Immigration and low birthweight in the US: The role of time and timing

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Paper presented at the 2008 Population Association of America (PAA) Annual Meeting, New Orleans, LA

Introduction

The literature exploring the health consequences of immigration is largely dominated by efforts to replicate, across outcomes and populations, and explain two widely observed findings: that foreign nativity is protective (yielding the "healthy migrant effect" or "immigrant paradox") and that the health advantage of immigrants diminishes over time in the host country. In this study, we focus on the second of these patterns and provide evidence that a lifecourse perspective can help to explain the apparent deterioration in health by incorporating attention to immigrants' timing of arrival. We examine the role of immigrants' exposure to the US, in terms of both age at immigration and length of residence, in shaping birthweight, a well measured and consequential marker of health, and maternal smoking, an important risk factor for low birthweight.

Background

Patterns in immigrant health

Compared to their U.S. born racial/ethnic counterparts, immigrants consistently have favorable outcomes with respect to mortality (Guendelman and English, 1995; Hummer et al, 1999, Singh and Siahpush 2001) and birth outcomes (Landale, Oropesa and Gorman 1999; Markides and Coreil 1986; Cabral et al. 1990; David and Collins 1997; Fang et al. 1997; Fang et al. 1999; Singh and Yu 1996; Alexander et al. 1996). Studies comparing immigrants and the native-born on other health outcomes show similar patterns, though with somewhat greater variability across racial/ethnic or national-origin groups and outcomes.

Studies documenting deleterious effects of exposure to the host society focus primarily on time in the receiving country, most commonly measured as years or "duration" of residence. Although the empirical patterns are not always clean or consistent, results suggest and are interpreted to mean that health deteriorates with duration of residence, particularly in the U.S. This pattern has been observed for numerous health outcomes and behaviors, including BMI and obesity (Goel et al, 2004; Kaplan et al, 2004; Lauderdale and Rathouz, 2000; Singh and Siahpush, 2002; Barcenas et al, 2007; Antecol and Bedard, 2006; Himmelgreen et al, 2004; Abraido-Lanza et al, 2005), self-rated general health (Cho et al, 2004; Frisbie et al, 2001; Uretsky and Mathiesen, 2007; Antecol and Bedard, 2006), activity limitations (Frisbie et al, 2001; Antecol and Bedard, 2006), disability (Cho and Hummer, 2001), cancer (John et al, 2005), heart disease (Mooteri et al, 2004), mental and substance use disorders (Breslau et al, 2007a, Vega et al, 2004, Alegria et al, 2007; Williams et al, 2007), hypertension, chronic conditions, smoking (Singh and Siahpush, 2002; Abraido-Lanza et al, 2005), alcohol consumption (Abraido-Lanza et al, 2005), and fruit and vegetable consumption (Dubowitz et al, 2007). Some notable exceptions to the pattern have also been observed as in the case of physical exercise, which improves with duration (Abraido-Lanza et al, 2005) and suicide, which declines with years of residence (Kposowa et al., 2008). However, the vast majority of studies conclude that immigrant health deteriorates with duration of residence, and the theme of a convergence over time, independent of specific directionality, between immigrant and native born health profiles is pervasive (Argeseanu Cunningham et al, 2008; Antecol and Bedard, 2006).

Prevailing explanations for immigrant health trajectories

Explanations of the deterioration of immigrant health within and across generations are usually attributed to either of two classes of explanations: selection or measurement issues and "acculturation" or "assimilation." Regarding the former, differences in the characteristics of those who choose (and are able) to emigrate compared to those who stay behind are well documented (e.g., Borjas, 1994; Chiswick, 1986). It is also widely assumed (though less established empirically) that the bases of selection are associated with health status, latent or expressed, in some way. This observation, alone, would not account for a decline in immigrant health advantages over time. Some evidence suggests that the likelihood of staying in the destination country or re-emigrating also occurs selectively (Borjas and Bratsberg 1996; Lindstrom 1996), particularly at older ages (Palloni and Arias, 2004), which could account for changes in the relative health of immigrants with increased duration in the host country. Some scholars have attributed declining health trajectories of immigrants to an unspecified process of wearing off of the initial health advantage arising from selection (e.g., Nazroo, 2001; Williams 1993, Chaturvedi & McKeigue 1994; Thomas and Karagas, 1987; Johansson et al, 1997) or regression to the mean (e.g., Jasso et al, 2004).

Other methodological and "measurement" based explanations point to changes over time in immigration patterns (Cairney and Ostbye, 1999; Jasso et al, 2004; Newbold, 2005; Argeseanu and Cunningham et al, 2008), increased diagnoses and awareness of health problems with greater access to health care (Newbold, 2005; McDonald and Kennedy, 2004), and changes in immigrants' normative anchors (McDonald and Kennedy, 2004) and (perhaps healthier) reference groups when they evaluate and report their own health status (Linn and Linn, 1980; Wilson, Jerrett, and Eyles, 2001).

Alternatively, the "acculturation hypothesis" posits that these patterns are the result of immigrants losing culturally-specific protective factors over time and adopting the attitudes, values, and behaviors of the host culture (Lara et al., 2005; Abraido-Lanza et al., 2006). Although critiqued for its inadequate theoretical explication, assumptions of linear cultural change, and failure to account for both the heterogeneity of immigrant groups and experiences and the breadth of social and economic processes underlying immigrant adaptation (Lara et al., 2005; Abraido-Lanza et al., 2006; Livingston et al., 2007; Arcia et al, 2001; Gutmann, 1999), acculturation is the dominant paradigm with which immigration and health is studied. Within the acculturation framework, behavior change (as opposed to attitudes, beliefs, values, or identity) is the most emphasized mechanism, perhaps because health behaviors are easier to measure and the link to health outcomes is relatively direct and unambiguous.

Another, less prominent explanation (invoking the role of broad social contexts rather than individual behavioral factors) suggests that the health of immigrants deteriorates because of prolonged or cumulative exposure to a racial- or ethnically-specific toxic social environment in the host country (Nazroo, 2001; Singh and Siahpush, 2002; Reijneveld, 1998; Uretsky and Mathiesen, 2007). Though explicit attention to the role of contextual factors in the study of immigrant adaptation is pervasive in other disciplines, such as the "new sociology of immigration" (e.g., Portes, 1996; Portes and Rumbaut, 2000), this perspective and the corresponding empirical approaches have been far less common in the health literature.

Alternative explanations

Absent from most contemporary explanations of immigrant health is a life course perspective that emphasizes the potential importance of age at arrival to the U.S. This is surprising given that a life course perspective on immigrant adaptation and health would seem highly germane to the predominant mechanism (behavioral change) by which acculturation is hypothesized to affect health. A life course approach to health focuses on the influence of the timing of (usually harmful) exposures over the life cycle, often during "critical periods" in human development, on subsequent morbidity and mortality (Barker, 1991). Classic life course studies of critical periods have focused on exposures, often in early life including in utero, that initiate physiological processes affecting later life health, regardless of intervening exposures. This critical periods framework can be extended to stages throughout the life cycle as well as to behavioral and psychological outcomes. The immigrant experience may therefore impact health differently depending on the timing of arrival vis-à-vis these critical periods, in ways that operate independently of or synergistically with length of residence in the U.S.

The example of smoking illustrates how a life course or critical periods approach to immigration and health is potentially useful. It is well established that in the U.S. there is a fairly narrow and consistent age window of smoking initiation during adolescence/early adulthood, after which the risk of initiation decreases significantly (Elders et al, 1994; Kandel et al, 1998). Although recent studies have indicated that there is some racial/ethnic variation in peak age at smoking onset (Moon-Howard, 2003; Trinidad et al, 2004), overall, relatively few people begin smoking as mature adults. These age at initiation patterns are consistent across many immigrant-sending countries for which data are available (World Bank, 1999). Assuming this pattern applies to immigrants as well, one would expect immigration and time in the U.S. to have minimal impacts on smoking *initiation* among those who arrive after the critical period of risk. Those who arrive at an earlier age and are therefore exposed to U.S. smoking norms and influences during a formative period for smoking initiation would be considerably more affected. It is possible that immigrants could follow a different pattern and initiate smoking at a later age if the transition from one context to another also had the effect of prolonging this window of vulnerability, perhaps as a result of the stresses of immigration itself. However, exploratory analyses of 1999-2002 National Household Survey on Drug Abuse (NHSDA) data suggested that immigrants to the U.S. who had ever smoked had on average first tried smoking between ages 16 and 18 (Bates, 2005). On the whole, there is no evidence or reasoning to suggest that critical periods of risk for this outcome would not apply to immigrants.

Critical periods for acculturation should apply as well to other substance use practices and health behaviors such as diet. Studies suggest that age-of-onset patterns for substance use are highly similar across countries, despite significant divergence in prevalence of lifetime use (Vega et al, 2002). Although there are racial/ethnic and sex differences in rates of obesity onset, the literature shows fairly consistently a close correspondence between childhood overweight/obesity and adult obesity (Freedman et al, 2005a; Freedman et al, 2005b; Serdula et al, 1993). A life course approach has been applied to obesity and most of the presumed "critical periods," especially from a developmental versus a life events perspective, are before adulthood (Serdula et al, 1993; Gillman, 2004; Lawlor & Chaturvedi, 2006).

There may also be "critical periods" uniquely or especially relevant to immigrants. For example, adolescence is also an important period of identity formation and emerging cognizance of social position, and these processes may present unique challenges for first generation and multiracial youth (Waters, 1994; Herman, 2004). Similarly, language skills are known to be highly sensitive to age of acquisition and are an important determinant of immigrants' long-term social and economic trajectories. In a study of the effect of language ability on labor market performance, Bleakley and Chin (2003) draw on linguistic theory identifying a critical period of second language acquisition which suggests that if children do not start learning a new language by around age 11-12, fluency is unlikely and the chances of ever speaking without an accent are greatly diminished. They find that immigrants from non-English speaking countries had worse labor market outcomes than their counterparts from English speaking countries if they came after age 12 but not if they arrived at younger ages.

Empirical evidence of age at arrival effects on immigrant health outcomes
Although the literature is more limited, several studies of immigrant health outcomes support a critical periods perspective. In a study of breast cancer among Hispanic women, John et al (2005) found that risk was higher among women arriving by age 20 compared to those who arrived later in life. Similarly, examinations of immigration timing and psychiatric outcomes (the one outcome with multiple studies of this association) consistently suggest that arriving in childhood or early adolescence confers a significantly increased risk (Vega et al, 2004; Williams et al, 2007; Breslau et al 2007a, Breslau et al, 2007b; Alegria et al, 2007). An interesting study by Troe et al (2006) of infant mortality in The Netherlands suggested divergent effects of age at arrival for different immigrant groups. Comparing immigrant women who arrived after age 16, those who arrived by 16, and their native-born counterparts, they observed a monotonic increase in risk among Turkish immigrants, suggesting a protective effect of later arrival, and a decrease in risk among Surinamese immigrants. And mirroring the divergent pattern of a positive association between duration and physical activity, Evenson et al, 2004 found that arrival in the U.S. before versus after age 25 was associated with higher levels of activity among Latina immigrants in North Carolina.

These studies largely point to the role of early life socialization as the mechanism by which age at arrival influences subsequent health. However, there is also evidence that early life may not be the only critical period during which immigration can differentially impact health. Later arriving immigrants (e.g., after age 35) may confront other challenges related to language acquisition, social integration, conflict with children socialized in American society, and downward social mobility (Kaplan and Marks, 1990; Angel and Angel, 1992; Angel et al, 1999). And indeed, studies of self-assessed health, disability, emotional stress (Angel et al, 2001) and mental disorders (Williams et al, 2007; Mills and Henretta, 2001) suggest that late age at arrival is also associated with increased risk.

Additional empirical support for a critical periods or age at arrival approach may also come inadvertently from studies examining duration effects. As a function of the inter-relationship between current age, duration of residence, and age at immigration, patterns typically attributed to time since immigration could also reflect the influence of the *timing* of immigration. For example, given two individuals assessed at age 35, one with 15 years of residence in the U.S. and the other 20 years, observed differences between them could be due to a five year difference in

duration, a five year difference in age at arrival (age 20 versus 15, respectively), or both. Conversely, for two individuals having arrived in the U.S. at age 10, one having 15 years of residence in the U.S., and the other 20 years, differences in outcomes could be due to a five year difference in duration or a five year difference in age. The specific patterns of association between years of residence and health across studies are difficult to discern because of the variability in populations and outcomes and inconsistency in the coding of duration (Argeseanu Cunningham, et al, 2008). For the most part, however, the patterns in the published literature suggest a kind of "chunky" linearity – the overall direction of effect estimates is fairly consistent but without uniform monotonic increases at each level of duration. The most consistent finding from these studies is a marked inflection at 10 years or more or 15 years or more in the U.S.; the largest and most statistically significant effect estimates are observed at these levels of duration. Yet estimates based on duration categories without an upper bound (e.g., 15 years or more) are especially difficult to disentangle from early age at arrival effects because this category is disproportionately capturing immigrants who arrived in childhood and adolescence, regardless of the overall age distribution in the sample. Surprisingly, acknowledgement of this mathematical interrelatedness and its implication for the interpretation of apparent duration effects in studies of time since immigration is exceptionally rare (Vega et al, 2004; Alegria et al, 2007).

Most likely, both age at arrival and duration play a role in shaping immigrant health trajectories. Few studies have measured both (Williams et al, 2007; Troe et al, 2006; Alegria et al, 2007; Vega et al, 2004; John et al, 2004) and fewer yet have assessed their relative importance (Alegria et al, 2007; Vega et al, 2004). These studies do suggest that both the timing of immigration and time in the U.S. play a role, at least in the case of psychiatric outcomes.

Effects of the timing of and time since immigration on low birthweight

In the present study we assess the contribution of employing a life course perspective to understanding low birthweight among immigrant mothers in the U.S. Birthweight, and low birth weight (< 2500 grams) in particular, are very well measured and highly consequential markers of health. Low birth weight (< 2500 grams) is the second leading cause of infant mortality in the United States, after birth defects (Matthews et al. 2003), and is associated with long-term health and developmental problems among infants who survive (Hack et al. 1995). Birth outcomes have been the focus of many studies of nativity and ethnic differences. Among Hispanics (Landale et al, 1999; Markides and Coreil, 1986), blacks (Cabral et al, 1990; David and Collins, 1997; Fang et al, 1999; Singh and Yu, 1996), and Asians (Alexander et al, 1996; Singh and Yu, 1996), immigrants have more favorable birth outcomes than their U.S.-born racial or ethnic counterparts. Studies have also documented an absence of the immigrant advantage, however, among Whites and Asians (Acevedo-Garcia et al, 2005), Asian Indians (Gould et al, 2003), and island-born Puerto Ricans (Rosenberg et al, 2005).

Studies of time in the U.S. or the timing of arrival and pregnancy or birth outcomes are much more limited. Most available studies focus on "acculturation" as the exposure (measured variably) and on proximal outcomes like health behaviors during pregnancy. For example, acculturation has been shown to be associated with more smoking, alcohol, street drug use, and dietary intake during pregnancy (Heilemann et al, 2000; Wolff and Portis, 1996; Zambrana et al 1997; Harley and Eskenazi (2006) reported that Mexican women who had come to the US as children were five times as likely to smoke during pregnancy and half as likely to have a high

quality diet compared to women who arrived as adults. However, this study was based on a small, non-representative sample and 70% of the women who spent their childhood in the US were also born in the US, limiting the ability to disentangle the effects of nativity and age at arrival. Studies of the effects of exposure to the U.S. on actual birth outcomes among immigrants are even more limited. In a small, exploratory, non-representative sample of Mexican immigrant women in California, Guendelman and English (1995) observed a modest increase in low birthweight among the offspring of immigrants residing in the United States longer than 5 years versus less than 5 years. A few studies have documented a positive association between measures of acculturation (e.g., ethnic identity and language use) and low birthweight using the Hispanic Health and Nutrition Survey (HHANES) (Cobas et al, 1996; Scribner and Dwyer, 1989)

This study therefore attempts to address two important gaps in the literature: inadequate attention to the independent and synergistic effects of both time in the US and timing of arrival in immigrant health studies, particularly with respect to physical versus mental health outcomes; and the lack of nationally representative data on the effects of either of these exposures on birth outcomes among the foreign born. We pool two datasets to examine the impact of nativity, age at arrival and duration of residence on low birthweight among the offspring of a nationally-representative sample of women in the U.S., evaluating in particular the possibility of a "critical period" for immigration around adolescence. To explore whether and how the low birthweight patterns observed with respect to exposure to the US are behaviorally mediated, we also examine the intermediate outcome of smoking during pregnancy, one of the most important modifiable determinants of low birthweight (Wilcox, 1993).

Methods

Data

In order to obtain data on a sufficiently large and representative sample of foreign-born mothers that includes both maternal immigration related information and birth outcomes we pooled data from two birth cohort studies: the Early Childhood Longitudinal Study-Birth Cohort (ECLS-B), the Fragile Families and Child Wellbeing study (FF).

The ECLS-B is a longitudinal birth cohort study based on a nationally representative sample of 10,442 children born in 2001 and being followed until the end of first grade. Births were sampled from birth certificates, with low and very low birth weight infants, twins, and minority groups oversampled. The response rate for the first survey of the ECLS-B, conducted when the child was 9 months old, was 74 percent. From the ECLS-B we used the birth certificate data, the baseline survey, and the first follow-up (when the child was 24 months old). Together, these modules provided data on birth weight and gestational age, maternal nativity, age at arrival and number of years in the U.S. among foreign born women, and several covariates of interest, including age, race/ethnicity, marital status, parity, educational attainment, household income, and self-report of smoking during pregnancy.

The Fragile Families and Child Wellbeing Study follows a representative cohort of 4898 children born between 1998 and 2000 in U.S. cities with over 200,000 people. Births were sampled using

a multi-stage stratified probability design that oversampled births to unmarried parents. Baseline interviews were conducted with mothers at the hospital within 48 hours of the child's birth.

Measures

The primary outcome measure was low birthweight (<2500 g). The secondary outcome, smoking during pregnancy, was defined as any self-reported cigarette smoking during the pregnancy. These and all covariates used in the analyses were ascertained in comparable ways in the two datasets. The primary predictors of interests (time in the US and age at arrival) were ascertained in somewhat differently. In the ECLS-B, respondents were asked "How old were you when you first moved to the U.S.?" and in the FF, they were asked "In what year did you first come to the U.S. to live?" For the ECLS-B, duration of residence was determined by subtracting age at arrival from current age and for the FF, duration was generated by subtracting year of the mother's arrival from year of the child's birth, and age at arrival was based on the difference between maternal age at birth and years in the US.

We defined the nativity indicator as born on the US mainland (excluding US territories) versus in another country. Consistent with a life course perspective and following other studies of immigration *timing* and health, we defined the exposure categories in terms of coincidence with life cycle stages (Harley and Eskenazi et al, 2006; Vega et al, 2004; Alegria et al, 2007; Troe et al, 2006). We categorized age at arrival to correspond to critical developmental periods potentially relevant to the outcome of low birthweight: age 0-5 (infancy and early childhood); 6-12 (school age childhood); 13-18 (adolescence); 19-25 (majority status/young adulthood); and age 26+ (adulthood/post-college). Although we hypothesized that with respect to low birthweight age at arrival would exhibit a threshold effect around adolescence, we modeled multiple categories to facilitate greater precision and confidence in our interpretation of the pattern of association.

In contrast, the literature on *time* in the US does not suggest theoretically-based cut-points or thresholds for duration effects and implicitly assumes a linear association. The categorization of duration of residence in these studies is often unexplained (Barcenas et al 2007; Dubowitz et al, 2007; Williams et al, 2007), data driven (Evenson et al, 2004; Vega et al, 2004; Abraido-Lanza et al, 2005), or simply based on previous studies (Uretsky and Mathiesen, 2007). In many studies, the years of residence data used (e.g., the National Health Interview Survey (NHIS)) have been collected or are only available categorically, severely constraining the type of analysis possible. To be consistent with the assumption of linearity, but allow for deviations from it, we also chose to model duration categorically, and to be comparable with other studies, we followed the most commonly used categorization of years in the US: 0-4, 5-9, 10-14, and 15+ years.

Respondents' self-reported race and ethnicity was categorized to create 5 distinct groups: Hispanics and non-Hispanic Whites, Asians, Blacks and Other. "Other" race/ethnicity consisted of non-Hispanic individuals who reported belonging to more than one race. Education categories included less than high school, high school diploma or General Education Diploma (GED), some college or vocational education, and a bachelor's degree or higher. We collapsed information on household annual income to create 3 comparable categories across the two datasets: less than $25,000, $25,000-$50,000, and greater than $50,000. In the Fragile Families dataset a substantial percentage of the observations were missing data on income and these were dummy

coded and included in the analysis to maximize the sample size. Maternal age at birth was analyzed as a continuous variable, parity was dichotomized as first birth versus a higher order birth.

Analytic approach

As noted above, the numeric interrelatedness of age at arrival, duration of residence, and age makes isolating their independent effects and parsing their relative significance empirically challenging. This identifiability problem has been largely ignored in studies of immigrant health and time in the U.S. Unfortunately, large time series of cross sectional data with information on health, immigration status, and age at arrival to the U.S. that would allow the use of well established methods to address this issue (Ryder, 1964) do not exist.

We employed two strategies to deal with the age-at-immigration—age at birth—duration identifiability problem. First, we compared observed patterns in the data to theoretically-based predictions regarding the patterns of association between low birthweight and duration in the US, and between low birthweight and age at arrival. Specifically, if the processes (e.g., adaptation, assimilation, acculturation) underlying the health deterioration of immigrants are a function of years of residence or *time* in the U.S., we should observe a pattern of linear increases in the risk of low birthweight with years of residence in the US. Alternatively, if the *timing* of arrival vis-à-vis specific critical periods is what matters, we should observe an unambiguous inflection point in the association between age at immigration and low birthweight. We further hypothesized that, consistent with the developmental perspective articulated above, this threshold will appear around adolescence, particularly as health behaviors (e.g., diet, smoking, alcohol use) associated with birth outcomes are often acquired at this point in the life course. To explore this potential behavioral pathway between age at arrival and low birthweight, we also examined patterns of association between the two immigration-related variables and smoking during pregnancy and considered to what extent the critical periods perspective was consistent with the smoking behavior of immigrant mothers.

Second, we combine the measures of age at arrival and time in the US into 4 discrete, non-overlapping categories of exposure and estimate their relative effects, controlling for maternal age as a continuous covariate. We also use information on associations between maternal age and birthweight among U.S. born mothers to subtract the contribution of the maternal age effect from estimates of duration effects among immigrant women. The latter requires making an assumption that age effects are similar for native and foreign born mothers.

Analytic procedures

After accounting for missing data on immigration-related variables and covariates and restricting to singleton births, analyses of the pooled data were based on a sample of 12,120 births, 2,812 of which were of foreign born mothers. Using multiple logistic regression models we first estimated separately the odds of low birthweight associated with duration in the US and age at arrival, relative to the US born. We then compared the patterns of these associations to determine whether the results were more or less consistent with a duration or age at arrival effect. Next, we integrated these measures to explore further their relative and conditional importance. Because of multicollinearity, we could not model age at arrival, duration, and maternal age simultaneously as independent predictors. Instead, we estimated the associations

with low birthweight of 4 exposure categories combing duration (less than 10 years vs. 10 years or more) and age at arrival (by age 12 vs. age 13 or later). These cutpoints were based as much as possible on the findings from the analyses of the independent effects and on sample size limitations. This analysis was also restricted to women below age 35 in order to maximize comparability of maternal age across the categories, since maternal age is an important independent predictor of low birthweight. Next, we generated odds ratios for the association between maternal age and low birthweight using multiple logistic regression models stratified by nativity and age at arrival (among the foreign born). For immigrant women this relative risk represents the combined effect of both age and duration in the U.S. By comparing the effect sizes for the foreign born versus the US born we estimated the "excess risk" associated with aging that can be attributed to duration effects. For this analysis we restricted the sample to women who were ages 20-35 at birth since this is the range in which age effects were relatively small and linear. Finally, we also estimated the associations between the combined age at arrival-duration categories and smoking during pregnancy. All analyses controlled for maternal age, race/ethnicity, education, income, parity, marital status, and data source using a dummy variable indicating the ECLS-B versus FF datasets.

Results

Table 1 shows the weighted characteristics of the two samples separately and Table 2 shows key characteristics of just the foreign born sample using the pooled data. The prevalence of low birthweight was 5.8% and 7.7%, respectively in the ECLS-B and FF datasets. With respect to other characteristics the two datasets are also comparable, though the percentage of mothers who were unmarried at birth and had low birthweight babies was higher in FF, reflecting the oversampling on these characteristics. As expected, the prevalence of low birthweight is lower in the foreign born-only (Table 2) versus combined (Table 1) samples. The racial/ethnic distribution is also, not surprisingly, different: Whites are the majority in the combined samples while Hispanics are by far the largest group among the foreign born. A slight majority of the foreign born mothers arrived after age 18 and had been in the US for less than 10 years. With a truncated age distribution due to our focus on a birth outcome (maternal age range = 14-50), the correspondence between the duration and age at arrival categories in this sample is especially high; 68% of women who had been in the US for 15 years of more had arrived by age 12.

In both a crude analysis and adjusting for covariates, we observed the expected protective association between foreign nativity and low birthweight (Table, 3, Model 1: adjusted odds ratio = 0.74; 95% CI = (0.62, 0.88). We also observed the expected protective effects of both shorter duration of residence and later age at arrival among the foreign born compared to the US born (Table 3). Results for time in the US (Model 2) did not suggest a linear association between duration and low birthweight but rather a threshold effect at 10 years; compared to the US born, the odds of low birthweight were 0.53-0.68 times lower among immigrants in the US for less than 10 years but indistinguishable among immigrants who had been in the US for over 10 years. The difference between the 0-4 and 5-9 year duration categories was not statistically significant. While this may be due to power limitations, the direction of effects (e.g., lower odds associated with 5-9 years than 0-4 years) is still not consistent with a progressive, linear increase in the risk of low birthweight with time in the US.

In contrast, findings for maternal age at arrival (Table 3, Model 3) were more consistent with the hypothesized pattern of association. The results suggested an unambiguous threshold effect whereby arriving in the US after age 12 was protective; women who immigrated after age 12 had on average between 0.72 and 0.75 the odds of having a low birthweight infant compared to the US born. In contrast, the odds of having a low birthweight infant among immigrant mothers who arrived by age 12 were indistinguishable from those of US born mothers.

Table 4 shows the results for the 4 combined age at arrival-duration categories in order to examine whether and to what degree the effect of one exposure to the US variable is contingent on the other. The dichotomy of the age at arrival variable corresponds to the results in Table 3 (immigration by age 12 versus after), but the duration variable was dichotomized at less than 15 years in the US versus 15 or more to increase the sample size in the early arrival-short duration category. The ability to interpret these results is nevertheless still hampered by power limitations and the resulting wide confidence intervals. However, the patterns are suggestive: late age at arrival appears relatively protective, regardless of duration length, and long duration in the US appears deleterious only among those who immigrated at an early age.

The findings that duration in the US only increases the risk of low birthweight among immigrant women who arrived in childhood are further supported by the results presented in Table 5. The table shows the adjusted odds ratios for maternal age based on 5 separate logistic regression models for the US born and the foreign born of different ages of arrival. For US born women between the ages of 20 and 35 at birth, each year of age was associated with a statistically significant 1.05 times greater odds of having a low birthweight baby (95% CI: 1.03, 1.06). Among foreign born women who arrived by age 12 the odds ratio for maternal age was 1.20 and also statistically significant (95% CI: 1.09, 1.31). However, for all later age at arrival groups, the odds ratios for maternal age were no larger than that for the US born and the estimates were not statistically significant. Assuming that the true effect of aging is comparable for native and foreign born women, the difference in the relative risk associated with age for the US born and immigrant women who arrived by age 12 can be attributed to the influence of duration. This residual effect of duration does not appear to operate among women who immigrated after age 12.

Table 6 shows results for the smoking during pregnancy outcome. The odds of smoking during pregnancy were substantially lower among women who immigrated after age 12 compared to US born women and compared to foreign born women who arrived after age 12 (who were also at much lower risk vis-à-vis the US born). Unlike the results for low birthweight, length of residence in the US did not appear to modify the odds of smoking during pregnancy for either age at arrival group.

Discussion

We observed a deleterious association between exposure to the US, as measured by both duration of residence and age at immigration, and low birthweight. To our knowledge, ours are the first estimates of these associations using a nationally representative sample in the US. Consistent with other studies, the findings suggest convergence between the foreign born and the US born: the longer immigrants are in the US *or* the earlier they arrive, the more their health

resembles that of the US born. Where our analysis diverges from other studies, especially of physical health outcomes, is in comparing these two dimensions of immigrants' exposure to the US – the timing of immigration and time since immigration – on the basis of a priori predictions about the patterns of association implied by either approach. In the case of a duration effect, we followed other studies and predicted by default a linear association (for lack of a theoretically-based alternative) and for age at arrival, we anticipated a threshold effect around adolescence based on a life course or "critical periods" perspective.

Our results from analyses of both duration of residence and age at arrival overwhelmingly support a critical periods interpretation. We observed an unambiguous inflection point in the association between age at arrival and low birthweight at age 13, whereby immigrating to the US at this age or later was uniformly protective. We also observed a threshold in the association between duration and low birthweight suggesting less than 10 years of residence in the US was protective. This latter finding is highly consistent with the interpretation that immigrating before or during a critical developmental period in the life course is the primary temporal mechanism by which exposure to the US harms immigrant health; 48% of foreign born women who had been in the US for 10 years or more had arrived before age 13.

This does not necessarily mean, however, that duration does not play a role in the low birthweight patterns we observed. We also sought to understand the joint effect and relative importance of time in the US and age at arrival. Findings from the analysis of the combined age at arrival-duration categories suggest that time in the US matters, but less so among those who arrive at age 13 or beyond. This interpretation was further supported by the elevated maternal age effect among immigrants who arrived by age 12 relative to this US born; for the later arriving immigrants no such "excess" age (i.e., duration) effect was observed. In contrast, the smoking during pregnancy analysis indicated unambiguously that for this outcome the timing of immigration, again by age 12, was a more important predictor than duration of residence.

The findings were also consistent with our expectation that adolescence is the relevant critical period. However, the timing of immigration threshold we observed at age 13, with a uniform protective association for all age at arrival categories beyond this inflection point (13-18, 19-25, 26+), suggests that arriving in the US *during* adolescence did not confer increased risk. We subsequently explored whether the broad age at arrival category (13-18) masked a threshold more in the middle of adolescence, but this did not appear to be the case. The increased risk associated with immigration by age 12 is also consistent with studies of psychiatric and substance use disorders (Breslau et al, 2007a; Breslau et al, 2007b). Although multiple pathways are likely, the consistent patterns of association observed for the smoking during pregnancy results support the role for a behavioral mechanism by which immigrants' exposure to the US affects their risk of low birthweight. The results imply that the socialization processes hypothesized to be relevant to health behaviors do not happen instantaneously; immigrants who arrive in childhood may need time to establish peer groups and to internalize the norms and expectations of their new social environment. Other mechanisms as described above (e.g., language acquisition, identity) may also be operative and are not inconsistent with a possible threshold effect at the cusp of adolescence.

These analyses and interpretations are subject to several limitations. As noted throughout, our ability to definitively disentangle the effects of time in the US and the timing of arrival were hampered by the data structure, especially because of the limited age distribution in the sample and because of the strong association between age and the outcome of interest. However, the data necessary to empirically test their relative influence more rigorously are not available, and the present results highlight approaches to conceptualizing and analyzing duration and age at arrival patterns in health outcomes that can be replicated in existing datasets. In addition, although our results suggest that age at arrival plays a larger role than duration in driving low birthweight among immigrants, age at arrival patterns, like those for duration, also possibly reflect to some extent immigrant cohort differences and selection processes. Regarding the latter, it is possible that, as relatively "passive" immigrants accompanying their parents, immigrant children are not selected on health advantage to the same degree as their adult counterparts. However, this interpretation is not consistent with our finding of a relative birthweight advantage among immigrants who arrived in adolescence, the majority of whom presumably were also accompanying their parents.

Another set of limitations concerns the size and composition of the sample used in these analyses. Despite pooling the ECLS-B and FF datasets, the wide confidence intervals of many of the estimates, particularly for the combined age at arrival-duration categories, made our interpretation of differences speculative at best in many cases. However, the totality of the patterns of association, and their consistency with a priori predictions, were on the whole of greater interest than the identification of specific differences in association. Furthermore, although we controlled for race/ethnicity to account for the sizeable racial/ethnic differences in nativity and exposure to the US, we would ideally be able to disaggregate the data to examine the extent to which the patterns observed in the whole sample applied across subgroups. Sample sizes were only sufficient for subgroup analyses among Hispanic women; supplementary analysis of the associations between duration and low birthweight and age at arrival and low birthweight in this group suggested similar patterns. Finally, differences between the two datasets in the elicitation and coding of country of origin and ancestry prohibited us from controlling for these variables. As a result, it is possible that some of the patterns observed were confounded by national origin if, for example, certain national origin groups have on average lower birthweight babies and tend to immigrate to the US as children. However, our examination of the composition of the two datasets suggests that no one group was over-represented to such a large degree to drive the results in this fashion. In future analyses we will use US census data to identify any national origin patterns in the timing of immigration and then determine the correspondence between patterns in age at arrival observed and average national origin group differences in low birthweight.

In conclusion, most likely both the timing of immigration and the time since immigration play a role in determining immigrant health trajectories to at least some degree, and the relative importance of each will depend largely on the specific outcome under study. As these results suggest, it is useful and important to recognize the conceptual distinction between duration and age at arrival, as well as their numeric interrelatedness, even if analytically it is not possible to completely disentangle them. The effects of the timing of arrival may underlie at least to some extent observed associations with duration of residence. Age at arrival interpretations of observed duration effects may seem particularly warranted in the case of health behaviors or

other outcomes believed to be behaviorally-mediated, as many relevant health behaviors are likely to be established in childhood or adolescence. Age at arrival (along with nativity and duration) may also be an important source of heterogeneity within panethnic immigrant groups that should be considered, at least in interpreting results, when comparing health outcomes across racial/ethnic and immigrant groups. This heterogeneity may help explain variation and inconsistency in observed patterns in the effects of "acculturation" (Alegria et al, 2007).

The finding of a critical period for immigration around adolescence resonates with recognition of the special status and adaptation experiences of immigrant children, often referred to as the "1.5 generation" (Rumbaut and Ima, 1988; Rumbaut, 1991). Greater attention to the timing of immigration in studies of health outcomes will facilitate better understanding of both how exposure to US society shapes the health of immigrants and, more broadly, how social changes over the life course affect health. The question of the relative role of time versus timing also has important implications for targeting interventions to better facilitate immigrant adaptation and positive health trajectories over time.

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Table 1. Weighted sample characteristics, ECLS-B and Fragile Families (FF) datasets

	ECLS-B (N = 7512) %	FF (N = 4608) %
Low birthweight infants	5.9	7.7
Maternal characteristics		
Mean age (SD)	27.3 (6.3)	26.5 (6.2)
Race/ethnicty		
Non-Hispanic White	58.2	44.0
Non-Hispanic Black	14.1	27.6
Asian	3.4	4.6
Hispanic	22.5	22.7
Other	1.8	1.1
Educational attainment		
Less than high school	27.2	27.9
High school	21.7	25.3
Vocational/some college	26.6	25.0
College or higher degree	24.5	21.9
Income		
<$25,000	34.9	31.8
$25,000-50,000	29.5	20.4
>$50,000	35.7	27.8
Missing	--	20.0
First birth	40.6	41.3
Married	67.4	56.0
Smoked during pregnancy	12.8 (N=6274)	15.8 (N=4599)
Foreign born	20.1	19.7
Time in US among foreign born		
0-4 yrs	35.5	33.4
5-9 yrs	23.9	27.3
10-14 yrs	18.0	18.2
15+ yrs	22.7 (N=2039)	21.1 (N=773)
Age at arrival among foreign born		
0-5 yrs	10.0	11.0
6-12 yrs	11.1	10.9
13-18 yrs	23.0	26.7
19-25 yrs	34.8	32.0
26+ yrs	21.2 (N=2039)	19.4 (N=773)

Table 2. Weighted characteristics of the foreign born sample, pooled ECLS-B and FF data

	(N = 2812) %
Low birthweight	5.3 (5.5)
Maternal age (SD)	27.8
Race/ethnicty	
Non-Hispanic White	12.3
Non-Hispanic Black	7.4
Asian	16.8
Hispanic	62.9
Other	0.7
Time in US	
0-4 yrs	34.7
5-9 yrs	25.2
10-14 yrs	18.1
15+ yrs	22.1
Age at arrival	
0-5 yrs	10.4
6-12 yrs	11.0
13-18 yrs	24.4
19-25 yrs	33.7
26+ yrs	20.6

Table 3. Multiple logistic regression of low birthweight on time in the US, age at arrival and covariates, pooled ECLS-B and FF data

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Maternal age	1.04 (1.03, 1.05) ***	1.04 (1.03, 1.05) ***	1.04 (1.03, 1.05) ***
Race/ethnicty			
Non-Hispanic White (ref)	1.00	1.00	1.00
Non-Hispanic Black	1.70 (1.49, 1.95) ***	1.70 (1.48, 1.95) ***	1.71 (1.49, 1.96) ***
Asian	0.47 (0.36, 0.62) ***	0.47 (0.36, 0.62) ***	0.48 (0.37, 0.62) ***
Hispanic	0.85 (0.72, 1.01)	0.85 (0.72, 1.01)	0.86 (0.72, 1.01)
Other	0.58 (0.40, 0.84) **	0.58 (0.40, 0.84) **	0.58 (0.40, 0.84) **
Educational attainment			
Less than high school (ref)	1.00	1.00	1.00
High school	0.92 (0.80, 1.05)	0.91 (0.80, 1.04)	0.91 (0.79, 1.04)
Vocational/some college	0.75 (0.65, 0.87) ***	0.75 (0.64, 0.86) ***	0.74 (0.64, 0.86) ***
College or higher degree	0.59 (0.48, 0.72) ***	0.59 (0.48, 0.72) ***	0.58 (0.48, 0.71) ***
Income			
<$25,000 (ref)	1.00	1.00	1.00
$25,000-50,000	0.90 (0.79, 1.02)	0.87 (0.77, 1.01)	0.89 (0.78, 1.02)
>$50,000	0.65 (0.55, 0.77) ***	0.65 (0.55, 0.76) ***	0.65 (0.55, 0.76) ***
Missing	1.31 (1.05, 1.63) *	1.32 (1.06, 1.64) *	1.32 (1.06, 1.64) *
Parity	1.64 (1.46, 1.82) ***	1.64 (1.47, 1.84) ***	1.64 (1.47, 1.83) ***
Married	0.74 (0.65, 0.85) ***	0.75 (0.66, 0.86) ***	0.75 (0.66, 0.86) ***
Foreign born	0.74 (0.62, 0.88) ***		
Time in US (ref = US born)			
0-4 yrs		0.68 (0.53, 0.87) **	
5-9 yrs		0.53 (0.39, 0.71) ***	
10-14 yrs		0.90 (0.67, 1.20)	
15+ yrs		0.94 (0.72, 1.23)	
Age at arrival (ref = US born)			
0-5 yrs			1.00 (0.69, 1.46)
6-12 yrs			0.95 (0.66, 1.35)
13-18 yrs			0.65 (0.49, 0.88) **
19-25 yrs			0.67 (0.52, 0.86) **
26+ yrs			0.70 (0.53, 0.93) *
N	12120	12120	12120

Models are restricted to singleton births and control for data source
*p<.05 **p<.01 ***p<.001

Table 4. Multiple logistic regression of low birthweight on combined age at arrival-duration categories, pooled ECLS-B and FF data

	OR (95% CI)	N	Maternal age^ Mean	Range
US born (ref)	1.00			
Early arrival-short duration§	0.74 (0.42, 1.27)	143	20.2	15-26
Early arrival-long duration	1.07 (0.77, 1.47)	407	26.5	16-34
Late arrival-short duration	0.66 (0.53, 0.82) **	1712	27.1	15-34
Late arrival-long duration	0.50 (0.21, 1.19)	97	31.7	28-34

^Sample is restricted to maternal age below 35 to maximize overlap of the maternal age ranges for each age at arrival-duration category.
§ Early arrival refers to arrival by age 12 and short duration refers to residence in the US less than 15 years; the inflection in duration at less than 10 years versus 10 years or more was not used in this analysis because of insufficient cell size for the first age at arrival-duration category.
Model is restricted to singleton births and controls for maternal age, race, education, income, parity, marital status, and data source.
*p<.05 **p<.01 ***p<.001

Table 5. Adjusted odds ratios for the association between maternal age/duration and low birthweight for different nativity/age at arrival groups, pooled ECLS-B and FF data

Strata	OR (95% CI)	N	Maternal age Mean	Range
M1 US born	1.05 (1.03, 1.06) ***	6953	26.9	20-35
M2 Age age arrival <13 yrs	1.20 (1.09, 1.31) ***	457	26.3	20-35
M3 Age age arrival 13-18 yrs	1.04 (0.95, 1.14)	469	26.1	20-35
M4 Age age arrival 19-25 yrs	1.00 (0.93, 1.06)	848	27.2	20-35
M5 Age age arrival 26+ yrs	1.06 (0.94, 1.23)	443	31.0	26-35

Models are restricted to singleton births and control for race, education, income, parity, marital status, and data source.
*p<.05 **p<.01 ***p<.001

Table 6. Multiple logistic regression of smoking during pregnancy on combined age at arrival-duration categories, pooled ECLS-B and FF data

	OR (95% CI)	N	Maternal age Mean	Range
US born (ref)	1.00			
Early arrival-short duration§	0.37 (0.15, 0.96) *	93	20.4	15-26
Early arrival-long duration	0.41 (0.23, 0.73) **	326	27.7	16-45
Late arrival-short duration	0.08 (0.05, 0.14) ***	1339	28.9	16-48
Late arrival-long duration	0.06 (0.01, 0.41) **	133	35.4	28-46

§ Early arrival refers to arrival by age 12 and short duration refers to residence in the US less than 15 years; the inflection in duration at less than 10 years versus 10 years or more was not used in this analysis because of insufficient cell size for the first age at arrival-duration category. Model is restricted to singleton births and controls for maternal age, race, education, income, parity, marital status, and data source.
*p<.05 **p<.01 ***p<.001