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Behavioral and Perceived Stressor Effects on Urinary Catecholamine Excretion in Adult Samoans

Meredith R. Bergey¹, Matthew S. Steele², David A. Bereiter³, Satupaitea Viali⁴, and Stephen T. McGarvey⁵

¹International Health Institute, Brown University, Providence, RI 02912

²PATH, Seattle, WA 98107

³ Department of Diagnostic and Biological Sciences, University of Minnesota, Minneapolis, MN 55455

⁴Ministry of Health, Government of Samoa, Apia, Samoa

Abstract

Objectives—The effects of perceptions and behaviors related to culturally-patterned socioeconomic obligations on catecholamine excretion rates were studied in a cross-sectional sample of Samoan adults.

Methods—378 participants, ages 29–62 years, from 9 villages throughout Samoa, provided timed overnight urine specimens, and self-reported perceptions and behaviors associated with contributions to one's family, *aiga*, and chief, *matai*, and communal gift exchanges, *fa'alavelave*. Urinary norepinephrine and epinephrine excretion rates were measured by high performance liquid chromatography with electrochemical detection. Age (≤ 40 vs. > 40 years) and gender-specific regression models were estimated to detect associations with catecholamine excretion.

Results—Young women who contribute more to their *matai*, who consider *fa'alavelave* to be a financial strain, and who view their contribution to their *matai* to be 'just right', had significantly higher residence-adjusted norepinephrine excretion. Young women who contribute more to their *matai*, who consider *fa'alavelave* to be a financial strain, and who consider their contribution to their *aiga* not to be a burden, had higher epinephrine excretion. Older men who contribute more to their *aiga* and who perceive their contribution to their *aiga* to be 'just right' had increased residence-adjusted epinephrine excretion.

Conclusions—Individual-level perceptions and behaviors related to traditional socioeconomic obligations are a significant correlate of increased overnight catecholamine excretion rates. Higher excretion rates may be attributed to psychosocial stress arousal associated with a discordance between personal desires for upward social mobility, and family and community-based socioeconomic obligations. Changes in patterns of individual-level psychosocial stress arousal may contribute to cardiovascular disease risk in modernizing Samoans.

Keywords

Epinephrine; norepinephrine; Samoans; psychosocial stress

⁵Corresponding Author: Stephen T. McGarvey, PhD, MPH International Health Institute Box G – S121 Brown University Providence, RI 02912 Telephone: (401) 863-1354 Fax: (401) 863-1373 Stephen_McGarvey@brown.edu.

Introduction

There has been a marked increase in cardiovascular disease (CVD)-related morbidity and mortality in developing nations in recent decades (Kaufman et al., 1996; Murray and Lopez, 1996; Hodge et al., 1997; Caballero, 2001; Ezzati et al., 2005). While processes of development are often experienced heterogeneously, they frequently bring about alterations in social, cultural, economic, and psychological environments (Dressler, 1995; McGarvey, 1999). Emerging market economies tend to exhibit a decreased reliance on the natural environment for subsistence, an increase in wage labor opportunity and individuation, and increased reliance on imported goods, services, and technologies (Dressler, 1999). Changing lifestyles and the adoption of attitudes and behaviors that conflict with sociocultural norms and expectations, may produce unique patterns of psychosocial stress arousal by modifying individual, household, and community-level interactions (James et al., 1985; Dressler, 1990; Chin-Hong and McGarvey, 1996; McGarvey, 1999; Bitton et al., 2006). Incommensurate adaptation to new patterns of stress arousal may in turn contribute to CVD risk (Sapolsky, 1994; James and Brown, 1997; Merz et al., 2002).

Significant exposure to industrialized nations over the 20th century initiated processes of rapid economic development and social change in Samoa (Baker et al., 1986; James et al., 1987; Pearson et al., 1993; Newman et al., 1999). Such changes included urbanization; increased foreign trade; increased political, religious, economic, and social interactions with individuals from industrialized countries; and a shift from a predominantly communal, subsistence-based agrarian economy to a wage labor-based economy with increased private ownership of resources (Meleisea, 1987; O'Meara, 1995).

Germany controlled Samoa from 1899 until 1917 and supported private commercial plantations for cattle and various crops (Gage, 1986; Meleisea, 1987). New Zealand's post World War I administration actively promoted health care and education, set up marketing programs for cash crops, and encouraged the commercialization of agriculture and a shift from communal to individual land tenure (Gage, 1986; O'Meara, 1995). Rapid urbanization, economic expansion and emigration continued after Samoa gained its autonomy in 1962, with the capital city of Apia and surrounding villages on Upolu developing to a greater extent than the more rural villages on Upolu and Savai'i (James et al., 1985; Pearson et al., 1993; Western Samoa Department of Statistics, 1995).

The prevalence and incidence of CVD and its concomitant risk factors have increased with economic development in the Samoan Islands (McGarvey and Baker, 1979; Zimmet et al., 1980; Baker and Hanna, 1981; McGarvey et al., 1989; McGarvey et al., 1993; Hodge et al., 1994; Gershater and McGarvey, 1995; Galanis et al., 1999; Keighley et al., 2007). While much of this increased burden of disease has been attributed to changing activity levels and dietary patterns (McGarvey et al., 1989; Galanis et al., 1999; McGarvey, 1999; Keighley et al., 2006; DiBello et al., 2009), research suggests that changing patterns of psychosocial stress arousal also contribute to CVD risk in this population (James et al., 1985; McGarvey and Schendel, 1986; James et al., 1987; McGarvey, 1992; Steele and McGarvey, 1996; McGarvey, 1999; McDade, 2003; Roberts et al., 2004; Bitton et al., 2006; Ezeamama et al., 2006; Bergey et al., 2010). The adoption of non-traditional practices and values may influence stress arousal as new social roles are juxtaposed upon customary socioeconomic obligations (McGarvey, 1999).

Traditional social relationships in Samoa are based upon large kinship networks (*aiga*) that exist within a set of shared social and cultural norms, or *fa'aSamoa* (the Samoan way) (Hecht et al., 1986; O'Meara, 1990). The *aiga*, or extended family, is the foundation of Samoan society. Families are typically large, providing an important network of resources,

labor, and support. Samoan society is hierarchical and predominantly patriarchal. *Matai*, the *aiga* chiefs, govern the *aiga* at the local level. Chiefs are typically male and their title represents the highest social rank - a rank that symbolizes maturity and prestige, or *mamalu* (Pitt, 1970). Despite substantial emigration, the *aiga* and village remain important influences to those residing in other parts of Samoa or abroad, resulting in substantial migrant remittances, active involvement in social and political life, and feelings of connectedness (Ahlberg, 1995; Lilomaiava-Doktor, 2009; Macpherson and Macpherson, 2000; Macpherson and Macpherson, 2009, McGarvey and Seiden, 2010).

A central goal of *fa'aSamoa* is to increase the *aiga's* social, economic, and cultural prestige (Maiava, 2001). Socioeconomic obligations are integral to that process. Individuals are expected to contribute money, goods, or services to both their *aiga* and to their community. *Matai* coordinate the latter practice of public gift exchange, or *fa'alavelave* and make requests for resources that are used to mark important community events (e.g. conferral of a *matai* title, church openings, weddings, funerals, and cricket matches) (Shore, 1982; Cahn, 2008). Attendance at *fa'alavelave* is considered an important component of *tautua* (service) to one's *aiga* (Cahn, 2008) and participation can enhance an *aiga's* social prestige.

One's ability to contribute toward their *aiga*, *matai*, or to *fa'alavelave* also can shape an individual's social status and sense of self worth (James, 2000; Macpherson and Macpherson, 2000). Socioeconomic obligations may elicit stress if individual's lack sufficient resources or if obligations conflict with personal desires for upward social mobility. McDade (2003) examined culture change, immune function, and stress among Samoan adolescents and found an interaction between household socioeconomic status and the occurrence of *fa'alavelave* over the preceding year on an immunological correlate of chronic stress (EBV antibodies). Debts associated with traditional socioeconomic obligations may be significant sources of psychosocial stress.

Samoan men and women experience unique patterns of psychosocial stress arousal based upon their separate age and gender-specific roles in Samoan society (Hecht et al., 1986; Howard, 1986; O'Meara, 1990). Young men often migrate to urban areas in and around Apia seeking educational and occupational opportunity and they tend to engage in wage labor employment (e.g. cash cropping). The rising financial ability of young, urban males and concomitant rising monetary requests by family heads may lead to decreased material displays of wealth (Chin-Hong and McGarvey, 1996). Many young males are still obligated to donate a large proportion, if not all, of their income from wage labor to their *aiga* or *matai*. The *matai* often redistributes these financial resources in the form of an allowance back to males and others based on age and traditional status (O'Meara, 1990). Furthermore, young adult males are often invited to *fa'alavelave* ceremonies where they are obligated to contribute large sums of money if they are to enhance their own prestige within the *aiga* and village.

Utilizing the lifestyle incongruity (LI) model (Dressler, 1990; Dressler, 1991), Chin-Hong and McGarvey (1996) found age and adiposity-adjusted blood pressure (BP) was negatively associated with LI among young Samoan men. Financial demands from one's *aiga* and community may increase stress in young men who wish to achieve a specific material lifestyle based upon their economic resources. A conflict between socioeconomic obligations and one's material lifestyle, coupled with feelings of anger, may explain higher age and BMI-adjusted BP among young men whose occupational level exceeded their material lifestyle, and who reported frequent feelings of Samoan culture-specific anger (Bitton et al., 2006).

Though they are increasingly entering the work force, Samoan women typically participate in household chores, child rearing, and activities related to *fa'alavelave* (e.g. the preparation of food, fine mats, and other gifts). Bitton et al. (2006) observed an association between increased BP and anger suppression in young Samoan women whose educational rank surpassed their material lifestyle. This finding followed earlier work showing a relationship between anger suppression and BP in all young women from Samoa (Steele and McGarvey, 1997). Limited employment opportunities and traditional gender-specific obligations may prevent well-educated women from entering the workforce and contributing toward their own or their *aiga's* income. Gender-specific norms related to emotional suppression may increase BP in this cohort (Bitton et al., 2006).

Older members of an *aiga* may have less access to educational or occupational opportunities and thus fewer resources with which to support their own or their *aiga's* income. Such individuals may experience stress from discordance between their desire and their ability to contribute toward their *aiga's* social prestige. Excess material consumption, as a means of acquiring or advancing social prestige, may explain the increased BP Chin-Hong and McGarvey (1996) observed in older women whose occupation was not concomitant with their material lifestyle.

Increased biomarkers of stress have been associated with general cohort-specific residential exposure to socioeconomic development and non-traditional lifestyles in urban villages (James et al., 1985; James et al., 1987; Bergey et al., 2010). James et al. (1985, 1987) found that Samoan men who held less traditional occupations in Samoa's urban capital city of Apia had higher catecholamine excretion and higher BP than villagers with more neotraditional lifestyles. In a prior cross-sectional study, we identified the independent effects of peri-urban versus rural residence and caffeine consumption on catecholamine excretion rates in a sample of adults from Samoa (Bergey et al., 2010). The findings may be attributed to psychosocial stressors associated with general exposures to economic development that differ by age and gender, and that are not attributable to education or occupation. Analysis of more direct, personal attitudes and behaviors, related to potential psychosocial stressors associated with traditional socioeconomic obligations, may reveal the mechanisms underlying these previously observed group-level differences in stress arousal.

The current analysis explores the relationship between individual-level psychosocial stressors and norepinephrine (NE) and epinephrine (EPI) excretion. The rationale for using the catecholamines NE and EPI as biological indicators of stress has been illustrated in other Samoan populations (Martz et al., 1984; James et al., 1985; Hanna et al., 1986; James et al., 1987; James, 1989; Pearson et al., 1990; Pearson et al., 1993), in other Pacific populations (Brown, 1982; Jenner et al., 1987), and in various non-Pacific populations (Harrison, et al. 1981; Reynolds et al., 1981). Caffeine intake and cigarette consumption have known positive effects on catecholamine excretion (Kershbaum et al. 1963; Rall, 1990; Reynolds et al., 1981; Lane et al., 1990; Jarvis, 1993; James, 1997). They also have been associated with increased, sustained, and clearer cognition, improved memory, decreased fatigue, and increased mood (Lieberman et al., 1987; Smith et al., 1992; Smith et al., 1993; Smith et al., 1994; Warburton, 1995; Kumari et al. 1996; Kumari et al. 1997; Rusted, 1999; Delfino et al. 2001; Brice and Smith, 2002; Kumari et al. 2003). The role of caffeine and nicotine consumption as both covariates and as individual stress coping mechanisms was thus considered here. The present analysis tests the age and sex-specific effects of self-reported perceptions and behaviors, related to traditional Samoan socioeconomic obligations, on catecholamine excretion. Three sources of such traditional socioeconomic obligation are examined: the *aiga*, the *matiai*, and *fa'alavelave*.

METHODS

Study Population

The current cross-sectional analysis is part of an ongoing interdisciplinary study of CVD risk factors in the Samoan islands (McGarvey, 1991; McGarvey, 1994; Chin-Hong and McGarvey, 1996; Steele and McGarvey, 1996; Steele and McGarvey, 1997; McGarvey, 2001; Roberts et al., 2004; Bitton et al., 2006; Ezeamama et al., 2006; Dai et al., 2008, Aberg et al., 2009, DiBello et al., 2009, Bergey et al., 2010). The study population for this research resides in the independent island nation of Samoa (formerly Western Samoa). Samoa, with a 1991 population of 161,000 people, consists of two main islands: Upolu (with the capital city of Apia) and Savai'i, and two small islands Apolima, and Manono.

Study Sample

The effects of ecological, socioeconomic, and lifestyle factors on urinary catecholamine excretion were previously examined in 507 adult Samoans, 268 females and 239 males (Bergey et al., 2010). Those individuals represent a randomly selected sub-sample from a larger four-year longitudinal study of CVD risk factors in the Samoan islands. The 507 participants were studied in 1991 and were then available for follow-up in 1995. Both the previous and current analysis examine data specific to the 1995 follow-up. The present study uses a sub-sample of 378, 194 females and 184 males, of the 507 participants who provided responses to self-administered questionnaires about attitudes and behaviors related to traditional Samoan socioeconomic obligations. Not all participants responded to all items and we defined inclusion in the study sample based on having any response to the 9 items. Thus, effective sample size for each analysis varied. The similarity of the sub-sample to the larger sample of 507 is described in the results.

Participants were selected from nine different villages from the two Samoan islands of Upolu and Savai'i. Five of the villages were peri-urban, and were located on the rapidly modernizing island of Upolu. Two of the five Upolu villages were located in the capital city region of Apia; three of the Upolu villages were connected to Apia by paved roads. The remaining four villages were located on the rural, more traditional island of Savai'i. More detailed rationale for the study sampling has been described elsewhere (Chin-Hong and McGarvey, 1996). Protocols for this study were approved by the Brown University Institutional Review Board and the Government of Samoa, Ministry of Health, Health Research Committee. All participants provided their informed written consent.

Measures

Stature and weight were measured using standard techniques, with participants wearing light tropical clothing. Stature was measured via a portable GPM anthropometer (Siber and Hegner, Zurich, Switzerland); weight was measured using a portable Healthometer platform scale (Detecto Scales, Inc, Brooklyn, NY). Dietary intake questionnaires were used to quantify average daily consumption of caffeine via tea, coffee, and soft drinks. Participants were asked to specify weekly frequency of consumption and portion size (DiBello et al., 2009). Caffeine consumption was converted to cups of coffee based on a standard value of 85mg of caffeine per 5 ounces of ground coffee (Barone and Roberts, 1996). The median intake of the relevant age, sex, and island group was imputed for individuals who were missing caffeine data. Median values were used to account for a skewed distribution. Imputation prevented an approximate 9% decrease in sample size for this variable for both the entire sample of 507 individuals and the sub-sample of 378 individuals (8.9% and 8.7%, respectively). Those with no imputed caffeine values did not differ significantly from those without imputed values with respect to age, BMI, sex, or residence (peri-urban Upolu versus rural Savai'i), for either the larger sample or the sub-sample. Smoking status was assessed

using the same set of questionnaires; it was operationalized as a dichotomous variable based upon individual responses to the question: 'Do you now smoke cigarettes?'

Behavioral and attitudinal measures, related to perceived social obligations and participants' self-reported contributions to meet those obligations, were assessed via self-administered questionnaires. The questions included perceived responsibility to the *aiga* and *matai*, the reported proportion of one's income that is contributed to the *aiga* and *matai*, the perceived burden from making such contributions, as well as perceived financial strain from participation in *fa'alavelave* (Appendix I). These questions are the operational definitions of potential financial and non-financial, resource-based stressors at the individual level that were derived both from research experiences in the Samoan Islands and from ethnography (Pitt, 1970; Howard, 1979; Shore, 1982; Gerber, 1985; O'Meara, 1990; Mageo, 1999; James, 2000; Macpherson and Macpherson, 2000; Maiava, 2001; Cahn, 2008).

Catecholamine excretion was measured from overnight, timed, fasting urine samples for each participant (Bergey et al., 2010). Sample volume was recorded and the antioxidant sodium metabisulfite was added to each aliquot. Aliquots were then frozen at -18° to -29° C in Samoa, shipped on dry ice to Rhode Island, and stored at -57° C, to avoid degradation. Urine samples were assayed between 1996 and 1997. Catecholamine samples were extracted using a Bio Rad Catecholamine Kit and were analyzed using standard techniques on a high performance liquid chromatograph (HPLC) with electrochemical detection (Bereiter et al., 1990). Excretion rates in nanograms/minute were calculated ((concentration x urine volume)/time).

Statistical Analysis

Analyses were stratified by age (≤ 40 versus >40 years old) and sex to account for biological changes associated with aging, inherent sex-specific physiological differences, age and sex-specific differences in neuroendocrine response to certain stressors, and the varied socio-cultural experiences of different age and sex-specific cohorts (Levi, 1972; Johansson and Post, 1974; Frankenhauser et al., 1976; Ziegler et al., 1976; Collins and Frankenhauser, 1978; Palmer et al., 1978; Esler et al., 1981; Chen et al., 1986; Pollack and Steklis, 1986; Christensen and Jensen, 1994). The sample was also divided into peri-urban villages on Upolu island and rural villages on Savai'i island (Bergey et al., 2010). Natural log transformations were performed to adjust for right-skewed NE and EPI distributions. The chi-square test or Fisher's exact test, as appropriate, was used to compare categorical independent variables. Spearman's rho was used to explore patterns of association between caffeine consumption and catecholamine excretion. Oneway analysis of variance was used to detect significant differences in unadjusted catecholamine excretion rates by smoking status, by residence, and by individual's responses to the attitudinal and behavioral questions. Multivariate linear regression models were run to test the independent main effect of these variables on catecholamine excretion. Variables were included in final regression models if they had an independent main effect on NE or EPI levels at the $p < 0.200$ level. A p -value < 0.05 was considered statistically significant.

Results

Table I presents sex and location-specific socio-demographic, anthropometric, and catecholamine data for the sample of 378 participants. Ages range from 29 to 62 years old, with a mean (SD) age of 42.4 (8.1) years for women and 42.7 (9.0) for men. Mean (SD) BMI is 29.9 (5.6) kg/m^2 , with a mean (SD) BMI of 31.3 (5.6) kg/m^2 for women and 28.4 (5.2) kg/m^2 for men. From the larger sample of 507 participants, 128 individuals (55 men, 73 women) had no responses to the nine behavioral and perceived stressor questions examined here; one additional individual was excluded due to missing BMI data. The 128

individuals with missing responses to the behavioral and perceived stressor questions were slightly older (mean (SD) age of 45.3 (8.8) years; $p=0.002$) than the 378 participants with the requisite data but they did not differ significantly with respect to BMI (30.4 (6.3) kg/m²; $p=0.418$), NE excretion (2.3 (0.9) ln(ng/min); $p=0.511$), EPI excretion (-0.09 (0.9) ln(ng/min); $p=0.365$), or the proportion of individuals residing in peri-urban Upolu versus rural Savai'i ($p=0.573$). Caffeine consumption was significantly, positively associated with NE excretion among young women ($\rho=0.30$, $p=0.004$). It was marginally, positively associated with NE excretion among older women ($\rho=0.17$, $p=0.087$) and significantly, positively related to EPI excretion among older women ($\rho=0.21$, $p=0.034$). Caffeine consumption was not significantly related to catecholamine excretion in either of the male cohorts.

Table II describes the responses to the questions about attitudes and behaviors related to traditional socioeconomic obligations for the sub-sample. Note that sample size varies across the 9 items, ranging from 78% to 91% of the total sample of 378. The items about *matai* had consistently lower response proportions. Compared to young women, older women reported significantly higher perceived responsibility to their *matai* (85% vs. 57%; $p<0.001$) and significantly higher actual contributions to their *aiga* (88% vs. 75%; $p=0.030$). Older women were also significantly more likely to report that they perceived their contribution to their *matai* to be a burden than women in the younger cohort (57% vs. 39%; $p=0.025$). Older men reported significantly higher perceived responsibility to their *aiga* (93% vs. 81%; $p=0.012$) and to their *matai* (80% vs. 52%; $p<0.001$) than younger men. Older men also were significantly more likely than younger men to report they perceived their contribution to their *aiga* to be 'too large' (24% vs. 4%; $p=0.002$), and were marginally more likely to report that their contribution to their *aiga* was a burden (47% vs. 33%; $p=0.085$).

Table III presents unadjusted and BMI-adjusted age and sex-specific catecholamine excretion rates by the different attitudinal and behavioral variables. In young women, BMI-adjusted NE was marginally related ($p=0.054$) to perceived contribution to their *matai*; young women who perceived their contribution to be 'just right' had higher NE than individuals who reported their contribution to be 'too large' ($b=-0.55$; 95% CI: -1.17, 0.07; $p=0.081$) or 'too little' ($b=-0.70$; 95% CI: -1.30, -0.10; $p=0.023$). Adjusted EPI was significantly higher ($b=0.57$; 95% CI: 0.09, 1.06; $p=0.021$) in young women who contribute a moderate to a great deal of their income to their *matai* compared to young women who contribute little or none of their income. Adjusted NE and EPI excretion levels were significantly higher ($b=0.73$; 95% CI: 0.23, 1.22; $p=0.005$ and $b=0.59$; 95% CI: 0.13, 1.05; $p=0.012$, respectively) among young women who responded that their participation in *fa'alavelave* was very or somewhat of a financial strain. BMI-adjusted EPI excretion was significantly related to one's perceived contribution to their *aiga* among older men ($p=0.004$); EPI excretion was significantly lower among older men whose perceived contribution to their *aiga* was 'too large' ($b=-0.94$; 95% CI: -1.53, -0.35; $p=0.002$) compared to individuals whose contribution was 'just right.' Adjusted EPI excretion was also positively, marginally related to actual contribution to one's *aiga* among older men ($b=0.46$; 95% CI: -0.02, 0.95; $p=0.061$).

Table IV presents age and sex-specific final multivariate linear regression models using factors identified in the above analyses, and rural/urban residence, based on our earlier results (Bergey et al., 2010). Smoking status was not significantly related at the $p<0.20$ level to outcomes that showed significant relationships to attitudinal or behavioral measures at the bivariate level; it was thus not included in the final models. Independent variables in the final models were examined for strong degrees of association and did not exhibit multicollinearity. Among young women, NE remained significantly higher among

individuals from Upolu ($b=0.50$; 95% CI: 0.003, 0.99; $p=0.049$). Perceived contribution to one's *matai* also was significantly related to NE among young women ($p=0.032$); individuals who perceived their contribution to be 'just right' had significantly higher NE than individuals who perceived their contribution to be 'too little' ($b=-0.74$; 95% CI: -1.33, -0.16; $p=0.014$), and marginally higher NE than individuals who perceived their contribution to be 'too large' ($b=-0.59$; 95% CI: -1.21, 0.03; $p=0.061$). Young women who contributed a great deal or moderate amount of their income to their *matai* had significantly higher NE than young women who contributed little or none of their income ($b=0.67$; 95% CI: 0.10, 1.24; $p=0.023$). Among young women, NE remained significantly higher among individuals who reported that participation in *fa'alavelave* was a financial burden ($b=0.64$; 95% CI: 0.10, 1.18; $p=0.021$).

EPI was significantly, negatively associated with perceived burden from one's contribution to their *aiga* ($b=-0.54$; 95% CI: -1.01, -0.06; $p=0.027$), and significantly, positively related to actual, reported contribution to one's *matai* ($b=0.76$; 95% CI: 0.22, 1.30; $p=0.007$), and the perception that *fa'alavelave* is a financial burden ($b=0.68$; 95% CI: 0.18, 1.18; $p=0.009$) among young women.

A previously observed significant, residential contrast remained significantly related to EPI excretion in older men ($p=0.007$); older men from peri-urban Upolu had higher EPI excretion than their rural Savai'i counterparts ($b=0.45$; 95% CI: 0.13, 0.78; $p=0.007$). Perceptions about one's contribution to their *aiga* remained significantly related to EPI among older men ($p=0.010$); older men who perceived their contribution to be 'just right' had significantly higher EPI than individuals who perceived their contribution to be 'too large' ($b=-0.90$; 95% CI: -1.49, -0.31; $p=0.003$), and marginally higher EPI than individuals who perceived their contribution to be 'too little' ($b=-0.50$; 95% CI: -1.05, 0.04; $p=0.070$). Older men who reported higher actual contributions to their *aiga* had marginally higher EPI excretion ($b=0.45$; 95% CI: -0.05, 0.94; $p=0.075$).

Discussion

The present findings provide detail on the association of individual-level perceptions and behaviors with catecholamine excretion, and go beyond our previously observed ecological, residence-based stressor effects (Bergey et al., 2010). We found consistent evidence in young women ≤ 40 years of age that biomarkers of stress were associated with self-reports of responsibilities, contributions and burdens of the late 20th century Samoan ways of life. Young women who contributed a moderate to a great deal of their income to their *matai*, and reported a financial strain from participation in *fa'alavelave* had significantly higher residence-adjusted NE and EPI. Young women may feel that their social standing is dependent upon the extent to which they participate in *fa'a Samoa* via contributing to the *matai* and to *fa'alavelave*. These women may experience stress if they lack the resources to meet such obligations or if they wish to use their resources to support their own material lifestyle and upward social mobility as opposed to donations to their *matai* and to support the costs of funerals, weddings and other key extended family activities. Limited employment opportunity also may prevent young women from entering the work force and may constrain their ability to acquire an income for themselves or for their family (Bitton et al., 2006). The finding in young women is interesting despite their general tendency to report that these social obligations are less burdensome than do older women (Table II). The present findings may be consistent with studies that found psychosocial stress due to a discrepancy between one's educational and occupation resources and familial obligations in young Samoan women (Chin-Hong and McGarvey, 1996; Bitton et al., 2006).

Our findings support detailed studies of the changing nature of perceived obligations and increase in expectations for size of donations to the *aiga* and *matai* associated with *fa'alavelave* (Schoeffel, 1999; Meleisea, 2000; Tuimalei'ifano, 2006). The present findings are also in keeping with research that has shown that socioeconomic debts associated with *fa'alavelave* are significant sources of psychosocial stress (McDade, 2003). However, generalizations across studies with different methodologies must be made cautiously. McDade (2003) examined EBV antibodies and his sample consisted of Samoan adolescents.

It is not clear why young women who perceived their contribution to their *aiga* to be a burden had lower EPI excretion. The direction of this association is the opposite of what we would expect to see if such a burden elicits stress. Further analysis is necessary to explore the extent to which such perceptions may be related to psychosocial stress in this cohort. It is noteworthy that this inverse association is detected for the items that ask about perceptions of obligations which are contradictory compared to their actual contributions to the *matai* and overall burden of *fa'alavelave*. This disjunction between self-reported perceptions of contributions and the actual contributions deserves further inquiry. Asking questions about actual contributions may be better than general perceptions.

Among older men, those who reported their contribution to their *aiga* to be 'just right' had significantly higher EPI than those who considered their contribution to be 'too large' and had marginally higher adjusted EPI than those who perceived their contribution to be 'too little.' Older men who contributed more to their *aiga* also had increased EPI. Prior Samoan studies of BP as an indicator of stress in relation to LI and anger coping, did not find any associations among older men (Chin-Hong and McGarvey, 1996; Bitton et al., 2006). It is not clear why adjusted EPI might be higher among men who consider their contribution to their *aiga* to be 'just right.' These older men may find it difficult to contribute towards their *aiga*, regardless of how they perceive their contribution. This may result in some underlying stress related to acquiring that contribution. Stress due to a discrepancy between one's educational and occupational resources and desired individual or immediate family and household material lifestyle has been observed in young men, young women, and older men from Samoa (Chin-Hong and McGarvey, 1996; Bitton et al., 2006) and may be reflected here in older men. Further study of the status, roles and material life and well-being among older men is needed in the context of processes of economic development and social change.

A previously observed significant, positive effect of caffeine in this cohort (Bergey et al., 2010) was attenuated when the *fa'alavelave* and *matai* measures were added to the model. A previously observed significant effect of peri-urban versus rural residence (Bergey et al., 2010), remained significant; young women from peri-urban villages on Upolu had higher adjusted NE excretion than young women from rural villages on Savai'i. Further analysis of individual level correlates of psychosocial stressors are necessary to elucidate other biopsychosocial aspects of individual exposure to socio-economic change and cardiovascular disease risk that may underlie the residential differences in adjusted NE in this cohort.

The significant effects of the attitudinal and behavioral findings for older men did not attenuate a previously observed effect of a rural vs. peri-urban residential contrast and EPI excretion. Older men from peri-urban Upolu had significantly higher EPI than their rural Savai'i counterparts, after adjusting for the attitudinal and behavioral variables in the final model. Further analysis of individual level correlates of psychosocial stress arousal may help to elucidate biopsychosocial aspects of individual exposure to socio-economic change and cardiovascular disease risk that are not captured in the present analysis.

This study has several limitations. Participant's self-reports to sensitive questions about socioeconomic responsibilities were taken at face-value. Individuals may have been reluctant to express frustrations related to extended family and community obligations. An important value in Samoan culture is also control over one's emotions (Gerber, 1985; Howard, 1979; Howard, 1986; Steele and McGarvey, 1996; Mageo, 1999). Such factors may have shaped people's responses or their willingness to answer a specific question. As noted in the results section, some items had a sizeable portion of missing responses and those items tended to be about *matai*. This pattern of missing data limits clear interpretability of our results. Despite the few differences between those with and without data on any self-reported stressors, variation in characteristics among those who responded to some items versus all or most items may influence results. Perceptions and attitudes regarding socioeconomic obligations also may vary between individuals holding *matai* titles and those who do not. A small number of *matai* in the present sample limited our ability to explore the extent to which such differences might exist.

The study's cross-sectional design prevents inferences from being made about a causal pathway between psychosocial stress arousal associated from changing social roles and traditional socioeconomic obligations, and increased risk of cardiovascular disease. The present study also lacks data on potential stress mediators, such as social support, social involvement, anger expression, and anger suppression that have been shown to modify stress arousal (Dressler, 1982; Hanna et al., 1986; Howard, 1986; Janes, 1990; Steele and McGarvey, 1996; Bitton et al., 2006). Physical activity level has a known effect on catecholamine levels. Data pertaining to physical activity for this study sample were unavailable. Using overnight catecholamine samples, however, minimizes the effects of physical activity on these hormones; such samples are less sensitive to acute fluctuations related to physical activity level. Overnight samples increase the likelihood that chronic stress arousal is being measured.

Despite these limitations, our analysis supports the use of individual-level, self-report data on perceived stressors in the domains of financial and service obligations to the larger family and traditional leadership. The observed cross-sectional associations between catecholamine excretion and responses to questions about traditional Samoan socioeconomic obligations suggest that young women and older men may experience increased psychosocial stress due to financial demands from their *aiga*, *matai*, and from participation in *fa'alavelave*. When used in conjunction with biomarkers of stress like urinary catecholamine excretion rates, such measures provide a more holistic view of psychosocial stress arousal than using general measures of exposure to economic development and social change alone (James et al. 1987; Pearson et al. 1990; Bergey et al., 2010). Further analysis, using qualitative methods such as semi-structured interviews, could provide a deeper understanding of individual perceptions and behaviors related to traditional socioeconomic obligations and psychosocial stress arousal in Samoa. Such analysis may also elucidate biopsychosocial aspects of individual exposure to socio-economic change and cardiovascular disease risk underlying previously observed ecological differences in psychosocial arousal (Bergey et al., 2010) that persisted after adjustment for the individual-level differences observed in the present analysis. Finally, economic development, migration, emigrant remittances to *aiga* and *matai*, and changing opportunities for social, political, and economic advancement within villages continue to occur in Samoa and American Samoa and among Samoan communities outside of the archipelago (Macpherson and Macpherson, 2009; McGarvey and Seiden, 2010). Further research on stress and health in the Samoas, and elsewhere, must consider and attempt to assess the historical and socio-cultural context of these dynamic changes.

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Appendix I. Behavioral and Perceived Stressor Questionnaire

1. How much responsibility do you feel to your *aiga*?
 - a. Very much
 - b. Some
 - c. A little
 - d. None
2. How much responsibility do you feel to your *matai*?
 - a. Very much
 - b. Some
 - c. A little
 - d. None
3. What proportion of your income do you contribute to your *matai*?
 - a. A great deal
 - b. Quite a bit
 - c. Moderate
 - d. A little
 - e. None
4. Do you feel your contribution to your *matai* is _____
 - a. Too large
 - b. Too little
 - c. Just right
5. Do you think contributing to your *matai* is a burden?
 - a. Definitely
 - b. Somewhat
 - c. Not much
 - d. Not at all
6. What proportion of your income do you contribute to your *aiga*?
 - a. A great deal
 - b. Quite a bit
 - c. Moderate
 - d. A little

- e. None
- 7. Do you feel your contribution to your *aiga* is _____
 - a. Too large
 - b. Too little
 - c. Just right
- 8. Do you think contributing to your *aiga* is a burden?
 - a. Definitely
 - b. Somewhat
 - c. Not much
 - d. Not at all
- 9. How much of a financial strain is your participation in *fa'alavelave*?
 - a. Very
 - b. Somewhat
 - c. Not very
 - d. None

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Table I

Characteristics of the Perceived Stress and Attitudinal Study Sample

Residence N (%)	Women (n=194)		Men (n=184)	
	Upolu 105 (54%)	Savai'i 89 (46%)	Upolu 89 (48%)	Savai'i 95 (52%)
Age (years)	43.3 (8.4)	41.4 (7.5)	43.0 (9.1)	42.4 (9.0)
BMI (kg/m ²)	32.6 (5.8)	29.7 (5.1)	29.9 (5.2)	27.1 (4.8)
Caffeine (mg) [†]	1.2 (1.0)	1.0 (0.6)	1.2 (1.0)	1.3 (0.8)
Norepinephrine (ng/min)	19.2 (20.3)	9.73 (10.5)	23.3 (17.2)	14.2 (10.6)
Norepinephrine ln(ng/min) [*]	2.53 (1.01)	1.84 (1.03)	2.87 (0.855)	2.34 (0.904)
Epinephrine (ng/min)	1.54 (2.04)	0.924 (0.697)	1.81 (1.65)	1.42 (1.38)
Epinephrine ln(ng/min) [*]	-0.043 (0.939)	-0.325 (0.715)	0.296 (0.763)	0.029 (0.797)

^{*} Data represent mean (SD), unless otherwise specified.

[†] Missing values imputed based on median values for age, sex, and island-specific cohorts; data represent median (IQR) cups of coffee (85mg caffeine)/day

[†] Values reflect natural log transformation to adjust for right skew

Table II

Participant Responses to Attitudinal and Behavioral Questions *

Age Group	Women (n=194)		Men (n=184)	
	≤40 yrs.	>40 yrs.	≤40 yrs.	>40 yrs.
Perceived Responsibility				
<i>Aiga</i> (extended family)	n=83	n=93	n=77	n=91
Very much/Some	67 (81%)	80 (86%)	62 (81%)	85 (93%)
Little/None	16 (19%)	13 (14%)	15 (19%)	6 (7%)
<i>Matai</i> (<i>aiga</i> chief)	n=76	n=84	n=69	n=85
Very much/Some	43 (57%)	71 (85%)	36 (52%)	68 (80%)
Little/None	33 (43%)	13 (15%)	33 (48%)	17 (20%)
Perceived Contribution				
<i>Aiga</i> (extended family)	n=82	n=87	n=72	n=87
Too large	19 (23%)	22 (25%)	3 (4%)	21 (24%)
Just right	12 (15%)	10 (11%)	14 (19%)	10 (11%)
Too little	51 (62%)	55 (63%)	55 (76%)	56 (64%)
<i>Matai</i> (<i>aiga</i> chief)	n=70	n=80	n=65	n=81
Too large	20 (29%)	28 (35%)	18 (28%)	33 (41%)
Just right	28 (40%)	29 (36%)	30 (46%)	31 (38%)
Too little	22 (31%)	23 (29%)	17 (26%)	17 (21%)
Actual Contribution				
<i>Aiga</i> (extended family)	n=80	n=84	n=74	n=84
Great deal/Moderate	60 (75%)	74 (88%)	56 (76%)	72 (86%)
Little/None	20 (25%)	10 (12%)	18 (24%)	12 (14%)
<i>Matai</i> (<i>aiga</i> chief)	n=75	n=80	n=68	n=81
Great deal/Moderate	55 (73%)	58 (73%)	58 (85%)	63 (78%)
Little/None	20 (27%)	22 (28%)	10 (15%)	18 (22%)
Perceived Burden				
<i>Aiga</i> (extended family)	n=81	n=86	n=69	n=85
Definitely/Somewhat	35 (43%)	40 (47%)	23 (33%)	40 (47%)
Not much/Not at all	46 (57%)	46 (53%)	46 (67%)	45 (53%)
<i>Matai</i> (<i>aiga</i> chief)	n=70	n=81	n=69	n=85
Definitely/Somewhat	27 (39%)	46 (57%)	40 (58%)	55 (65%)
Not much/Not at all	43 (61%)	35 (43%)	29 (42%)	30 (35%)
<i>Fa'alavelave</i> (<i>aiga</i> events)	n=76	n=84	n=69	n=81
Very/Somewhat	54 (71%)	63 (75%)	48 (70%)	62 (77%)
Not very/None	22 (29%)	21 (25%)	21 (30%)	19 (23%)

Percentages may not sum to 100% due to rounding

* Not all participants answered all questions; age and sex-specific sample sizes vary across the nine items.

Table III
Age and Sex-Specific Catecholamine Relationships by Behavioral and Perceived Stressor Questions

	Unadjusted Catecholamine Excretion [‡]		BMI-Adjusted Catecholamine Excretion [‡]	
	Women	Men	Women	Men
	≤40 yrs.	>40 yrs.	≤40 yrs.	>40 yrs.
Perceived Responsibility ¹				
<i>Aiga</i>				
<i>Matai</i>		NE*		
Perceived Contribution ²				
<i>Aiga</i>			-EPI**	-EPI**
<i>Matai</i>	-NE*		-NE ⁺	
Actual Contribution ¹				
<i>Aiga</i>			EPI ⁺	EPI ⁺
<i>Matai</i>	NE ⁺ , EPI*		EPI*	
Perceived Burden				
<i>Aiga</i> ³				
<i>Matai</i> ³				
<i>Fa'alavelave</i> ⁴	NE**, EPI*		NE**, EPI*	

- inverse relation

⁺ $p < 0.10$

^{*} $p < 0.05$

^{**} $p < 0.01$

[‡] Results reflect natural log transformation to adjust for right skew

¹ Reference category = 'Little/None'

² Reference category = 'Just right'

³ Reference category = 'Not much/Not at all'

⁴Reference category = 'Not very/None'

Table IV

Multivariable Regression Models for Catecholamines

	Coefficient	95% CI	P-Value	R ² [^]
Dependent Variable: Norepinephrine				
<i>Women ≤40 years old</i>				
Residence				
Upolu vs. Savai'i [†]	0.50	0.003, 0.99	0.049	0.27
Perceived Contribution – Matai			0.032 ^a	
‘Too large’ vs. ‘Just right’ [†]	-0.59	-1.21, 0.03	0.061	
‘Too little’ vs. ‘Just right’ [†]	-0.74	-1.33, -0.16	0.014	
Actual Contribution - Matai				
‘Great deal/Moderate’ vs. Little/None’ [†]	0.67	0.10, 1.24	0.023	
Burden - Fa'alavelave				
‘Very/Somewhat’ vs. ‘Not very/None’ [†]	0.64	0.10, 1.18	0.021	
Dependent Variable: Epinephrine				
<i>Women ≤40 years old</i>				
Perceived Burden - Aiga				
‘Definitely/Somewhat’ vs. ‘Not much/Not at all’ [†]	-0.54	-1.01, -0.06	0.027	0.20
Actual Contribution - Matai				
‘Great deal/Moderate’ vs. Little/None’ [†]	0.76	0.22, 1.30	0.007	
Burden - Fa'alavelave				
‘Very/Somewhat’ vs. ‘Not very/None’ [†]	0.68	0.18, 1.18	0.009	
<i>Men >40 years old</i>				
Residence				
Upolu vs. Savai'i [†]	0.45	0.13, 0.78	0.007	0.18
Perceived Contribution - Aiga			0.010 ^a	
‘Too large’ vs. ‘Just right’ [†]	-0.90	-1.49, -0.31	0.003	
‘Too little’ vs. ‘Just right’ [†]	-0.50	-1.05, 0.04	0.070	
Actual contribution - Aiga				
‘Great deal/Moderate’ vs. ‘Little/None’ [†]	0.45	-0.05, 0.94	0.075	

[†]Comparison groups represent villages sampled from peri-urban Upolu and rural Savai'i

^aOverall p-value

[†]Reference Category

[^]Adjusted R²