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Ecological and sociodemographic effects on urinary catecholamine excretion in adult Samoans

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Abstract

Background—Ecological and sociodemographic correlates of stress may contribute to cardiovascular disease risk in modernizing Samoans.

Aim—The effects of peri-urban vs rural residence, education, occupation, caffeine intake and cigarette consumption on urinary catecholamine excretion were studied in Samoan adults.

Subjects and methods—Five hundred and seven participants, aged 29–69 years, were randomly selected from nine villages throughout Samoa. Sociodemographic and lifestyle factors were assessed by questionnaire. Epinephrine and norepinephrine excretion rates were measured by high performance liquid chromatography with electrochemical detection in overnight urine samples. Age (40 vs >40 years) and gender-specific regression models were estimated to detect associations with BMI-adjusted catecholamine excretion.

Results—Norepinephrine was significantly higher in peri-urban young men and older women. Epinephrine was significantly higher in peri-urban older men. Adjustment for caffeine attenuated the relationship between residence and norepinephrine in young women.

Conclusion—General residential exposure to modernization in urban villages is a significant correlate of increased overnight catecholamine excretion rates and is consistent with past studies. Caffeine consumption in younger women plays a complex role in stress-related catecholamine excretion. Further studies of individual level attitudinal and behavioural factors in Samoans are needed to understand psychosocial stress, physiologic arousal and health.

Keywords

Epinephrine; norepinephrine; Samoans; psychosocial stress

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INTRODUCTION

The Samoan Islands have experienced a marked increase in cardiovascular disease-related morbidity and mortality in recent decades. Research indicates that the prevalence and incidence of CVD and its concomitant risk factors have increased with economic development (McGarvey and Baker 1979; Zimmet et al. 1980; Baker and Hanna 1981; McGarvey and Schendel 1986; McGarvey et al. 1989; 1993; McGarvey 1991; 1992; Hodge et al. 1994; Gershater and McGarvey 1995; Galanis et al. 1999). While much of this increase has been attributed to changing diets and activity levels (McGarvey et al. 1989; Galanis et al. 1999; McGarvey 1999; DiBello et al. 2009), there is growing evidence to suggest that changing patterns of psychosocial stress arousal also contribute to the increased risk of CVD (McGarvey and Baker 1979; James et al. 1985; 1987; McGarvey and Schendel 1986; McGarvey 1992; 1999; Steele and McGarvey 1996; McDade 2003; Roberts et al. 2004; Bitton et al. 2006; Ezeamama et al. 2006).

Lifestyle changes associated with economic development produce unique patterns of psychosocial stress arousal by altering individual, household and community-level interactions (McGarvey 1999). The adoption of non-traditional values and behaviours can also affect stress arousal as new social roles are juxtaposed upon traditional socioeconomic obligations (McGarvey 1999). Insufficient adaptation to new patterns of stress arousal may in turn lead to increased risk of CVD (Sapolsky 1994; James and Brown 1997; Merz et al. 2002).

In their 1981–1982 study of catecholamine excretion in Samoa, James et al. (1985; 1987) found that rural Samoan villagers with more neotraditional lifestyles had lower catecholamine excretion and lower blood pressure (BP) than Samoan men who performed less traditional occupations in Samoa's urban capital city of Apia. Rural Samoan agriculturalists exhibited lower overnight and morning rates of catecholamine excretion than urban sedentary workers and urban college students (James et al. 1987). Overnight NE and EPI excretion for urban labourers was similar to that of rural villagers; however, it was similar to urban levels in the morning samples. James et al. (1987) found that the strongest correlates of catecholamine excretion were such behavioural factors as physical activity, food intake and stimulant intake. Other studies have found an association between exposure to modern life and increased BP in Samoan youth and adults (McGarvey and Baker 1979; McGarvey and Schendel 1986; McGarvey 1992; Roberts et al. 2004).

Recent studies by Chin-Hong and McGarvey (1996) and Bitton et al. (2006) utilized the lifestyle incongruity model (Dressler 1990a; b; 1991) to provide a more ethnographic context to the study of psychosocial stress in Samoa. Chin-Hong and McGarvey (1996) found age and adiposity-adjusted BP was negatively associated with lifestyle incongruity among young Samoan men and positively associated with lifestyle incongruity among older Samoan women. The authors speculate that financial demands from one's family and community may increase stress in young men who wish to achieve a specific material lifestyle based on their economic resources. Excess material consumption for the purposes of acquiring or advancing social prestige may explain increased BP in older women whose occupation does not support such consumption (Chin-Hong and McGarvey 1996).

Bitton et al. (2006) examined the mediating effects of anger expression on psychosocial stress arousal and found an association between increased BP and anger suppression in young Samoan women whose educational rank exceeded their material lifestyle. They speculate that limited employment opportunities and traditional gender-specific obligations may prevent well-educated women, who wish to enter the workforce, from doing so. Gender-specific norms related to emotional suppression may increase BP in this cohort.

Bitton et al. (2006) also found an interaction between anger expression and an observed relationship between occupational lifestyle incongruity and BP in young Samoan men. Young men whose occupational level exceeded their material lifestyle and who reported frequent feelings of Samoan culture-specific anger had higher age and BMI-adjusted BP. A conflict between socioeconomic obligations and individual material lifestyle, coupled with feelings of anger, may account for this association (Bitton et al. 2006).

McDade (2003) examined culture change, immune function, and stress among Samoan adolescents. His research found an interaction between household socioeconomic status and the occurrence of the traditional Samoan practice of gift exchange 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.

The purpose of the present study was to explore the social and behavioural correlates of overnight, fasting, urinary excretion rates of norepinephrine (NE) and epinephrine (EPI) by age, sex, and residence in a representative sample of modernizing adult Samoans studied in 1995. This study focuses on residential, ecological effects by contrasting residents from the more developed island of 'Upolu with those from the rural, more traditional island of Savai'i. We also test the effects of individual measures of exposure to economic development and social change-occupation, education, caffeine consumption and smoking status on catecholamine excretion.

The rationale for using NE and EPI as biological indicators of stress has been illustrated in other Samoan studies (Martz et al. 1984; James et al. 1985; 1987; Hanna et al. 1986; James 1989; Pearson et al. 1990; 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 relationships with catecholamine excretion (Kershbaum et al. 1963; Levi 1967; Robertson et al. 1978; Rall 1990; Reynolds et al. 1981; Lane et al. 1990; Jarvis 1993; James 1997) and are thus typically treated as covariates in stress research. Both factors can, however, confound an association between psychosocial stress and these outcomes. Caffeine intake has been associated with increased, sustained and clearer cognition, improved memory, decreased fatigue and increased mood (Lieberman et al. 1987; Smith et al. 1992; 1993; 1994; Warburton 1995; Rusted 1999; Brice and Smith 2002). Nicotine has also been shown to reduce anxiety, increase alertness and improve and increase performance in various tasks (Kumari et al. 1996; 1997; 2003; Delfino et al. 2001). The role of caffeine and cigarette consumption as individual stress coping mechanisms was thus considered in this analysis and the effect of these variables as both confounders and as covariates was explored.

METHODS

Study population

This analysis is part of an ongoing long-term study of ecological, behavioural, genetic, physiological and psychosocial determinants of such CVD risk factors as overweight/obesity, hypertension, type 2 diabetes mellitus (T2DM) and blood lipids in the Samoan Islands (McGarvey 1991; 1994; 2001; Chin-Hong and McGarvey 1996; Steele and McGarvey 1996; 1997; Roberts et al. 2004; Bitton et al. 2006; Ezeamama et al. 2006; Dai et al. 2007; 2008; Åberg et al. 2009; DiBello et al. 2009). The study population for this particular research resides in the independent island nation of Samoa (formerly Western Samoa). Samoa, with a 1991 population of 161 000 people, was briefly a territory of Germany from 1899–1917. Samoa then became a protectorate of New Zealand before gaining its independence in 1962. The country consists of four main islands: 'Upolu (with the capital city of Apia), Savai'i, Apolima and Manono. The neighbouring islands of Tutuila,

Aunu'u, Ofu, Ta'u and Olosega comprise the American protectorate of American Samoa. Together, Samoa and American Samoa form an archipelago in the South Pacific Ocean, 2330 km northeast of New Zealand (Gage 1986).

Significant exposure to industrialized nations over the past century initiated processes of rapid economic development and urbanization in Samoa (Gage 1986; Newman et al. 1999). Such changes were gradual at first, with the majority of the economy still based in rural subsistence fishing and farming. More rapid urbanization and economic growth have occurred in recent decades, with concomitant increases in wage labour opportunity and increased reliance on imported goods and services. Change in Samoa has occurred heterogeneously, with the capital city of Apia and its surrounding villages on 'Upolu expanding and developing to a greater extent than the more rural villages on Savai'i (O'Meara 1990). Individuals are increasingly migrating to the Apia region from rural villages, seeking educational and occupational opportunity, with young men and women from 'Upolu participating in wage labour employment and attaining increasingly higher levels of education and wage and salary occupation than their Savai'i counterparts (Western Samoa Department of Statistics 1995). With the exception of some limited cash cropping, inhabitants of the rural island of Savai'i continue to engage in more traditional, family and village-based fishing and farming (McDade et al. 2000).

Study sample

This research is cross-sectional in design. The sample size consists of 268 females and 239 males who were studied in 1995 as the 4-year follow-up to a study of CVD risk factors. These 507 individuals comprise a randomly-selected sample aged 25–65 years seen in 1991 (Chin-Hong and McGarvey 1996), who were also available for the 4-year longitudinal follow-up study in 1995. Participants represent nine different villages from the two Samoan islands of 'Upolu and Savai'i. These villages were chosen to ensure representation at the village level across the spectrum of exposure to modern ways of life in Samoa in 1991 (Chin-Hong and McGarvey 1996). Two of the five 'Upolu villages are located in the capital city region of Apia. Three of the 'Upolu villages are linked by paved roads to Apia and are exposed to the forces of modernization. The remaining four villages are located on the rural, more traditional island of Savai'i. Further rationale for the study sampling has been described elsewhere (Chin-Hong and McGarvey 1996).

Measures

Stature and weight were measured using standard techniques; stature was measured via a portable GPM anthropometer and weight was measured using a portable Healthometer platform scale. Study participants wore light tropical clothing during the measurements. One woman >40 years old from 'Upolu was missing data for BMI; mean BMI for that age, sex and island group was used for that individual. Catecholamine excretion was measured from overnight, timed, fasting urine samples for each participant. Sample volume was recorded and the antioxidant sodium metabisulphite was added to each aliquot. Aliquots were then frozen at 0 to –20 F in Samoa, shipped on dry ice to Rhode Island and stored at –70 F, to avoid degradation. Urine samples were assayed between 1996–1997. Catecholamine samples were extracted using a Bio Rad Catecholamine Kit and were analysed 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 × urine volume)/time).

Food frequency dietary intake questionnaires were used to quantify average daily consumption of caffeine via tea, coffee and soft drinks by asking about weekly frequency of consumption and portion size (DiBello et al. 2009). Caffeine intake was imputed for those

with missing data, using the median intake of the relevant age, sex and island group; median values were used to account for a skewed distribution. Imputation prevented an ~9% decrease in sample size for this variable. Those with no imputed caffeine values did not differ from those without imputed values with respect to age, BMI, sex or location. Caffeine values were converted to cups of coffee based on a standard value of 85 mg of caffeine per 5 ounces of ground coffee (Barone and Roberts 1996). Smoking status was assessed via the same set of questionnaires and was operationalized into a dichotomous variable, based upon individual responses to the question: 'Do you now smoke cigarettes?'

Occupation was self-reported in the interview and was categorized according to sex groups. Women were classified as either employed or unemployed. The rationale for this dichotomy lies in the small proportion of women participating in wage-earning jobs. Men were categorized into one of four groups: (1) unemployed, (2) subsistence work, (3) wage labour/clerical work or (4) managerial work/traditional leader. Although greater variation in occupational scores allowed for several employment categories in men, sample sizes for some of the categories were small and results of analyses using these categories must be interpreted with caution.

Education was measured on a three-point ranking scale (0–7 years, 8–9 years and 10 or greater years). These ranks closely resemble the stages of educational attainment in Samoa. Villages were grouped by island, 'Upolu or Savai'i, to test the ecological effect of peri-urban vs rural residence on catecholamine excretion. This grouping is based upon census data and our own project data (Western Samoa Department of Statistics 1995). Both sources indicate that villages on Savai'i have undergone economic development and modernization to a much lesser extent than villages on 'Upolu. Table I shows sex-specific socioeconomic differences by island.

Statistical analysis

Analyses were stratified by age (< 40 vs ≥40 years old) and sex to account for inherent physiological differences between males and females, biological changes associated with ageing and the varied socio-cultural life experiences of different age and gender-specific cohorts. Neuroendocrine response to certain stressors differs by age and sex (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). Samoan men and women also experience unique patterns of psychosocial stress arousal based on their separate age and gender-specific roles in Samoan society (Hecht et al. 1986; Howard 1986; O'Meara 1990).

Natural log transformations were performed to adjust for right-skewed NE and EPI distributions. One-way analysis of variance was used to detect significant differences in unadjusted excretion rates by peri-urban vs rural residence, education, occupation and smoking status when stratified by age and sex. The Kruskal-Wallis test was used to examine differences in caffeine consumption by education and occupation. Significant relationships were further analysed using the Mann-Whitney test; adjustments to the *p*-value were not made, following the suggestion of Rothman (1990). Pearson's correlations were estimated to explore patterns of association among covariates, potential confounders and outcomes; Spearman's rho was used for analyses involving caffeine intake. The Chi-square test or Fisher's exact test was used, as appropriate, to compare categorical independent variables. Multivariate linear regression models were run to test the independent main effect of the potential covariates and confounders on catecholamine excretion. Variables were included in the final models if they were significant at the univariate level. A *p*-value <0.05 was considered statistically significant. Although not significantly related to EPI excretion (*p* = 0.120) in older men, we included smoking status in the final regression model because prior

stress research supported the role of smoking as both a covariate and a confounder (Reynolds et al. 1981; Kumari et al. 1997; 2003; Delfino et al. 2001). BMI was included in all models to adjust for the known effect of this variable on catecholamine excretion.

RESULTS

Table I provides sex and location-specific socio-demographic, anthropometric and psychosocial descriptive statistics for the study sample. Ages range from 29–69 years old, with a mean age of 43 years for both women and men. Mean BMI was significantly higher in young men ($p = 0.001$), young women ($p = 0.026$), older men ($p = 0.035$) and older women ($p < 0.001$) from peri-urban 'Upolu than from rural Savai'i. Smoking status did not differ significantly by island for the four cohorts. Education was marginally related to residence among young women ($p = 0.092$); young women from 'Upolu were more likely to have 0–7 or 10 or more years of education, whereas women from Savai'i were more likely to have 8–9 years of education. Older women ($p = 0.005$) and young men ($p = 0.002$) from 'Upolu were more likely to be employed than their Savai'i counterparts. Caffeine intake was significantly higher among young ($p = 0.016$) and older women ($p = 0.023$) from 'Upolu, when compared to their age and sex counterparts residing in Savai'i.

Caffeine was also related to occupation in young women ($p = 0.047$), young men ($p = 0.024$) and older men ($p = 0.002$) (Table II). Young, employed women consumed greater daily amounts of caffeine than young, unemployed women. Caffeine consumption was marginally higher in young men who were managers than in subsistence workers ($p = 0.09$) and significantly higher in unemployed men vs subsistence workers ($p = 0.018$). Older men in the managerial/traditional leader category consumed significantly more caffeine than older men who engaged in subsistence work ($p = 0.012$) and older unemployed men ($p = 0.027$). Older men who participated in wage labour/clerical work also consumed significantly greater amounts of caffeine than older men who engaged in subsistence work ($p = 0.004$) and older unemployed men ($p = 0.032$) (Table II).

BMI was positively correlated with NE in all four age and sex sub-groups (young women: $r = 0.25$, $p = 0.009$; older women: $r = 0.32$, $p < 0.001$; young men: $r = 0.31$, $p = 0.001$; older men: $r = 0.26$, $p = 0.003$). There was a positive relationship between caffeine consumption and NE, not adjusted for BMI, among young women ($\rho = 0.26$, $p = 0.006$), and a marginally significant relationship among older women ($\rho = 0.14$, $p = 0.079$). Caffeine consumption was also related to unadjusted EPI excretion in older women ($\rho = 0.18$, $p = 0.028$). Among older men, current smokers had marginally higher mean unadjusted ($p = 0.080$) and BMI-adjusted ($p = 0.086$) NE excretion than non-smokers. Neither education nor occupation was significantly related to unadjusted or BMI-adjusted catecholamine excretion in either of the four age and sex sub-samples.

Unadjusted mean NE levels were significantly higher in 'Upolu than in Savai'i for young men ($p = 0.002$), young women ($p = 0.010$), older men ($p = 0.037$) and older women ($p < 0.001$). Unadjusted EPI levels were also significantly higher in older men ($p = 0.010$) from the 'Upolu sample. BMI-adjusted mean NE remained significantly higher in young men ($p = 0.024$), young women ($p = 0.035$) and older women ($p = 0.003$) from 'Upolu (Table III). Adjusted EPI also remained significantly higher ($p = 0.013$) in older men from 'Upolu (Table III).

We also explored the relationship between BP and urinary catecholamine excretion, in order to assess whether there was any variation in the latter, associated with BP, that was due to a potential influence of stress on both these variables. No relationship was found between age

and BMI-adjusted BP (either systolic or diastolic blood pressure) and either NE or EPI, for men or women.

The observed significant relationship between residence and BMI-adjusted NE in young women was attenuated ($p = 0.141$) with further adjustment for the significant, positive association with caffeine ($p = 0.046$) (Table IV). BMI-adjusted EPI remained significantly higher in older men from 'Upolu ($p = 0.028$), after adjusting for smoking status ($p = 0.149$).

It is important to note that neither the age- and gender-specific BMI-adjusted island differences in catecholamine excretion nor the relationships observed in our final multivariate models changed when the analyses were re-run just for individuals with non-imputed caffeine data. This consistency suggests that it is unlikely that individuals with and without imputed caffeine values differ in some way that might bias the results.

DISCUSSION

The findings of this study provide more detail about the relationship between general measures of exposure to economic development and culture change, assessed by residence, and biomarkers of psychosocial stress arousal in Samoa, measured by urinary catecholamine excretion. The pattern of significantly higher NE values in the 'Upolu sample than in the Savai'i sample for most age and sex groups and the significantly higher EPI values among older men are consistent with the notion that men and women living in peri-urban villages on 'Upolu may experience increased stress due to greater general exposure to economic development, urban life and changing social interactions and role expectations than individuals from rural Savai'i.

The significantly higher NE and EPI values in 'Upolu than Savai'i for male cohorts in this sample are also consistent with research indicating a relationship between increased catecholamine excretion and greater modern orientation in Samoan men (James et al. 1985; 1987; Pearson et al. 1993). James et al. (1987) found higher NE and EPI levels from overnight and morning samples in urban 'Upolu sedentary workers and students compared to rural 'Upolu villagers. Overnight catecholamine excretion for urban labourers was similar to that of rural villagers; it was similar to urban levels in the morning samples.

However, generalizations across studies with different methodology must be made cautiously. The 1981–1982 study of catecholamine excretion collected urine samples overnight and during the morning, whereas the present study only collected overnight samples. James et al.'s (1985; 1987) sampling strategy also differed from our own. The 1981–1982 sample was selected to try to maximize variation in occupation. Our sample was selected to ensure representation at the village level across the spectrum of exposure to modern ways of life in Samoa in 1991 and within the nine villages was a random sample of adults 25–65 years of age (Chin-Hong and McGarvey 1996).

Our finding of increased BMI-adjusted NE among young men from 'Upolu is consistent with the inferences about stressors from lifestyle incongruity and BP variation by Chin-Hong and McGarvey (1996). Obligations to family (*aiga*), village chiefs (*matai*) and community may conflict with more individual-based aspirations for social prestige and increases in material way of life (Howard 1986).

Although it is not clear why older 'Upolu men had greater BMI-adjusted EPI, they may also be experiencing greater stressors due to general economic development processes than their more rural Savai'i counterparts. Prior psychosocial stress and BP studies, with a focus on lifestyle incongruity and anger coping, did not find any associations among older 'Upolu men (Chin-Hong and McGarvey 1996; Bitton et al. 2006).

The higher level of adjusted NE in young women from 'Upolu compared to Savai'i is consistent with higher exposure to general modernization stressors. Young women may feel obligated to perform domestic chores and child-rearing, while also experiencing pressure to participate in wage-earning employment to support their family's income and social prestige (Janes 1990; O'Meara 1990; Lewis 1998; Mageo 1999). The finding that adjustment for caffeine consumption attenuates this residential difference in NE among young women along with the positive association between caffeine consumption and NE in all young women suggests a complex set of relationships among as yet undefined stressors, caffeine as a possible coping mechanism and health. It may be that the higher caffeine consumption in 'Upolu women is the reason for their higher NE levels and that modernizing young women consume caffeine to cope with expanding social roles and increased socioeconomic obligations. Caffeine consumption has been shown to increase mood and to positively effect cognition, concentration and memory (Lieberman et al. 1987; Smith et al. 1992; 1993; 1994; Jarvis 1993; Warburton 1995; Brice and Smith 2002). Increased attention from caffeine may help young women to complete work-related obligations. Caffeine consumption may provide an incentive for breaks from tedious or anxiety-inducing tasks. It may also help women to juggle both domestic and employment-related demands.

The present evidence for higher stress levels in young women on 'Upolu is similar to Steele and McGarvey's (1996) results on the same study sample 4 years earlier in 1991 on modernization, anger coping and BP in Samoan women. They also suggested that increased psychosocial stress due to role expansion may contribute to an observed association between higher age and BMI-adjusted BP in young Samoan women. Further work by Bitton et al. (2006) speculated that such stress may contribute to an association between age and BMI-adjusted BP in young women who suppress feelings of anger and whose educational rank exceeds their material lifestyle. Only more detailed individual level and longitudinal studies will help clarify the relationships among stressors among modernizing women, catecholamine or other stress biomarkers and BP variation.

Higher NE levels among older women from 'Upolu are consistent also with a higher level of exposure to the general stressors of modernization. Older women might feel pressure to be employed so they can supplement their family income (Chin-Hong and McGarvey 1996; Bitton et al. 2006). Although a large percentage of older women from 'Upolu reported 10 years or more of education (40.0%), only 23.5% were employed. Limited employment opportunity or constraints from traditional social and family obligations may prevent more-educated older women from entering the work force. More speculatively, stress from expanding social roles and from frustrated attempts at upward social mobility through material consumption may account for physiologic stress arousal among older women from 'Upolu (Chin-Hong and McGarvey 1996). Although we did not find significant differences in either NE or EPI by either occupation or education status, we suspect individual factors, related to these variables, might influence catecholamine excretion in this sample. Further analysis is necessary to try to elucidate specific sources of stress underlying the broader, more macro-level residential differences we observed.

The relationships among stressors from the changing way of life in Samoa, catecholamine excretion rates and BP is complex and likely depends on many factors not measured or not measured well. Chronic BP elevations and diurnal BP variations associated with work stress are not always associated with more direct biomarkers of arousal (James et al. 1993). The pace of modernization, the novelty of some of the stressors of modernization, the duration and frequency of psychosocial challenges and the various buffers that modulate arousal all are likely to change dynamically as individuals accommodate to non-traditional life. Our inability to find BP associations with NE differs from James et al.'s (1985) work for reasons

we cannot confidently explain. However, the complexity of stressor arousal, measured in different physiologic systems, and health risks remains a compelling research challenge.

This study has several limitations. The urinary catecholamine results are part of a larger study not designed with a focus on biomarkers and behaviours related to stress. The cross-sectional design makes it impossible to draw conclusions about causal relationships and aetiological processes influencing stress and catecholamine excretion in Samoa. Small sample sizes in occupational groups limit the extent to which our measures reflect variation in occupation-related psychosocial stress, particularly among women. Previous research suggests that specific behaviours (including physical activity, diet and stimulant intake) on the day of urine collection can influence catecholamine excretion levels; studies also indicate that catecholamine excretion can vary by day of the week (James et al. 1985; 1987; Pearson et al. 1993). Data were not available in the present study to account for potential variation in catecholamine excretion by day of the week. Nor were they available to account for the known effect of physical activity on catecholamine excretion. The latter limitation is minimized by using overnight samples; such samples are less responsive to acute fluctuations from physical activity and they increase the likelihood that chronic stress arousal is measured. While data were collected regarding stimulant intake, these measures reflected average daily values from the food frequency questionnaire, as opposed to consumption on the actual day of urine collection. This study also lacks data on the potential mediating effects of factors such as social support, anger expression and anger suppression on stress (Dressler 1980; 1984; 1991; Dressler et al. 1986; Hanna et al. 1986; Steele and McGarvey 1996; Bitton et al. 2006). We hope to use related data in future analyses on this 1995 sample.

The failure to detect any associations between catecholamine excretion and education or occupation suggests that more detailed assessment of the sources and patterns of psychosocial stressors is required to understand how modern life exactly influences chronic physiologic arousal and likely health. Despite our replication of prior studies, the finding that the ecological residential measure of modernization is associated with elevated catecholamine excretion must be treated with caution until we are able to isolate specific sources of psychosocial stress.

It is important to note that rural life in Samoa is not devoid of stress. Catecholamine excretion due to psychosocial stress undoubtedly exists in both peri-urban and rural populations, and the degree of excretion is related to various factors including individual stress mediation, social interactions and inherent physiological differences (James and Brown 1997). Ecological group-level differences in catecholamine excretion rates are the product of an aggregate pattern of individual interactions with one's personal, social, economic and cultural surroundings. Further research will examine in more detail individual measures of psychosocial stress arousal in this sample.

To conclude, general exposure to aspects of economic development, assessed by residence, is a significant correlate of increased overnight catecholamine excretion rates in older women and younger and older men. Caffeine consumption confounds the association in younger women and appears to play a complex role in the catecholamine stress arousal. The observed ecological differences suggest increased psychosocial stress arousal in urban vs rural settings. These findings add to a growing number of studies in developing populations that have shown associations between catecholamine excretion and measures of psychosocial stress (Brown 1982; Hanna et al. 1986; James et al. 1987; Pearson et al. 1990; 1993). This analysis also provides detail into the role of caffeine consumption as a potential stress coping mechanism for young Samoan women and lends support for further

examination of the biopsychosocial aspects of individual exposure to socio-economic change and cardiovascular disease risk.

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REFERENCES

- Åberg K, Dai F, Sun G, Keighley ED, Indugula SR, Roberts ST, Zhang Q, Smelser D, Viali S, Tuitele J, Jin L, Deka R, Weeks DE, McGarvey ST. Susceptibility loci for adiposity-related phenotypes on 8p, 9p and 16q in American Samoa and Samoa. *Obesity*. 2009; 17:518–524. [PubMed: 19238140]
- Baker, PT.; Hanna, JM. Modernization and the biological fitness of Samoans: A progress report on a research program.. In: Fleming, C.; Prior, I., editors. *Migration, adaptation and health in the Pacific*. Epidemiology Unit, Wellington Hospital; Wellington, New Zealand: 1981. p. 14-26.
- Barone JJ, Roberts HR. Caffeine consumption. *Food Chem Toxicol*. 1996; 34:119–129. [PubMed: 8603790]
- Bereiter DA, Benetti AP, Thirvikraman KV. Thermal nociception potentiates the release of ACTH and norepinephrine by blood loss. *Am J Physiol*. 1990; 259:1236–1242.
- Bitton A, McGarvey ST, Viali S. Anger expression and lifestyle incongruity interactions on blood pressure in Samoan adults. *Am J Hum Biol*. 2006; 18:369–376. [PubMed: 16634023]
- Brice CF, Smith AP. Effects of caffeine on mood and performance: A study of realistic consumption. *Psychopharmacology*. 2002; 164:188–192. [PubMed: 12404081]
- Brown DE. Physiological stress and culture change in a group of Filipino-Americans: A preliminary investigation. *Ann Hum Biol*. 1982; 9:553–563. [PubMed: 7181446]
- Chen M, Halter JB, Porte D. Plasma catecholamines, dietary carbohydrate, and glucose intolerance: A comparison between young and old men. *J Clin Endocr Metab*. 1986; 62:1193–1198. [PubMed: 3700584]
- Chin-Hong PV, McGarvey ST. Lifestyle incongruity and adult blood pressure in Western Samoa. *Psychosom Med*. 1996; 58:130–137.
- Christensen NJ, Jensen EW. Effect of psychosocial stress and age on plasma norepinephrine levels: A review. *Psychosom Med*. 1994; 56:77–83. [PubMed: 8197318]
- Collins A, Frankenhauser M. Stress responses in male and female engineering students. *J Hum Stress*. 1978; 4:43–48.
- Dai F, Keighley ED, Sun G, Indugula SR, Roberts ST, Åberg K, Smelser D, Tuitele J, Jin L, Deka R, Weeks DE, McGarvey ST. Genome-wide scan for adiposity-related phenotypes in adults from American Samoa. *Int J Obesity*. 2007; 31:1832–1842.
- Dai F, Sun G, Åberg K, Keighley ED, Indugula SR, Roberts ST, Smelser D, Viali S, Jin L, Deka R, Weeks DE, McGarvey ST. A whole genome linkage scan identifies multiple chromosomal regions influencing adiposity-related traits among Samoans. *Ann Hum Genet*. 2008; 72:780–792. [PubMed: 18616661]
- Delfino RJ, Jamner LD, Whalen CK. Temporal analysis of the relationship of smoking behavior and urges to mood states in men versus women. *Nicotine Tob Res*. 2001; 3:235–248. [PubMed: 11506767]
- DiBello JR, McGarvey ST, Kraft P, Goldberg R, Campos H, Laumoli TS, Quesada C, Baylin A. Dietary pattern variation and the metabolic syndrome in adult Samoans. *J Nutr*. 2009; 139(10):1933–1943. [PubMed: 19710163]
- Dressler WW. Coping dispositions, social supports, and health status. *Ethos*. 1980; 8:146–171.
- Dressler WW. Hypertension and perceived stress: A St. Lucian example. *Ethos*. 1984; 12(3):265–283.
- Dressler WW. Education, lifestyle and arterial blood pressure. *J Psychosom Res*. 1990a; 34:515–523. [PubMed: 2231485]

- Dressler WW. Lifestyle, stress, and blood pressure in a Southern black community. *Psychosom Med.* 1990b; 52:182–198. [PubMed: 2330391]
- Dressler WW. Social Support, lifestyle incongruity, and arterial blood pressure in a Southern black community. *Psychosom Med.* 1991; 53:608–620. [PubMed: 1758946]
- Dressler WW, Mata A, Chavez A, Viteri F, Gallagher P. Social support and arterial pressure in a Central Mexican community. *Psychosom Med.* 1986; 48:338–350. [PubMed: 3726049]
- Esler M, Skews H, Leonard P, Jackman G, Bobik A, Korner P. Age dependence of noradrenaline kinetics in normal subjects. *Clin Sci.* 1981; 60:217–219. [PubMed: 7237935]
- Ezeamama AE, Viali S, Tuitele J, McGarvey ST. The influence of socioeconomic factors on cardiovascular disease risk factors in the context of economic development in the Samoan archipelago. *Soc Sci Med.* 2006; 63:2533–2545. [PubMed: 16876925]
- Frankenhauser M, Dunne E, Lundberg U. Sex differences in sympathetic adrenal medullary reactions induced by different stressors. *Psychopharmacology.* 1976; 47:1–5. [PubMed: 959463]
- Gage, TB.; Baker, PT.; Hanna, JM.; Baker, TS. The changing Samoans: Behavior and health in transition. Oxford University Press; New York: 1986. Environment and exploitation.; p. 19-38.
- Galanis DJ, McGarvey ST, Quested C, Sio B, Afele-Fa'amuli SA. Dietary intake of modernizing Samoans: Implications for risk of cardiovascular disease. *J Am Diet Assoc.* 1999; 99:184–190. [PubMed: 9972185]
- Gershater E, McGarvey ST. Fourteen-year changes in adiposity and blood pressure in American Samoan adults. *Am J Hum Biol.* 1995; 7:597–606.
- Hanna, JM.; James, GD.; Martz, JM. Hormonal measures of stress.. In: Baker, PT.; Hanna, JM.; Baker, TS., editors. The changing Samoans: behavior and health in transition. Oxford University Press; New York: 1986. p. 203-221.
- Harrison GA, Palmer CD, Jenner D, Reynolds V. Association between rates of urinary catecholamine excretion and aspects of lifestyle among adult women in some Oxfordshire villages. *Hum Biol.* 1981; 53:617–633. [PubMed: 7327543]
- Hecht, JA.; Orans, M.; Janes, C. Social settings of contemporary Samoans.. In: Baker, PT.; Hanna, JM.; Baker, TS., editors. The changing Samoans: Behavior and health in transition. Oxford University Press; New York: 1986. p. 39-62.
- Hodge AM, Dowse GK, Toelupe P, Collins VR, Imo T, Zimmet PZ. Dramatic increase in the prevalence of obesity in Western Samoa over the 13 year period 1978–1991. *Int J Obesity.* 1994; 18:419–428.
- Howard, A. Samoan coping behavior.. In: Baker, PT.; Hanna, JM.; Baker, TS., editors. The changing Samoans: Behavior and health in transition. Oxford University Press; New York: 1986. p. 394-418.
- James GD. The relation of norepinephrine to blood pressure is independent of acculturation in Western Samoan men. *Am J Hypertens.* 1989; 2:471–473. [PubMed: 2757804]
- James GD, Baker PT, Jenner DA, Harrison GA. Variation in lifestyle characteristics and catecholamine excretion rates among young Western Samoan men. *Soc Sci Med.* 1987; 25:981–986. [PubMed: 3423848]
- James GD, Brown DE. The biological stress response and lifestyle: Catecholamines and blood pressure. *Ann Rev Anthropol.* 1997; 26:313–335.
- James GD, Jenner DA, Harrison GA, Baker PT. Differences in catecholamine excretion rates, blood pressure, and lifestyle among young Western Samoan men. *Hum Biol.* 1985; 57:635–647. [PubMed: 4086019]
- James GD, Schlüssel YR, Pickering T. The association between daily blood pressure and catecholamine variability in normotensive working women. *Psychosom Med.* 1993; 55:55–60. [PubMed: 8446742]
- James, JE. Understanding caffeine: A biobehavioral analysis. Sage Publications; London: 1997.
- Janes CR. Migration, changing gender roles and stress: The Samoan case. *Med Anthropol.* 1990; 12:217–248. [PubMed: 2233171]
- Jarvis MJ. Does caffeine intake enhance absolute levels of cognitive performance? *Psychopharmacology.* 1993; 110:45–52. [PubMed: 7870897]

- Jenner DA, Harrison GA, Prior IAM. Catecholamine excretion in Tokelauans living in three different environments. *Hum Biol.* 1987; 59:165–172. [PubMed: 3570252]
- Johansson G, Post B. Catecholamine output of males and females over a one year period. *Acta Physiol Scand.* 1974; 92:557–565. [PubMed: 4476979]
- Kershbaum A, Khorsandian R, Caplan RF, Bellet S, Feinberg LJ. The role of catecholamines in the free fatty acid response to cigarette smoking. *Circulation.* 1963; 28:52–57. [PubMed: 14032101]
- Kumari V, Checkley SA, Gray JA. Effect of cigarette smoking on prepulse inhibition of the acoustic startle reflex in healthy male smokers. *Psychopharmacology.* 1996; 128:54–60. [PubMed: 8944406]
- Kumari V, Cotter PA, Checkley SA, Gray JA. Effect of acute subcutaneous nicotine on prepulse inhibition of the acoustic startle reflex in healthy male non-smokers. *Psychopharmacology.* 1997; 132:389–395. [PubMed: 9298517]
- Kumari V, Gray JA, Ffytche DH, Mitterschiffthaler MT, Das M, Zachariah E, Vythelingum GN, Williams SCR, Simmons A, Sharma T. Cognitive effects of nicotine on humans: An fMRI study. *Neuroimage.* 2003; 19:1002–1013. [PubMed: 12880828]
- Lane JD, Adcock RA, Williams RB, Kuhn CM. Caffeine effects on cardiovascular and neuroendocrine responses to acute psychosocial stress and their relationship to level of habitual caffeine consumption. *Psychosom Med.* 1990; 52:320–336. [PubMed: 2195579]
- Levi L. The effect of coffee on the function of the sympathoadrenomedullary system in man. *Acta Med Scand.* 1967; 181:431–438. [PubMed: 6023454]
- Levi L. Stress and distress in response to psychosocial stimuli. *Acta Med Scand Suppl.* 1972; 528:28–54.
- Lewis ND. Intellectual intersections: Gender and health in the Pacific. *Soc Sci Med.* 1998; 46:641–659. [PubMed: 9522425]
- Lieberman HR, Wurtman RJ, Emde GG, Roberts C, Coviella ILG. The effects of low doses of caffeine on human performance and mood. *Psychopharmacology.* 1987; 92:308–312. [PubMed: 3114783]
- Mageo, J. *Theorizing self in Samoa.* University of Michigan Press; Ann Arbor: 1999.
- Martz J, Hanna J, Howard S. Stress in daily life: Evidence from Samoa. *Am J Phys Anthropol.* 1984; 63:191–192.
- Merz CNB, Dwyer J, Nordstrom CK, Walton KG, Salerno JW, Schneider RH. Psychosocial stress and cardiovascular disease: Pathophysiological links. *Behav Med.* 2002; 27:141–147. [PubMed: 12165968]
- McDade, TW. Life event stress and immune function in Samoan adolescents: Toward a cross-cultural psychoneuroimmunology.. In: Wilce, J., editor. *Social and cultural lives of immune systems: Contextualizing psychoneuroimmunology, embodying the social sciences.* Routledge; New York: 2003. p. 170-188.
- McDade TW, Stallings JF, Worthman CM. Culture change and stress in Western Samoan youth: Methodological issues in the cross-cultural study of stress and immune function. *Am J Hum Biol.* 2000; 12:792–802. [PubMed: 11534070]
- McGarvey ST. Obesity in Samoans and a perspective on its etiology in Polynesians. *Am J Clin Nutr.* 1991; 53:1586S–1594S. [PubMed: 2031491]
- McGarvey ST. Biocultural predictors of age increases in adult blood pressure among Samoans. *Am J Hum Biol.* 1992; 4:27–35.
- McGarvey ST. The thrifty gene concept and adiposity studies in biological anthropology. *J Polynesian Soc.* 1994; 103:29–42.
- McGarvey, ST. Modernization, psychosocial factors, insulin, and cardiovascular health.. In: Panter-Brick, C.; Worthman, CM., editors. *Hormones, health and behavior: A socio-ecological and lifespan perspective.* Cambridge University Press; Cambridge: 1999. p. 244-280.
- McGarvey ST. Cardiovascular disease (CVD) risk factors in Samoa and American Samoa (1990-1995). *Pacific Health Dialog J Commun Health Clin Med Pacific.* 2001; 8:157–162.
- McGarvey ST, Baker PT. The effects of modernization and migration on Samoan blood pressure. *Hum Biol.* 1979; 51:461–475. [PubMed: 527947]

- McGarvey, ST.; Bindon, JR.; Crews, DE.; Schendel, DE. Modernization and adiposity: Causes and consequences.. In: Little, MA.; Haas, JD., editors. Human population biology. Oxford Press; New York: 1989. p. 263-279.
- McGarvey ST, Levinson PD, Bausserman L, Galanis D, Hornick C. Population change in adult obesity and blood lipids in American Samoa from 1976-1978 to 1990. *Am J Hum Biol.* 1993; 5:17-30.
- McGarvey, ST.; Schendel, DE. Blood pressure of Samoans.. In: Baker, PT.; Hanna, JM.; Baker, TS., editors. The changing Samoans: behavior and health in transition. Oxford University Press; New York: 1986. p. 350-393.
- Newman JD, McGarvey ST, Steele MS. Longitudinal association of cardiovascular reactivity and blood pressure in Samoan adolescents. *Psychosom Med.* 1999; 61:243-249. [PubMed: 10204978]
- O'Meara, T. Samoan planters: Tradition and economic development in Polynesia. Holt, Rinehart and Winston Inc; Fort Worth, TX: 1990.
- Palmer GJ, Ziegler MG, Lake CR. Response of norepinephrine and blood pressure to stress increases with age. *J Gerontol.* 1978; 33:482-487. [PubMed: 752038]
- Pearson JD, Hanna JM, Fitzgerald MH, Baker PT. Modernization and catecholamine excretion of young Samoan adults. *Soc Sci Med.* 1990; 31:729-736. [PubMed: 2244214]
- Pearson JD, James GD, Brown DE. Stress and changing lifestyles in the Pacific: Physiological stress responses of Samoans in rural and urban settings. *Am J Hum Biol.* 1993; 5:49-60.
- Pollack AC, Steklis HD. Urinary catecholamines and stress in male and female police cadets. *Hum Biol.* 1986; 58:209-220. [PubMed: 3710462]
- Rall, TW. Central nervous system stimulants: The xanthines.. In: Gilman, AG.; Rall, TW.; Nies, AS.; Taylor, P., editors. Goodman and Gilman's pharmacological basis of therapeutics. 8th ed.. Pergamon; New York: 1990. p. 618-637.
- Reynolds V, Jenner DA, Palmer CD, Harrison GA. Catecholamine excretion rates in relation to lifestyles in the male population of Otmoor, Oxfordshire. *Ann Hum Biol.* 1981; 8:197-209. [PubMed: 7259097]
- Roberts ST, McGarvey ST, Viali S, Qusted C. Youth blood pressure levels in Samoa in 1979 and 1991-1993. *Am J Hum Biol.* 2004; 16:158-167. [PubMed: 14994315]
- Robertson D, Frolich JC, Carr RK, Watson JT, Hollifield JW, Shand DG, Oates JA. Effects of caffeine on plasma renin activity, catecholamines, and blood pressure. *New Engl Med.* 1978; 298:181-186.
- Rothman KJ. No adjustments are needed for multiple comparisons. *Epidemiology.* 1990; 1:43-46. [PubMed: 2081237]
- Rusted, J. Caffeine and cognitive performance: Effects on mood or mental processing?.. In: Gupta, BS.; Gupta, U., editors. Caffeine and behavior: Current views and research trends. CRC Press; Boca Raton, FL: 1999. p. 221-230.
- Sapolsky, RM. Why zebras don't get ulcers: A guide to stress-related diseases and coping. Freeman; New York: 1994.
- Smith A, Kendrick A, Maben A, Salmon J. Effects of breakfast and caffeine on cognitive performance, mood and cardiovascular functioning. *Appetite.* 1994; 22:39-55. [PubMed: 8172489]
- Smith AP, Brockman P, Flynn R, Maben A, Thomas M. Investigation of the effects of coffee on alertness and performance and mood during the day and night. *Neuropsychobiology.* 1993; 27:217-223. [PubMed: 8232842]
- Smith AP, Kendrick AM, Maben AL. Effects of breakfast and caffeine on performance and mood late in the morning and after lunch. *Neuropsychobiology.* 1992; 26:198-204. [PubMed: 1299795]
- Steele MS, McGarvey ST. Expression of anger by Samoan adults. *Psychol Rep.* 1996; 79:1339-1348. [PubMed: 9009791]
- Steele MS, McGarvey ST. Anger expression, age, and blood pressure in modernizing Samoan adults. *Psychosom Med.* 1997; 59:632-637. [PubMed: 9407584]
- Warburton DM. Effects of caffeine on cognition and mood without caffeine abstinence. *Psychopharmacology.* 1995; 119:66-70. [PubMed: 7675951]
- Western Samoa Department of Statistics. Western Samoa Census 1991. Government Printing House; Apia, Samoa: 1995.

- Ziegler MG, Lake CR, Kopin IJ. Plasma noradrenaline increases with age. *Nature*. 1976; 261:333–335. [PubMed: 1272412]
- Zimmet P, Taylor R, Jackson L, Faaivaso S, Ainuu J. Blood pressure studies in rural and urban Western Samoa. *Med J Australia*. 1980; 2:202–205. [PubMed: 7432287]

Table I

Characteristics of the study sample.

	Women (<i>n</i> = 268)^{a,b}		Men (<i>n</i> = 239)^{a,b}	
	'Upolu (<i>n</i> = 141)	Savai'i (<i>n</i> = 127)	'Upolu (<i>n</i> = 116)	Savai'i (<i>n</i> = 123)
Age (years)	44.1 (8.5)	42.8 (8.4)	42.8 (8.9)	43.2 (8.9)
BMI (kg/m ²)	33.2 (6.1)	29.8 (5.2)	29.4 (5.2)	27.2 (4.8)
Caffeine intake (85 mg cups/day) [‡]	1.2 (1.0)	1.0 (0.5)	1.3 (1.0)	1.3 (0.8)
Norepinephrine (ng/min)	18.6 (18.4)	9.84 (9.78)	21.8 (16.1)	14.8 (11.9)
Norepinephrine (ln(ng/min)) [‡]	2.50 (1.04)	1.91 (0.950)	2.79 (0.883)	2.37 (0.893)
Epinephrine (ng/min)	1.43 (1.83)	1.11 (1.34)	1.71 (1.59)	1.56 (2.56)
Epinephrine (ln(ng/min)) [‡]	-0.0860 (0.931)	-0.250 (0.778)	0.240 (0.764)	0.00750 (0.861)
Smoking status				
Non-smoker	103 (79%)	95 (75%)	44 (40%)	49 (43%)
Current smoker	28 (21%)	31 (25%)	67 (60%)	65 (57%)
Years of education (%)				
0–7 years	23 (16%)	22 (17%)	24 (21%)	36 (29%)
8–9 years	42 (30%)	38 (30%)	46 (40%)	38 (31%)
10 + years	76 (54%)	67 (53%)	46 (40%)	49 (40%)
Occupation (women) (%)				
Unemployed	113 (80%)	116 (91%)		
Employed	28 (20%)	11 (9%)		
Occupation (men) (%)				
Unemployed			6 (5%)	3 (2%)
Subsistence work			72 (62%)	101 (82%)
Wage labour/clerical			28 (24%)	10 (8%)
Managerial/traditional leader			10 (9%)	9 (7%)

⁺ The 'Upolu and Savai'i comparison represents villages sampled from peri-urban 'Upolu and rural Savai'i.^aData represent mean (SD) and column percentages.^bPercentages may not sum to 100% due to rounding.[‡]Missing values imputed based on median values for age, sex and island-specific cohorts; data represent median (IQR) cups of coffee (85 mg caffeine)/day.[‡]Values reflect natural log transformation to adjust for right skew.

Table II

Age- and gender-specific caffeine consumption (mg/day) by employment status.

	40 years old			>40 years old		
	<i>n</i>	Median (IQR)	<i>p</i> -value	<i>n</i>	Median (IQR)	<i>p</i> -value
<i>Women</i>						
Unemployed	98	1.0 (0.6)	0.047	131	1.1 (0.6)	0.299
Employed	14	1.2 (0.9)		25	1.2 (0.8)	
<i>Men</i>						
Management/Traditional Leader	6	1.7 (2.2)	0.024	13	1.6 (0.8)	0.002
Subsistence work	85	1.2 (0.8)		88	1.3 (0.8)	
Unemployed	4	1.8 (0.4)		5	0.8 (1.0)	
Wage labour/Clerical work	12	1.4 (1.0)		26	1.6 (0.7)	

Table III

BMI-adjusted norepinephrine and epinephrine levels by location.

	Norepinephrine				Epinephrine			
	40 years old		>40 years old		40 years old		>40 years old	
	<i>n</i>	<i>M</i> (SEM)	<i>p</i> -value	<i>n</i>	<i>M</i> (SEM)	<i>p</i> -value	<i>n</i>	<i>p</i> -value
<i>Women</i>								
'Upolu	56	2.3 (0.1)	0.035	85	2.5 (0.1)	0.003	56	<-0.1 (0.1) 0.147 85 -0.1 (0.1) 0.527
Savai'i	56	1.9 (0.1)		71	2.0 (0.1)		56	-0.3 (0.1) 71 -0.2 (0.1)
<i>Men</i>								
'Upolu	53	2.7 (0.1)	0.024	63	2.7 (0.1)	0.108	53	0.2 (0.1) 0.843 63 0.3 (0.1) 0.013
Savai'i	54	2.3 (0.1)		69	2.5 (0.1)		54	0.2 (0.1) 69 -0.1 (0.1)

⁺The 'Upolu and Savai'i comparison represents villages sampled from peri-urban 'Upolu and rural Savai'i.

Table IV

Multivariable regression models for catecholamines.

	Coefficient	95% CI	p-value	$R^2 - \text{adj.}^{\wedge}$
<i>Dependent variable: Norepinephrine</i>				
Women 40 years old				
BMI	0.04	0.01, 0.08	0.028	0.11
'Upolu vs Savai'i [†]	0.30	-0.10, 0.71	0.141	
Caffeine Intake	0.29	0.01, 0.58	0.046	
Women >40 years old				
BMI	0.04	0.01, 0.06	0.003	0.14
'Upolu vs Savai'i [†]	0.48	0.17, 0.80	0.003	
Men 40 years old				
BMI	0.06	0.01, 0.10	0.014	0.12
'Upolu vs Savai'i [†]	0.38	0.05, 0.71	0.024	
<i>Dependent variable: Epinephrine</i>				
Men >40 years old				
BMI	<0.01	-0.02, 0.03	0.869	0.04
'Upolu vs Savai'i [†]	0.37	0.08, 0.66	0.013	
Men >40 years old				
BMI	<-0.01	-0.03, 0.02	0.900	0.04
'Upolu vs Savai'i [†]	0.33	0.04, 0.63	0.028	
Current smoker vs non-smoker [†]	0.22	-0.08, 0.52	0.149	

[†]The 'Upolu and Savai'i comparison represents villages sampled from peri-urban 'Upolu and rural Savai'i.[†]Reference category.[^]Adjusted R^2 .