Socioeconomic status, stressful life events and immune function in The National Longitudinal Study of Adolescent Health

Jennifer B. Dowd, Ph.D.[1,2], Tia Palermo, Ph.D[3], Laura Chyu, Ph.D[4], Emma Adam[4,6], Ph.D., Thomas W McDade, Ph.D[5,6]

[1]CUNY School of Public Health, Hunter College
[2]CUNY Institute for Demographic Research (CIDR)

[3]Program in Public Health, Department of Preventive Medicine, Stony Brook University (SUNY)

[4]School of Education and Social Policy, Northwestern University

[5]Department of Anthropology, Northwestern University

[6]Cells to Society: The Center on Social Disparities and Health, Institute for Policy Research, Northwestern University

Abstract

Stress may be an important mediator of the association between social factors and health outcomes. Markers of immune function are useful tools to study the impact of stress on health due to the consistent association between stress and suppressed immunity. This study utilizes newly released data from Wave IV of the National Longitudinal Study of Adolescent Health (Add Health) to examine the association between socioeconomic status (SES), the Cohen perceived stress scale (PSS), exposure to stressful life events (SLE), and markers of immune function, specifically antibody levels of Epstein-Barr virus (EBV) among adults aged 24-32. We tested both the potential mediating role of SLE for any SES-EBV association, as well as any moderating role of SES in the association between SLE and EBV. We found significant associations between higher SLE and higher EBV antibody levels for females but not for males. While we found strong associations between SES and both perceived stress and SLE, neither current or childhood SES variables were associated with EBV levels. Black race/ethnicity was associated with significantly higher EBV levels compared to whites, providing evidence of racial differences in cell-mediated immunity that were only slightly diminished after inclusion of stress variables. These results suggest that severe life stressors can impact immune function in ways that are measureable even in early adulthood.

Introduction

Stress is hypothesized to be an important determinant of multiple health outcomes as well as a potential mediator of the strong association between social factors and health over the life course (Seeman, Epel et al. 2010). Moreover, there is strong evidence that the immune system plays a mediating role in the association between psychosocial stress and health outcomes (Segerstrom and Miller 2004). Thus far, the majority of population-based studies of stress and biological indicators have come from middle-aged and older populations (Seeman, Singer et al. 1997; Glei, Goldman et al. 2007), with little data available on these interactions earlier in the life course. Early environments can model immune system development through nutritional and infectious exposures as well as stress-related neuroendocrine pathways (McDade 2005; Coe and Laudenslager 2007).

One approach to investigating the immune system *in vivo* is the latent reactivation of herpes viruses, such as Epstein-Barr virus (EBV), herpes simplex virus (HSV), varicella zoster virus (VZV), or cytomegalovirus (CMV)(McDade, Stallings et al. 2000; Glaser and Kiecolt-Glaser 2005). These viruses are distinctive because once infected, the host is not able to eliminate the virus, beginning a life-long competition between the immune system and the pathogen. In immune competent hosts, the virus mostly remains in a dormant (i.e., non-replicating) state, denoted as latency. However, when immune control is weakened, the virus begins to replicate, which in turn stimulates memory B lymphocytes to increase output of virus-specific IgG antibody. This results in the seemingly paradoxical observation that increased antibody levels ('titers') reflects poorer immune control (Glaser, Pearson et al. 1991; Kuo, Wu et al. 2008).

The psychoneuroimmunological literature has found consistent associations between herpesvirus antibody titers and stress-related immune suppression (Glaser and Kiecolt-Glaser 2005), although these findings are most often measured via short-term stressors in specialized populations. In particular, studies that have linked herpesvirus antibodies to stressors include academic stress in medical students and military cadets (Glaser, Friedman et al. 1999; Sarid, Anson et al. 2002), caregiving for a family member with Alzheimer's disease (Glaser and Kiecolt-Glaser 1997), involvement in a poor quality marriage (Herbert and Cohen 1993), anticipation of space flight by astronauts (Mehta, Stowe et al. 2000) and early childhood adversity including institutionalization and physical abuse (Shirtcliff, Coe et al. 2009). Elevated EBV antibodies specifically have been found to be associated with chronic psychosocial stress in Samoan adolescents, discrimination-related stress in Latino immigrants in Oregon, and in U.S. adolescents in the Great Smoky Mountains exposed to life strain and traumatic events (McDade, Stallings et al. 2000; McDade, Stallings et al. 2000; McClure, Martinez et al. 2010). Thus far, the majority of this research has come from small-scale, typically non-representative samples that may not generalize to the broader U.S. population.

The current study utilizes newly released data from Wave IV of the National Longitudinal Study of Adolescent Health (Add Health) to examine the association between socioeconomic status (SES), perceived stress, exposure to stressful life events (SLE), and markers of immune function, specifically antibody levels of Epstein-Barr virus (EBV). Previous work using nationally representative data from the National Health and Nutritional Examination Survey (NHANES) has linked markers of socioeconomic status to elevated antibody titers of a related herpesvirus, cytomegalovirus (CMV)(Dowd

and Aiello 2009; Dowd, Palermo et al. 2012). With the limited data on chronic or acute stress available in NHANES, the connection between SES, stress, and impaired immune function was only speculative in these studies. The current study will extend this work by fully examining the connections between SES, stressful life events, and immune function in young adults.

DATA AND METHODS

Data used in this analysis come from the National Longitudinal Study of Adolescent Health (Add Health), a longitudinal study of a nationally representative sample of adolescents begun in 1994-1995 and followed through 2008. Four waves of data are available, and the surveys collect data on social, economic, psychological and physical well-being with contextual data on the family, neighborhood, community, school, friendships, peer groups, and romantic relationships. These data provide unique opportunities to study how social environments in adolescence are linked to health outcomes in young adulthood. Collection of biological data including EBV via dried blood spot was expanded in Wave IV to understand the social, behavioral, and biological linkages in health trajectories as the Add Health cohort ages through adulthood (Carolina Population Center). At the time of the Wave IV interview, respondents were between 24 and 32 years old. Trained and certified interviewers used a finger prick to obtain whole blood spots that were dried and shipped to the University of Washington Medical Center Immunology Lab, in Seattle WA for analysis. The blood spots were frozen until processing, and then analyzed for EBV antibodies using an adaptation of a previously validated protocol(McDade, Stallings et al. 2000). IRB approved Add Health contracts

for restricted data access are in place at both Stony Brook University and Northwestern University.

Measures

Recent national estimates show that EBV is highly seroprevalent in the U.S. by early adulthood (Dowd under review). Because the stress and reactivation of latent infection model depends on having been previously infected, the primary outcome variable in this analysis was EBV IgG antibody titers for those respondents who are EBV seropositive (87.5% in this sample*)*. EBV antibody levels were measured as a continuous variable in the data and were logarithmically transformed to normalize the distribution in our analysis for continuous analysis, and also categorized into quartiles for examination of non-linear associations.

The main explanatory variables of interest were socioeconomic status (SES), perceived stress, and stressful life events (SLE). Perceived stress was measured with a validated 4-item shortened version of the Cohen Perceived Stress scale (Cohen, Kamarck et al. 1983). The items assessed stress in the past two weeks (felt unable to control important things in your life; felt confident about your ability to handle your personal problems; felt that things were going your way; felt difficulties were piling so high that you could not overcome them) using a 5-level response scale. Responses for each of the four items were summed, and total scores range from 0 to 16. Scores were then categorized into low (0-3), medium (4-6) and high (7-16) perceived stress.

SLE was assessed with an two indices (lifetime and 12 months), both based on a previously utilized additive index (Adkins 2009) and modified to reflect events reported

at Wave IV. The lifetime index summed affirmative responses to questions about specific life events, including death of parent; death of sibling; injury resulting from suicide attempt; having had a friend of family member commit suicide; having witnessed violence; having been the victim or perpetrator of violence or threat of violence (knife or gun pulled, shot or stabbed, slapped/hit/choked/beaten up); victim of theft; child physical abuse; child sexual abuse; loss of job; experience of combat zone; experience of miscarriage, stillbirth, abortion or child death; victim of intimate partner violence; having received welfare benefits recently or before age 18; having received an STI diagnosis; being separated, widowed or divorced; and having spent time in jail. The 12-month SLE index includes the following events occurring in the 12 months prior to the Wave IV interview: death of parent; sibling death; victim of theft; witnessing violence; victim of violence; spent time in jail; pregnancy ended in miscarriage, abortion, stillbirth; injury resulting from suicide attempt; friend or family member committed suicide; experience of intimate partner violence. These measures were reported retrospectively at Wave IV.

Adult SES was measured using completed education levels (less than a high school degree; high school degree, general equivalency diploma, or vocational training instead of high school; vocational training after high school or some college; college graduate or professional training beyond college) and adult household income coded as the midpoint of reported income brackets (upper income bracket ≥$150,000 was coded as $193,456 to reflect the median household income in the US in 2007 among households earning more than $150,000 as calculated from the Current Population Survey). Income was then log transformed due to right-skewness of the distribution. Childhood SES was coded as highest completed educational level of either parent in the household, including

step-parents (less than high school, completed high school, some college, college and postgraduate degree; coded as), as reported by the one parent interviewed at Wave I, and if either mother or father's educational status was missing, the other parent's educational status was used.

Other covariates included race/ethnicity (white, black, Hispanic, Asian, or other race). Race/ethnicity was coded as mutually exclusive categories, though respondents may have self-identified as multiple categories. If the respondent answered "yes" to the question "Are you of Hispanic or Latino origin?" that respondent was given a race designation of "Hispanic." If the respondent marked "black or African American" and any other race, they were designated as black or African American, and eliminated from the other marked categories. The process was repeated for the remaining race categories in the following order: Asian, Native American, other, and white.

We also control for continuous body-mass index (BMI) calculated from measured height and weight in Wave IV and acute infection reported in the last month, which could impact immune parameters (Visser, Bouter et al. 2001).

Statistical Analysis

We first summarized characteristics of our sample by EBV seropositivity status and ran multivariate Poisson regressions to describe the key sociodemographic (age, sex, and race/ethnicity, household income, education) and physical risk factors (BMI and recent infection) for EBV seroprevalence. Results are reported in prevalence ratios. Next, we used ordered logistic regression to examine how socioeconomic factors were associated with the Cohen Perceived Stress scale and logistic regressions for factors associated with the highest quartile of stressful life events; both sets of analyses are run

on the seropositive sample only. Finally, we examined the associations of the SES, stress, and EBV antibody levels (among seropositives) in sequential models that first examine the SES predictors without including stress and then adding the stress variables as potential mediators. We ran linear regression models with continuous log(EBV) as the outcome as well as logistic regression models for the odds of falling into the highest quartile of EBV antibody response. Substantive results were very similar, and we present results from the logistic models to facilitate interpretation. We stratified our analysis by gender, as previous research has found EBV to be correlated with life events in girls but not in boys (McDade, Stallings et al. 2000). We also tested whether identified associations between SLE and EBV were moderated by childhood SES or race/ethnicity using interaction terms between SLE and parent's education reported at Wave I and SLE and race/ethnicity. All analyses were conducted with weights and account for the complex survey design.

Results

Sample description

Of the 15,701 individuals interviewed at Wave IV, 14046 had valid data on EBV IgG levels, and 13244 of these had valid weights. Among individuals with information on EBV IgG levels and valid weights, we had complete data for covariates of interest for 11,657 individuals (88%), which is our analysis sample. The overall seroprevalence of EBV in our sample for analysis was 87.5%, and we present sample characteristics by EBV seropositivity status in Table 1.

EBV seropositivity

Males were less likely to be EBV seropositive than females (PR 0.95; CI 0.94, 0.97; Table 2), and the likelihood of infection increased with age (PR 1.01; CI 1.00-1.01). Individuals with lower levels of education were more likely to be seropositive than individuals who completed college or beyond (PR range: 1.03 (CI 1.01, 1.06) to 1.06 (CI 1.02, 1.10). Parental education but not current household income was associated with seroprevalence; individuals whose parents completed some college (PR=1.03; CI 1.00-1.06) had a higher risk than individuals whose parents completed college/above. Blacks (PR=1.06; CI 1.04, 1.08), Hispanics (PR=1.04; CI 1.02, 1.07), and individuals of other race (PR=1.76; CI 1.01, 1.13) all had higher seroprevalence compared to whites.

Sociodemographic predictors of Perceived and Lifetime Stress

Increased levels of education and household income were strongly associated with lower perceived stress (Table 3). Compared to whites, Asians had higher levels of perceived stress except when controlling for 12-month SLE, and males (but not females) of "other" race have higher levels of perceived stress than females. Lifetime SLE [OR=1.22 (CI1.16, 1.28) among females and OR=1.18 (CI 1.13, 1.24) among males] and 12-month SLE [OR=1.19 (CI1.11, 1.28) among females and OR=1.23 (CI 1.17, 1.30) among males] were both associated with increased perceived stress.

In logistic regressions examining factors associated with being in the highest quartile of lifetime SLE (Table 4), lower levels of education and income were again strongly associated with the highest SLE quartile. Blacks were more likely than whites to be in the highest SLE quartile [OR range: 2.40 (CI 1.83, 3.13) to 3.12 (CI 2.47, 3.94)

among females and OR range: 1.69 (CI1.25, 2.30) to 1.89 (CI1.39, 2.58) among males. Asian females were less likely to be in the highest SLE quartile compared to white females [OR=0.45; CI (0.21-0.94)], but the association for Asian males was not robust to the inclusion of controls for perceived stress and childhood SES.

SES, Stress, and EBV Antibody Levels

Overall, SES (current and childhood) was not associated with being in the highest EBV quartile; the one exception was for females with less than a high school education, who were *less* likely to be in the highest EBV quartile than females who had completed college or beyond (Table 5, Model 2, OR=0.69; CI 0.48, 1.00). Race/ethnicity, in contrast, was strongly associated with EBV antibody levels. Specifically, blacks were more likely to be in the highest EBV quartile than whites [female black OR=1.46 (CI 1.20, 1.77)]; [male black OR= 1.72 (CI 1.36, 2.19), Table 4]. Similar results were found for Hispanics, but only among females [OR=1.54 (CI 1.17, 2.03), Table 4].

Stressful life events were positively associated with the odds of being in the highest quartile of EBV antibody levels for both SLE measured as lifetime (OR=1.06; CI 1.01, 1.12) and past 12 months (OR=1.08; CI 1.00, 1.17)], but only for females (Tables 5 and 6). Perceived stress was not associated with EBV in any model. BMI was positively associated with being in the highest EBV quartile among females (OR=1.03; CI (1.01, 1.04), but not among males. Of all of the SES*SLE interactions and race/ethnicity*SLE interactions explored, only one was significant; the effect of an increase in lifetime SLE on EBV was less for black females than for whites. No moderating effect of SES on the SLE-EBV association was observed.

Discussion

This study explored the associations among socioeconomic status, perceived stress, stressful life events, and immune function in the well-characterized Add Health cohort. Our results suggest that stressful life events early in the lifecourse may influence the long-term functioning of the immune system as measured by elevated EBV antibody levels, and that these differences can emerge by early adulthood. We found that adult education and income levels were strong predictors of perceived stress and reported lifetime stressful events at ages 24-32. Contrary to our expectations however, neither childhood or adult socioeconomic factors were associated with reduced cell-mediated immune function, though substantial race/ethnic differences did emerge, with blacks at elevated risk compared to whites, as well as an elevated risk for Hispanic females. Both 12-month and lifetime stressful life event indices were associated with higher EBV levels in women, with no associations found for perceived stress. These results suggest that a history of severe life stressors may impact immune function more than transient perceived stress, and that important sex differences in the association between stress and immune function may exist.

Previous studies using Add Health have investigated the link between stressful life events and health behaviors and outcomes such as smoking and depression (Brown, Meadows et al. 2007; Adkins 2009) and recent work identified significant associations between adverse relationship histories and self-reported health and depressive symptoms in Add Health (Adam, Chyu et al. 2011). A recently published study is the first to our knowledge to examine the EBV antibody levels in Add Health (Slopen, McLaughlin et al. 2013). Slopen, et al examined the association between the frequency and timing of

childhood physical and sexual abuse and EBV antibody levels. They found that respondents with a high frequency of sexual abuse (>10 times) had elevated EBV titers compared to those reporting none, and that among those physically abused, those whose first abuse began between ages 3-5 had heightened levels relative to those first abused in adolescence. They also found that parental occupation and some categories of parental education were significantly associated with EBV levels. It is important to note that in this study, the authors did not restrict their EBV antibody analysis to those who were EBV seropositive. Even though a high percentage (87.5%) of the sample was seropositive, it can be seen from Table 2 in our analysis that the risk of seropositivity varies significantly according to important demographic variables. Thus the failure to exclude those who were EBV seronegative from continuous antibody analysis would lead to an estimate that is a combination of the association of the risk factors with seropositivity and continuous antibody response (reflecting subclinical reactivation) among the positive. While we do not look specifically at physical and sexual abuse, our results suggest that this approach may have influenced the estimate of parental SES in their analysis. To our knowledge no other studies have examined the association of SES, life stressors, and physical health in Add health.

Our results are consistent with the small previous literature on associations between early-life stressors and later life cell-mediated immune function in more specialized populations. Shirtcliff, et al identified higher levels of Herpes Simplex Virus Type 1 (HSV-1) antibody levels in adolescents who had been institutionalized (foreign orphanages) or physically abused in early childhood (Shirtcliff, Coe et al. 2009). McDade, et al and identified an association between traumatic life events and elevated

Epstein-Barr virus antibody levels for girls but not boys among 205 adolescents in the Great Smoky Mountains Study (McDade, Stallings et al. 2000). Dowd, et al identified higher levels of CMV antibodies in children aged 6-17 in NHANES III for those with more extreme levels of disadvantage (below the poverty line), but no differences by family income above this threshold (Dowd, Palermo et al. 2012). Taken together with the current findings, these studies suggest that severe life stressors can impact the developing immune system, whereas less dramatic variation in perceived stress or across the SES distribution may not result in measureable immune differences at earlier ages.

Several previous studies have identified associations between lower SES and higher herpesvirus antibody levels including CMV in the overall U.S. population (Dowd and Aiello 2009), CMV and HSV-1 in an sample of elderly Latino Americans (Dowd, Haan et al. 2008) and for HSV-1 in a community-based sample from Texas (Stowe, Peek et al. 2010). It is likely that our estimates of the association between SES and cell-mediated immune function is slightly underestimated, since our analysis requires respondents to be EBV positive to measure stress-induced antibody response. We have shown that even though a high percentage (87.5%) of the overall sample is EBV seropositive, those with higher SES are more likely to be negative and thus excluded from the antibody analysis, reducing the overall SES variation in the analysis sample. We would expect this non-random selection to be more important in populations with lower seroprevalence rates, but it is an important factor to bear in mind in interpreting results of this type of analysis.

Of note, Stowe, et al found that those with higher levels of education had *higher* levels of EBV antibody despite lower levels of HSV-1 antibody in their sample,

somewhat consistent with our findings for SES and EBV. Together these results suggest that the association of SES with EBV may differ from that of other herpesviruses; an unexpected result that deserves further investigation. It is possible that there is immune competitive inhibition among herpesviruses; compared to EBV, CMV has been shown to be dominant in the clonal expansion of dysregulated CD8 cells that are an important component of immunosenescence (Pawelec, Derhovanessian et al. 2009). Nonetheless, elevated EBV antibodies were seen in blacks compared to whites, confirming an association of elevated EBV antibodies and racial/ethnic if not SES disadvantage in our sample.

Our findings also confirm potential gender differences in the early adversity-immune function association, which were also found by McDade et al and Panter-Brick et al (McDade, Stallings et al. 2000; Panter-Brick, Eggerman et al. 2008). Although there are well-known sex differences in susceptibility to immune disorders, there is scant literature on sex-differences in the immunosuppressive affects of stress, though recent work found gender differences in cell-mediated immunity after surgical stress (Rahmani, Abbas Hashemi et al. 2012). Dube, et al also found that the odds of first hospitalization for an autoimmune disease were higher among adults with two or three childhood adversities compared to none, but this was significant only for women (Dube 2009). These differences may be mediated by functional interactions of the hypothalamicpituitary-adrenal (HPA) and hypothalamus-pituitary-gonadal (HPG) axes (Rohleder, Schommer et al. 2001; Bourke, Harrell et al. 2012). Future population-based studies should be aware of these differences and stratify analysis of stress and health outcomes by sex accordingly.

Our results suggest that differences in cell-mediated immunity related to life stressors can emerge by early adulthood, prior to typical onset of chronic disease and age-related immune decline. Cell-mediated immune function plays important an important role in eliminating viral infections, destroying bacteria and tumor cells, and defending against autoimmune diseases (Marshall Jr 2011). Despite this, the clinical implications of decreased cell-mediated immunity in the general and especially younger populations are not well known. Decreased cell-mediated immune function as measured by increased antibody titer to a similar herpesvirus, CMV, has been shown to be associated with impairment of immune competence via poor flu vaccine responses in young and elderly people (Trzonkowski, Mysliwska et al. 2003), shorter immune cell telomeres, a hallmark of immunological aging, and lowered restorative leukocyte telomerase activity (Effros 2011; Dowd, Bosch et al. 2013). CMV antibody levels have also been associated with increased cardiovascular risk factors (Nieto 1998; Hsue, Hunt et al. 2006; Cheng, Ke et al. 2009; Haarala, Kähönen et al. 2012), and all-cause and cardiovascular-related mortality (Roberts, Haan et al. 2010; Gkrania-Klotsas, Langenberg et al. 2013). EBV infection or reactivation has also been associated with lupus (James and Robertson 2012), multiple sclerosis (Levin, Munger et al. 2010), and breast cancer (Huo, Zhang et al. 2012). Hence, herpesvirus reactivation has been proposed as a putative link between stress, aging, and immunity (Bosch, Rector et al. 2013).

In summary, we have identified strong associations between SES and reported stress, as well as between stressful life events and decreased cellular immune function in young adulthood. Nonetheless, since SES and EBV antibodies were not associated in our sample, we cannot conclude that stressful life events mediate the association between

social factors and later life immune function in our sample. Importantly, stressful life events appear to have biologically measurable impacts on health even at a relatively young age in a population-based sample, highlighting the continued importance of identifying how the early social environment influences exposure to such stressors and the development of health inequalities over the life course.

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Table 1. Sample characteristics, Add Health, Wave IV, weighted (n=11,657)

	EBV seropositives (n=10,259)		EBV seronegatives (n=1,398)	
	Mean/ proportion	Standard error	Mean/ proportion	Standard error
EBV antibodies	165.52	1.42	38.89	0.28
log(EBV)	4.96	0.01	3.64	0.01
Lifetime stressful life events	3.92	0.05	3.67	0.08
0-2 events	0.25	0.01	0.31	0.02
3-4 events	0.45	0.01	0.45	0.02
5-6 events	0.21	0.01	0.17	0.01
7-8 events	0.15	0.01	0.12	0.01
9 or more events	0.03	0.00	0.03	0.01
12 month stressful life events	0.76	0.03	0.76	0.05
0 events	0.57	0.01	0.56	0.02
1 event	0.25	0.01	0.27	0.02
2-3 events	0.13	0.01	0.13	0.01
4 or more events	0.04	0.00	0.04	0.01
Cohen Perceived stress scale	4.75	0.05	4.57	0.10
Low stress	0.38	0.01	0.39	0.02
Medium stress	0.35	0.01	0.37	0.02
High Stress	0.27	0.01	0.24	0.02
Female	0.51	0.01	0.43	0.02
Completed education				
Less than high school	0.08	0.01	0.07	0.01
High school	0.17	0.01	0.14	0.02
Some college	0.44	0.01	0.41	0.02
College and above	0.31	0.02	0.37	0.02
Race/ethnicity				
White	0.69	0.03	0.77	0.03
Black	0.15	0.02	0.10	0.02
Hispanic	0.12	0.02	0.09	0.02
Asian	0.03	0.01	0.04	0.01
Other race	0.01	0.00	0.01	0.00
Active infection past month	0.04	0.00	0.03	0.01
BMI	28.64	0.13	28.57	0.25
Parent's education				
Less than high school	0.14	0.01	0.14	0.02
High school	0.31	0.01	0.29	0.02
Some college	0.22	0.01	0.18	0.01
College and above	0.33	0.02	0.38	0.02

Table 2. Poisson regression of Epstein-Barr Virus seropositivity, Add Health Wave IV (n=11,657), weighted

	(1) RR (CI)
Male	0.95**
	(0.94 - 0.97)
Age	1.01*
	(1.00 - 1.01)
Completed education (ref=college/above)	
Less than high school	1.06**
	(1.02 - 1.10)
High school	1.05**
	(1.02 - 1.09)
Some college	1.03*
	(1.01 - 1.06)
Log(household income)	1.01
	(0.99 - 1.02)
Race/ethnicity (ref=white)	
Black	1.06**
	(1.04 - 1.08)
Hispanic	1.04**
	(1.02 - 1.07)
Asian	1.00
	(0.95 - 1.05)
Active infection past month	1.04
	(0.99 - 1.08)
BMI	1.00
	(1.00 - 1.00)
Parent's education (ref=college/above)	
Less than high school	0.99
	(0.95 - 1.02)
High school	1.01
	(0.99 - 1.04)
Some college	1.03*
	(1.00 - 1.06)
Constant	0.67**
	(0.55 - 0.80)

** p<0.01, * p<0.05

Notes: Robust confidence intervals in parentheses; models also control for "other" race.

Table 3. Ordered logistic regression of characteristics associated with Cohen Perceived Stress Scale, Add Health Wave IV, weighted

	Females (n=5683)			Males (n=4576)		
	(1) OR (CI)	(2) OR (CI)	(3) OR (CI)	(4) OR (CI)	(5) OR (CI)	(6) OR (CI)
Lifetime stressful life events		1.22**			1.18**	
		(1.16 - 1.28)			(1.13 - 1.24)	
12-month stressful life events			1.19**			1.23**
			(1.11 - 1.28)			(1.17 - 1.30)
Age	1.01	1.00	1.01	1.03	1.03	1.04
	(0.97 - 1.06)	(0.96 - 1.04)	(0.97 - 1.05)	(0.99 - 1.07)	(0.99 - 1.07)	(0.99 - 1.08)
Completed education (ref=college/above)						
Less than high school	2.38**	1.91**	2.27**	2.40**	1.80**	2.04**
	(1.73 - 3.26)	(1.42 - 2.57)	(1.65 - 3.11)	(1.75 - 3.28)	(1.29 - 2.50)	(1.49 - 2.78)
High school	1.74**	1.51**	1.66**	1.78**	1.56**	1.66**
	(1.43 - 2.12)	(1.23 - 1.86)	(1.36 - 2.04)	(1.38 - 2.30)	(1.20 - 2.04)	(1.28 - 2.15)
Some college	1.67**	1.48**	1.63**	1.38**	1.24*	1.31**
	(1.46 - 1.93)	(1.29 - 1.69)	(1.42 - 1.87)	(1.14 - 1.68)	(1.01 - 1.51)	(1.08 - 1.60)
Log(household income)	0.69**	0.75**	0.70**	0.64**	0.67**	0.65**
	(0.62 - 0.76)	(0.68 - 0.82)	(0.63 - 0.78)	(0.58 - 0.70)	(0.61 - 0.74)	(0.59 - 0.71)
Race/ethnicity (ref=white)						
Black	1.17	1.00	1.11	1.15	1.01	1.04
	(0.97 - 1.40)	(0.83 - 1.21)	(0.92 - 1.35)	(0.93 - 1.42)	(0.82 - 1.24)	(0.84 - 1.28)
Hispanic	0.98	0.93	0.95	1.23	1.23	1.21
	(0.74 - 1.30)	(0.72 - 1.21)	(0.71 - 1.25)	(0.96 - 1.58)	(0.96 - 1.57)	(0.95 - 1.56)
Asian	1.41*	1.44*	1.39	2.13**	2.23**	2.23**
	(1.01 - 1.97)	(1.05 - 1.97)	(1.00 - 1.94)	(1.46 - 3.11)	(1.52 - 3.27)	(1.53 - 3.24)
Active infection past month	1.17	1.15	1.15	1.18	1.14	1.15
	(0.84 - 1.63)	(0.82 - 1.62)	(0.82 - 1.60)	(0.75 - 1.85)	(0.71 - 1.82)	(0.72 - 1.84)
BMI	1.00	1.00	1.00	0.99	0.99	0.99
	(0.99 - 1.01)	(0.99 - 1.01)	(0.98 - 1.01)	(0.97 - 1.00)	(0.98 - 1.00)	(0.98 - 1.00)
Parent's education (ref=college/above)						
Less than high school	1.00	0.96	1.00	1.02	0.94	0.98
	(0.80 - 1.27)	(0.76 - 1.21)	(0.79 - 1.25)	(0.79 - 1.31)	(0.73 - 1.22)	(0.75 - 1.27)
High school	1.08	1.03	1.07	1.08	1.05	1.08
	(0.91 - 1.28)	(0.87 - 1.22)	(0.90 - 1.26)	(0.91 - 1.27)	(0.89 - 1.24)	(0.92 - 1.27)
Some college	1.16	1.12	1.16	1.18	1.16	1.16
	(0.96 - 1.40)	(0.93 - 1.36)	(0.96 - 1.40)	(0.95 - 1.47)	(0.93 - 1.44)	(0.93 - 1.44)
Cutpoint 1 (SE)	-3.98	-2.80	-3.77	-4.23	-3.25	-3.85
	(0.77)	(0.76)	(0.77)	(0.76)	(0.77)	(0.75)
Cutpoint 2 (SE)	-2.44	-1.22	-2.22	-2.55	-1.54	-2.14
	(0.77)	(0.76)	(0.77)	(0.76)	(0.77)	(0.75)
F-statistic	14.96	17.66	19.14	17.25	19.29	19.32

** p<0.01, * p<0.05

Notes: Robust confidence intervals in parentheses; models also control for "other" race.

Table 4. Logistic regression of characteristics associated with highest quartile of lifetime stressful life events, Add Health Wave IV, weighted

	Females (n=5683)			Males (n=4576)		
	(1) OR (CI)	(2) OR (CI)	(3) OR (CI)	(4) OR (CI)	(5) OR (CI)	(6) OR (CI)
Cohen Perceived Stress Scale (ref=low)						
Medium		1.73**	1.72**		1.75**	1.76**
		(1.35 - 2.21)	(1.34 - 2.20)		(1.31 - 2.34)	(1.31 - 2.36)
High		2.33**	2.33**		2.64**	2.64**
		(1.77 - 3.07)	(1.76 - 3.08)		(1.90 - 3.66)	(1.90 - 3.68)
Age	1.04	1.05	1.05	1.02	1.03	1.03
	(0.98 - 1.11)	(0.99 - 1.12)	(0.99 - 1.12)	(0.96 - 1.10)	(0.96 - 1.10)	(0.96 - 1.10)
Completed education (ref=college/above)						
Less than high school	9.70**	4.78**	4.31**	10.26**	7.00**	6.28**
	(6.74 - 13.98)	(3.19 - 7.17)	(2.73 - 6.80)	(6.97 - 15.10)	(4.69 - 10.44)	(4.19 - 9.41)
High school	6.06**	4.04**	3.75**	3.53**	2.69**	2.51**
	(4.30 - 8.55)	(2.79 - 5.86)	(2.52 - 5.57)	(2.38 - 5.24)	(1.77 - 4.08)	(1.64 - 3.84)
Some college	4.43**	3.39**	3.22**	2.85**	2.48**	2.42**
	(3.32 - 5.91)	(2.53 - 4.54)	(2.37 - 4.38)	(2.07 - 3.92)	(1.76 - 3.48)	(1.71 - 3.40)
Log(household income)		0.65**	0.65**		0.74**	0.74**
		(0.57 - 0.73)	(0.58 - 0.73)		(0.66 - 0.82)	(0.66 - 0.83)
Race/ethnicity (ref=white)						
Black	3.12**	2.42**	2.40**	1.89**	1.71**	1.69**
	(2.47 - 3.94)	(1.87 - 3.14)	(1.83 - 3.13)	(1.39 - 2.58)	(1.26 - 2.32)	(1.25 - 2.30)
Hispanic	1.19	1.25	1.19	1.04	1.06	0.97
	(0.81 - 1.74)	(0.87 - 1.81)	(0.82 - 1.72)	(0.74 - 1.47)	(0.76 - 1.48)	(0.68 - 1.39)
Asian	0.47	0.45*	0.45*	0.46*	0.48	0.47
	(0.22 - 1.01)	(0.22 - 0.94)	(0.21 - 0.94)	(0.22 - 0.96)	(0.22 - 1.03)	(0.22 - 1.01)
Active infection past month	1.39	1.36	1.38	1.05	1.00	1.00
	(0.83 - 2.33)	(0.81 - 2.29)	(0.82 - 2.30)	(0.59 - 1.87)	(0.57 - 1.74)	(0.57 - 1.76)
BMI	1.00	1.00	1.00	0.98*	0.98	0.98
	(0.99 - 1.01)	(0.98 - 1.01)	(0.98 - 1.01)	(0.96 - 1.00)	(0.96 - 1.00)	(0.96 - 1.00)
Parent's education (ref=college/above)						
Less than high school			1.34			1.45*
			(0.95 - 1.87)			(1.01 - 2.07)
High school			1.12			1.03
			(0.87 - 1.45)			(0.76 - 1.40)
Some college			1.15			1.08
			(0.85 - 1.55)			(0.76 - 1.54)
F-statistic	27.5	34.97	28.94	17.17	16.31	12.79

** p<0.01, * p<0.05

Notes: Robust confidence intervals in parentheses; models also control for "other" race.

Table 5. Logistic regression of highest quartile of Epstein-Barr Virus antibodies on lifetime stressful life events, Add Health Wave IV, weighted

	Females (n=5683)		Males (n=4576)	
	(1)	(2)	(3)	(4)
	OR (CI)	OR (CI)	OR (CI)	OR (CI)
Lifetime stressful life events		1.06*		1.00
		(1.01 - 1.12)		(0.94 - 1.06)
Cohen Perceived Stress Scale (ref=low)				
Medium		0.98		1.03
		(0.80 - 1.20)		(0.81 - 1.32)
High		0.90		0.91
		(0.71 - 1.14)		(0.69 - 1.21)
Age	1.03	1.03	1.00	1.00
	(0.98 - 1.08)	(0.98 - 1.07)	(0.95 - 1.05)	(0.95 - 1.05)
Completed education (ref=college/above)				
Less than high school	0.73	0.69*	1.07	1.09
	(0.51 - 1.05)	(0.48 - 1.00)	(0.68 - 1.70)	(0.68 - 1.75)
High school	1.03	1.00	1.06	1.07
	(0.77 - 1.38)	(0.75 - 1.33)	(0.74 - 1.51)	(0.74 - 1.53)
Some college	1.05	1.01	1.24	1.24
	(0.86 - 1.28)	(0.82 - 1.25)	(0.96 - 1.60)	(0.96 - 1.61)
Log(household income)	0.97	0.98	1.02	1.01
	(0.86 - 1.09)	(0.87 - 1.11)	(0.88 - 1.18)	(0.87 - 1.17)
Race/ethnicity (ref=white)				
Black	1.53**	1.46**	1.71**	1.72**
	(1.26 - 1.85)	(1.20 - 1.77)	(1.34 - 2.19)	(1.36 - 2.19)
Hispanic	1.56**	1.54**	0.95	0.94
	(1.18 - 2.05)	(1.17 - 2.03)	(0.65 - 1.37)	(0.65 - 1.37)
Asian	1.20	1.22	0.70	0.70
	(0.81 - 1.79)	(0.83 - 1.81)	(0.43 - 1.13)	(0.43 - 1.14)
Active infection past month	1.34	1.33	0.55	0.56
	(0.94 - 1.91)	(0.93 - 1.92)	(0.28 - 1.08)	(0.28 - 1.09)
BMI	1.03**	1.03**	1.01	1.01
	(1.01 - 1.04)	(1.01 - 1.04)	(0.99 - 1.03)	(0.99 - 1.03)
Parent's education (ref=college/above)				
Less than high school	1.09	1.07	1.04	1.04
	(0.81 - 1.46)	(0.79 - 1.43)	(0.70 - 1.54)	(0.70 - 1.55)
High school	1.13	1.12	1.18	1.18
	(0.90 - 1.43)	(0.89 - 1.41)	(0.91 - 1.54)	(0.91 - 1.54)
Some college	1.11	1.11	1.29	1.30
	(0.84 - 1.47)	(0.84 - 1.46)	(0.95 - 1.77)	(0.95 - 1.77)
F-statistic				

** p<0.01, * p<0.05

Notes: Robust confidence intervals in parentheses; models also control for "other" race.

Table 6. Logistic regression of highest quartile of Epstein-Barr Virus antibodies on 12-month stressful life events, Add Health Wave IV, weighted

	Females (n=5683)		Males (n=4576)	
	(1)	(2)	(3)	(4)
	OR (CI)	OR (CI)	OR (CI)	OR (CI)
Stressful life events (12 months)		1.08*		1.04
		(1.00 - 1.17)		(0.97 - 1.11)
Cohen Perceived Stress Scale (ref=low)				
Medium		0.98		1.03
		(0.80 - 1.21)		(0.80 - 1.31)
High		0.92		0.89
		(0.73 - 1.16)		(0.68 - 1.18)
Age	1.03	1.03	1.00	1.00
	(0.98 - 1.08)	(0.98 - 1.08)	(0.95 - 1.05)	(0.95 - 1.05)
Completed education (ref=college/above)			1.07	1.06
Less than high school	0.73	0.72	(0.68 - 1.70)	(0.66 - 1.69)
	(0.51 - 1.05)	(0.51 - 1.03)		
High school	1.03	1.02	1.06	1.06
	(0.77 - 1.38)	(0.77 - 1.36)	(0.74 - 1.51)	(0.74 - 1.52)
Some college	1.05	1.04	1.24	1.23
	(0.86 - 1.28)	(0.85 - 1.28)	(0.96 - 1.60)	(0.95 - 1.59)
Log(household income)	0.97	0.97	1.02	1.01
	(0.86 - 1.09)	(0.86 - 1.09)	(0.88 - 1.18)	(0.88 - 1.17)
Race/ethnicity (ref=white)				
Black	1.53**	1.50**	1.71**	1.69**
	(1.26 - 1.85)	(1.24 - 1.82)	(1.34 - 2.19)	(1.33 - 2.15)
Hispanic	1.56**	1.54**	0.95	0.94
	(1.18 - 2.05)	(1.16 - 2.03)	(0.65 - 1.37)	(0.65 - 1.37)
Asian	1.20	1.20	0.70	0.71
	(0.81 - 1.79)	(0.81 - 1.78)	(0.43 - 1.13)	(0.44 - 1.14)
Active infection past month	1.34	1.34	0.55	0.55
	(0.94 - 1.91)	(0.93 - 1.91)	(0.28 - 1.08)	(0.28 - 1.09)
BMI	1.03**	1.03**	1.01	1.01
	(1.01 - 1.04)	(1.01 - 1.04)	(0.99 - 1.03)	(0.99 - 1.03)
Parent's education (ref=college/above)	1.09	1.08		
Less than high school	(0.81 - 1.46)	(0.80 - 1.45)	1.04	1.03
			(0.70 - 1.54)	(0.69 - 1.54)
High school	1.13	1.13	1.18	1.18
	(0.90 - 1.43)	(0.90 - 1.43)	(0.91 - 1.54)	(0.91 - 1.54)
Some college	1.11	1.11	1.29	1.29
	(0.84 - 1.47)	(0.84 - 1.47)	(0.95 - 1.77)	(0.95 - 1.77)
F-statistic				

** p<0.01, * p<0.05

Notes: Robust confidence intervals in parentheses; models also control for "other" race.