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Life Events Trajectories, Allostatic Load, and the Moderating Role of Age at Arrival from Puerto Rico to the US Mainland

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Abstract

Our aim was to examine the effects of trajectories of stressful life events on allostatic load, measured over a two year time period, and to investigate the roles of language acculturation and age at migration in this association, in a sample of Puerto Rican migrants. We used data from the Boston Puerto Rican Health Study; a population-based prospective cohort of older Puerto Ricans recruited between the ages of 45 and 75 years. The Institutional Review Boards at Tufts Medical Center and Northeastern University approved the study. We used latent growth mixture modeling (LGMM) to identify different classes of two-year trajectories of stressful life events; analysis of variance to examine group differences by stress trajectory; and linear regression to test for the modifying effects of age at arrival on the association of stress trajectory with allostatic load at follow-up. In LGMM analysis, we identified three distinct stress trajectories; low, moderate ascending, and high. Unexpectedly, participants in the low stress group had the highest allostatic load at follow-up ($F=4.4$, $p=0.01$) relative to the other two groups. Age at arrival had a statistically significant moderating effect on the association. A reported two year period of moderate but repetitive and increasingly bad life events was associated with increases in allostatic load for participants who arrived to the U.S. mainland after the age of 5 years, and was particularly strong for those arriving between 6–11 years, but not for those arriving earlier or later. Results from this study highlight the complex effects of stress during the life course, and point to certain vulnerable periods for immigrant children that could modify long term effects of stress.

Keywords

Stressful life events; stress trajectories; age at arrival; migration related stress; allostatic load; Latinos/Hispanics; Puerto Rican migrants

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INTRODUCTION

Identifying factors related to the deterioration of immigrant health following migration is relevant for understanding and reducing existing health disparities among racial and ethnic groups in the United States and other Western societies (Jasso, Massey, Rosenzweig, & Smith, 2004; Williams, 2005). Immigrant populations face unique stressors when transitioning into new societies (Zambrana & Carter-Pokras, 2010). The process of migration and subsequent social adaptation involves novel and stressful experiences such as language barriers, the logistics of moving and changing physical environments, adapting to new values and customs, leaving behind loved ones and other support networks, and changing views of self, an immigrant self, in relation to others (Yakhnich, 2008).

Allostatic Load

Chronic stress exposure may result in high allostatic load, the physiological wear and tear on the body caused by the dysregulation of multiple metabolic systems, including the neuroendocrine, immune, and cardiovascular systems, in response to environmental stressors over time (McEwen & Seeman, 1999; McEwen & Stellar, 1993). Dysregulation in multiple systems increases the risk of early development of age-related chronic conditions such as hypertension, obesity, and diabetes (McEwen, 1998; McEwen & Seeman, 1999; Seeman, Lusignolo, Berkman, & Albert, 2001). Individual differences in the frequency and quantity of stress exposure as well as the developmental stage of high exposure may influence the patterns of physiological activity and reactivity (Danese & McEwen, 2012; Seeman, Epel, Gruenewald, Karlamangla, & McEwen, 2010).

Stressful Life Events

There is growing evidence of the harmful effects of stressful life events on health; however, few studies have examined this association in immigrant populations. In the general population, stressful life events have been found to be adversely associated with chronic diseases such as heart disease, diabetes, obesity and depression (Barry & Petry, 2008; Cutrona et al., 2005; Engstrom, Hedblad, Rosvall, Janzon, & Lindgarde, 2006; Engstrom et al., 2004; Kendler, Karkowski, & Prescott, 1999; Pyykkonen et al., 2010). Recent studies have also found that stressful life events were positively associated with individual biological markers such as cortisol concentration (Karlen, Ludvigsson, Frostell, Theodorsson, & Faresjo, 2011; Wong et al., 2012) and with increased odds for metabolic syndrome (Raikonen, Matthews, & Kuller, 2007). However, limited evidence exists for the effect of stressful life events on multisystem dysregulation, such as that captured by a composite measure of allostatic load, which may precede harmful health outcomes (McEwen & Stellar, 1993; Seeman, Singer, Rowe, Horwitz, & McEwen, 1997).

Migration-Related Stressors

Stress related to the process of acculturation has been examined in immigrant health research. A number of well-developed assimilation/acculturation theories exist; however, the general expectation is for immigrants to acquire the behaviors and customs of the host society (Viruell-Fuentes, Miranda, & Abdulrahim, 2012). Better outcomes are hypothesized with higher acculturation, but findings on Latino health are mixed and relatively complex

(Lara, Gamboa, Kahramanian, Morales, & Bautista, 2005). Although less explored, acculturation may mediate the effects of stress on immigrant health as greater acculturated individuals may have greater access to social resources and therefore greater knowledge of social and institutional resources that may serve to cope with stress (Berry, 1997).

Stressors related to the process of migration (Torres & Wallace, 2013; Viruell-Fuentes et al., 2012) and accompanying social and structural changes are experienced differently depending on the immigrant's age. Immigrant children and adolescents experience stress related to school, peer-pressure, ethnic identity, and family conflict (Hovey, 2000; Patterson, Kyu, & Georgiades, 2013; Rumbaut, 2005). Adult immigrants are more likely to experience stress related to dissonant language, the loss of family and other supportive networks, socioeconomic difficulties, changes in social status, and perceived racial/ethnic discrimination (Alegria et al., 2008; Link & Phelan, 1995; Takeuchi, Alegria, Jackson, & Williams, 2007; Viruell-Fuentes, 2007). Stress related to health problems and feelings of isolation may be more common among older adult immigrants (Patterson et al., 2013).

The process of migration is considered to be a stressful life event (Schwarzer & Schulz, 2003) and for many immigrant children this process may be accompanied by a number of adverse childhood experiences (Oxman-Martinez et al., 2012). Compared to non-immigrant children, immigrant children are at greater risk of experiencing psychological and social isolation, economic hardship, and racial and ethnic discrimination from school peers and teachers (Oxman-Martinez et al., 2012). This additional burden is of consequence given the influential effect of early experiences on the development of social, emotional and cognitive capacities (Eccles, 1999; Knudsen, Heckman, Cameron, & Shonkoff, 2006), as well as the lasting changes in multiple metabolic systems found to be associated with high exposure to stress and disadvantaged socioeconomic environments during sensitive developmental periods (Ben-Shlomo & Kuh, 2002; Danese & McEwen, 2012; Eccles, 1999; Hertzman, 1999). Evidence on migration to a new society during middle childhood and/or adolescence, compared to other ages, suggests greater odds of poorer self-rated health (Leao, Sundquist, Johansson, & Sundquist, 2009), of mortality from melanoma (Khlat, Vail, Parkin, & Green, 1992), of becoming overweight (Oza-Frank & Narayan, 2010; Roshania, Narayan, & Oza-Frank, 2008), and higher risk for mood and anxiety disorders (Alegria et al., 2007; Breslau, Borges, Hagar, Tancredi, & Gilman, 2009; Patterson et al., 2013; Vega, Sribney, Aguilar-Gaxiola, & Kolody, 2004). Nonetheless, no studies have examined the effect of age at migration on allostatic load, a measure that captures the development of multi-system dysregulation over the life course in response to chronic or repeated exposure to stress (McEwen, 1998).

Puerto Rican Migrants

Puerto Ricans are the second largest Latino subgroup in the United States (Landale, 1994). Unlike other Latino subgroups, the migration of Puerto Ricans is officially classified as internal migration as they enjoy the social and political benefits of U.S. citizenship. However, the magnitude of the migration and cultural, linguistic, racial, and socioeconomic differences have led to a migratory process that is more comparable to that of immigrants

from Latin America and the Caribbean than to U.S. internal migrants (Landale & Oropesa, 2001).

Puerto Rico's process of industrialization and economic development in the 1950s, 1960s, and 1970s substantially improved the quality of life of many of its citizens; however, this economic success did not reach a large segment of the population with low education (Falcon, 1990) and was predicated on the out-migration of a large segment of the island's population. High unemployment rates in the island, the demand and active recruitment of labor workers in the mainland, and low airfares facilitated Puerto Rican migration, distinguished by a bilateral flow between Puerto Rico and the U.S. mainland (Duany, 2002; Ramos, 1992). Over time, Puerto Rican migration has been highly sensitive to economic fluctuations on the island and mainland. Further, the ability to travel freely, the social networks, and economic fluctuations have contributed to a very distinctive pattern of circular migration (Duany, 2002; Falcon, 1990). Circular migration is hypothesized to weaken social and family ties, as individuals remain in a state of transitory residence. The socio economic and political factors associated with the Puerto Rican migration have influenced the socio-economic characteristics of Puerto Ricans in the U.S. mainland, who tend to have fewer socioeconomic resources than other Latino subgroups (Ramos, 1992).

Despite increased interest in understanding the determinants of immigrant health, most of this research has focused on cultural aspects and factors associated with acculturation. Additional attention to the effect of other social stressors that emerge from contextual structures of inequity and social disadvantage affecting the health of immigrants during their life course is needed.

We created trajectories of stress from reported stressful life events measured at five time points between baseline and approximately two-year follow-up interviews. The primary aim was to examine the association of stressful life events trajectories with allostatic load measured at follow-up. Repeated measures over a two-year period of stressful life events allowed us to examine their cumulative effect, as well as the effect of individual differences in exposure to life stressors on allostatic load at follow-up. The second aim was to test age at arrival and language acculturation as effect modifiers and potential mediators, based on the literature reporting the unique effect that stressors related to the process of acculturation have on the health of immigrants to the U.S. (Caplan, 2007; Guarnaccia et al., 2007)

Following the existing literature, we formulated 4 main hypotheses to be tested:

H1: Given evidence of positive associations between stressful life events and biological markers (Karlen et al., 2011; Raikkonen et al., 2007; Wong et al., 2012), we hypothesized that higher allostatic load would be associated with having experienced a higher number of stressful life events during the prior two years.

H2: Language proficiency, specifically, permits immigrants to navigate more effectively in the host society to locate social and economic resources, and may facilitate adaptation to the host society, reducing adaptation related stress (Berry, 1997). Therefore, we hypothesized that lower allostatic load would be associated with higher

language acculturation; and that language acculturation would mediate the negative effects of stressful life events on allostatic load.

H3: The greater likelihood of experiencing poverty before migration (Landale, Oropesa, & Gorman, 2000; Oropesa, Landale, & Davila, 2001), and the greater racial and ethnic residential segregation among Puerto Ricans in the mainland compared to other Latino groups (Alba, Logan, Stults, Marzan, & Zhang, 1999; Burgos & Rivera, 2012), are social conditions that expose Puerto Rican migrant children to adverse social and economic conditions at time of arrival to the U.S. mainland. Therefore, we hypothesized that Puerto Ricans who migrated to the U.S. mainland during middle childhood and adolescence would have higher allostatic load than those arriving at earlier or later ages.

H4: Taking account of life course and current stressors, as well as the interaction between the two, can provide a better understanding of their individual and combined effects on health (Hertzman, 1999). Based on this premise and previous findings, we hypothesized a significant interaction effect between age at arrival and stressful life events on allostatic load—with the highest allostatic load among those who both arrived to the U.S. mainland during childhood or adolescence, and who experienced a high number of stressful life events during the past two years.

METHODS

Data were obtained from the Boston Puerto Rican Health Study, a population-based prospective cohort of older Puerto Ricans between the ages of 45 and 75 years at baseline. The Institutional Review Boards at Tufts Medical Center and Northeastern University approved the study. All participants provided signed informed consent in their language of choice (Spanish or English). Baseline recruitment occurred between 2004 and 2009 (specifics of the study and recruitment are described in detail elsewhere) (Tucker et al., 2010). In addition to the survey questionnaire, biomarker collection included anthropometry (height, weight and waist circumference), blood pressure (systolic and diastolic blood pressure, calculated as the average of the second and third of three seated readings), and a 12-h overnight urine sample for measurement of neuroendocrine markers. Fasting blood samples were obtained by venipuncture, processed, placed on ice, and delivered within three hours to the Jean Mayer USDA Human Nutrition Research Center on Aging (HNRC) laboratory at Tufts University. The initial data collection yielded a baseline cohort of 1,499 participants. A follow-up conducted approximately two years after baseline, had a high re-interview response rate of 85% or 1,276 participants. The availability of the biomarker data at both baseline and follow-up restricted the final analytical sample to 984 participants. Results from t-tests and Chi Square tests between included participants (n=984) and those excluded because of missing data showed no significant differences (refer to Annex 1).

Measures

Allostatic Load—The allostatic load score used in this study consists of 11 biomarkers that represent the function of neuroendocrine (serum DHEA-S, urinary cortisol, urinary norepinephrine, urinary epinephrine), immune (C-reactive protein (CRP)), cardiovascular (systolic blood pressure (SBP), diastolic blood pressure (DBP)), and metabolic (plasma total

and HDL cholesterol, plasma HbA1c and central adiposity (waist circumference)) systems. Allostatic load, as a composite score for this study, has been described previously (Mattei, Demissie, Falcon, Ordovas, & Tucker, 2010). Briefly, a summary score was constructed for the number of biomarkers in which participants fell into the upper or lower clinically defined cutoff point, except for serum DHEA-S and urinary epinephrine and norepinephrine, for which the upper quartile was used as the cutoff point. To account for medication use, a point was assigned if a participant was taking medication for hypertension, diabetes, hyperlipidemia, or testosterone, but had the respective parameter within the defined cutoff (see Annex 2).

Stressful Life Events—Life events were assessed with the Life Events Questionnaire (LEQ) (Norbeck, Lindsey, & Carrieri, 1981). Similar to other life events scales, LEQ targets recent life events that are primarily acute, unpleasant or threatening (Monroe & Reid, 2008). The LEQ was part of the inperson baseline and two-year questionnaire. Additionally, as part of maintaining contact with participants, LEQ data were collected during telephone interviews at six month intervals between baseline and follow-up. Thus, LEQ data were collected at five-time points during the study, via in-person interview at baseline, via telephone at 6-months, 12-months, and 18-months, and via in-person interview at the two-year follow-up point. The LEQ consists of 80 life events (see Annex 3 for list of items). Participants are first asked whether or not they had experienced the event in the past six months (0=*no*; 1=*yes*), and if so, they were asked to categorize the event as “*good*” or “*bad*”, and to rate its effect using a 4-point Likert scale, from 1=*no effect*, 2=*some effect*, 3=*moderate effect*, and 4=*great effect*. For the current analysis, we limited our analysis to the sum score of the effects of all *bad* stressful life events.

Language Acculturation—Language acculturation was measured with seven items from the Acculturation Scale for Hispanics (Marin, Sabogal, Marin, Otero-Sabogal, & Perez-Stable, 1987) and modified for the Puerto Rican population (Falcon & Tucker, 2000). These items assess language use in various activities (e.g., watching TV, listening to the radio, reading newspapers, talking with family and friends) with a 5-point Likert scale (only Spanish, more Spanish than English, both equally, more English than Spanish, only English). Summated scores range from 0–100, with higher scores indicating higher level of English language proficiency. The Cronbach’s alpha for the scale was 0.90, which suggests high reliability.

Age at Arrival—A five category age-at-arrival variable was created using responses to questions about year and age at the time of arrival to the U.S. mainland. The five age-categories represent human developmental stages characterized by particular biological, psychological, cognitive and social changes: infancy/pre-school (0–5 years), middle childhood (6–11 years), adolescence (12–18 years), young adulthood/adulthood (19–39 years) and maturity (>40 years) (Côté & Levine, 1987; Eccles, 1999; Erickson, 1950; Piaget & Inhelder, 1973). The reference category used in the analysis, 0–5, included participants who were born in the U.S. or who arrived before the age of 6 years.

Potential Confounders—We included a number of variables known to be associated with variation in allostatic load (Seeman et al., 1997) including age, sex, educational attainment (< 5th grade=ref; vs. 5th–8th grade, 9th–12th grade, or some college) and health behaviors such as smoking (never=ref; vs. past, or current smoker) and alcohol use (not currently drinking=ref; vs. moderate (1 drink/day for women, or 2 drinks/day for men), or heavy (greater than this)).

Analytical Strategy—We first used latent growth mixture modeling (LGMM) (Muthen & Shedden, 1999) to identify potentially distinct classes of trajectories of bad stressful life events experienced by our participants. LGMM models were fit for one, two, three and four latent groups using Mplus version 5.0 (Muthen & Shedden, 1998–2010). LGMM is designed for the analysis of longitudinal data and uses all available scores from each participant to determine sub-groups, using estimated values associated with the intercept and slope of individuals that have similar trajectories. We examined group differences in outcome, predictors and potential confounders by stress trajectory group using ANOVA and Chi Square tests for continuous and categorical variables respectively.

We conducted linear regression to test associations of allostatic load with stressful life events trajectories, language acculturation, age at arrival, smoking, and alcohol use. We used multivariable linear regression to examine change in allostatic load at two-year follow up, by adjusting for baseline allostatic load score. This method controls for initial differences between groups, thus final differences in two-year scores are less likely to be attributed to initial differences (Dalecki & Willits, 1991). Multivariable linear regression analyses adjusted for sex, age, education, smoking, alcohol use, and baseline allostatic load in model 1. Language acculturation was added in model 2, age at arrival in model 3, and the interaction of age at arrival and stress trajectories in model 4. Figure 1 shows a path diagram representation of the moderation model tested in this study.

RESULTS

Our final sample included 702 females (71%), and 282 males (29%); the average mean age at baseline was 57 years (SD=7.5); 22% had <5th grade education, 25% had completed middle school, 39% high school, and 14% had at least some college education. Forty-six percent of the sample had never smoked, 30% were past smokers, and 24% were currently smoking; 56% were not current drinkers, 36% were moderate drinkers and 8% were heavy drinkers. The average duration between baseline and follow-up was 2.2 years. Mean allostatic load scores were 4.5 (SD=1.9) at baseline, and 4.8 (SD=1.8) at follow-up ($p<0.0001$, paired t-test)

Fit indices for the estimated latent growth mixture models (Table 1) suggested a three model solution, given the nonsignificant value of the Lo–Mendell–Rubins Adjusted Likelihood Ratio Test (LRT; Asparouhov & Muthén, 2012; Lo, Mendell, & Rubin, 2001). Figure 2 shows the three identified trajectories; 1) low stress, 2) moderate-ascending stress (also referred to as chronic stress), and 3) high-descending stress (also referred as acute stress). Sixty-two percent of the participants were in the low stress trajectory, 24% in the moderate ascending, and 15% in the high descending trajectories. Each participant was assigned to

one of the three trajectories and this categorical variable was subsequently used to predict change in allostatic load at follow-up.

Participants in the low stress group were older, more likely to be men, least likely to have college education, had lowest language acculturation, and were least likely to engage in risky health behaviors such as smoking and alcohol use. Unexpectedly, participants in the low stress group had the highest allostatic load at follow-up. There were no differences in age at arrival by stress trajectory (see Tables 2a and 2b).

With bivariate analyses, participants in the moderate ascending stress trajectory had significantly lower allostatic load at follow-up ($\beta=-0.377$; $SE=0.131$; $p<0.01$, Table 3) compared to participants in the low stress trajectory. Language acculturation was significantly associated with lower allostatic load at baseline ($\beta=-0.007$; $SE=0.003$; $p<0.01$, Table 3) and follow-up ($\beta=-0.010$; $SE=0.002$; $p<0.01$, Table 3). Age at arrival was significantly associated with allostatic load at follow-up, but not at baseline (Table 3). Compared to non-drinkers, moderate and heavy alcohol users had lower allostatic load at baseline and follow-up; and non-smokers had lower allostatic load at baseline than past smokers.

In multivariate analysis, the association of two year trajectories of stress with allostatic load at follow-up became nonsignificant after adjusting for age, sex, smoking, alcohol use and allostatic load at baseline (see Table 4, Model 1). No significant main effects on allostatic load at follow-up remained with language acculturation (see Table 4, Model 2) or age at arrival (see Table 4, Model 3) after adjustment. However, there was a significant interaction of stress trajectory with age at arrival (see Table 4, Model 4). Compared to participants in the low stress trajectory and to those with other ages at arrival, significant increases in allostatic load over the two years was seen in participants in the ascending stress group who arrived to the U.S. mainland between 6–11 years of age ($\beta=1.584$; $SE=0.585$; $p<0.01$, Table 4, Model 4). Although marginally significant, higher allostatic load was also found in the 6–11 years group when experiencing very high stressful life events. In addition, marginally significant higher allostatic load at follow-up was seen in participants with moderate ascending stressful trajectories who arrived to the U.S. between 12–19 years and 20–39 years of age.

Interactions of age at arrival with stressful life event trajectories (Figure 3) show relatively low allostatic load at follow-up in participants with chronic stress exposure (ascending trajectory) who arrived to the U.S. mainland before the age of 6 years; and relatively high allostatic load at follow-up in participants with chronic stress exposure (ascending trajectory) or acute stress exposure (descending trajectory) who migrated between 6 and 11 years of age.

Sensitivity Analysis

To test for potential bias in participant perceptions of stressor effects, we replicated the analyses using a count of stressful live events, rather than the sum score of participant's rated stress effect. Results from these models (available upon request) showed similar patterns, although associations were stronger using the sum score. In addition, we examined

two types of trajectories of stressful life events, one including all the items, and a second excluding the six items related to health issues. Stress patterns and results from multivariate analyses were similar using trajectories with and without the health items; however, results were stronger using the full set of items.

DISCUSSION

These results suggest a significant association between two-year trajectories of stressful life events and resulting allostatic load. This finding is in line with previous reports of significant associations between stressful life events and individual biological markers (Karlen et al., 2011; Wong et al., 2012) (Raikkonen et al., 2007). Our study adds to this literature by examining this association in a sample of Puerto Rican migrants to the United States mainland, and by using allostatic load, a measure of multisystem dysregulation including 11 biological markers. In contrast to our initial hypothesis, our findings do not support a direct association between stressful life events and higher allostatic load at follow-up. Rather, participants with trajectories of low stress had the highest allostatic load. This unexpected result may be related to the fact that this group tended to be older men, with low education and acculturation, who likely had had higher exposure to social disadvantage prior to the current measures. Older age and lower education have been found to be associated with higher allostatic load scores (Seeman et al., 2010).

Although we know of no studies that have examined associations between acculturation and allostatic load, many studies have seen worse health outcomes with low acculturation among Latinos (Lara et al., 2005). A large number of the men in this group migrated to the U.S. mainland between the ages of 19 and 39 with just over half of the sample (52.6%) arriving in the 1950s and 1960s—which coincided with large-scale out-migration from the island and very high unemployment in Puerto Rico's economy (Falcon, 1990). It is likely that economic instability could have contributed to an experience of higher levels of stress prior to migration, compared to the other age groups. Physiological responses to stress related to socioeconomic factors can accumulate over the life course and affect metabolic systems (Seeman et al., 2004; Seeman et al., 2010).

Consistent with our second hypothesis, bivariate analysis showed that greater acculturation was associated with lower allostatic load. However, language acculturation did not appear to mediate the effects of stressful life events on allostatic load. The lack of a mediating effect may suggest that acculturation itself may be a weak coping mechanism for individuals confronted with high poverty rates in the U.S. and overall low socioeconomic position. Theories of acculturation suggest that immigrants who are able to adapt to their new societies may move up in the social hierarchy and reduce, to a certain degree, the stress related to the acculturation process. However, the receiving society is a key determinant of an immigrants' ability to adapt (Berry, 1997). Previous studies suggest that Puerto Ricans migrants, particularly those entering the U.S. mainland during the 1950s and 1960s period, have faced greater stigma than other Latino sub-groups because of their arrival during a period of rapid social and economic change exemplified by the movement of other racial groups from inner city areas and clashes around the availability of political and economic resources. This context may have influenced the adoption of a stronger Puerto Rican identity

over a more assimilated or acculturated one (Ortega, Feldman, Canino, Steinman, & Alegria, 2006). A low preference to assimilate coupled with the economic uncertainty encountered in a U.S. economy transitioning from manufacturing to service based jobs are two factors (Berry, 1997) that may have contributed to isolating Puerto Rican migrants from social and economic opportunities in the U.S. mainland.

Our findings lend partial support to our third hypothesis. However, while we found significant positive associations between age at arrival and recent change in allostatic load, we did not find a significant association with the baseline allostatic load. Although, no studies were found that examine the effect of age at arrival on allostatic load, some studies, in line with our findings, have reported worse physical health among people who migrate to a new society in middle childhood and or adolescence (Alegria et al., 2007; Breslau et al., 2009; Patterson et al., 2013; Vega et al., 2004). Three potential life course factors are proposed to understand the link between childhood environments/experiences and adults' health, a latent effect –early experiences affect adult health independent of other factors; a pathway effect –early environments influence future life trajectories; and a cumulative effect – duration and intensity of the exposure are relevant (Hertzman, 1999).

We hypothesized that Puerto Ricans who migrated as children or adolescents, given their high likelihood of having a history of exposure to adverse social and economic conditions, would have higher allostatic load due to high poverty before migration (Landale et al., 2000; Oropesa et al., 2001) and to experienced racial and ethnic residential segregation on the U.S. mainland (Alba et al., 1999; Burgos & Rivera, 2012). The lack of significant association of age of migration with baseline allostatic load suggests that, without direct measurement of the potential adverse conditions experienced during early ages, the age at arrival alone does not have a sufficiently direct latent or cumulative effect to be measureable in later adult's allostatic load. Rather, a pathway effect seems to be a more plausible mechanism, given the significant effect found with change in allostatic load at two-year follow-up. Early life experiences may lead individuals into different pathways in which children may fail to acquire effective coping skills to face future stressors, get into environments that expose them to more stressors, or influence the way they perceive and are affected by future stressors. Our findings of higher allostatic load in the groups who migrated to the U.S. mainland during middle childhood and adolescence only after experiencing an approximate two-year period of chronic stress suggest that this group may be more vulnerable to the effects of stress relative to the other groups. Greater exposure to psychological and social stressors at younger ages may hinder an individuals' ability to develop effective and appropriate coping techniques to deal with negative stressful life events (Cohen, Janicki-Deverts, & Miller, 2007; Cohen, Tyrrell, & Smith, 1993). Adults who experienced high levels of psychosocial adversity during their childhood have been shown to have higher CRP, an indicator of inflammation (Appleton et al., 2011), more chronic physical conditions and higher prevalence of depression (Danese, Moffitt, Harrington, & et al., 2009), cardiovascular disease (Appleton, Buka, et al., 2013; Appleton, Loucks, Buka, Rimm, & Kubzansky, 2013; Parrish et al., 2013; Stein et al., 2010) chronic fatigue syndrome (Heim et al., 2006), and cancer-related fatigue (Bower, Crosswell, & Slavich, 2014; Hertzman, 2013) compared to those with less psychosocial adversity during childhood.

In line with our fourth hypothesis, we found the effects of stress trajectories on change in allostatic load at follow-up to be more detrimental and significant in Puerto Ricans who migrated to the U.S. mainland during middle childhood and, marginally significant, during adolescence. Previous studies have shown the influence of age of migration on immigrant's physical and mental health (Alegria et al., 2007; Ben-Shlomo & Kuh, 2002; Breslau et al., 2009; Danese & McEwen, 2012; Eccles, 1999; Hertzman, 1999; Patterson et al., 2013; Vega et al., 2004); however, no previous studies have examined the interaction with more current stressors and their combined effect on allostatic load, a biological measure of cumulative stress. Our findings add to the stress and immigrant health literature by examining these interactions. Future research should examine in more detail the stressors faced by immigrant children and adolescents, given the established link between childhood adverse events and adult health, and the greater likelihood that immigrant children experience social, economic, and psychological adversities.

The findings of the present study must be interpreted in light of a number of limitations. The sample included only adult Puerto Ricans; therefore, additional studies are needed to examine the generalizability of our findings to other groups and other ages. This study was not designed to examine the variety and specificity of migration related stressors at age at arrival; therefore, our analysis was limited to the use of age at arrival to the U.S. mainland as a proxy for exposure to migration related stress at different developmental life periods. Future mixed methods studies are needed to explore and qualitatively identify the type of stressors specific to immigrant groups at various developmental age stages, and to then, quantitatively examine effects on health outcomes.

Strengths of the present study include a large sample size of Puerto Rican adults with longitudinal measures of both stressful life events and physiological biomarkers of stress. The present study is the first, to our knowledge, to examine the associations of trajectories of stressful life events with allostatic load in a sample of Puerto Ricans using a longitudinal design that supports causality inferences; and to examine the modifying effect of age at arrival in this association.

CONCLUSION

Results from this study highlight the complex effects of lifecourse stress and point to vulnerable periods for immigrant children that could modify the effects of stress during the life span. Little is known about the unique stressors experienced by immigrant children during their acculturation process, and how the effects of these experiences may later interact with additional life stressors to affect their health in harmful ways. Our study shows that a lifespan development approach to stress and health may provide relevant information conducive to the identification of pathways to explain the documented health deterioration of immigrants the longer they reside in the host society. Early life stressors may influence the development of different pattern of vulnerability and resilience, manifesting its effects later during periods of higher negative life events. More studies are needed to understand the causal nature of these relationships and to design and test programs to assist immigrant children during the school age years as they incorporate into a new environment.

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Appendix

Annex 1

Comparison of Participants included vs. those with incomplete

Baseline variables	Final Sample n=984 η(%) or M±SD		Sample NIA ¹ n=515 η(%) or M±SD		ρ-value ²
Allostatic load	4.5	(±0.1)	4.5	(±0.1)	0.990
Age (years)	56.9	(±0.2)	57.4	(±0.3)	0.279
Gender					0.184
Male (ref)	282.0	(28.7)	164.0	(36.8)	
Female	702.0	(71.3)	349.0	(68.0)	
Education (categories)					0.448
No schooling or <5th grade(ref)	212.0	(21.5)	105.0	(20.6)	
5th-8th grade	244.0	(24.8)	127.0	(25.0)	
9-th-12th grade	388.0	(67.2)	189.0	(37.1)	
College/graduate	140.0	(14.2)	88.0	(17.3)	
Smoker					0.658
Never (ref)	454.0	(46.2)	223.0	(43.7)	
Past-not currently	292.0	(29.7)	157.0	(30.8)	
Currently smoke	237.0	(24.1)	130.0	(25.5)	
Alcohol					0.988
Not currently drinking (ref)	542.0	(55.5)	280.0	(55.8)	
Moderate	356.0	(36.5)	183.0	(36.5)	
Heavy	78.0	(8.0)	39.0	(7.8)	
Age at arrival to the U.S. mainland					0.193
5yrs & US born (ref)	66.0	(6.9)	43.0	(8.8)	
6-11 yrs	55.0	(5.7)	34.0	(6.9)	
12-18 yrs	282.0	(29.3)	160.0	(32.6)	
19-39 yrs	445.0	(46.2)	205.0	(41.8)	
40y yrs>	115.0	(11.9)	49.0	(10.0)	
Language acculturation	24.2	(±0.7)	24.6	(±1.0)	0.746

¹ Sample Not Included in this Analysis due to study attrition or missing Allostatic Load measure at baseline or 2-year follow-up

² ρ-values from two group t-tests performed for continuous variables and Chi Square test for categorical variables

Annex 2

Definition of Allostatic Load in the Boston Puerto Rican Study (Mattei et al 2010)

Biomarker	Cut-off Points
Neuroendocrine System	
DHEA-S (ng/mL) ^a	Men <= 589.5 or taking medications Women <= 368.5 or taking medications
Cortisol: (µg/g creatinine) ^b	Men >= 41.5 Women >= 49.5
Norepinephrine: (µg/g creatinine) ^b	Men >= 30.5 Women >= 46.9
Epinephrine: (µg/g creatinine) ^b	Men >= 2.8 Women >= 3.6
Immune System	
C-reactive protein: CRP (mg/L) ^c	> 3
Cardiovascular system	
Systolic Blood Pressure: SBP (mmHg) ^d	> 140 or taking medications
Diastolic Blood Pressure: DBP (mmHg) ^d	> 90 or taking medications
Metabolic System	
<i>Lipid metabolism</i>	
Total Cholesterol: TC (mg/dl) ^e	>= 240 or taking medications
High Density Lipoprotein: HDL-C (mg/dl) ^e	< 40 or taking medications
<i>Glucose metabolism</i>	
Glycosylated hemoglobin: HbA1c (%) ^f	> 7 or taking medications
<i>Adipose tissue deposition</i>	
Waist Circumference: WC (cm) ^g	Men > 102 Women > 88

^aTrivedi and Khaw (2001);

^bGoldman et al (2004);

^cPearson et al (2003);

^dNHLBI (2004);

^eNHLBI (2002);

^fADA (2008);

^gNHLBI (2002)

Annex 3

List of stressful life events by category

Event
Health
Major personal illness or injury
Major change in eating habits
Major change in sleeping habits
Major change in usual type and/or amount of recreation
Major dental work
FEMALE: Started menopause

Event

Work

Difficulty finding a job
 Beginning work outside the home
 Changing to a new type of work
 Changing your work hours or conditions
 Change in your responsibilities at work
 Troubles at work with your employer or co-workers
 Major business readjustment
 Being fired or laid off from work
 Retirement from work
 Taking courses at home to help you in your work

School

Beginning or ceasing school, college or training program
 Change of school, college or training program
 Change in career goal or academic major
 Problem in school, college, or training program

Residence

Difficulty finding housing
 Changing residence within the same town or city
 Moving to a different town, city, state, or country
 Major change in your life conditions

Love and Marriage

Began a new, close, personal relationship
 Became engaged
 Girlfriend or boyfriend problems
 Breaking up with a girl/boyfriend or breaking an engagement
 MALE: Wife or girlfriend's pregnancy
 MALE: Wife or girlfriend's having a miscarriage or abortion
 Getting married (or beginning to live with someone)
 A change in closeness with your partner
 Infidelity
 Trouble with in-laws
 Separation from spouse or partner due to conflict
 Separation from spouse or partner due to work, travel, etc.
 Reconciliation with spouse or partner
 Divorce
 Change in your spouse or partner's work outside the home (beginning to work, ceasing work, changing jobs, retirement, etc).

Family and Close Friends

Gain of a new family member (birth/adoption/relative moving in/etc)
 Child or family member leaving home (due to marriage/college/other)
 Major change in the health or behavior of a family member or close friend

Event
Death of spouse or partner
Death of a child
Death of family member or close friend
Birth of a grandchild
Change in marital status of your parents
Parenting
Change in child care arrangements
Caring for a grandchild
Conflicts with spouse or partner about parenting
Conflicts with child's grandparents (or other important person) about parenting
Taking on full responsibility for parenting as a single parent
Custody battles with former spouse or partner
Personal or Social
Major personal achievement
Major decision regarding your immediate future
Change in your personal habits (your dress, lifestyle, hobbies, etc.)
Change in your religious beliefs
Change in your political beliefs
Loss or damage of personal property
Took a vacation
Took a trip other than a vacation
Change in family get-togethers
Change in your social activities (clubs, movies, visiting, etc)
Made new friends
Broke up with a friend
Acquired or lost a pet
Major change in finances (increased or decreased income)
Took on a moderate purchase, such as TV, car, freezer, etc.
Took on a major purchase or a mortgage loan
Experienced a foreclosure on a mortgage or loan
Credit rating difficulties
Crime and Legal Matters
Being robbed or a victim of identity theft
Being a victim of a violent act (rape, assault, etc.)
Involved in an accident
Involved in a law suit
Involved in a minor violation of the law (traffic ticket, disturbing the peace, etc.)
Legal troubles resulting in your being arrested or held in jail
Other: Other recent experiences that had an impact on your life.

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Research Highlights

- Stressful life events trajectories (SLE) are associated with allostatic load (AL)
- Migrant's age at arrival may modify the SLE-AL association
- Migrants' arriving during middle-childhood and adolescence may be more vulnerable
- Migrants arriving during these two periods had a positive and stronger SLE-AL
- Stress during vulnerable periods could modify the effects of lifecourse stress

Figure 1.

Path diagram representations of the moderation model. W= independent Variable 1 (2y trajectories of stress); X= independent variable 2 (language acculturation); Y= the dependent variable (allostatic load at follow-up), Z= the moderator variable (age at arrival), WZ= the product of W and the moderator variable Z.

Figure 2.
Predicted trajectories for the three stressful life events classes

Figure 3.
Interactions of age at arrival with life stress trajectory in final model

Table 1

Fit Indices for the Estimated Latent Growth Mixture Models with Classes 1 Through 4

Classes	Log likelihood	AIC	BIC	2 BIC	Adj. LRT	Adj. LRT p-value
1	-20224.5	40469.0	40052.2	40490.4		
2	-19970.3	39970.6	40050.4	40002.7	494.8	<0.0001
3	-19861.7	39759.4	39855.1	39798.0	207.7	0.005
4	-19812.5	39667.0	39778.6	39711.9	94.2	0.227

Table 2

a. Group comparisons by stressful bad life events trajectories						
	All	Bad Life Events Trajectory Groups			Anova Test	F-test Prob>F
		Low	Mod_Ascd	Hgh_Des		
Allotatic load at 2-year follow-up	4.8 (±1.8)	4.9 (±1.8)	4.5 (±1.9)	4.7 (±1.8)	4.4	0.01
Allostatic load at baseline	4.5 (±1.9)	4.6 (±1.9)	4.4 (±1.9)	4.4 (±2.0)	1.5	0.22
Age (years)	56.9 (±7.5)	57.8 (±7.6)	55.8 (±7.2)	54.9 (±6.7)	11.8	<.0001
Language acculturation	24.2 (±22.4)	22.7 (±22.1)	25.3 (±22.2)	29.8 (±23.2)	5.6	<.01
b. Group comparisons by stressful bad life events trajectories ¹						
	All	Bad Life Events Trajectory Groups			Chi-Sq	Prob
		Low	Mod_Ascd	Hgh_Des		
Gender					22.9	<0.0001
Male (ref)	282 (29)	205 (73)	61 (22)	16 (13)		
Female	702 (71)	411 (59)	184 (26)	107 (15)		
Education (categories)					16.5	<0.05
No schooling or <5th grade(ref)	212 (22)	136 (22)	58 (24)	18 (15)		
5th–8th grade	244 (25)	169 (27)	50 (20)	25 (20)		
9–th–12th grade	388 (39)	235 (38)	101 (41)	52 (42)		
College/graduate	140 (14)	76 (12)	36 (15)	28 (23)		
Smoker					9.7	0.05
Never (ref)	454 (46)	302 (49)	98 (40)	54 (44)		
Past-not currently	292 (30)	183 (30)	73 (30)	36 (29)		
Currently smoke	237 (24)	130 (21)	74 (30)	33 (27)		
Alcohol					12.0	<0.05
Not currently drinking (ref)	542 (56)	363 (60)	123 (50)	56 (46)		
Moderate (<=1d-Women; <=2d-Men)	356 (36)	204 (34)	98 (40)	54 (44)		
Heavy (>1d-Women; >2d-Men)	78 (8)	42 (7)	23 (9)	13 (11)		
Age at arrival to the U.S. mainland					11.5	0.18

b. Group comparisons by stressful bad life events trajectories ^J								
	All		Bad Life Events Trajectory Groups					
			Low	Mod_Ascd	Hgh_Des			
	n (%)						Chi-Sq	Prob
<=5yrs& US born (ref)	66	(7)	36	(6)	22	(9)	8	(7)
6-11 yrs	55	(6)	27	(4)	18	(8)	10	(8)
12-18 yrs	282	(29)	170	(28)	70	(29)	42	(34)
19-39 yrs	445	(46)	295	(49)	100	(42)	50	(41)
40y yrs>	115	(12)	74	(12)	29	(12)	12	(10)

^J Not all categories add to n=984 due to missing data in some variables

^J Not all categories add to n=984 due to missing data in some variables

Table 3

Bivariate Associations with Allostatic Load

	Bivariate associations			
	Allostatic Load at Baseline		Allostatic Load at Follow-up	
	β	(SE)	ρ -value	β (SE) ρ -value
2-y trajectories of bad life events				
Low (ref)	–	–	–	–
Moderate-ascending	–	–	–0.377	(0.131) 0.004**
High-descending	–	–	–0.237	(0.169) 0.162
Language acculturation -M(SD)	–0.007	(0.003)	0.005**	–0.010 (0.002) <0.0001***
Age at arrival				
5yrs & USborn (ref)	–	–	–	–
6–11 yrs	–0.591	(0.341)	0.084	0.200 (0.315) 0.526
12–18 yrs	0.158	(0.256)	0.536	0.567 (0.237) 0.017*
19–39yrs	0.112	(0.247)	0.649	0.517 (0.228) 0.024*
40yrs>	0.287	(0.289)	0.321	0.611 (0.270) 0.024*
Smoker				
Never (ref)	–	–	–	–
Past-not currently	0.311	(0.141)	0.027*	0.132 (0.131) 0.313
Currently smoke	–0.035	(0.150)	0.815	–0.117 (0.139) 0.398
Alcohol				
Not currently drinking (ref)	–	–	–	–
Moderate	–0.359	(0.127)	0.005**	–0.271 (0.118) 0.022*
Heavy	–0.435	(0.226)	0.054+	–0.608 (0.211) 0.004**

 p 0.001;**
 p 0.01;*
 p 0.05;+
 p 0.10

Table 4

Effect of trajectories of stressful bad life events on allostatic load at 2yr-follow-up among participants of the Puerto Rican Health Study

	Model 1 (a)			Model 2 (b)			Model 3 (c)			Model 4 (d)		
	β	(SE)	p-value	β	(SE)	p-value	Coeff	(SE)	p-value	Coeff	(SE)	p-value
2yr trajectories of stressful bad life events												
Low (ref)												
Moderate ascending	-0.162	(0.112)	0.147	-0.159	(0.112)	0.155	-0.171	(0.113)	0.131	-0.928	(0.391)	0.018*
High descending	0.060	(0.147)	0.683	0.070	(0.147)	0.634	0.042	(0.148)	0.777	-0.168	(0.564)	0.766
Language acculturation				-0.003	(0.002)	0.176	-0.004	(0.003)	0.191	-0.004	(0.003)	0.147
Age at arrival												
5yrs (ref)												
6-11 yrs							0.272	(0.267)	0.308	-0.489	(0.369)	0.185
12-18 yrs							0.199	(0.211)	0.346	-0.159	(0.278)	0.567
19-40yrs							0.069	(0.212)	0.744	-0.196	(0.274)	0.476
40yrs>							0.046	(0.251)	0.854	-0.241	(0.320)	0.452
2yr trajectories $\times$ Age at arrival												
Low stress $\times$ 5yrs (ref)												
Moderate ascending $\times$ Age at arrival=6-11yrs							1.584	(0.585)	0.007**			
Moderate ascending $\times$ Age at arrival=12-18yrs							0.833	(0.442)	0.059 +			
Moderate ascending $\times$ Age at arrival=19-40yrs							0.818	(0.425)	0.055 +			
Moderate ascending $\times$ Age at arrival=40>yrs							0.513	(0.503)	0.308			
High descending $\times$ Age at arrival=6-11yrs							1.329	(0.776)	0.087 +			
High descending $\times$ Age at arrival=12-18yrs							0.485	(0.615)	0.431			
High descending $\times$ Age at arrival=19-40yrs							-0.229	(0.604)	0.704			
High descending $\times$ Age at arrival=40>yrs							0.614	(0.719)	0.394			
N		974			974			953			953	
R ²		0.381			0.382			0.390			0.401	
Adj R ²		0.376			0.376			0.382			0.388	

p 0.001;

**
p 0.01;

* p 0.05;
+ p 0.10

(a) Model 1= sex + age + education + smoking + alcohol use + baseline-allostatic load + stress trajectories

(b) Model 2= sex + age + education + smoking + alcohol use + baseline-allostatic load + stress trajectories + language acculturation

(c) Model 3= sex + age + education + smoking + alcohol use + baseline-allostatic load + stress trajectories + language acculturation + age at arrival

(d) Model 4= sex + age + education + smoking + alcohol use + baseline-allostatic load + stress trajectories + language acculturation + age at arrival + [stress trajectories × age at arrival]