

Culture Change and Stress in Western Samoan Youth: Methodological Issues in the Cross-Cultural Study of Stress and Immune Function[†]

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ABSTRACT This study was designed to pursue three objectives: 1) investigate the impact of culture change on children and adolescents in Western Samoa; 2) introduce a cross-cultural perspective to studies of psychosocial stress and immune function; and 3) evaluate the utility of minimally invasive methods for assessing immune function. Seven hundred sixty individuals between the ages of 4 and 20 years were recruited from three distinct geographic regions within Western Samoa that differ in degree of westernization. Finger prick samples of whole blood were collected from each individual and analyzed for antibodies against the Epstein-Barr virus (EBV; an indirect marker of cell-mediated immune function) and C-reactive protein (a nonspecific marker of current infection). After controlling for age, sex, and current infection, EBV antibody levels were significantly elevated in urban Apia and rural Upolu, indicating lower levels of cell-mediated immune function. The results suggest a higher degree of psychosocial stress in these regions, possibly due to exposure to westernizing influences. *Am. J. Hum. Biol.* 12:792–802, 2000. © 2000 Wiley-Liss, Inc.

Culture change, stress, and health are topics of frequent consideration by human biologists and biological anthropologists. Several studies have documented a range of adverse health outcomes associated with the processes of westernization and urbanization, as individuals are forced to adapt to novel sociocultural and ecological environments (Brown, 1982; Dressler, 1982; Patrick et al., 1983; Jenner et al., 1987; Dressler, 1991; Wessen et al., 1992). The majority of this research has been conducted among adults, and only a handful of studies have considered culture change as a source of psychosocial stress for children and adolescents.

Outside of anthropology, the relationships among psychosocial experience, illness, and human immune function have been topics of rigorous investigation for some time. The growing subfield of psychoneuroimmunology examines the extensive neural and endocrine connections that interdigitate with the immune system and demonstrates that psychosocial processes

are potentially important modulators of immune function (Ader et al., 1991; Herbert and Cohen, 1993; Glaser and Kiecolt-Glaser, 1994). However, this research has been conducted almost exclusively on homogenous, western middle class samples—often college students or clinic-based referrals—and it typically employs laboratory challenges or negative life events as stressors. With the exception of recent work in Dominica (Flinn and England, 1997), psychoneuroimmunology has yet to consider

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the relationships between stress and immune function in cross-cultural contexts.

In an attempt to bring these perspectives together, a study was designed to address three objectives: 1) investigate the impact of culture change on children and adolescents to complement the current emphasis on adults; 2) introduce a cross-cultural perspective to psychoneuroimmunology; and 3) evaluate the utility of new "field-friendly" methods for assessing stress and immune function.

RESEARCH CONTEXT: WESTERN SAMOA

Human biology research in the islands of Polynesia has contributed greatly to current knowledge of the relationships among culture change, stress, and health (McGarvey and Baker, 1979; Baker et al., 1986; James et al., 1987; Pearson et al., 1993; Bindon et al., 1997). Following this tradition, this study was conducted in Western Samoa, a sovereign nation comprised of a chain of islands 14 degrees south of the equator in the South Pacific.

Western Samoa can be divided into three primary geographic areas: Savaii, rural Upolu, and Apia—regions that differ in the degree of western influence. Savaii is the largest island at 660 miles² and is home to approximately 45,000 people in 100 villages (Department of Statistics, 1991). Electricity has only recently become available, and most villagers engage in subsistence cultivation of family-owned lands with some limited cash-cropping. Due to their relative isolation, families on Savaii embody what Samoans recognize as the most traditional forms of Samoan culture practiced today.

The remainder of Western Samoa's 160,000 people live on Upolu, where a good natural harbor, abundant fresh water, and fertile soil have contributed to population growth and development. Approximately 34,000 people live in the urban area of Apia, where economic development has created extensive commercial activity and opportunities for wage labor and education as well as demand for retail stores, movie theaters, discos, and restaurants. Outside of Apia, people on Upolu live in rural villages with easy access to the urban core of Apia through regular bus service and high-quality roads. Compared with Apia and Savaii, rural Upolu represents an economic and cultural transition zone (O'Meara, 1990).

On the basis of this gradient of development from rural Savaii to rural Upolu and to urban Apia, region was used as a proxy for degree of exposure to, and engagement in, nontraditional, western ways of life. Regional differences in Epstein-Barr virus (EBV) antibody level and C-reactive protein (CRP) were investigated to address the hypothesis that westernization is associated with physiological stress within Western Samoa.

EBV ANTIBODIES: MARKER OF CELL-MEDIATED IMMUNE FUNCTION

The Epstein-Barr virus is a ubiquitous herpesvirus. By 18 years of age, 25–50% of adolescents in industrialized nations have become infected, while 80–90% of adults test positive by the age of 40 (Jones and Straus, 1987). In developing countries such as Western Samoa, infection rates approach 100% during the first 5 years of life. About 40% of primary infections in adolescence and adulthood result in acute infectious mononucleosis, while most individuals remain clinically asymptomatic (Henle and Henle, 1982). Once infected, individuals harbor the virus for life in infected cells.

Adequate cell-mediated immune function is critical for maintaining the virus in a latent state: immunosuppression allows EBV to reactivate and release viral antigens into circulation, to which a humoral antibody response may emerge (Glaser et al., 1991). As a result, levels of antibodies against EBV antigens provide an indirect measure of cell-mediated immune function, analogous to an *in vivo* "bioassay" of immunocompetence (Fig. 1). Like memory responses to other previously encountered antigens, EBV-specific antibody levels can be expected to rise 2–7 days after viral antigen re-exposure (Kuby, 1994). As such, the duration of time elapsing between stressor and EBV antibody response is on the order of days, and EBV antibody levels are not subject to short-term fluctuation.

The utility of the EBV model has been demonstrated in a number of studies of stress-induced immunosuppression. Stress associated with medical school exams has been linked to increases in EBV antibody levels, and concurrent reductions in EBV-specific memory T cell proliferation and cytotoxic T cell killing of infected cells (Glaser et al., 1987, 1993). Similar results have been reported for individuals involved in a poor-

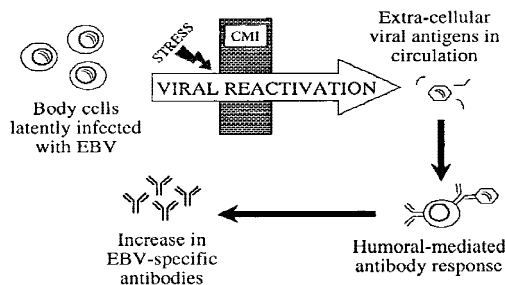


Fig. 1. Relationship between stress, cell-mediated immunity (CMI), and EBV antibody level.

quality marriage (Kiecolt-Glaser et al., 1987a, 1988) and for those enduring the chronic stress associated with caring for a family member with Alzheimer's disease (Kiecolt-Glaser et al., 1987b). Additionally, loneliness, defensiveness, and anxiety have all been positively associated with EBV antibody levels (Glaser et al., 1985; Esterling et al., 1993). Conversely, stress management interventions and disclosure of previously repressed trauma have been associated with decreases in EBV antibody levels (Esterling et al., 1992; Lutgendorf et al., 1994). These studies validate the EBV model as an indirect measure of stress-induced cell-mediated immune suppression such that higher stress burdens are reflected in higher levels of EBV antibodies.

METHODS

Data collection protocol

Participants were recruited from three villages on Savaii, six villages in rural Upolu, and five urban neighborhoods in Apia. Overall, 760 individuals between the ages of 4 and 20 years participated, with comparable age and sex distributions in each of the three regions (Table 1). The study was conducted under conditions of informed consent, as approved by the Emory University Human Investigations Committee and the Western Samoa Health Research Council.

Dried spots of whole blood were collected from each individual for laboratory analysis. A sterile disposable lancet was applied to the participant's finger, and 2–5 drops of blood were placed directly on standardized filter paper commonly used for neonatal screening (#903 Schleicher and Schull, Keene, NH). This relatively non-invasive blood collection protocol minimizes pain and inconvenience to the participants and facili-

tates the collection of large numbers of blood samples despite the constraints of field conditions. After collection, samples were covered and allowed to dry overnight. They were then refrigerated prior to shipment to the Laboratory for Comparative Human Biology at Emory University, where they were frozen at -23°C until analysis. Samples were stored at room temperature for a total of less than 10 days, within the limits necessary to maintain sample integrity (McDade et al., 1997).

Following blood sample collection, standard anthropometric measures were taken according to procedures described by Lohman et al. (1988) using a Leicester portable height measurer, a Soehnle digital scale, and Holtain skinfold calipers (CMS Weighing Equipment Ltd., London). Observable symptoms of respiratory disease were recorded at this time. In addition, demographic and psychosocial information was collected during interviews with individuals 10 years and older. The participants were asked about their housing style and ownership of western goods, their travel experience, and the occupation of their parents.

EBV antibody method

Epstein-Barr virus antibodies were measured in whole blood spots by enzyme-linked immunosorbent assay (ELISA). Previous work has shown that dried blood spots are a convenient and accurate medium for measuring specific antibodies (Farzadegan et al., 1987; Stevens et al., 1992) as well as hormones such as cortisol, testosterone, estradiol, and gonadotropins (Worthman and Stallings, 1994). This study is the first field application of a recently developed blood spot EBV antibody method (McDade et al., 1997; in press).

The method is an adaptation of a commercially available kit for measuring EBV viral capsid antigen (VCA) IgG antibodies in serum (DiaSorin Corporation, Stillwater, MN, product no. 7590). The assay measures antibodies against the p18 peptide, a VCA-specific marker protein containing immunodominant epitopes of the viral capsid antigen complex. Discs of whole blood are eluted overnight, and the eluate is added to microtiter wells. Antigen-antibody complexes form between EBV-VCA IgG antibodies present in the sample and synthetic peptide p18 bound to the surface of the

TABLE 1. Age and sex distribution of the sample by region

Age (years)	Apia			Upolu			Savaii			Total by age
	Female	Male	Total	Female	Male	Total	Female	Male	Total	
4-6	26	29	55	28	27	55	28	27	55	165
7-9	30	30	60	36	32	68	26	24	50	178
10-12	28	26	54	26	20	46	34	29	63	163
13-15	29	18	47	34	18	52	17	12	29	128
16-20	23	18	41	24	25	49	19	17	36	126
	136	121	257	148	122	270	124	109	233	
	Total females: 413			Total males: 357			Total sample: 760			

wells. Horseradish peroxidase-labeled anti-human IgG in the presence of a chromogen substrate reacts with the antigen-antibody complex resulting in color development. The concentration of EBV-VCA IgG antibodies is directly related to the absorbance of the solution measured at 450 nm. Control and sample values are interpolated from a standard curve using a linear data reduction protocol, and reported in ELISA units (Soft-Max Pro, Molecular Devices, Sunnyvale, CA).

The accurate determination of previous exposure to EBV, and subsequent seroconversion, is critical since the model linking stress to suppressed cell-mediated immune function and increased EBV antibody level does not apply to seronegative individuals. Analyses must therefore focus exclusively on seropositive individuals. Previous comparison of matched plasma and blood spot samples for seronegative and seropositive individuals established a blood spot seropositivity cutoff value of 20 ELISA units (McDade et al., in press). Individuals with EBV antibody levels below this value were assumed to be seronegative for EBV and were excluded from analysis.

Potential confounders

Studies of psychosocial stress and immune function conducted outside of the western industrial cultural context are challenged by the need to control for a wide range of ecological stressors that can confound stress-immune function relationships. Whereas psychoneuroimmunologists study individuals from well-nourished populations at low risk of infectious disease, this is not the case for many populations of interest to human biology, where seasonal food shortages and endemic disease are frequently unfortunate realities. Undernutrition and current infection can both independently suppress immune function, and must

be controlled for in order to investigate the effects of psychosocial stress (Kiecolt-Glaser and Glaser, 1988).

Nutritional Status. Anthropometric dimensions were used to evaluate the nutritional status of the sample and to screen for stunting and wasting. Standardized scores for height-for-age (HAZ), weight-for-age (WAZ), and weight-for-height (WHZ) were obtained using ANTHRO software (Version 1.01, CDC, 1990). The *z*-scores were calculated for height and weight values using the CDC/WHO International Growth Reference based on data from the National Center for Health Statistics (NCHS). Height-for-age and weight-for-age were calculated for individuals under 18 years of age. Weight-for-height was calculated for boys ≤ 11 years and < 145 cm in height, and for girls < 10 years and < 137 cm. Body mass index (BMI) was also calculated for all participants, and triceps and subscapular skinfolds were recorded.

Current Infection. Two measures of current infection were evaluated to identify individuals who were sick at the time of the survey: observable symptoms of respiratory infection and blood levels of CRP. The presence of rhinorrhea and/or cough was taken as evidence of respiratory infection, while elevated CRP (≥ 5 mg/l) was used as a non-specific marker of infection (see below).

C-reactive protein. C-reactive protein is a central component of the acute phase response, a nonspecific, systemic response to infection or injury that provides the body's first line of defense against pathogens. C-reactive protein is the prototypical acute phase protein: trace amounts are normally detectable in circulation, but concentrations increase by a factor of 100-1,000 during the 24-72 hr following an injury or infectious challenge as a result of increased production by liver hepatocytes (Fleck, 1989; Baumann and Gauldie, 1994). Levels remain elevated

during the course of infection, and the half-life of circulating CRP is approximately 18 hr (Gillespie et al., 1991). Detectable levels of CRP are present for about a week following insult (Mortensen, 1994). CRP has important effector functions in activating phagocytes and complement, and opsonizing bacteria, fungi, and parasites. Cytokines (IL-6 in particular) are the major mediators of CRP production (Ballou and Kushner, 1992). C-reactive protein has been shown to increase in response to a wide range of viral, bacterial, and parasitic agents, making it a potentially useful marker of pathogen exposure and infection status.

Blood spot CRP

An ELISA method was developed for the quantification of CRP in whole-blood spots (McDade, 1999; McDade et al., submitted). Blood spot samples are eluted overnight and incubated with rabbit anti-human CRP (Dako Corporation, Carpinteria, CA, product no. A073) previously bound to the surface of microtiter wells. Peroxidase-conjugated rabbit anti-human CRP (Dako Corporation, product no. P227) binds to the CRP-antibody complexes in each well, and color forms with the addition of chromogenic substrate. The absorbance of the solution is read at 490 nm in a spectrophotometric plate reader (SpectraMax 250, Molecular Devices). The quantity of CRP in each sample is determined based on comparison with calibrator values (Dako Corporation, product no. X0923) using a spline-fit standard curve. During assay validation, the correlation between 72 matched plasma and blood spot samples from a pool of normal individuals was found to be linear and high (Pearson $r = 0.98$) (McDade 1999).

Levels of plasma CRP above 5–10 mg/l have been associated with infection and inflammatory processes in a number of studies (Gillespie et al., 1991; Ballou and Kushner, 1992; Filteau et al., 1995). Since this study analyzes CRP in whole-blood spots, not plasma, previously reported cutoff points are not directly applicable. In order to determine an appropriate cutoff, 47 matched plasma and blood spot samples with low CRP levels were analyzed concurrently. According to the equation relating these samples, i.e., plasma = 1.38(blood spot) – 0.97, a plasma value of 5 mg/l corre-

TABLE 2. Markers of lifestyle in Apia, Upolu, and Savaii

	Apia	Upolu	Savaii
Television			
Yes	76.6	57.1	53.6 ^a
No	23.4	42.9	46.6
Car			
Yes	37.8	33.0	21.6 ^b
No	62.2	67.0	78.4
Travel outside W. Samoa			
Yes	34.1	15.0	7.8 ^a
No	65.9	85.0	92.2
Type of house			
European	57.6	40.9	40.5 ^b
Traditional	42.4	59.1	59.5
Father occupation			
Professional	26.7	6.3	2.4 ^a
Unskilled labor	41.0	3.5	3.2
Planter	32.4	90.1	94.5
Mother occupation			
Professional	8.1	0.0	0.9 ^b
Unskilled labor	13.0	1.4	0.0
Housewife	78.9	98.6	99.2

^a $P < 0.01$ for χ -square statistic.

^b $P < 0.05$.

sponds to a blood spot value of 4.6 mg/l. For the purposes of this study, a blood spot value of 5 mg/l, corresponding to a plasma value to 5.9 mg/l, was used to identify individuals with elevated CRP.

Statistical analysis

Analyses were conducted using Statistical Analysis Software (SAS Institute, Release 6.12, Cary, NC). Prior to analyses, EBV antibody levels were log-transformed to normalize the distribution. Age was considered as an ordinal variable, broken down into the following groups: 4–6, 7–9, 10–12, 13–15, and 16–20 years, inclusive. The criterion for statistical significance was set to $\alpha = 0.05$.

RESULTS

Regional differences in lifestyle

Consistent regional differences in multiple markers of lifestyle validate region as a proxy for westernization in Western Samoa (Table 2). In Apia, individuals over 10 years reported a significantly more western orientation than residents of rural Upolu and Savaii. The difference in experience between individuals in Upolu and Savaii is less striking, although rural Upolu appears to be less traditional than Savaii, likely as result of its proximity to Apia.

TABLE 3. Anthropometric dimensions by region and sex (mean (SD))*

	Apia		Upolu		Savaii	
	Female	Male	Female	Male	Female	Male
HAZ	0.11 (0.99)	-0.21 (1.04)	0.10 (1.03)	0.03 (1.13)	-0.07 (1.02)	-0.03 (1.23)
WAZ	0.32 (0.92)	0.08 (1.12)	0.36 (0.99)	0.22 (1.01)	0.19 (0.99)	0.08 (1.02)
WHZ	0.16 (0.70)	0.26 (0.93)	0.25 (0.74)	0.30 (0.69)	0.19 (0.87)	0.16 (0.71)
Triceps (mm)	12.4 (5.8)	9.2 (4.0)	12.6 (5.6)	8.7 (3.8)	12.1 (5.0)	8.2 (2.0)
Subscap (mm)	10.4 (4.6)	8.0 (3.7)	11.1 (5.9)	8.0 (4.4)	11.2 (5.4)	7.3 (2.4)

*Height-for-age (HAZ), weight-for-age (WAZ), and weight-for-height (WHZ) z-scores are based on NCHS reference values.

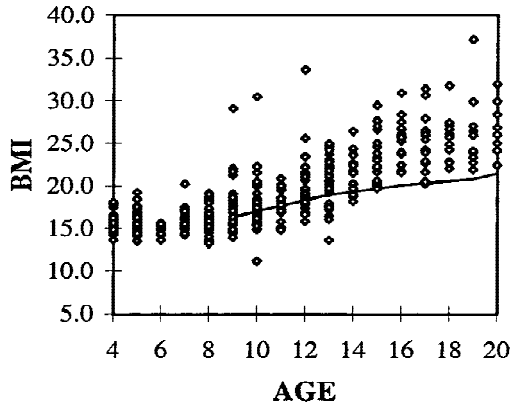


Fig. 2. Body mass index by age: girls. The NHANES reference median is indicated by the superimposed line.

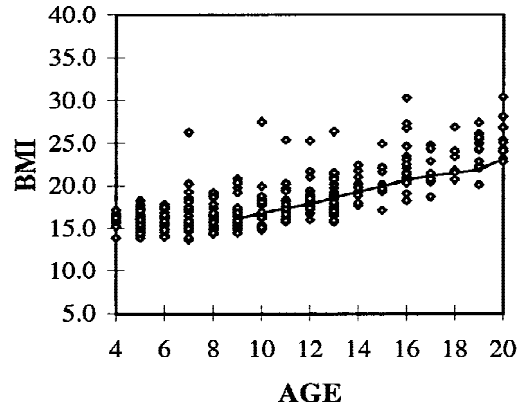


Fig. 3. Body mass index by age: boys. The NHANES reference median is indicated by the superimposed line.

Potential confounders

Mean z-scores of anthropometric measures, as well as skinfold measures, are presented in Table 3. No significant differences across region were found for any of these measures. Mean z-scores hover around zero for both males and females, and BMI increases with age relative to the NHANES reference median (Figs. 2 and 3). No children had WHZ scores <-2 standard deviations from the reference median, only two children had WAZ scores <-2, and 20 children had HAZ values <-2. A larger number of children exceeded +2 standard deviations: 27 on HAZ, 30 on WAZ, and 5 on WHZ.

The results indicate that undernutrition is not a significant problem in this sample. There is no consistent pattern of difference in anthropometric dimensions across region that indicates significant differences in nutritional status. Furthermore, none of these markers was found to be significantly related to EBV antibody level, leading to the conclusion that nutritional status is not likely to be a significant confounder in this well-nourished population.

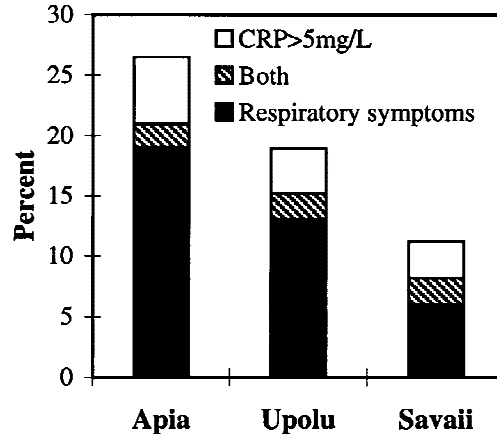


Fig. 4. Regional differences in the prevalence of current infection, as defined by the presence of respiratory symptoms and/or elevated CRP.

This was not the case for current infection. Overall, 14.9% of individuals had observable symptoms of respiratory infection at the time of sampling (Fig. 4). A maximum likelihood logistic regression model including age, sex, and region was used to explore

the predictors of infection. For the entire sample, individuals in Apia were more than three times as likely to have respiratory symptoms than individuals in Savaii (OR = 3.34, 95% CI = 1.90, 5.87). Individuals in rural Upolu were twice as likely to be sick as those in Savaii (OR = 2.20, CI = 1.23, 3.94). Individuals in Apia appear to be more likely to be sick than individuals in Upolu, although this relationship falls short of significance (OR = 1.52, CI = 0.96, 2.39). Sex was not associated with the probability of symptoms (males compared to females: OR = 0.97, CI = 0.65, 1.47), while younger children were more likely to be sick (older compared to younger: OR = 0.70, CI = 0.59, 0.82). Markers of nutritional status (BMI, HAZ, WAZ, WHZ, tricep, and subscapular skinfold) were not significantly associated with respiratory symptoms.

In the entire sample, 47 (6.2%) individuals had CRP levels greater than or equal to 5 mg/l. Age approached significance (OR = 0.84, CI = 0.67, 1.04), while sex (OR = 1.09, CI = 0.60, 1.97) and region (relative to Savaii: Apia OR = 1.53, CI = 0.72, 3.22; Upolu OR = 1.19, CI = 0.55, 2.58) were not significantly related to the likelihood of CRP \geq 5 mg/L. Individuals with symptoms of respiratory infection were more than three times as likely to have high CRP (OR = 3.26, CI = 1.72, 6.18). Markers of nutritional status were not associated with the probability of CRP \geq 5 mg/L.

For the purposes of controlling for current infection, a variable combining the presence of respiratory symptoms and/or elevated CRP (\geq 5mg/L) was created. Overall, 19.0% of the sample had evidence of current infection according to this definition. There appears to be relatively good agreement between observations of respiratory symptoms and the presence of detectable levels of CRP. Of those individuals with observable respiratory symptoms, 14.2% had CRP \geq 5, compared to 4.8% of individuals without symptoms. Of those individuals with CRP \geq 5, 34.0% had observable symptoms, compared to 13.7% without elevated CRP. Respiratory symptoms and CRP are significantly related in the expected direction (χ -square = 14.4, P = 0.001). Despite the significant overlap, these results highlight the absence of a one-to-one relationship between CRP and respiratory symptoms, emphasizing the fact that there are many ailments other than respiratory disease that

elevate CRP, and there are causes of respiratory symptoms (e.g., allergy) that may not involve CRP.

In a logistic model, the probability of current infection was significantly related to region and age. Residents of Apia were three times more likely than residents of Savaii to have respiratory symptoms and/or elevated CRP (OR = 3.05, CI = 1.85, 5.04), while residents of rural Upolu were nearly twice as likely (OR = 1.96, CI = 1.17, 3.29). Residents of Apia were also more likely to have a current infection than individuals in rural Upolu (OR = 1.56, CI = 1.02, 2.37). The probability of current infection was higher in younger children (OR = 0.73, CI = 0.63, 0.84), while no gender differences were found (OR = 1.04, CI = 0.71, 1.51). With respect to EBV antibody level, individuals with evidence of current infection had slightly, but not significantly, elevated antibody levels (1.87 vs. 1.91 log ELISA units, Student's t -test, P = 0.15).

The results indicate significant differences in infectious disease risk that may confound regional comparisons of immune function. To minimize this possibility, individuals with evidence of current infection were removed from the sample prior to analysis. This is a conservative step that biases results toward the null, as individuals with current infection may be the same individuals who are suffering from the infectious consequences of stress-induced immunosuppression.

Regional differences in immune function

Levels of EBV antibodies ranged from 15.4 to 308.5 ELISA units, with a mean of 95.3 (SD = 65.8). Only 9 of the 760 participants had EBV antibody values below 20 ELISA units, for a seropositivity rate of 98.8%.

General linear models procedures (PROC GLM) were used to evaluate the effects of age, sex, region, and their interactions on log-transformed EBV antibody levels. No interaction terms approached significance (P > 0.25 in each case), and the final model including age, sex, and region is presented in Table 4. Both region and sex were significantly related to EBV antibody level. Females had slightly, but significantly, higher antibody levels than males (1.90 vs. 1.85 ELISA units). Post-hoc Scheffe pairwise comparisons indicate that EBV antibody levels were significantly higher in Apia and

TABLE 4. Linear model results investigating the effects of age, sex, and region on log-transformed EBV antibody levels

	df	MS	F	P
Model	4	0.559	6.32	0.0001
Sex	1	0.376	4.26	0.040
Age	1	0.119	1.35	0.25
Region	2	0.804	9.09	0.0001

rural Upolu than in Savaii (Fig. 5). There was no significant difference between Apia and Upolu.

DISCUSSION

Among children and adolescents in Western Samoa, EBV antibody levels were significantly higher in Apia and rural Upolu than in Savaii, indicating lower levels of cell-mediated immune function. These results suggest a higher degree of psychosocial stress in Apia and rural Upolu than in Savaii, possibly due to exposure to westernizing influences. Individuals in Apia are surrounded by the diversity and demands of an expanding urban environment. Although individuals in rural Upolu live in villages, Apia is only 1–2 hr away by bus or car, and people take advantage of its proximity for employment, education, and commerce.

The regional difference reported here is consistent with previous ecological studies in the South Pacific linking westernization to physiological markers of stress. In a study of 150 young Samoan men and women, catecholamine levels were highest in urban Honolulu, lowest in rural Western Samoa, and intermediate in American Samoa (Pearson et al., 1990, 1993). Within Western Samoa, blood pressure and catecholamine levels were found to be higher in Apia than in rural villages (Zimmet et al., 1980; James et al., 1985; Pearson et al., 1993). Similarly, 5–7-year-old children in an urban village have been shown to have consistently higher catecholamine levels than children in a rural village (Sutter, 1980). In American Samoa, McGarvey and Baker (1979) found an association between blood pressure and distance from the urban harbor area, where residents of traditional rural villages had significantly lower blood pressure than residents of urban Pago Pago.

Previous work among Samoan adults has reported sex-differentiated responses to a number of stressors, although there is no consistent pattern to these results (McGarvey and Baker, 1979; Janes, 1990; Chin-

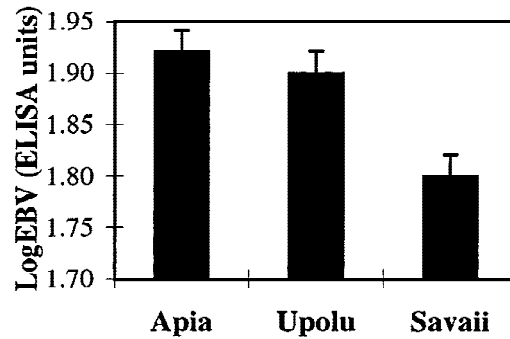


Fig. 5. EBV antibody level, by region (mean + SE).

Hong and McGarvey, 1996). In the results reported here, girls had slightly elevated EBV antibody levels compared to boys. Although this difference was small, it suggests that girls may experience more stress than boys in childhood and adolescence. However, the absence of a significant interaction between sex and region precludes the conclusion that westernization is having a differential impact on boys and girls across the regions within Western Samoa.

Alternatively, a biological or ecological factor could be responsible for the difference. However, there was no sex difference in any measure of nutritional status or infectious disease risk that could explain the slightly higher levels of EBV antibodies in females.

The frequency of various lifestyle markers varies for households in Apia, rural Upolu, and Savaii, demonstrating that region can be a useful indicator of exposure to non-traditional ways of living. However, the differences across region are small, suggesting that within-region variation in westernization experience may be more meaningful, and warning against the assumption that each region represents a homogenous and qualitatively distinct developmental context.

Furthermore, if exposure to nontraditional lifestyles is responsible for regional differences in psychosocial stress, then EBV antibody levels should be higher in urban Apia than in the rural villages of Upolu. This implies that the psychosocial effects of westernization are more complicated than indicated by simple regional comparisons, and suggests that although their EBV antibody levels are comparable, youth in Apia and rural Upolu may experience stress for

different reasons. For example, Apia may present challenges associated with managing a more western lifestyle, while rural Upolu may force individuals to confront contradictions between old and new ways of living.

Early work on culture change and health has suggested that social change and disorganization is a key source of stress, contributing to a range of adverse health outcomes (Scotch and Geiger; 1963; Henry and Cassel, 1969; Cassel, 1974). In particular, discordance between traditions and expectations set up during childhood socialization, and a rapidly changing cultural environment encountered in adulthood, was hypothesized to produce stressful ambiguity and conflict. Although these conclusions were based on research conducted among adults, the results of this study suggest that children and adolescents may also experience ambiguity and conflict associated with culture change, even though they are still undergoing the process of socialization. Future analysis of this dataset will explore these processes in more detail in an attempt to understand the proximate social dynamics associated with culture change and stress.

FUTURE DIRECTIONS

Despite the considerable efforts of psychoneuroimmunology in western contexts, the relationships between stress and immune function have been scarcely investigated cross-culturally. Human biology is uniquely positioned to explore these issues in populations around the world, and to document the range of variation in contextual and constitutional variables that define the social ecology of immune function. This study represents a concerted effort to introduce a cross-cultural and ecological perspective to psychoneuroimmunology, and to lay the foundation for future field-based studies of immunity.

Blood spot EBV antibody level appears to provide a new methodological tool for measuring stress to complement the hormonal and cardiovascular methods currently employed by human biologists. Samples are easy to collect and transport, and remain stable for weeks in the field. Epstein-Barr virus antibodies are not subject to difficulties associated with diurnal variation, pulsatile release, and acute context effects, thus facilitating their interpretation as a baseline marker of stress. This measure

also links mental and physical health, and illuminates the socioecological factors that constrain or facilitate adaptation and resistance to disease.

Methodological constraints pose a formidable barrier to field-based studies of stress and immune function, and have limited most psychoneuroimmunologists to clinic or laboratory-based studies of opportunistic western samples. The development of "field-friendly" blood spot methods for assessing immune function eases these constraints, and opens up the possibility of future studies in a range of populations and ecological contexts around the world. Blood spot assays for EBV antibodies and CRP provide a starting point, and future work should consider developing new field measures, including specific cytokines, thymic peptides, and antibody responses to vaccine challenge.

Research in Western Samoa represents a good first step in promoting cross-cultural studies of stress and immune function. Despite the fact that the cultural and ecological context of Western Samoa is dramatically different from that currently considered by psychoneuroimmunology, rates of infectious disease were low, and nutritional status was high. As such, this study could explore the immunosuppressive effects of a number of novel sociocultural stressors while controlling for the potentially confounding effects of infection and undernutrition.

Future work should address the following question: How do psychosocial stressors interface with ecological stressors in modulating immune function? To what extent do the stress-immune function relationships documented in western populations (and in Western Samoa) play out under conditions of malnutrition or high pathogen load? Although psychoneuroimmunology research has not considered this possibility, several studies suggest a number of vulnerability factors that increase one's physiological sensitivity to psychosocial stress (Boyce et al., 1977; Haggerty, 1980; Schleifer et al., 1986; Brosschaft et al., 1994; Uchino et al., 1996). It is possible that the burdens of infectious disease and malnutrition, as well as other ecological stressors, are significant vulnerability factors placing certain individuals—and populations—at increased risk of stress-induced immunosuppression. Integrative, field-based studies of stress and immune function can address this issue, and

complement current work by considering the realities of everyday life around the world where psychosocial and ecological stressors are inseparable.

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