Published in final edited form as:
Am J Hum Biol. 2012 ; 24(4): 551–557. doi:10.1002/ajhb.22269.

Modernization and Cardiometabolic Risk in Samoan Adolescents

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Abstract

Objective—To describe the prevalence of cardiometabolic risk factor clustering in Samoan adolescents and to relate risk factor clustering to weight status and general modernization.

Methods—Anthropometric and biochemical data collected from adolescents aged 12–17.9 years who participated in the Samoan Family Study of Overweight and Diabetes were used to describe the prevalence of cardiometabolic risk factors (high waist circumference, high blood pressure, high triglyceride level, low–high-density lipoprotein cholesterol, and high fasting serum glucose). A total of 436 adolescents were included in this analysis; 237 (54.4%) from American Samoa (n = 123 males) and 199 (45.6%) from Samoa (n = 90 males). Risk factor clustering was indicated by the presence of ≥3 risk factors.

Results—Cardiometabolic risk factor clustering was greater in American Samoan adolescents (17.9% males, 21.9% females) than Samoan adolescents (1.1% males, 2.8% females). The frequency of risk factor clustering varied according to body mass index status. In males, risk factor clustering was entirely confined to obese adolescents, whereas female adolescents who were overweight or obese were at risk.

Conclusions—Cardiometabolic risk factor clustering is prevalent in the young American Samoan population and is likely to become more prevalent with increasing modernization in Samoan youth. Screening and intervention should be targeted at this age group to reduce the non-communicable disease burden faced by these populations. Am. J. Hum.

In both the US territory of American Samoa and the independent nation of Samoa, the traditional subsistence culture of fishing and farming is being replaced by a more sedentary way of life as well as a dietary shift toward increased caloric, sodium, and animal-origin saturated fat intakes. As a result, mortality and morbidity in these island nations is being increasingly accounted for by non-communicable diseases (NCDs) such as cardiovascular disease (CVD), obesity, and type 2 diabetes mellitus, with a diminishing role for infectious disease and maternal and perinatal mortality.

In these, and many other developing countries, this pattern of health transition can be attributed to economic and social development characteristic of ongoing modernization. Increased urbanization, improvements in sanitation, and greater access to healthcare

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generally reduce infectious disease, particularly lowering infant mortality. With this reduction in early life mortality, however, most of the population reach adulthood and experience the common NCDs of ageing including CVD and cancer. Other characteristics of modernization can be directly linked to increases in the shared risk factors for NCD: smoking, unhealthy diet, alcohol consumption, and lack of physical activity. Improvements in transport infrastructure impact physical activity, technological advances in packaged food, and tobacco processing make mass production and wide distribution possible, and media promotion of snack food and alcohol increase demand (Berrigan and Troiano, 2000; Hawkes et al., 2009).

The Global Burden of Disease study projects that NCD mortality worldwide will rise from 28.1 million deaths in 1990 to 49.7 million in 2020, with heart disease and stroke continuing to be the most common causes of death (Murray and Lopez, 1997). Low- and middle-income countries undergoing modernization are, and will continue to be, disproportionately affected with 80% of worldwide deaths related to NCDs currently occurring in these countries (Murray, 1994). The most recent estimates from the Western Pacific region (2004), in which the Samoan islands lie, suggest that proportional mortality attributable to NCDs in the region as a whole was 75.4% in males and 79.7% in females (WHO, 2004), with the island countries and territories bearing most of the NCD burden.

As the burden of NCD grows, the age of onset of many of the contributing diseases is also rapidly declining in both developed and developing countries. The populations in which children and adolescents may be most at risk for the early development of NCD are those characterized by ongoing economic and health transition and an already established prevalence of adult overweight and obesity. The Samoan population exhibits extremely high rates of adult obesity, type 2 diabetes, and CVD (Dibello et al., 2009a; McGarvey, 2001). Furthermore, in adult Samoans the clustering of cardiome-tabolic risk factors is common (McGarvey et al., 2005). Although individual elevated biomarkers for CVD, type 2 diabetes, and associated disorders indicate a propensity to develop the corresponding disease, the co-occurrence or “clustering” of these risk factors has been shown to confer risk in an additive fashion in adults (Gami et al., 2007; Isomaa et al., 2001), although the mechanism by which this occurs remains unclear. In 2002, 49.4% of adults in American Samoa, aged 18–74 years exhibited the clustering of three or more cardio-metabolic risk factors (as defined by the Adult Treatment Panel [ATP] III criteria) as did 30.6% of adults in the same age range in Samoa (Dibello et al., 2009b).

Clustering of dyslipedemia, hypertension, and other cardiovascular risk factors is present in overweight children and adolescents in a similar pattern to adults (Chu et al., 1998; Webber et al., 1979). Autopsy studies suggest that obese adolescents are likely to show accelerated coronary atherosclerosis indicative of progression toward coronary heart disease (McGill et al., 2002), whereas type 2 diabetes and insulin resistance are also becoming health concerns for this age group, particularly in some susceptible minority populations (Pinhas-Hamiel and Zeitter, 2005). The previous studies in adolescents have largely focussed on reporting the prevalence of risk factor clustering in developed countries (Invitti et al., 2006; Mark and Janssen, 2008; Weiss et al., 2004). The level of adult NCD is substantially higher in Samoa than in any of the settings of the previous adolescent studies. Thus, this study was designed to examine the prevalence of cardiometa-bolic risk in the 12- to 17.9-year old adolescents from the Samoan islands with the expectation that prevalence may be higher than the previously reported in this age group in other populations.

METHODS

Study design

This study reports the findings from an adolescent sub-sample recruited as part of an extended family-based genetic linkage analysis of cardiometabolic traits (Åberg et al., 2009; Dai et al., 2007; Dai et al., 2008). Probands and relatives were unselected for obesity or related phenotypes. The study was approved by the Brown University Institutional Review Board, American Samoan Institutional Review Board and the Government of Samoa, Ministry of Health, Health Research Committee.

Participants

The study sample of those 12–17.9 years was recruited from extended families from the Samoan islands during 2002–2003 as part of the Samoan Family Study of Overweight and Diabetes, a genetic epidemiological study of adiposity and related CVD risk factors. The recruitment process and criteria used for inclusion in this study are described in detail by Dai et al. (2007). Briefly, recruitment into this study was based on the random selection of probands previously seen in a 1990 study undertaken in American Samoa (McGarvey et al., 1993). Adult participants were recruited based on their previous participation and their belonging to one of the selected pedigrees for genetic linkage analysis. Members of their households and extended families, including the adolescents whose data are presented here, were subsequently recruited into the study. In total, 237 adolescents from American Samoa were recruited in 2002 ($n = 123$ males). Recruitment in the independent nation of Samoa began in 2003 with the identification of members of the American Samoan pedigrees who were residing in Samoa. In Samoa, 199 adolescents were recruited ($n = 90$ males). The age distribution of participants within each of the samples was similar. In American Samoa, the number of participants in each age groups was 12.0–13.9 years: males $n = 42$, females $n = 51$; 14.0–15.9 years: males $n = 42$, females $n = 28$; 16.0–17.9 years: males $n = 39$, females $n = 35$. In Samoa, the number of participants in each group was 12.0–13.9 years: males $n = 35$, females $n = 45$; 14.0–15.9 years: males $n = 27$, females $n = 31$; 16.0–17.9 years: males $n = 28$, females $n = 33$. In both settings, participants were from villages located in urban, peri-urban, and rural areas and reflected varying degrees of socio-economic position as measured by educational attainment, occupation, and material wealth (Keighley et al., 2006).

Measures

Anthropometric measures were taken by trained observers with participants in minimal island clothing. Stature was measured using a portable GPM anthro-pometer (Pfister Imports, New York) and weight with a Healthometer calibrated spring-balance scale (Sunbeam Products, Boca Raton, FL) according to the standard anthropometric procedures. Based on the calculated body mass index (BMI) (kg/m^2), adolescents were categorized as being normal, overweight, or obese using the international classifications developed by Cole et al. (2000). Abdominal circumference was measured in duplicate at the level of the umbilicus and the average value included in analyses. Systolic and diastolic blood pressures (SBP, DBP) were measured three times using a Baum mercury sphygmomanometer using American Heart Association procedures. Participants were seated for 10 min prior to measurement. Mean values for SBP and DBP were calculated from all three blood pressure measurements.

Fasting venous blood samples were collected from participants after a 10-h minimum overnight fast. Serum was separated by centrifugation in the field and then stored at −40°C. Serum was transported on dry ice to Brown University, USA, for analysis. Total cholesterol and triglycer-ide content was determined by enzymatic assays using a Gilford Impact 400 computer-directed analyzer. High-density lipoprotein (HDL) cholesterol was determined following precipitation of lower density lipoproteins with 0.091 M $MnCl_2$-heparin (1.26 mg/mL) by the double precipitation method of Gidez et al. (1982). Serum glucose was measured with an automatic analyzer, Beckman CX4 (Dibello et al., 2009a).

Cardiometabolic risk factor criteria

The present study uses the age- and sex-specific cutoffs for adolescents developed by Jolliffe and Janssen (2007). These cutoffs are linked to the National Cholesterol Education Program ATP III criteria for the metabolic syndrome in adults (NCEP, 2001). At-risk levels were identified as follows: Abdominal Circumference ≥92nd percentile (males), ≥72nd percentile (females), Triglycer-ides ≥89th percentile, HDL-cholesterol ≤26th percentile (males), ≤43rd percentile (females), SBP ≥92nd percentile (males), ≥93rd percentile (females), DBP ≥97th percentile (males), ≥99th percentile (females), Fasting Glucose ≥5.6 mmol/L. Cardiometabolic risk factor clustering was indicated where participants presented with three or more individual risk factors.

Statistical analysis

Statistical analyses were performed using SPSS for Windows 17.0 (SPSS, Chicago, IL) and SAS 9.2 (SAS Institute, Cary, NC). To acknowledge known differences in the prevalence of adult overweight and obesity and the differing levels of modernization and development, analyses were conducted separately for Samoa and American Samoa. Male and female participants were also analyzed separately to examine the differences between the sexes both in terms of risk factor prevalence and differences in risk factor clustering. Owing to the relatively small sample size available, 12 to 17.9-year olds were combined for analysis purposes. Age was included as a covariate where appropriate to acknowledge potential differences between the youngest and the oldest members of the age range, particularly in BMI and abdominal circumference. Differences in each of the cardiometabolic risk factors, presented as continuous variables, were examined both between locations (within sex) and between sexes (within location) using univariate general linear models (ANCOVA) with age as a covariate. Dichotomous variables were created for each cardiometabolic risk factor according to whether the participant met the criteria for being at risk. Prevalence of these risk factors was again compared between locations and between sexes using categorical data analyses. As the sample was drawn from a family-based analysis, we controlled for household clustering in all analyses. Odds ratios for cardiometabolic risk factor clustering were calculated according to adolescent weight status with the inclusion of age and a random effects term for household number in an attempt to control for shared genetic and/or environmental exposures. This approach has been used previously in our Samoan research by DiBello et al. (2009a).

RESULTS

Characteristics of the study population are summarized in Table 1. Fifty-four percent of participants were from American Samoa, and overall the study population consisted of more females than males. There was no difference in the distribution of sex between locations and mean age did not differ between locations or between sexes.

Within American Samoa, there were significant between sex differences in anthropometric and biochemical measures when tested using ANCOVA with age as a covariate. Females had a greater mean age-adjusted BMI ($F = 21.64$, $P < 0.01$) and abdominal circumference ($F = 12.82$, $P < 0.01$) compared to males, whereas males showed higher age-adjusted SBP ($F = 10.44$, $P < 0.01$) and DBP ($F = 6.81$, $P < 0.01$). Within Samoa, there were similar age-adjusted sex differences. Females had greater mean BMI ($F = 26.39$, $P < 0.01$), abdominal circumference ($F = 30.56$, $P < 0.01$), and triglycerides ($F = 3.22$, $P < 0.05$). Males had higher SBP ($F = 11.61$, $P < 0.01$) and DBP ($F = 3.07$, $P < 0.05$).

ANCOVA between locations (within sex) with age as a covariate showed that American Samoan adolescents of both sexes were significantly larger than Samoan adolescents, with significantly higher BMI (males $F = 42.73$, $P < 0.01$; females $F = 36.35$, $P < 0.01$) and abdominal circumferences (males $F = 46.14$, $P < 0.01$; females $F = 28.79$, $P < 0.01$). American Samoans also had greater tri-glycerides (males, $F = 5.92$, $P < 0.01$; females, $F = 3.35$, $P < 0.05$), HDL cholesterol (males, $F = 21.44$, $P < 0.01$; females, $F = 20.48$, $P < 0.01$), SBP (males, $F = 11.19$, $P < 0.01$; females, $F = 10.32$, $P < 0.01$), and DBP (males, $F = 6.85$, $P < 0.01$; females, $F = 4.43$, $P < 0.01$). Samoan females had significantly higher mean blood glucose levels ($F = 11.50$, $P < 0.01$) than their American Samoan contemporaries; however, blood glucose levels did not differ between locations in males.

In both localities, when risk factor cutoffs were applied, females were more likely to be considered at risk for CVD based on their abdominal circumference (Table 2). More than half of the American Samoan females were classified as being at risk based on this measure (58.8%) as compared to 26.8% of their male counterparts. Having low HDL-cholesterol levels was widespread among both study locales, but substantially higher in females in both locations. More males than females exhibited high blood pressure in both locations. The prevalence of high fasting blood glucose, indicative of type 2 diabetes mellitus, was low across both locations although slightly more common in males than females.

Overall, the presence of cardiometabolic risk factors was significantly lower in Samoan adolescents as compared with their American Samoan peers. American Samoa 78.1% of adolescents met at least one criterion for cardiometabolic risk as compared to 54.8% of adolescents in Samoa (χ^2 (1) = 26.71, $P < 0.001$). Adolescents of both sexes in American Samoa were more likely to be considered at risk for CVD based on every risk criterion aside from fasting blood glucose.

Clustering of three or more cardiometabolic risk factors, consistent with the ATP definition of the “metabolic syndrome” in adults, was present in 17.9% of the male adolescents and 21.9% of the females from American Samoa (Table 3). Very few adolescents in Samoa exhibited clustering of three or more risk factors (1.1% of males and 2.8% of females). Where clustering of three or more risk factors occurred, the most common clusters were high abdominal circumference, low HDL-cholesterol and high triglycerides (this pattern accounted for 37.3% of all cases), and high abdominal circumference, low HDL-cholesterol and high blood pressure (37.3% of cases). The pattern of clustering did not vary according to sex or location.

The frequency of risk factor clustering varied according to BMI status. BMI was positively correlated with number of cardiometabolic risk factors present after controlling for age as a possible confounder ($r = 0.633$, $P < 0.001$). In both locations, males who were classified as being either normal or overweight were unlikely to exhibit clustering of risk factors. Clustering of three or more risk factors was almost entirely confined to the group classified as being obese. In females, however, clustering occurred at a lower weight status where 16.7% of American Samoan females classified as being overweight exhibited clustering of three or more risk factors, as did 5.9% of females in Samoa.

The odds of having clustering of cardiometabolic risk factors were calculated for those adolescents who were obese, with their normal or overweight peers as the reference category. Clustering showed similar patterns in both locations and hence the sample was combined for the purpose of this analysis. The risk of clustering was signifi-cantly greater in obese adolescents (OR = 18.1, 95% CI: 8.3–39.3) after adjusting for age, sex, location, and household.

DISCUSSION

Modernization, nutrition transition, and cardiometabolic risk factors

The prevalence of cardiometabolic risk factors in these Polynesian populations varies according to location and sex. Adolescents residing in American Samoa had signifi-cantly higher proportions of overweight and obesity than their peers in Samoa, and cardiometabolic risk factors were more prevalent. More American Samoan adolescents (71.8%) met at least one criterion for cardiometabolic risk compared to adolescents in Samoa (54.8%). In both locations, it was males who were most likely to have high cholesterol, high blood pressure, and high fasting blood glucose, whereas females had significantly higher BMI and central obesity as well as a greater number of risk indicators overall.

At the ecological or group level, modernization has been consistently linked with increasing cardiometabolic risk in adults in these locations (Baker and Bindon, 1993; Bindon and Baker, 1985; McGarvey and Baker, 1979). This trend is present in numerous other transitioning societies (Dressler, 2004; Jørgensen et al., 2006; Sorensen et al., 2005). The higher prevalence of cardiometabolic risk in adolescents residing in American Samoa as compared to Samoa is, therefore, likely owing to the difference in stages of economic and social transition between the two locations. For example, gross domestic product per capita in American Samoa in 2002 was $8,668 (US Department of Commerce, 2010) as compared to $1479 in Samoa in the same year (United Nations Statistics Division, 2011). An individual level description of parental socio-economic characteristics in this sample supports group-level differences in modernization. After taking into account household clustering, there are differences in parental education and occupation between locations. In American Samoa, mothers had an average of 12.1 years of education and fathers 11.3 years. In Samoa, years of education were less: 10.0 years for mothers and 9.6 years for fathers. In American Samoa, 40.1% of mothers were unemployed compared with 73.8% in Samoa. Unemployment among fathers was low in both locations (2.3% in American Samoa and 5.2% in Samoa) but occupation differed greatly with only 4.0% of American Samoa fathers farming for a living and the rest in the formal workforce compared to 64.2% of Samoan fathers who were employed in farming or subsistence activities. The next step in our analysis of these data will be to use both these family level measures and other individual behavioural measures, such as dietary intake and physical activity levels, to determine the predictors of cardiometabolic risk factor clustering.

Accompanying the economic transition in the Samoan Islands has been a nutritional transition, a move away from reliance on the locally grown products of subsistence farming toward imported, and often calorie-dense foods (Dibello et al., 2009b; Galanis et al., 1999; Hanna et al., 1986; Seiden et al., 2012), as well as a decline in the formerly widespread subsistence activities of farming and fishing (Greksa et al., 1986; Keighley et al., 2006). The shift toward less physically demanding jobs, in offices and factories, started earlier and has occurred faster in Ameri-can Samoa, as our individual level data suggest. These nutritional transition processes are occurring in a heterogeneous manner throughout low- and middle-income countries and have been extensively described (Amuna and Zotor, 2008; Drewnowski and Popkin, 1997; Popkin, 2004). In Samoa, increased exposure to global trade markets increases the availability of imported foods (Seiden et al., 2012), whereas retaining culturally valued food practises, such as larger portion size for village elders or traditional feasting, ensures their consumption, driving the rising prevalence of overweight and obesity in both locations (FAO/Fiti-Sinclair, 2004). Differences in the pace and timing of these transitions means that the future adiposity levels of adolescents and adults in Samoa may well be foreshadowed by the current high level of adiposity and metabolic conditions in American Samoan family members and throughout society.

Assessments of cardiometabolic risk in adolescents

Adolescence is a period during which many risk behaviors associated with later NCD development may be adopted and the globalization occurring in these nations may have particular implications for this age group. Poor nutritional behaviors, for example, may be associated not only with the increased physiological demand for nutrients and energy associated with dramatic physical growth during this period but also with acculturation to nontraditional attitudes about diet and other lifestyle choices. The level of exposure to, and engagement with, western-style media is increasing in both locations with widespread television and radio ownership (McGarvey, unpublished data) and it is likely that adolescents are more exposed to, and influenced by, mass media promotion of fast food or sedentary behaviors (Strasburger, 2004).

Although cardiometabolic risk factor prevalence is widely reported in adolescents, comparisons between Samoans and others, both Polynesian and otherwise, are problematic. Use of the criteria for elevated levels of these risk factors in adolescents employed here is not yet standard. There has been little follow-up in adolescents identi-fied as at risk to observe later adult morbidity and mortality. Of note, and worthy of the caution for human biologists studying these conditions in adolescents is the issue that insulin resistance is often seen as fundamental or unifying to this clustering of cardiometabolic traits and risk (Reaven, 1988). Yet, insulin concentrations fluctuate substantially across childhood and insulin resistance rises during pubertal development (Bloch and Clemons, 1987; Goran and Gower, 2001).

Although some studies use adult definitions, this research aimed to use more age-relevant cutoff criteria for cardiometabolic risk. The criteria used are linked the National Cholesterol Education Program ATP III criteria for the metabolic syndrome in adults, and were developed using data from adolescents in the Third National Health and Nutrition Examination Survey (NCEP, 2001). The ATP-linked criteria were chosen for this research as opposed to the alternative, International Diabetes Foundation (IDF) criteria (Alberti et al., 2005), as the age- and sex-specific IDF criteria given are based on waist circumference cutoffs recommended for those of European descent and were likely to have less relevance to this Poly-nesian population. The criteria used, while attempting to use age- and sex-specific thresholds, did fail to incorporate a measure of pubertal development, which is known to influence many of these cardiometabolic risk factors. One study reports the prevalence of cardiometabolic risk factor clustering, using the same definitions used here, as being 5.9% in 12- to 19-year olds from the 1990–2004 US National Health and Nutrition Examination Survey, which is substantially lower than the prevalence reported here in American Samoan youth (Mark and Janssen, 2008).

Role of adiposity in adolescent cardiometabolic risk

In both locations, there was a clear relationship between adiposity and cardiometabolic risk. BMI was positively associated with number of risk factors in all groups and in males particularly, clustering of three or more risk factors occurred only in the obese. This finding is consistent with the previous adolescent studies (Csábi et al., 2000; Weiss et al., 2004). The relatively low number of participants in the study, and especially obese participants in Samoa, does, however, limit our ability to interpret these findings as being definitive. A further limitation is the lack of data on pubertal development collected here as ongoing pubertal development is known to influ-ence cholesterol and triglyceride levels as well as the hormonal control of blood glucose (Bertrais et al., 2000; Smith et al., 1988; Tell et al., 1985).

As discussed above, the metabolic syndrome in adults based on clustering of three or more cardiometabolic risk factors has centered on the assumption that insulin resistance is the central mechanism. The present results among an overweight adolescent sample suggest that central obesity plays a key role. Although certain metabolic abnormalities, such as increases in blood pressure, occur relatively quickly with increased adiposity, there is a delay between rise in adiposity and change in lipid levels and a longer delay for changes in insulin resistance and glucose tolerance. This may be even more pronounced among adolescents owing to the dynamic pubertal and physical growth and developmental processes. In our study sample, we assume that the adolescents in American Samoa, who exhibit more of these risk factors, are likely to have been overweight for a longer amount of time than their Samoan peers. Future research in childhood and adolescence should focus on the early development of insulin resistance, using such biomarkers as adiponectin (Dibello et al., 2009a) or indices such as HOMA-IR (Cutfield et al., 2003).

CONCLUSIONS

Whether reporting the “metabolic syndrome” or cardio-metabolic risk factor clustering is clinically relevant in the adolescent population remains unclear. Further studies are necessary to address the degree of further CVD risk with which clustering of three or more risk factors is associated in this age group relative to the existence of a single risk biomarker. The development of population-specific cutoffs and weighting of diagnostic criteria based on their contribution to cardiovascular risk are both necessary if risk factor clustering is to be used as a screening tool. Perhaps, the more important message here is that even the presence of one or more risk factors in this young population should be a cause for concern.

The rising NCD prevalence worldwide has obvious implications, both for the affected individuals and the wider healthcare community. Earlier onset of NCDs and their associated disorders expose individuals to increased healthcare costs over a lifetime, disability, and lack of income, extending the poverty which, in this setting, likely contributed to the development of disease. Developing countries face the challenge of adapting healthcare systems, traditionally built to manage episodic infectious disease, to cope with the demands and costs of chronic care, while operating within financial limitations and with a poorly equipped health workforce. Therefore, it is important to focus on early detection and prevention of NCDs alongside lifelong management.

A comprehensive public health response in the Samoan islands must take into account the rising prevalence of cardiometabolic risk factors in the adolescent population. The suggestion here is that these risk factors are associated with the accumulation of central adiposity and consequent obesity. Although there is no evidence among Samo-ans regarding structural and behavioural interventions to prevent and reverse obesity, screening targeted at adolescents in the modernizing Samoan Islands should be conducted to identify those at risk so that medical therapies may begin using existing standards of care. The development of adolescent interventions for obesity and other NCDs risk factors among ethnic minorities remains a challenge. Our next analysis of these data focusing on family and individual behavioural characteristics associated with NCD clustering risk factors may help address this need for Samoans.

Acknowledgments

Contract grant sponsor: The National Institutes of Health (NIH); Contract grant numbers: DK59642, L093093.

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TABLE 1

Sample characteristics

	American Samoa		**Samoa**	
	Male (Mean [SD])	**Female (Mean [SD])**	**Male (Mean [SD])**	**Female (Mean [SD])**
N	123	114	90	109
Age (years)	14.90 (1.9)	14.68 (1.8)	14.76 (1.8)	14.83 (1.8)
BMI (kg/m^2)	25.85 (6.9)	28.44 (7.4)**	21.05 (3.2)‡	23.04 (3.8)**,‡
Abdominal circumference (cm)	87.22 (16.1)	88.71 (14.2)**	74.23 (8.2)‡	79.25 (10.1)**,‡
Triglycerides (mmol/L)	1.34 (1.4)	1.12 (0.5)	0.83 (0.3)†	0.96 (0.4)*,†
HDL-cholesterol (mmol/L)	1.07 (0.3)	1.10 (0.2)	1.28 (0.3)‡	1.30 (0.3)‡
SBP (mm Hg)	113.43 (12.6)	110.75 (10.9)**	110.78 (10.6)‡	107.77 (9.1)**,‡
DBP (mm Hg)	72.59 (10.7)	71.49 (9.7)**	68.31 (8.7)‡	70.90 (6.8)**,‡
Fasting glucose (mmol/L)	4.53 (0.6)	4.49 (0.6)	4.70 (0.5)	4.73 (0.4)‡
BMI classification				
Normal (*n* [%])	58 (47.2)	31 (27.2)	71 (78.9)	68 (62.4)
Overweight (*n* [%])	20 (16.3)	42 (36.8)	17 (18.9)	34 (31.2)
Obese (*n* [%])	45 (36.6)	41 (36.0)	2 (2.2)	7 (6.4)

ANCOVA between sex (within location) with age as a covariate.

$^{*}P < 0.05$,

$^{**}P < 0.01$.

ANCOVA between location (within sex) with age as a covariate.

$^{\dagger}P < 0.05$,

$^{\ddagger}P < 0.01$.

TABLE 2

Number of Samoan adolescents considered at risk for cardiovascular disease based on a single cardiometabolic risk criterion[a]

	American Samoa				Samoa			
	Male (n = 123)		**Female (n = 114)**		**Male (n = 90)**		**Female (n 109)**	
	Normal N (%)	**At risk N (%)**	**Normal N (%)**	**At risk N (%)**	**Normal N (%)**	**At risk N (%)**	**Normal N (%)**	**At risk N (%)**
Abdominal circumference (cm)[b]	90 (73.2)	33 (26.8)	47 (41.2)	67 (58.8)	89 (98.9)	1 (1.1)**	78 (71.6)	31 (28.4)**
Triglycerides (mmol/L)[c]	100 (81.3)	23 (18.7)	94 (82.5)	20 (17.5)	87 (96.7)	3 (3.3)**	101 (92.7)	8 (7.3)**
HDL-cholesterol (mmol/L)[d]	51 (41.5)	72 (58.5)	25 (21.9)	89 (78.1)	66 (73.3)	24 (26.7)**	59 (54.1)	50 (45.9)**
SBP (mmHg)[e]	102 (82.9)	21 (17.1)	102 (89.5)	12 (10.5)	81 (90.0)	9 (10.0)*	105 (96.3)	4 (3.7)**
DBP (mmHg)[f]	93 (75.6)	30 (24.4)	102 (89.5)	12 (10.5)	79 (87.8)	11 (12.2)*	106 (97.2)	3 (2.8)**
Fasting glucose (mmol/L)[g]	120 (97.6)	3 (2.4)	112 (98.2)	2 (1.8)	87 (96.7)	3 (3.3)	107 (98.2)	2 (1.8)

[a] χ^2 tests between locations (within sex).

* $P < 0.05$,

** $P < 0.01$.

[b] Abdominal circumference ≥92nd percentile (males), ≥72nd percentile (females).

[c] Triglycerides ≥89th percentile.

[d] HDL-cholesterol ≤26th percentile (males), ≤43rd percentile (females).

[e] SBP ≥92nd percentile (males), ≥93rd percentile (females).

[f] DBP ≥97th percentile (males), ≥99th percentile (females).

[g] Fasting glucose ≥5.6 mmol/L.

TABLE 3

Clustering of cardiometabolic risk factors in Samoan adolescents according to BMI category

	American Samoa				Samoa			
	Male (*n* = 123)		**Female (*n* = 114)**		**Male (*n* = 90)**		**Female (*n* = 109)**	
Number of risk factors	**<3 *N* (%)**	**≥3 *N* (%)**	**<3 *N* (%)**	**≥3 *N* (%)**	**<3 *N* (%)**	**≥3 *N* (%)**	**<3 *N* (%)**	**≥3 *N* (%)**
Normal	57 (98.3)	1 (1.7)	31 (100.0)	0 (0.0)	71 (100.0)	0 (0.0)	68 (100.0)	0 (0.0)
Overweight	20 (100.0)	0 (0.0)	35 (83.3)	7 (16.7)	17 (100.0)	0 (0.0)	32 (94.1)	2 (5.9)
Obese	24 (53.3)	21 (46.7)	23 (56.1)	18 (43.9)	1 (50.0)	1 (50.0)	6 (85.7)	1 (14.3)