assistance income or food stamps; proportion of families with income below the federal poverty level; proportion of population age 16+ unemployed) within a neighborhood as defined at the ZCTA level, ranging from 0 to 1.0 *Neighborhood affluence* is a factor score based on three census indicators, including proportion of households with income greater than $75K, proportion of population age 16+ employed in professional or managerial occupations; proportion of adults with bachelor's degree or higher within a neighborhood as defined at the ZCTA level, ranging from 0 to 1.0.

Neighborhood racial-ethnic and immigrant structure

Neighborhood racial-ethnic and immigrant structure was assessed using three indices: a) proportion of non-Hispanic white residents, b) proportion of Hispanic origin residents, and c) proportion of residents who are foreign born within a neighborhood as defined at the ZCTA level. Higher values indicate higher proportion of specific residents living in the neighborhood.

Analysis plan

Data analyses were conducted in SPSS 22.0 and Mplus 8.3 (Muthén & Muthén, 2012) in two steps. Firstly, descriptive analysis and Pearson product-moment correlation of study variables were conducted in SPSS 22.0. Secondly, given that families are nested within neighborhoods, multilevel analyses were conducted to examine the association between family and neighborhood indices and adolescents' hair cortisol. Each neighborhood indices (i.e., neighborhood disadvantage and neighborhood affluence, proportion of non-Hispanic white residents, proportion of Hispanic origin residents and proportion of residents who are foreign born) was modelled separately to avoid multicollinearity. Little's Missing Completely at Random Test showed that the missingness of study variables is completely at random ($\chi^2(8) = 15.160$, $p = .056$). Thus, families that have all study variables were included in the multilevel analyses, resulting in a sample size of 222 families.

Results

Descriptive statistics and Pearson correlation

Table 1 shows the correlation and descriptive information of study variables at the family level. Higher neighborhood affluence was associated with higher levels of adolescents' HCC. Moreover, living in neighborhood with a higher proportion of Hispanic origin residents was associated with lower HCC, whereas living in neighborhood with a higher proportion of non-Hispanic white residents was associated with higher levels of HCC among adolescents.

Question 1. What are the associations among neighborhood SES and neighborhood racial-ethnic and immigrant structuring?

As shown in Table 2, when examining at the neighborhood level, neighborhood with a higher proportion of non-Hispanic white residents was associated with higher neighborhood affluence and lower neighborhood disadvantage. In contrast, neighborhoods with a higher proportion of Hispanic origin residents and foreign-born residents were associated with higher neighborhood disadvantage and lower neighborhood affluence.

Question 2. What are the association between household and neighborhood SES and HCC among Mexican-origin adolescents from low-income immigrant families?

Multilevel modelling indicated that living in more affluent neighborhood was associated with *higher* levels of HCC (b = 4.073, $p < .05$, Table 3; Figure 1a) among Mexican-origin adolescents from low-income immigrant families, above and beyond effects of household SES and after accounting for adolescents' sex, nativity, and age. Male adolescents had higher HCC than female adolescents. No other significant association was found.

Question 3. What are the associations among neighborhood racial-ethnic and immigrant structuring and HCC among Mexican-origin adolescents from low-income immigrant families?

Multilevel modelling indicated that living in neighborhood with higher proportion of Hispanic origin residents was significantly associated with *lower* levels of HCC (b = -3.362, SE = 0.883, $p < .001$, Table 4; Figure 1b) among Mexican-origin adolescents from low-income immigrant families, above and beyond effects of household SES and after accounting for adolescents' sex, nativity, and age. Moreover, living in neighborhood with a higher proportion of foreign-born residents was associated with lower adolescents' HCC at a marginally significant level (*b* = -4.204, *SE* = 2.192, *p* = .055).

Sensitivity Analyses

Sensitivity analyses were further conducted to differentiate the distinct effect of neighborhood SES and neighborhood racial-ethnic and immigrant structure, after controlling for each other in the same model. The residual of neighborhood affluence and proportion of Hispanic origin residents were correlated in the model given the high correlation between the two neighborhood indices. The results indicated that neighborhood with higher proportion of Hispanic origin residents was associated with lower HCC among adolescents at a marginally significant level (*b* = -3.625, *SE* = 2.089, *p* = .083) after controlling for neighborhood affluence. However, neighborhood affluence was no longer associated with adolescents' HCC (*b* = -0.416, *SE* = 3.298, *p* = .900) when proportion of Hispanic origin residents was controlled. The sensitivity analysis suggests that the association between higher neighborhood affluence and higher adolescents' HCC shown in the main results may be driven or explained by the negative association between neighborhood affluence and proportion of Hispanic origin residents. That is, the reason why adolescents who live in more affluent neighborhood had higher HCC may be because those in affluent neighborhoods had lower proportions of Hispanic origin residents, which was associated with higher HCC for Mexican-origin adolescents in immigrant families.

Discussion

The broad conditions in which people born, grow, live, work, and age in are upstream macro-social conditions that have downstream consequences on people's health (Marmot et al., 2012). Mexican-origin youth, who are disproportionately concentrated in disadvantaged and impoverished neighborhoods are therefore particularly susceptible to neighborhood detriments, which may help us understand why they often bear the brunt of health disparities in the U.S (Leventhal & Dupéré, 2019). Despite attempts made in US housing mobility programs that aim to alleviate the living situation for Mexican-origin populations through residential integration of low-income families into more affluent and whiter neighborhoods (Leventhal & Dupéré, 2019), Mexican-origin youths continue to show worse than commensurate levels of adverse adolescent development (Lopez & Velasco, 2011; Reardon et al., 2015). Thus, a primary aim of the current study was to investigate the associations between Mexican-origin youths' neighborhood factors and their physiological response to stress. Specifically, we showed that adolescents' neighborhood-concentrated (1) socioeconomic status (SES; as measured by both affluence and disadvantage) and (2) ethnic-racial and immigrant structure were related with modulations in their HPA axis as indexed by hair cortisol concentration (HCC) - a physiological marker of chronic stress response.

Our findings here demonstrated that neighborhoods with higher proportions of people of Hispanic origin as well as foreign born were indeed associated with higher levels of neighborhood disadvantage and lower levels of neighborhood affluence. In contrast, neighborhoods with higher proportions of non-Hispanic whites was associated with lower levels of disadvantage and higher levels of neighborhood affluence. These findings are consistent with the extensive literature on structural racism, which have revealed how racial residential segregation detrimentally impacts Hispanics' (including adolescents) life chances (Massey, 1996). Further, the racial contexts in which people are born and grow up in moulds personal beliefs and influences the types of social networks they become familiar with (see also perpetuation theory; Goldsmith, 2016). It is likely that racial-ethnic segregation has further downstream repercussions on Hispanics (and potentially intergenerational consequences on later generations) as they continue to live in residential areas with a similar racial composition and are subjected to high levels of neighborhood disadvantage.

We found evidence that neighborhood SES was related to adolescents' HCC levels. Specifically, adolescents who lived in neighborhoods with higher (as compared to lower) affluence showed higher levels of HCC (which has been suggested to index higher physiological stress response). Our findings are intriguing considering the significant body of literature that has documented the positive relationship between affluence and healthy adolescent development; that is, more affluence is generally associated with better adolescent health (Beyers et al., 2003; Leventhal & Dupéré, 2019). While the exact mechanisms underlying the positive association between neighborhood affluence and HCC remains unclear, we speculate several reasons explaining this finding. First, although affluent neighborhoods attract higher quality health-promoting services, infrastructure, and organizations (e.g., parks and recreational services) that indirectly benefit residents' health (Browning & Cagney, 2003; Clarke et al., 2014), it is important to be mindful that Mexican-origin families remain poor (in relative comparison with their White neighbors) despite living in more affluent neighborhood conditions. It is likely that Mexican-origin youths living in these affluent neighborhoods lack resources to gain access to the amenities in their living spaces (e.g., local services may have higher retail prices or specialized amenities that cater particularly to local rich residents). Second, our findings may be driven primarily by the inverse association between affluence and proportion of Hispanic origin residents, as documented in our sensitivity analyses. Perhaps, Hispanic youths living in affluent neighborhood may feel more secluded in their less coethnic environment. Put differently, high affluent neighborhoods may exacerbate Mexican-origin adolescents' awareness of the distinctions between their impoverished situations, and what their affluent neighbors have.

Somewhat consistent also with skin deep resilience theory (Brody et al., 2013; Chen et al., 2015), our findings demonstrate the physiological toll borne by Mexican-origin American adolescents, despite their more affluent living situations. It also raises the question if moving to more affluent neighborhoods are necessarily helpful. Our findings here may suggest the need to provide greater social and community support to low-income youth living in affluent neighborhoods. Consequently, housing policies (e.g., neighborhood revitalization and housing mobility) that simply relocate Mexican-origin families to more affluent neighborhoods without providing support could counterintuitively elevate adolescents' cortisol levels instead.

It was interesting that we did not find associations between neighborhood disadvantage and adolescents' HCC levels. It is often assumed that living in neighborhoods with high disadvantage constitutes a chronic stressor which can in turn activate the biological systems that regulate responses to environmental stressors and manifest in greater vulnerability to disease (Hackman et al., 2012; McEwen & Akil, 2020). How do we explain our non-significant findings then? It is important to note that the prior literatures did not assess immigrant youths, so one reason for our findings is that the associations between neighborhood disadvantage and HCC may not be generalizable to low-income immigrant youth. It is also possible that the observed null findings are due to the limited range of neighborhood disadvantage in our data (the sample we had here was primarily a low-income sample). In other words, we might be able to detect the effects if we had a more diverse sample, such as one with wider range in SES. However, insofar as neighborhood disadvantage may indeed be associated with activation in adolescents' HPA axis, we posit that perhaps, adolescents in our sample likely also enjoyed strong support from co-ethnics living in their neighborhood, which buffered the detrimental effects of neighborhood disadvantage (see discussion below). This hypothesis is supported by positive bivariate correlations between neighborhood disadvantage and proportion of co-ethnics. Relatedly, we interpret our sensitivity analyses to suggest that racial-ethnic and immigrant structuring was a stronger factor on adolescents' HCC levels as compared to their neighbourhood SES. We also point out that the literature has shown mixed associations for the link between neighborhood disadvantage and adolescent well-being (particularly after controlling for individual or family level factors) (see White et al., 2021 for a review). Thus, it remains important for researchers to broaden their examinations to include neighborhood SES together with racial-ethnic and immigrant structuring in future work to clarify whether neighborhood disadvantage may (or may not) relate to adolescents' HCC levels.

We note also that the large body of existing studies typically focus on neighborhood disadvantages and ignore effects of neighborhood affluence. However, given that recent research has documented mixed associations neighborhood disadvantage and affluence (i.e., the two constructs do not lie on opposing ends on the same continuum), we cannot assume that disadvantage and affluence are dichotomously associated with adolescents' HCC levels (White et al., 2021). Thus it is a strength of the present study that we (1) examined both neighborhood disadvantage and affluence in the same study and (2) provided greater clarity to the less studied area of affluence by showing the links between living in an affluent neighborhood and the potential dysregulations in Mexican American adolescents' HPA axis. More work with physiological markers is needed to ascertain how neighborhood affluence, disadvantage and household SES independently and collectively contribute to adolescents' biological development.

In line with our hypotheses, we found that Mexican-origin adolescents living in neighborhood with a higher proportion of Hispanic residents showed lower levels of hair cortisol concentration (which has been linked to better biological health). Our findings are consistent with other studies with ethnic minorities, which showed that Mexican American adolescents who resided in neighborhoods comprising of more co-ethnics showed less externalizing and internalizing symptoms (Basáñez et al., 2013; Martinez & Polo, 2018). Living in an area with a large proportion of co-ethnics is helpful because there is greater access to social support from ingroup neighbors, which have direct positive links with health promotion behaviors (White et al., 2020). For instance, the literature on ethnic enclave theory suggests that neighborhoods with more within-ethnic group residents can promote healthy behavioral development, reduce incidence of behavioral problems and lower depressive symptoms (Portes & Manning, 2019). Additionally, living in neighborhoods with more co-ethnics can help to amplify the values that are salient to the Mexican-origin community (ethnic identity, social integration, emphasis on family values), which can contribute to greater acceptance, adoption and internalization of these core cultural beliefs (Martinez & Polo, 2018). Crucially, adolescents may also be subjected to less frequent experiences of racism and discrimination living in neighborhoods with more co-ethnics, reducing experienced stress and in turn their physiological toll (White, Kho, et al., 2021).

It was Interesting that we found no evidence of household SES and their links with to hair cortisol. It is possible that the links between household SES and HCC may be sample specific, and these associations may not have been present in our sample of low-income immigrant racial-ethnic minoritized families. Relatedly, there could potentially be limited variability in household SES in our sample given that our sample is low-income. More convincingly, our findings are in line with some research suggesting weak association of household SES (Bryson et al., 2021). Our findings here thus highlight the importance of considering neighborhood contextual factors (in addition to individual and family factors), and the need to capture the multifaceted ecological contexts (e.g., neighborhood, family, household) in which youth is living to understand adolescent development.

Based on our findings, we also highlight the implications our present work here has on U.S. social housing policy. The effects of upward residential mobility on HPA axis are not well understood. On the one hand, neighborhood-effects theories (Sharkey & Sampson, 2010) have predicted that students who move to higher-income neighborhoods will show improved educational outcomes, especially for large changes of context. On the other hand, some theories of mobility – which are rarely discussed in the literature on neighborhoods – suggest that the benefits of residing in an affluent neighborhood may be mitigated by moving to it. For instance, mobility has been shown to reduce educational attainment, especially for moves that reduce social capital (Haynie et al., 2006). We did not directly measure residential racial segregation in our study, and we did not examine mobility here, thus we suggest it is important to understand how the change in Mexican American social mobility plays a role in affecting adolescent biological and psychological development. We also suggest that it may be important for future research to better understand the candidate mechanisms that may play a role in explaining or effecting these outcomes. For example, social capital and support, community cohesion and discrimination may be explanatory mechanisms that differentially predict how residential mobility impacts Mexican American adolescents' social, biological and psychological outcomes. Relatedly, it is important to consider how individual heterogeneity in features of stress exposure such as chronicity and developmental timing of neighborhood conditions affect stress response of the HPA axis.

Despite the merits of the study, there are limitations that are worth mentioning. First, our methods used to estimate neighborhood effects assume that all adolescents in a given neighborhood have equal exposure to it (Matthews & Yang, 2013) and future studies can be benefited from using global positioning systems (GPS) and ecological momentary assessment (EMA) to capture adolescents' routine activities locations (White et al., 2020). Second, we used a homogeneous sample of Mexican-origin adolescents in our study because previous works have documented that Mexican-origin households are more likely to reside in highly disadvantaged neighborhoods (Lopez & Velasco, 2011), yet few representative work has been conducted on adolescents' HCC for youths in Mexican-origin immigrant families. As such, generalizability of our present findings to another racial-ethnic group or more heterogeneous sample (e.g., mix of first- and second-generation) may be limited. We suggest that future work extend the current study design to other samples of youth to examine how neighborhood factors can implicate their development. Third, ACS comes from a sample survey, and they combine five years of data collection in this fashion in order to have an increased statistical reliability of the data for less populated area and small population subgroups. However, there might be substantial changes to youth's living conditions within the 5 years, and it is hard to accurately identify the time that youths have spent living in their neighborhood. It may be vital then for future work to look at timing effects. Fourth, we only included one-time point of assessment and future studies that examined stability and change of residential neighborhoods are needed to examine causal relations. Finally, the study was limited as we only measured physiological response of stress through adolescents' hair cortisol levels. Our findings are therefore likely confined to associations with adolescents' HPA axis activation, but it remains unclear how higher and lower cortisol associated can be differentially linked to adolescents' functional and behavioral outcomes (Hackman, Betancourt, et al., 2012). Our findings here offer but a thin slice of the experiences of Mexican-origin adolescents who live in neighborhoods with greater proportion of co-ethnics, but we suggest that future research may benefit from adopting a more comprehensive account of adolescents' physiology, neurology as well as their behavioral outcomes to better comprehend the macro-social exposure such as neighborhood contexts and its downstream health consequences (e.g., Ip et al., 2022).

Conclusion

Addressing adolescents' physiological health and their related issues requires a multilevel approach that incorporates upstream macrosocial causes (i.e., neighborhood contexts), as well as probing the biologic mechanisms during adolescent development – when processes may be more malleable for intervention or prevention. Our findings here underscore the importance of neighborhood research by demonstrating that neighborhood contexts and household/individual factors implicates adolescents' HPA axis. Critically, our findings here suggest a need for more thorough and critical evaluations of US social housing policy, as they shed light on how good intentions may fail to deliver their intended consequences. Contrary to contextual models that have assessed objective indicators of neighborhood conditions, we argue that social policies that have argued for relocating Mexican-origin families to more affluent neighborhoods without understanding its racial-ethnic and immigrant structuring and providing social support in mitigating effects of racism misses out on the complexity of this process, and requires careful consideration of low-income Mexican-origin households' subjective experience while living in affluent neighborhoods.

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Table 1

Family-level Correlation and Descriptive Information of Study Variables

	1	2	3	4	5	6	7	8	9	10	11
1. Sex (0=male, 1=female)	-										
2. Nativity (0 = U.S., 1=Mexico)	-.024	-									
3. Adolescent age	-.048	.101	-								
4. Family income	-.054	-.079	-.164*	-							
5. Mother education	-.009	.070	-.082	.073	-						
6. Proportion of Hispanic origin residents	.012	.022	.009	-.045	-.059	-					
7. Proportion of non-Hispanic white residents	.016	-.025	-.030	-.016	.060	-.917**	-				
8. Proportion of foreign-born residents	.013	.056	.073	-.076	-.078	.663**	-.764**	-			
9. Neighborhood disadvantage (from 2013 to 2017)	-.037	.034	.087	-.101	-.119*	.745**	-.781**	.689**	-		
10. Neighborhood affluence (from 2013 to 2017)	.030	.000	-.006	.034	.108	-.869**	.833**	-.580**	-.778**	-	
11. Adolescent hair cortisol (pg/mg)	-.127*	-.058	-.024	.033	.028	-.147*	.121*	-.096	-.110	.123*	-
N	297	297	285	245	292	279	279	279	279	279	297
Mean or % of 1	54%	24%	17.611	2.278	5.031	0.493	0.350	0.205	0.122	0.341	4.463
SD	-	-	0.934	1.549	2.283	0.171	0.176	0.087	0.045	0.122	3.210
Skewness	-	-	0.405	1.564	0.337	-0.022	0.381	0.400	0.332	0.570	2.082
Kurtosis	-	-	0.364	4.927	-0.529	-0.637	-0.628	-0.732	0.150	-0.162	5.775

Note. * $p < .05$; ** $p < .01$.

Table 2

Neighborhood-level Correlation and Descriptive Information of Study Variables (n = 49)

	1	2	3	4	5
1. Neighborhood Hispanic population percentage	-				
2. Neighborhood white population percentage	-.914**	-			
3. Neighborhood foreign-born population percentage	.647**	-.753**	-		
4. Neighborhood disadvantage (from 2013 to 2017)	.726**	-.727**	.625**	-	
5. Neighborhood affluence (from 2013 to 2017)	-.841**	.748**	-.418**	-.717**	-

Note. * $p < .05$; ** $p < .01$.

Table 3.
Multi-level modelling of the effect of household and neighborhood SES on adolescent hair cortisol concentration

	Neighborhood disadvantage		Neighborhood affluence	
	b (SE)	*p*	*b (SE)*	*p*
Intercept	5.071 (0.344)	<.001	5.117 (0.350)	<.001
Sex	-0.805 (0.341)	.018	-0.789 (0.337)	.019
Nativity	-0.462 (0.504)	.360	-0.448 (0.507)	.377
Adolescent age	-0.021 (0.240)	.930	-0.047 (0.233)	.839
Household level				
Parental income	0.021 (0.150)	.890	0.039 (0.150)	.795
Mother education	0.035 (0.089)	.696	0.031 (0.093)	.737
Neighborhood level				
Neighborhood SES	-9.504 (6.392)	.137	4.073 (2.035)	.045
AIC	1002.538		1088.524	
Adjusted-BIC	1005.108		1091.093	
CFI	0.974		0.979	

Note. N = 222 adolescents, number of neighborhoods = 45; Sex: 0 = Male, 1 = Female; Nativity: 0 = U.S., 1 = Mexico; AIC = Akaike information criterion; BIC = Bayesian information criterion.

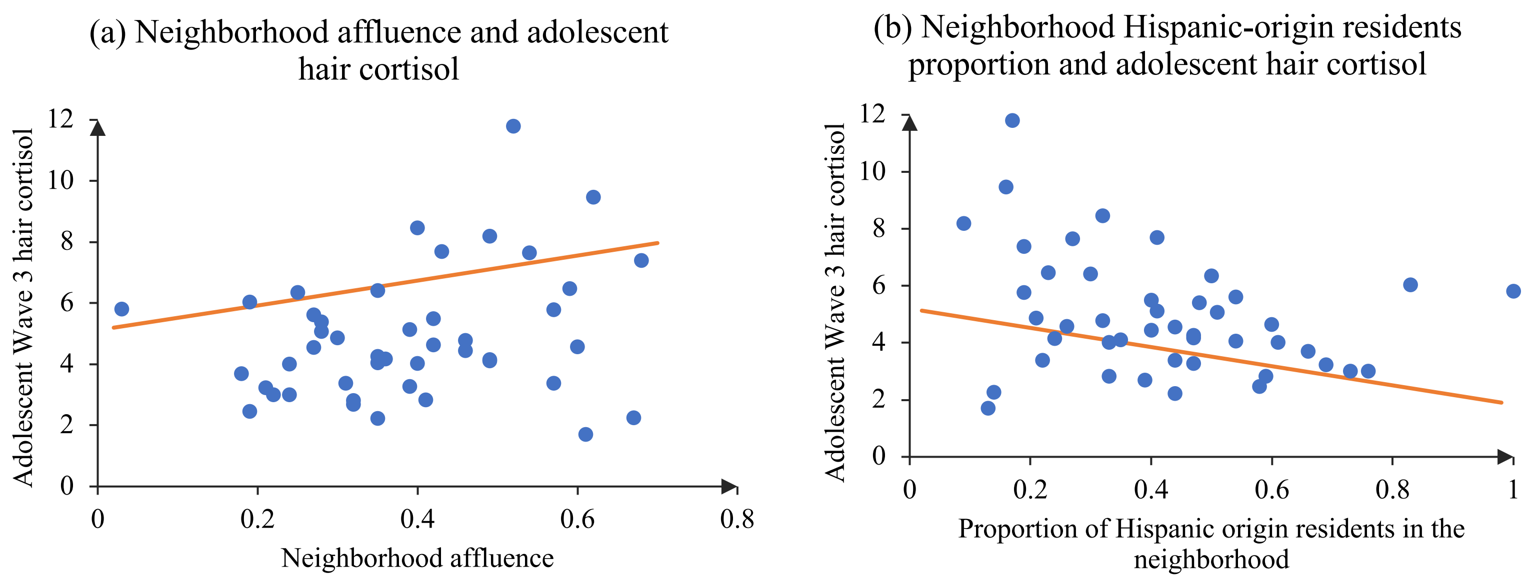
Table 4.
Multi-level modelling of the effect of household SES and neighborhood racial-ethnic and immigrant structure on adolescent hair cortisol concentration

	Proportion of non-Hispanic white residents		Proportion of Hispanic origin residents		Proportion of foreign-born residents	
	b (SE)	*p*	*b (SE)*	*p*	*b (SE)*	*p*
Intercept	5.216 (0.444)	<.001	5.197 (0.363)	<.001	5.067 (0.336)	<.001
Sex	-0.797 (0.462)	.085	-0.747 (0.331)	.024	-0.775 (0.337)	.021
Nativity	-0.444 (0.521)	.395	-0.449 (0.509)	.377	-0.409 (0.511)	.424
Adolescent age	-0.029 (0.255)	.910	-0.050 (0.237)	.834	-0.027 (0.244)	.911
Household level						
Family income	0.053 (0.154)	.730	0.028 (0.148)	.850	0.028 (0.147)	.850
Mother education	0.040 (0.093)	.669	0.041 (0.094)	.664	0.040 (0.090)	.652
Neighborhood level						
Neighborhood racial-ethnic and immigrant structure	2.925 (4.871)	.548	-3.362 (0.883)	<.001	-4.204 (2.192)	.055
AIC	1115.778		1114.035		1041.205	
Adjusted-BIC	1118.348		1116.604		1043.775	
CFI	0.981		0.985		1.000	

Note. *N* = 222 adolescents, number of neighborhoods = 45; Sex: 0 = Male, 1 = Female; Nativity: 0 = U.S., 1 = *Mexico*; AIC = Akaike information criterion; BIC = Bayesian information criterion.

Figure 1

Scatter plots of (a) neighbourhood affluence, (b) proportion of Hispanic-origin residents, and adolescent Wave 3 hair cortisol at neighbourhood-level



Note. The orange solid line shows the estimated regression coefficient from the multilevel results[1]. Y-axis shows the aggregated adolescent hair cortisol at the neighbourhood level.

[1] The level 2 outcome (i.e., hair cortisol) in the multilevel analysis is the intercept of the level 1 hair cortisol, which is the hair cortisol after accounting for the level 1 individual difference within each neighborhood.