OBESITY AND RELATED SERIOLOGICAL VARIABLES IN A MIGRANT SAMOAN POPULATION

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ABSTRACT

Human adaptability is a major focal point of anthropological inquiry and the physical changes resulting in response to a new environment are an important aspect of the process of human adaptability. Obesity and elevated blood pressure are two examples of these physical changes. High levels of obesity are relatively recent occurrences in the evolution of mankind and in modern times, obesity, blood pressures and serum lipids tend to be more elevated in Western, urbanized populations, including several Westernized Polynesian societies.

The adverse effects of associations between obesity, blood pressure and certain biochemical variables have long been recognized and studied. High levels of obesity have been found to produce numerous adverse health effects and have been implicated in elevated blood pressures and serum lipids. Obesity is also associated with cardiovascular disease, as well as being a risk factor in coronary heart disease, a major health problem in Western industrialized societies.

A group of Samoan migrants residing on the North Shore of Oahu provided the opportunity to measure obesity, blood pressure and serum lipids, and their relationships to the length of residence in the Westernized environment. Weights and blood pressures were elevated and similar to those observed in other Westernized Polynesians. However, choles-

terol and plasma sodium levels were lower than anticipated. A modification in the renin-angiotensin-aldosterone system was suggested as promoting the low sodium values and perhaps influencing blood pressures. Weight and biacromial diameter also had significant relationships to blood pressure. Length of residence in Hawaii did not have a significant effect on blood pressures, weights or serum lipids. It was proposed that the subject population may not have yet resided a sufficient time on Oahu for a significant relationship to occur.

Levels of acquired weight were examined through the use of skinfold measurements. Acquired weight categories were based on the size of the subscapular and triceps skinfolds which measured trunkal adipose tissue and were thought to represent acquired fat. The categories appeared useful in identifying individuals with elevated blood pressures and cholesterol values. It appeared that higher innate obesity, as well as acquired obesity, may influence these values. Also, women were found to attain higher levels of obesity than were males. The statistical evaluation of acquired weight categories was disappointing, but would probably improve with a larger sample size.

TABLE OF CONTENTS

TABLE OF CONTENTS, cont'd.

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

GENERAL INTRODUCTION

This thesis is an attempt to examine some of the biological aspects of obesity among a migrant Samoan population on the North Shore of Oahu. The subjects were surveyed to obtain blood pressures and several anthropometrical measurements. In addition, blood samples were obtained and several biochemical variables were assayed, including cholesterol and triglycerides. The relationships between obesity and blood pressures and serum lipids will be discussed, with attempts at identifying individuals with high values and effectuating comparisons with other modern Polynesian and acculturated groups.

The adverse health effects of associations between obesity, blood pressure and certain biochemical variables have long been recognized and studied (Kannel and Dawber, 1973; Miall, Bell and Lovell, 1968; Albrink and Meigs, 1965). Particular emphasis has been placed on elevated blood pressure accompanying obesity. Obesity and high blood pressure along with elevated serum lipids have been implicated in various conditions, such as coronary heart disease. In this study, attempts will be made to ascertain associations between these variables, as well as to observe any corresponding sexual differences and age trends.

EVOLUTIONARY ASPECTS OF OBESITY

In evolutionary terms, obesity is a relatively recent phenomenon. If a major portion of human existence has been spent in a hunting and gathering economy with associated feast or famine conditions, the lower mean caloric intake and the greater physical activity of this lifestyle would have made obesity rare (Neel, 1962). The !Kung Bushmen have a hunting and gathering economy similar to that of early man. They maintain no surplus of food, so that daily subsistance activity must be maintained throughout the entire year. Still, they are able to obtain an adequate diet, averaging 2140 calories and 93.1 grams of protein per day. While this is adequate, it allows little excess for fat accumulation (Lee, 1968). In circumstances where higher food consumption is possible, groups which expect regular periods of food scarcity may view a certain amount of obesity as beneficial (Mayer, 1973). It has been suggested that during famine, stores of adipose tissue may have been advantageous, allowing individuals to survive until food was once more available. More recently, excess food consumption may have promoted high levels of obesity which can be disadvantageous. Thus, obesity and variances in obesity levels are aspects of human variability which are of interest to physical anthropologists. Obesity is also a condition which has shown to produce disadvantageous consequences.

ADVERSE EFFECTS OF OBESITY

Obesity is related to many health problems. It is an aggrevating, related or etiological factor in disorders of lipid metabolism, diabetes and gout (Hollister, Overall and Snow, 1967). Similarly, overweight conditions also appear to be related to gallbladder disease and arthritis (Gordon and Kannel, 1973). Obesity also increases pressure on joints and decreases mobility. Increased weight on the chest wall can make breathing more difficult, and hence obesity can lead to problems in keeping the body properly oxygenated (Mayer, 1973).

Obesity is also associated with cardiovascular diseases as well as a risk factor in coronary heart disease, a major health problem in industrialized societies. In addition, it is associated with other risk factors such as elevated plasma lipids, cholesterol, and hypertension (Annonymous, 1972). In the Framingham, Massachusetts population, it was found that existing hypertension was related to relative weight, an index of obesity. Initially normotensive, obese subjects subsequently developed hypertensive cardiovascular disease at an increased rate over those of lower relative weight (Kannel and Dawber, 1972). The converse is also indicated in a study of Israeli hypertensive patients. A significant correlation was reported for reduction of relative weight and reduction in blood pressure. This was observed in both sexes, all age groups and among the moderate as well as very obese subjects (Reisin et al, 1978).

While high levels of obesity are associated with major health problems, one still cannot assign precise risks to health for moderate obesity. However, obesity in general is associated with ischemic heart disease, osteoarthiritis, postoperative complications, poor obstetric performance, lack of physical fitness and above certain indefinite limits, is likely to reduce life expectancy (Annonymous, 1977).

MEASUREMENT OF OBESITY

The term "obesity" refers to excessive adipose tissue. The human body is composed of fat, bone, muscle, various other tissues and fluids, but body fat appears to be the most variable compartment (Mayer, 1973; Seltzer et al, 1970). In "normal" adults of a given height, a large part of differences in body weight is due to adipose tissue, although other compartments may also vary (Brozek, 1961).

Obtaining the best measure of obesity without influence from its confounding factors is important. Several methods have been used, the most popular being relative body weight. Relative weight is expressed as the percent of actual weight as related to a standard weight which may be based upon one of several standards. Body weight for height and age of a general population, body weight of a particular population, body weight of the study population and average weights of some actuarial study or the "ideal" or "desireable" weights of the Metropolitan Life Insurance Company have been used (Seltzer et al, 1970). Values over 100 are used to indicate overweight conditions. Relative weight, however, does not appear to be a good predictor of relative obesity. In a study of adult males, relative weight was demonstrated to be a poor measure of obesity when the triceps skinfold was used for comparison. Relative weights were arranged in five-unit categories which ranged from less than 84 to 125 and above. Even the highest relative body weight category was a poor descriminator of obesity. Only 22 percent of those with the highest relative weight value of 125 or above were still considered obese if a triceps skinfold of 23 mm or more was used in defining obesity (Seltzer et al, 1970).

As an alternative to relative weight, Quetelet's index, (weight/height^2) x 100, may be a better measure of obesity. Evans and Prior (1969) believe this to be a satisfactory index of overweight within genetically homogeneous groups, such as Polynesians, although they caution that it may be misleading in comparisons between different groups because of biacromial differences. Tyroler, Hayden and Hames (1975) have reported this to be the index least correlated with height and most correlated with independent measures of obesity. This index can therefore be employed in obtaining obesity levels which can be compared to those determined on the basis of skinfold measurements.

Many investigators believe that skinfolds are a more direct measure of obesity than relative weight (Kannel and Dawber, 1973; Montoye, Epstein and Kjelsberg, 1966). It has been demonstrated that skinfolds correlate well with subcutaneous fat thickness at the same sites when measured by surgical incision and x-ray (Montoye, Esptein and Kjelsberg, 1965). Skinfolds also have the advantages of rapidity of measurement and simplicity of interpretation (Brozek et al, 1963).

While a variety of skinfolds have been used to estimate body fat, the triceps site is favored by most. Seltzer and Mayer (1967) list several reasons for preferring the triceps skinfold as the best criterion of obesity. Among the obese, it has the highest correlation with body density values, is the easiest to measure, gives highly reproduceable results, is the least incovenient and embarassing and from clinical observations, appears to be the most representative of total body fat. They also report no advantage in using any other skinfold in addition to the triceps (Seltzer and Mayer, 1965). Several other studies also confirm the ability of the triceps skinfold to predict body fat. It exhibited the highest correlation value of several skinfolds with body density in samples of college women (Katch and Michael, 1968), obese adolescent girls (Seltzer, Goldman and Mayer, 1965), male soldiers (Pascale et at, 1956) and college men and middle aged men (Brozek and keys, 1951). Correlations with body density ranged from

.68 to .82.

The usefulness of the triceps skinfold site as an indicator of adiposity and for establishing standards of obesity levels is exemplified by Garn, Clarke and Guire's study in which obesity is defined entirely in terms of this particular fat fold. Measurements were obtained for several thousand subjects, with an obese groups being defined as one above the 85th percentile for the triceps site by age and sex (Garn, Clark and Guire, 1975). In a study of male hospital patients, the obese were defined as having triceps skinfolds of 26 mm or greater and the lean as having values of 17 mm or less (Hollister, 1967). Thus, while Quetelet's index may give a more general estimate of obesity, skinfold values may be utilized to gain a more refined estimate. Both of these methods are preferred over the use of relative weight.

DEPOSITION OF ADIPOSE TISSUE

The amount of individual body fat varies with age and sex, as indicated by numerous studies. Kannel and Dawber (1973), for example, reported that after musculoskeletal growth is complete, changes in weight primarily reflect changes in the size of the adipose tissue deposit. Similarly, after age nine, females show a higher percentage of fat in their total body weight than do males. Both sexes exhibit an increase in obesity with age, the amount increasing at a faster rate in males than in females. At all ages though, women are more obese on the average than are men (Chiang, Perlman and Epstein, 1969).

Fat also appears to be deposited preferentially in certain body areas, particularly on the trunk. However, it does not give the appearance of being deposited evenly throughout the connective tissue of the body. Certain regions of the body show more thickening of the fat deposits than do others. Less fat tissue is seen on the hands, feet, ears and nose than on the abdominal wall, buttocks and shoulders. As an illustration of regional adipogenic differences, Wells describes the case of an abdominal skin graft being placed on a woman's hand, which in later years thickened as she gained weight and eventually resembled a boxing glove (Wells, 1940). Bjurulf (1959) demonstrated a higher positive correlation between the fat cell count of two regions of the trunk than between the count of the trunk and those of the extremities. Therefore, fat deposits appear to be larger in areas of the trunk, and in addition, excess weight added in adult life appears to be concentrated on the trunk.

In a 1965 study, Albrink and Meigs demonstrated that weight gain after age 25 correlated significantly with the costal and subscapular skinfolds and to a less extent with the triceps skinfold, but not with the ulnar skinfold (Albrink and Meigs, 1965). In an earlier study, they proposed that the ulnar skinfold may be used to represent inherited obesity, while the subscapular or costal skinfolds might represent acquired obesity, innate obesity or both. Acquired obesity, or weight gained after age 25 and added on to an innate level of obesity, was seen as resulting from overeating, underactivity after maturity and as being largely an obesity of the trunk (Albrink and Meigs, 1964). Thus, the ulnar skinfold, measuring fat on an extremity, may be used to define inherited obesity. Acquired adiposity, which has been shown to localize on the trunk, is measured by more central skinfolds; the costal, subscapular and triceps. Although the studies by Albrink and Meigs (1964, 1965) were the only studies found to be using these particular methods, the technique based on skinfolds appears promising for determining individuals who have acquired the most adipose tissue above their innate body size.

RELATIONSHIPS BETWEEN OBESITY AND SERUM LIPIDS

Acquired weight in adult life appears related to increased serum lipid levels. Triglyceride levels of obese subjects were shown to be somewhat higher than those in nonobese subjects at all ages in a study by Waxler and Craig (1964). Among male hospital patients, Hollister (1967) demonstrated that body fat correlated significantly with serum triglyceride levels and to a lesser degree with serum cholesterol. Levels of triglycerides and cholesterol were also significantly correlated. Elevated serum triglycerides are often, though not always, associated with elevated serum cholesterol (Annonymous, 1972).

Cholesterol values also appear related to obesity, as shown by Garcia-Palmieri et al (1972) who indicated relative weight to be a determinant of serum cholesterol levels among Puerto Ricans. In addition, an interesting result of the Tecumseh study was that at ages 10-19, persons already having higher serum cholesterol levels generally had larger skinfolds. Beyond age 50, little relationship was found between cholesterol and skinfolds (Montoye, Epstein and Kjelsberg, 1966).

Change in weight over time has been demonstrated as having a strong positive correlation with cholesterol levels (Ashley and Kannel, 1974; Albrink, Meigs and Granoff, 1963; Gordon and Kannel, 1973). Ashley and Kannel (1974) discussed the relative weights of the Framinham study, or the ratio of body weight to median weight by sex-height group at first examination. A 20-unit positive change in this ratio would indicate that the subject added a large amount of weight. In examining changes in relative weight, a change of 11.3 mg/dl of cholesterol in men and 6.3 mg/dl cholesterol in women with each 10-unit change in relative weight was observed. Albrink, Meigs and Granoff (1963) also reported that cholesterol levels were higher in those who gained weight as adults, but a stronger relationship was found between weight gain and triglycerides. In their sample of factory workers, a group identified as being weight stable since age 25 had a mean serum triglyceride level of 4.6 mEq/l, while those who had gained more than 4.5 kg since age 25 had a mean serum triglyceride level of 7.1 mEq/l. The lowest levels were found in those who were the leanest and had a negative family history for coronary artery disease or diabetes. Those who had gained weight exhibited markedly higher triglyceride levels regardless of family history.

In a later study, Albrink and Meigs (1965) concluded that change in weight exercised a more important effect on triglyceride level than did the degree of obesity. The very obese had higher levels than did the very lean, but it was noted that the very obese appeared to tolerate weight gain with less increase in triglycerides than did moderately obese weight-gainers. By dividing the male subjects into groups on the basis of ulnar skinfolds, it was demonstrated that men with the lowest ulnar skinfolds had the greatest rise in serum triglycerides with increased obesity of the trunk. Therefore, triglyceride levels were believed to be related more to acquired obesity than to innate obesity. Men with heavier forearms, indicating higher innate obesity, could attain higher obesity of the trunk without abnormal triglyceride levels, but upon becoming sufficiently obese, their triglyceride levels also rose. A possible explanation offered by the authors was that hyperglyceridemia may be a manifestation of overloaded fat cells, rather than too many fat cells, which then interfere with their metabolic functioning. Thus, both obesity and changes in the level of obesity appear related to serum lipid levels. In addition, categories based on skinfolds may be established to contrast inherited and acquired obesity and used to examine lipid values in relation to these categories.

Hemoglobin concentration may also be related to obesity. Garn, Clarke and Guire (1975) found higher hemoglobin levels in obese adults, along with a tendency toward relative polycythemia. In the Framingham study, a relationship between blood pressure, obesity and blood hemoglobin levels was also noted (Kannel and Dawber, 1973).

RELATIONSHIPS BETWEEN OBESITY AND BLOOD PRESSURE

Several studies have revealed that obese subjects also show a tendency toward elevated blood pressures. Among alcohol addicts and control subjects in India, Shah found that increased systolic and diastolic blood pressures increased with elevated weight regardless of age (Shah,1967). In a survey of hypertension and obesity, Chiang, Perlman and Epstein (1969) concluded that the evidence overwhelmingly supports a positive correlation between blood pressure and weight. Furthermore, it was noted that obese young adults or those becoming obese in the following decades had a greater risk of developing sustained hypertension than those of normal or lower weight who remained lean. Taylor's (1967) "underweight-lean" class of railroad workers, based on relative weights and skinfolds, had significantly lower systolic and diastolic pressures. In the discussion section of the same article, Stamler provided data from his study of Chicago gas company employees. He reported that young male adults at or below a ratio of observed weight to desireable weight of less than 1.05, who showed little or no weight gain in later years, had the lowest risk of developing diastolic hypertension. Those above desireable weight as young adults, with a ratio of 1.05-1.14 who showed a weight gain of 1.5 pounds or more per year, had an almost six times higher prevalence rate of hypertension at age 50.

Blood pressure values have been shown to vary in relation to change in weight. Each 10-unit change in Framingham relative weight produced a corresponding change of 6.6 mmHg systolic blood pressure in men and 4.5 mmHg in women (Ashley and Kannel, 1974). A study of American servicemen in the Philippines reported that an increase in blood pressure with age increased standard weight. It was suggested that a 20 percent difference in standard weight might account for a five millimeter difference in mean systolic pressure (Epstein and Eckoff, 1967). In Evans County, an association between both baseline weight and blood pressure levels was documented. Diastolic blood pressures were shown to change four millimeters with a 120 pound change in weight. Overweight subjects, or those having a Quetelet's index value in the upper 12.5 percent of their five-year age-sex specific distribution, and who gained at least ten pounds since the beginning of the study, showed an almost six times greater risk of developing elevated diastolic pressure than those of normal weight who did not gain (Tyroler, Hayden and Hames, 1975). In Wales, it was observed that men who differed in weight by 100 pounds showed a variation of approximately 15 mmHg systolic pressure and 11 mmHg diastolic pressure, while women differing by 100 pounds varied in systolic and diastolic pressures by 20 mmHg and 14 mmHg, respectively. Weight and blood pressure and changes in each showed a positive correlation to those under age 50 (Miall, Bell and Lovell, 1968). A recent study of Israeli hypertensive patients revealed a highly significant positive correlation between reduction in weight and reduction of blood pressures in both sexes and all ages studied. Those subjects on a reducing diet, including some patients receiving medication for hypertension, lost a mean of 10.5 kg, and in 79 out of 81 subjects, systolic and diastolic pressures were reduced by at least eight millimeters of mercury. In the group not on a reducing diet but receiving medication, 65 percent maintained the same blood pressure, while in 27 percent, blood pressures became larger (Reisin et al, 1978).

Data from the Framingham study also indicated a rise in pressure with weight gain, the relationship being more striking in males than in females. Systolic pressures also rose in proportion to the triceps and subscapular skinfolds, with positive correlations being higher in females. In addition, hemoglobin levels exhibited an association with blood pressures. It was shown that those who were obese and had high hemoglobin levels appeared more vulnerable to hypertension (Kannel and Dawber, 1973).

Environmental change also appears to influence blood pressure. According to Cassel (1975), populations with lower blood pressures generally tend to reside in small, cohesive societies which are relatively isolated from more Westernized or industrialized cultures. He further states that several studies have suggested that altered environmental circumstances, such as moving to a more Westernized environment, can affect blood pressures. These effects can operate over decades, rather than generations, to produce change. He also discusses two hypotheses concerning possible environmental factors operating on blood pressure. One concerns physical factors such as disease, amount of calories or physical activities. The other hypothesis stresses psychosocial factors that may lead to repeated autonomic system arousal which would then affect blood pressure levels. This concept of "defense alarm reaction" or arousal leading to essential hypertension was further documented by Henry and Cassel (1969).

Weights may also increase among migrants to a more Westernized environment. For example, weights and blood pressures have been shown to be elevated among Polynesians living in the Westernized environments of Hawaii (Basset et al, 1966), New Zealand (Prior, 1974) and Rarotonga (Hunter, 1962).

The means by which obesity affects blood pressure is still uncertain. Chiang, Perlman and Epstein (1969) proposed that the obese may suffer from hemodynamic and metabolic changes which have an adverse effect on hypertension. They view weight gain as constituting one possible kind of environmental stress, bringing a genetic predisposition toward hypertension into the open. According to Voors et al (1977), the mechanical causal influence on change of blood pressure and change of weight is still a matter of conjecture.

Weight appears to influence blood pressure early in life. A study of Israelis suggested that any effect on blood pressure level due to increased weight is achieved by age 40 (Sive et al, 1970). Lauer et al (1975) believe that the increased prevalence of higher blood pressure levels in children with higher relative weights indicates that the relationship between blood pressure and obesity begins in childhood.

SUMMARY

In summary, elevated blood pressures, serum lipids, obesity and their interrelationships, may operate to produce several adverse effects. In the Framingham study, it was demonstrated that the combination of elevated blood pressure and blood lipids resulted in a serious condition related to atheroma formation. In addition, systolic pressure was a powerful determinant of higher cardiovascular morbidity and mortality at all ages (Kannel and Dawber, 1973). Also among the Framingham subjects, subscapular skinfolds, relative weights and weight gain after 25 were shown to be related to coronary heart disease (Gordon and Kannel, 1973). In addition, it has been proposed that obese hypertensives have a greater risk of coronary heart disease, cerebrovascular disease and mortality than do persons either obese or hypertensive alone (Chiang, Perlman and Epstein, 1969).

Elevated blood pressures and several seriological variables, therefore, have been shown to be detrimental at elevated levels. There appears to be a relationship between obesity, or excessive adipose tissue, and the elevation of these variables. The method of measuring adiposity through skinfold thicknesses, thereby minimizing the confounding factors of body composition, has tended to strengthen these associations. The level of acquired obesity also accentuates detrimental consequences. Those who have added the most excess adipose tissue, feel the effects most strongly. For example, this relationship has been demonstrated by Albrink and Meigs (1965) for triglyceride values. Therefore, the use of high acquired weight categories based on skinfolds appears useful as a means of identifying individuals who have added the most adipose tissue and who may be manifesting elevated levels of the other variables.

Migration to a Westernized environment may also be expected to produce changes in blood pressures. Cassel (1975) noted that effects operating in the new environment may be physical, such as the amount of calories consumed, or psychosocial. That such effects may be operating may be suggested by elevated blood pressures being observed among acculturated Polynesians in New Zealand (Prior, 1974), Hawaii (Basset et al, 1966) and Rarotonga (Hunter, 1962).

Samoan migrants residing on Oahu provide an opportunity to examine obesity. This group was recently investigated by Hanna and Baker (1978). Anthropometrical measurements and blood pressures were obtained from approximately 1100 subjects. In this study, weights and diastolic blood pressures were elevated above those of U.S. Caucasians at all ages. Lower blood pressures were observed among urban Honolulu subjects than among the North Shore rural subjects. In addition, the newest migrants were found to have higher blood pressures than those who had resided in Hawaii over longer periods of time.

The Hanna and Baker study also revealed sexual differences in blood pressure. Among males, age had little relationship to blood pressure, while weight and trunk length showed a significant correlation to blood pressure. Weight was also significantly related to blood pressure among women, as were age, biacromial diameters and biiliocristal diameters. The study indicated that sustained increase in weight among women may be related to increases in blood pressure with age. Furthermore, the study suggested that upper body size, a site of fat deposition in adults, may be related to blood pressure. Thus, the addition of excess adipose tissue in adults may result in elevated blood pressures.

The subjects discussed in this thesis were also used in the Hanna and Baker (1978) study. In addition to the anthropometrical measurements and blood pressures recorded in the Hanna and Baker study, blood samples were also obtained from these same individuals. Approximately 90 percent of the subjects resided in the North Shore area, where higher blood pressures than those of urban Honolulu were observed. In this thesis, this group of individuals will be examined for the possibility of determining age trends in individuals having elevated weights, blood pressures and serum lipids. Attempts will also be made to determine the possibility of any male-female differences in these values.

STATEMENT OF THE PROBLEM

Weight acquired in adulthood appears related to increased serum lipids (Ashley and Kannel, 1974; Albrink, Meigs and Granoff, 1963; Gordon and Kannel, 1973) and blood pressures (Taylor, 1967; Ashley and Kannel, 1974; Tyroler, Hayden and Hames, 1975). One possible method which could be used to determine the amount of acquired weight is to construct categories on the basis of skinfolds, as discussed by Albrink and Meigs (1964). Blood pressures and serum lipids can then be examined in terms of these categories. Therefore,

1. In the Samoan population living on the island of Oahu those individuals with the highest acquired weight gain, as estimated by skinfolds, will also show elevated cholesterol, triglycerides and blood pressure.

In addition, Samoan women characteristically continue weight gain later into adult life than do men and women tend to become more overweight as well (Hanna and Baker, 1978). Thus,

2. In this population, women will show a higher degree of acquired weight gain, as measured by skinfolds, than do men.

Acquired weight has also been shown to relate to increased mortality and morbidity from cardiovascular disease (Kannel and Dawber, 1973). As discussed above, serum lipids and blood pressures appear related to acquired weight and may also constitute health risks (Albrink, Meigs

Granoff, 1963; Annonymous, 1972). Thus,

3. There will be similar age trends observed for weights, skinfolds, blood pressures and serum lipids.

Polynesians have been shown to manifest a tendency toward obesity (Basset et al, 1966; Prior, 1974; Hunter, 1962). The Samoans residing on Oahu are Polynesians and also an obese population (Hanna and Baker, 1978). As previously discussed, changes in surplus food consumption and activity patterns may lead to changes in weight, which also influence blood pressure and serum lipid levels. Samoans living on Oahu would therefore be expected to resemble other acculturated Polynesians in terms of obesity, blood pressure and serum lipids. Thus,

4. The blood pressures, serum cholesterols and weights of Samoan migrants residing on Oahu will be similar to those observed in other acculturated Polynesian populations.

Since change in weights, blood pressures and serum lipids might be expected to respond to change in environment, as discussed by Cassal (1975) and observed among other acculturated Polynesians (Basset et al, 1966; Hunter, 1962),

5. There will be a positive relationship between cholesterol, blood pressure and weight and years of residence in Hawaii.

MATERIALS AND METHODS

The subjects used in this study were participants in a larger study on hypertension in Samoan migrants to Hawaii. Approximately 100 of these subjects agreed to giving blood samples. Blood was obtained from those ages 12 to 74. In total, only 94 subjects could be used in the data analysis, as only this many had all the necessary anthropometrical measurements taken. Subjects were usually measured in their homes, or in certain cases, at the chief's residence, and on one occasion at the Aloha Job Corps Clinic.

Weight was measured on a portable scale, with correction being made for light clothing. Heights, measured without shoes, were taken with an anthropometer. Triceps, ulnar and subscapular skinfolds were obtained from the left side of the body, using a Lange skinfold caliper. Blood pressures were obtained using a mercury manometer. Alternative cuff sizes were employed depending on the circumferance of the subject's arm. Pressures, in the left arm, were measured with the subject seated and after having rested five to ten minutes. Diastolic pressures were recorded with the disappearance of sound. The lowest value for both systolic and diastolic pressures was recorded for each individual.

Blood samples were drawn during the morning hours and the subjects were requested to fast from midnight; however, there was no guarantee of all the subjects being in the desired fasting state. Subsequently, this could affect the interpretation of triglyceride values, but probably none of the other seriological variables. Blood samples were packed in ice and returned to the lab, where they were frozen until used. Values for hematocrits, hemoglobin, osmolarity, sodium and potassium were obtained by other members of the team. Total cholesterol values were determined by using Hycel Stable Cholesterol Reagent for the non-saponification procedure. Readings were taken on the Dow Diagnostest Photoelectric Colorimeter. Triglyceride samples were assayed with the Technicon Auto-Analyzer, using the method based on the work of Kessler and Lederer (1965).

RESULTS

BIOCHEMICAL ASSAYS

Values for the biochemical variables are given in tables 1 and 2 and figure 1. The mean hemoglobin value is 13.80 g/100ml for females and 15.88 g/100ml for males. These results are similar to the average hemoglobin value of 15 g/100ml found among Caucasians (Guyton, 1977). Male values are higher than those for females in each age group. Analysis of variance indicated that hemoglobin values were influenced by sex (p less than 0.01) and perhaps by diastolic pressure ($p \geq 0.056$). Sexual differences were also observed in hematocrit values. The mean female hematocrit reading was 42.73 and the male mean was 47.93. Male values were higher than those for females in each age group, the greatest difference being in the 30-39 and 50-59 age groups. Analysis of variance yielded a significance value of 0.056 due to sexual differences. According to Guyton (1977), the normal male hematocrit reading averages 42 percent, while the female average is 38 percent. Among Hawaiian males on Niihau, Basset et al (1966) reported a value of 53 percent. Thus, hematocrit values in the present sample appear elevated over the normal Caucasian values, but lower among males than the mean for Niihau. For females, the mean serum osmolarity was 284.5 mOsm/l, serum sodium was 129.54 mEq/l and serum potassium was 4.04 mEq/l. Among males, the mean serum osmolarity was 286.2 mOsm/l, serum sodium was

129.24 mEq/l and serum potassium was 4.78 mEq/l. Normal values are 285-295 mOsm/l for serum osmolarity, 137-142 mEq/l for serum sodium and 3.5-5.0 mEq/l for serum potassium (Osol, 1972). Values for these three variables appear to be lower in this sample. The lower sodium values were also reflected in relationships to other variables, as will be discussed in greater detail later.

Serum cholesterol and triglyceride values were found to be significantly correlated ($r = 0.298$). Analysis of variance determined that cholesterol level was affected by age (p less than 0.05) and diastolic blood pressure (p less than 0.05). The mean female cholesterol value was 146.25 mg/100 ml, while for males it was 170.12 mg/100 ml. Male values peak in the 40-49 age group, while female values increase steadily until age 49 when they then decreased slightly. These values are lower than those seen among Atiu-Mitiaroans (Hunter, 1962), Maoris and New Zealand Europeans (Prior, 1974), U.S. adults (Abraham, Johnson and Carroll, 1977) and Tokelauans (Prior et al, 1974). Male values are similar to those of Rarotongan males (Prior et al, 1974; Hunter, 1962), while female values are not as elevated as those recorded for Rarotongan females. Both male and female values, however, are elevated over those seen among the more isolated atoll dwellers of Puka Puka (Prior et al, 1974). Male values are lower than among Minnesotans or Japanese in Hawaii, but higher than those of Japanese in Japan (Keys et al, 1958). The male mean of 170.12 mg% is

Table 1

Mean Hemoglobin, Hematocrit and Sodium Values by Ten Year Age Groups

Age	Hemoglobin (gm/100ml)				Hematocrit				Sodium (mEq/1)			
	M	N	F	N	M	N	F	N	M	N	F	N
10-19	15.38	14	13.70	14	47.00	9	42.11	9	130.88	19	130.07	16
20-29	15.78	8	13.30	8	47.75	8	43.17	6	128.53	10	130.59	9
30-39	16.46	5	13.50	5	49.00	3	42.75	4	128.98	5	127.55	6
40-49	16.23	6	14.84	5	48.33	3	43.50	2	129.06	8	128.20	5
50-59	16.80	6	14.22	4	50.25	4	44.00	1	127.18	6	129.78	4
60-69	14.45	2	--	0	44.00	1	--	0	126.78	4	--	0
70-79	--	0	--	0	--	0	--	0	130.00	1	--	0

M - males

F - females

N - number of subjects

Table 2

Mean Cholesterol and Triglyceride Values by Ten Year Age Groups

Age	Cholesterol (mg/100ml)				Triglycerides (mg/100ml)				(mEq/l)			
	M	N	F	N	M	N	F	N	M	N	F	N
10-19	144.55	19	141.01	16	73.57	16	83.44	16	2.49	16	2.83	16
20-29	158.04	10	170.78	9	133.45	10	70.18	9	4.52	10	2.38	9
30-39	190.76	5	179.38	6	144.62	5	82.77	6	4.90	5	2.81	6
40-49	216.78	8	209.20	5	130.63	7	107.14	5	4.43	7	3.63	5
50-59	181.35	6	203.08	4	101.34	5	108.37	4	3.44	5	6.11	4
60-69	194.02	4	--	0	100.08	4	--	0	3.39	4	--	0
70-79	131.20	1	--	0	36.80	1	--	0	1.25	1	--	0

M - males

F - females

N - number of subjects

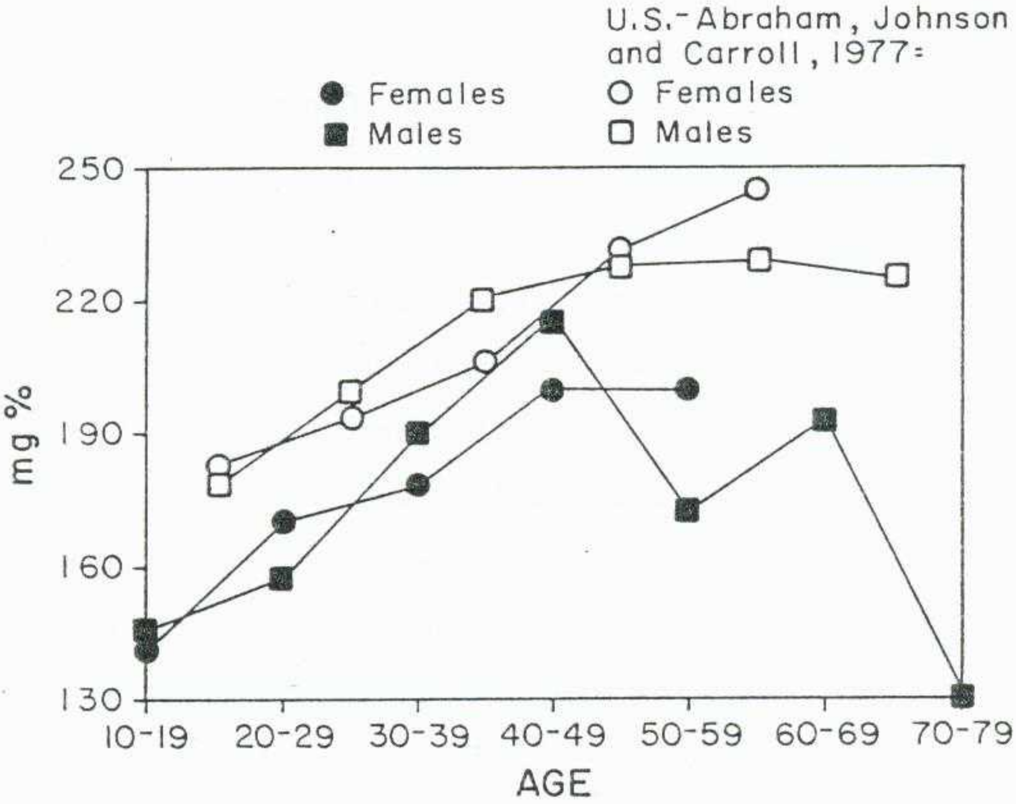

Figure I. Comparative Serum Cholesterol Levels of Samoan and U.S. Subjects lower than those reported for two samples of Hawaiian men who had means of 211 mg% (Healey et al, 1966) and 213.1 mg% (Basset et al, 1966). Also, this value is more similar to that recorded by Garcia-Palmieri et al (1972) for rural males in Puerto Rico (195 mg%) than that recorded for urban Puerto Rican males (206 mg%). The female values, though somewhat lower, were more similar to those determined for normal weight American women than for obese American women (Waxler and Craig, 1964).

Mean nonfasting triglyceride levels were 93.01 mg% for females and 106.10 mg% for males. Nonfasting triglycerides were also recorded for the male sample from Niihau (Basset et al, 1977); however, the Niihau mean of 231 mg% was much higher and the mean values were elevated at each age group. According to Brown, Hedin and Doyle (1963), a nonfasting triglyceride level exceeding 9.0 mEq/l (265.5 mg%) is probably abnormal. None of the mean values by age group in this sample approximate this value.

BLOOD PRESSURES

Mean systolic and diastolic blood pressures are shown in table 3 and figures 2 and 3. Mean values are 127.5 mmHg systolic and 82.0 mmHg diastolic for females, and 136.9 mmHg systolic and 88.3 mmHg diastolic for males. Female systolic pressures are higher than those of the males in the 30-39 and 40-49 age groups, while female diastolic blood pressures are higher than those for males only in the 40-49 age group.

The peaks for male systolic and diastolic pressures are in the 50-59 age group. Female systolic and diastolic pressures increase until age 49 and then decrease slightly. The male pattern contrasts with that found for the larger sample from which these subjects were drawn. In the total sample, male blood pressures showed no increase after the twenties. Female blood pressures plateaued in the thirties and then increased again in the sixties (Hanna and Baker, 1978). Male systolic pressures are higher than those among Rarotongan males (Hunter, 1962), except those in the 40-49 and 70-79 age groups, and much higher than Atiu-Mitiaro males, with the exception of those in the 70-79 age group. These same patterns are also true of diastolic pressure. Female systolic pressures are higher than in Roratongan females, except in the 40-49 age group, and Atiu-Mitiaro females in the 50-59 age group. Both male and female blood pressures are highly elevated in comparison with those recorded for Puka Pukans (Prior , 1974). Values are generally elevated over those for Rarotongans presented in the same study; however, female diastolic pressure is very similar to that of Rarotongan females. In every age group, both sexes also have pressures elevated above those reported for Tokelauans (Prior et al, 1974).

Correlation coefficients for blood pressures and several of the other variables are recorded in table 4. Male systolic pressures were found to have a significant positive correlation with age, weight, the subscapular skinfold and the ulnar skinfold. A significant negative correlation was obtained with sodium. Female systolic pressures exhibited significant positive correlations with cholesterol, age, weight and the triceps, subscapular and ulnar skinfolds. Diastolic pressures were significantly positively correlated to more of the biochemical variables than were systolic pressures. Significant positive correlations were demonstrated between male diastolic pressures and hemoglobin, hematocrits, cholesterol, triglycerides, age, weight, subscapular skinfold and Quetelet's index. A significant negative correlation was obtained for sodium. The greater number of significant positive correlations was also true for female diastolic pressures. These were found for hemoglobin, osmolarity, potassium, cholesterol, triglycerides, age, weight, triceps, subscapular and ulnar skinfolds and Quetelet's index. The positive significant relationship between weight and blood pressure is also supported by results from a study of Samoans in both Hawaii and Samoa (McGarvey and Baker, 1978). In the larger Samoan sample on Oahu (Hanna and Baker, 1978), weight exhibited a significant relationship to blood pressure among males, while in females, age and weight were important. Also, the biacromial and biiliocristal diameters were related to blood pressure among females. In the present sample, biacromial diameter showed a significant positive correlation with diastolic pressure among males ($r = 0.457$) and females ($r = 0.466$).

Table 3

Mean Systolic and Diastolic Blood Pressures
by Ten Year Age Groups

Age	Systolic (mmHg)				Diastolic (mmHg)			
	M	N	F	N	M	N	F	N
10-19	123.06	17	111.31	16	80.00	17	73.75	16
20-29	147.10	10	120.44	9	83.25	8	81.56	9
30-39	142.40	5	150.50	6	98.40	5	81.20	5
40-49	132.86	7	153.00	4	93.14	7	100.50	4
50-59	154.33	6	148.00	4	101.67	6	98.50	4
60-69	149.50	4	--	0	97.50	4	--	0
70-79	116.00	1	--	0	70.00	1	--	0

M = males

F = females

N = number of subjects

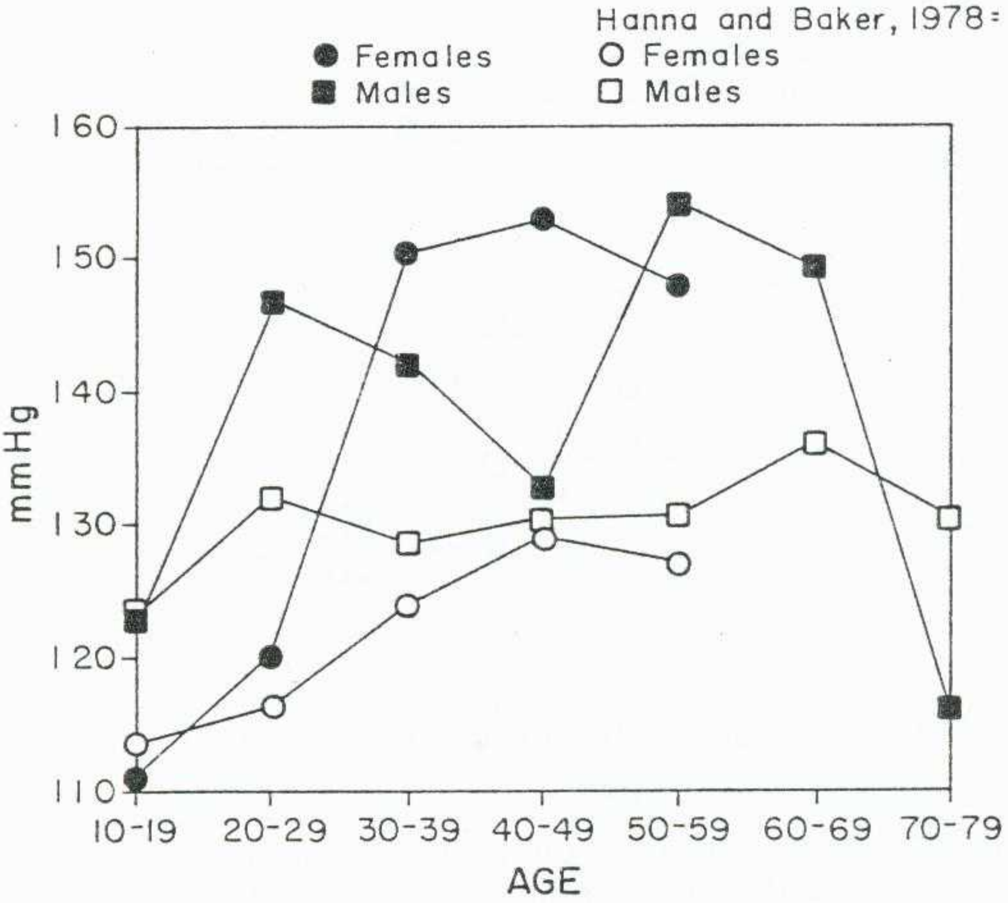

Figure 2. Comparative Systolic Blood Pressures of Samoans in Hawaii

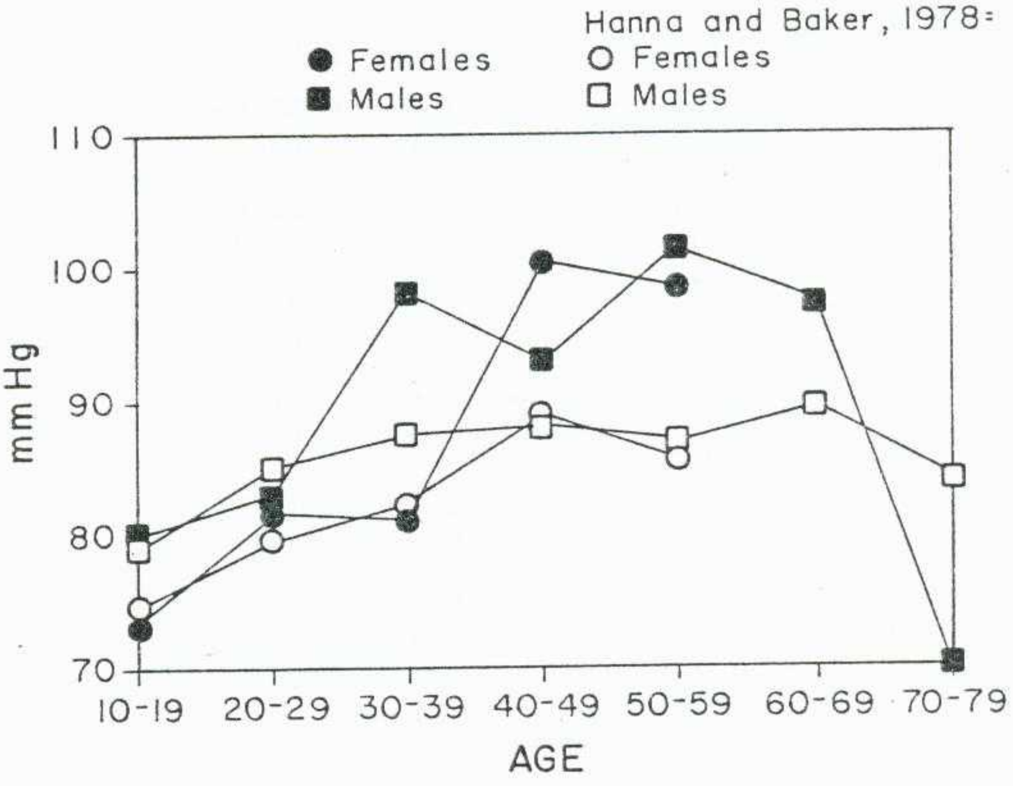

Figure 3. Comparative Diastolic Blood Pressures of Samoans in Hawaii

Table 4

Correlation Coefficients for Systolic and Diastolic Blood Pressures and Related Variables

	Systolic Pressure		Diastolic Pressure	
	M	F	M	F
Hemoglobin (Number)	0.02 (39)	0.20 (34)	0.45** (37)	0.46** (33)
Osmolarity	0.07 (50)	0.16 (36)	0.03 (48)	0.32* (35)
Sodium	-0.38** (50)	-0.07 (38)	-0.30* (48)	0.08 (37)
Potassium	-0.02 (50)	0.10 (38)	0.01 (48)	0.41** (37)
Hematocrits	0.26 (28)	-0.20 (22)	0.36* (26)	0.31 (21)
Cholesterol	0.13 (50)	0.46** (38)	0.43** (48)	0.48** (37)
Triglycerides	0.20 (45)	0.22 (38)	0.37** (43)	0.28* (37)
Age	0.26* (50)	0.56** (38)	0.47** (48)	0.64** (37)

M = males

F = females

* = p less than .05

** = p less than .01

Table 4. (Continued) Correlation Coefficients for Systolic and Diastolic Blood Pressures and Related Variables

	Systolic Pressure		Diastolic Pressure	
	M	F	M	F
Weight	0.49** (49)	0.33** (37)	0.44** (47)	0.58** (36)
Triceps Skinfold	0.03 (50)	0.72** (38)	0.01 (48)	0.54** (37)
Subscapular Skinfold	0.37** (50)	0.57** (37)	0.30** (48)	0.32* (36)
Ulnar Skinfold	0.55** (50)	0.68** (38)	0.13 (48)	0.39** (37)
Quetelet's Index	0.01	-0.10	0.50**	0.54**

HEIGHTS AND WEIGHTS

Mean heights and weights are given in table 5 and weights are also plotted in figure 4. Mean female height is 180.8 cm and weight is 82.5 kg. Mean male height is 214.9 cm and weight is 89.47 kg. Male weights are higher than those of females up to the 30-39 year age group. Female weights increase steadily until the 40-49 year age group and then increase only slightly. Male weights exhibit a different pattern, with values decreasing in the 40-49 year age group and again in the 70-79 year age group. A sustained weight increase by females was also noted among the larger sample (Hanner and Baker, 1978). Mean male weight is close to that recorded for Niihau males, their average value being 195 lbs. (88.64 kg) (Basset et al, 1966). The mean weight for another group of Hawaiian males was 85 kg (Healey et al, 1966). Weights appear elevated over those reported for Tokelauans (Prior et al, 1974), New Zealand Maoris (Prior, 1974), Rarotongans and subjects from Atiu-Mitiaro (Hunter, 1962), urban Zulus (Abramson et al, 1961) and above the 80th percentile for weights of the Tecumseh population (Montoye, Epstein and Kjelsberg, 1965).

As shown in table 6, significant positive correlations were demonstrated between male weights and age, systolic and diastolic pressures and the triceps and subscapular skinfolds. A significant negative correlation was found with sodium. Positive significant correlations were observed between female weights and osmolarity, cholesterol, systolic and diastolic pressures and the triceps and subscapular skinfolds.

In comparing figures 1 through 4, there appears to be several similar trends. For example, male systolic and diastolic pressures and weights decline in the 40-49 and in the 70-79 year age groups. There is also a trend toward rising blood pressures along with rising weights among females. Cholesterol also appears to rise with weight among females. Among males, cholesterol values drop in the 50-59 and 70-79 year age groups.

QUETELET'S INDEX

In table 5, values are listed for Quetelet's index. These figures tend to parallel the variations observed for weight with increasing age. Correlation coefficients are also given for Quetelet's index in table 6. Among males, the index was significantly positively correlated with cholesterol and age. Significant negative correlations appeared with sodium, potassium, height and the ulnar skinfold. For females, the index also showed a significant negative correlation with height, while a significant positive correlation was found with age. Negative correlations between height and the index are essential since the index was employed to measure weight while minimizing the influence from height.

Table 5

Mean Weights, Heights and Values for Quetelet's Index
by Ten Year Age Groups

Age	Weight (kg)				Height (cm)				Quetelet's Index[a]			
	M	N	F	N	M	N	F	N	M	N	F	N
10-19	82.02	19	66.65	16	239.66	19	152.95	16	0.24	19	0.26	15
20-29	87.76	10	80.47	9	229.59	10	161.91	9	0.26	10	0.31	9
30-39	98.52	5	93.77	6	173.06	5	240.33	6	0.33	5	0.31	6
40-49	98.80	8	108.08	5	228.35	8	246.72	5	0.30	8	0.35	5
50-59	98.12	5	108.53	3	169.23	6	162.70	4	0.34	5	0.41	3
60-69	98.80	4	--	0	163.90	4	--	0	0.37	4	--	0
70-79	79.60	1	--	0	176.70	1	--	0	0.25	1	--	0

a = (weight/height^2) X 100
M = males
F = females
N = number of subjects

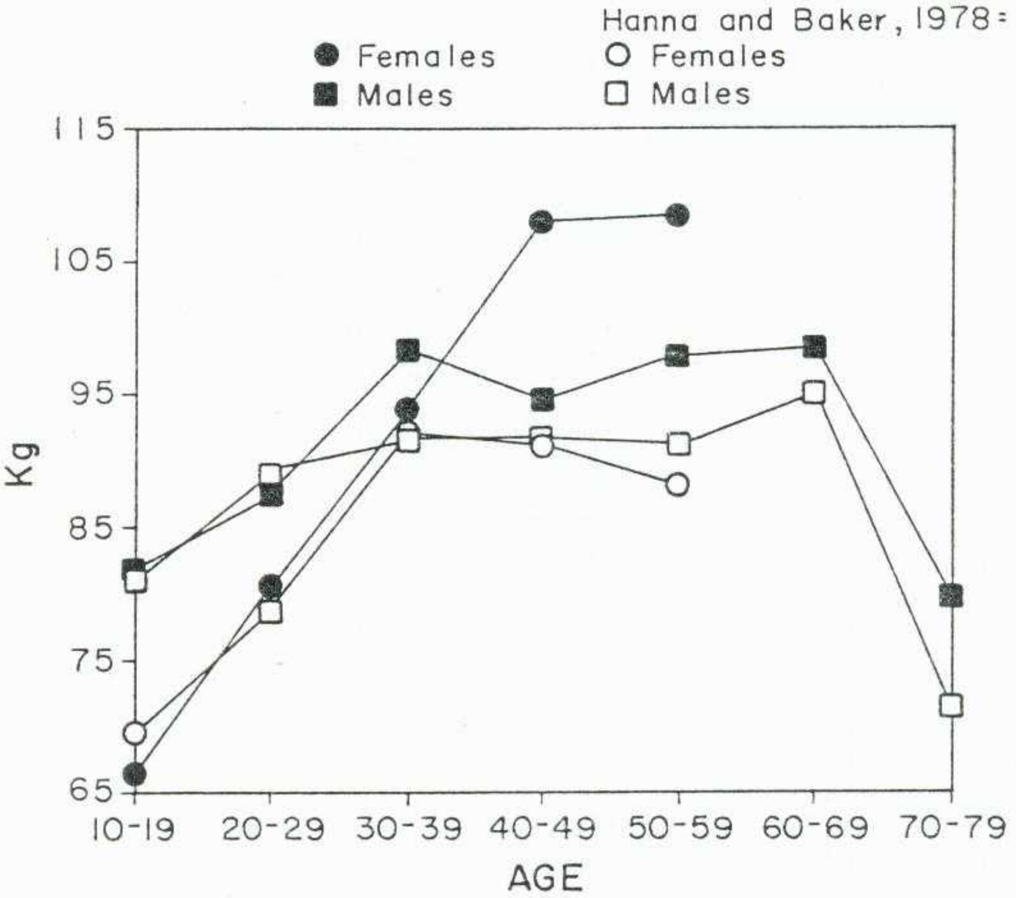

Figure 4. Comparative Weights of Samoans in Hawaii

Table 6

Correlation Coefficients for Weight and Quetelet's Index

	Weight		Quetelet's Index	
	M	F	M	F
Hemoglobin (Number)	0.26* (40)	0.16* (34)	0.24 (40)	0.01 (34)
Osmolarity	-0.01 (52)	0.29* (36)	-0.02 (52)	0.03 (36)
Sodium	-0.23* (52)	-0.26 (38)	-0.26* (52)	0.02 (38)
Potassium	-0.05 (52)	0.24 (38)	-0.24* (52)	0.11 (38)
Hematocrit	0.29 (28)	0.18 (22)	0.01 (28)	0.29 (22)
Cholesterol	0.20 (52)	0.55** (38)	0.27* (52)	0.06 (38)
Triglycerides	0.04 (47)	0.22 (38)	0.12 (47)	0.17 (38)
Age	0.32** (52)	0.79** (38)	0.38** (52)	0.40** (38)
Height	-0.01 (52)	0.16 (38)	-0.80** (52)	-0.70** (38)
Ulnar Skinfold	0.10 (52)	0.26 (38)	-0.62** (52)	-0.02 (38)
Subscapular Skinfold	0.43** (52)	0.50** (37)	-0.03 (52)	0.18 (37)
Triceps Skinfold	0.32** (52)	0.43** (38)	-0.12 (52)	0.24 (38)
Systolic Blood Pressure	0.49** (49)	0.33** (37)	0.01 (49)	-0.10 (37)
Diastolic Blood Pressure	0.44**	0.58**	0.50**	0.54**

M - males
F - females
* - less than .05
** - less than .01

SKINFOLDS

Mean values for the triceps, subscapular and ulnar skinfolds are contained in table 7. The mean triceps skinfold is 28.1 mm for females and 20.8 mm for males. Past the age of 19, female triceps skinfolds are larger than those of males. Subscapular skinfolds are larger in females than males at all ages. The mean value is 34.1 mm for females and 27.1 mm for males. Ulnar skinfolds are larger in females than in males after the age of 29. The mean value for female ulnar skinfolds is 15.6 mm, while for males it is 12.98 mm. Subscapular skinfolds in this sample are larger than those reported for Maoris (Prior, 1974), Tokelauans (Prior et al, 1974) and males on Niihau, whose average value was 17.2 mm (Basset et al, 1966). For males aged 20-39, values are similar to those recorded at the 80th percentile of the Tecumseh population, while the remainder of the age groups show elevated levels. Among females, all age group means are above the 80th percentile for subscapular skinfolds of the Tecumseh females (Montoye, Epstein and Kjelsberg, 1965), male and female values for the triceps skinfold are elevated over those observed among Maoris (Prior, 1974), and the male mean value is higher than that for Niihau males (Basset et al, 1966), 10.3 mm for Niihau males versus 20.8 mm for males in this sample. Male values are also elevated over Tokelauan male values (Prior et al, 1974). In females, triceps skinfold values are elevated over Tokelauan female values after age 30. In addition,

Table 7

Mean Ulnar, Subscapular and Triceps Skinfolds
by Ten Year Age Groups

Age	Ulnar (mm)				Subscapular (mm)				Triceps (mm)			
	M	N	F	N	M	N	F	N	M	N	F	N
10-19	13.16	19	8.94	16	22.74	19	23.12	16	26.58	19	18.69	16
20-29	14.10	10	10.00	9	19.80	10	29.11	9	14.40	10	19.67	9
30-39	6.60	5	22.33	6	23.40	5	55.00	6	13.80	5	45.83	6
40-49	18.50	8	22.60	5	41.12	8	52.00	5	16.38	8	46.40	5
50-59	7.67	6	13.75	4	34.17	6	36.33	3	22.67	6	35.00	4
60-69	15.50	4	--	0	35.75	4	--	0	26.25	4	--	0
70-79	8.00	1	--	0	12.00	1	--	0	11.00	1	--	0

M - males
F - females
N - number of subjects

male values are above those recorded at the 80th percentile among the Tecumseh population in the 10-19 and 50-69 age groups. Female values are above the 80th percentile after age 20 (Montoye, Epstein and Kjelsberg, 1965). Seltzer and Mayer (1965) established standards for determining obesity up to age 50 employing the triceps skinfold. Using this method, males in the present sample are above the obesity level to age 19 and then below until age 50. Females are above the obesity level from age 30 to 50.

As seen in table 8, the subscapular skinfold in males is significantly positively correlated with hemoglobin and age. In addition, among males the ulnar skinfold showed a significant positive correlation with potassium. Among females, all three skinfold sites exhibited a significant positive correlation with cholesterol and age. A significant negative correlation was found between all three sites and sodium.

ACQUIRED WEIGHT CATEGORIES

Categories constructed on the basis of ulnar and subscapular and ulnar and triceps skinfolds were composed. Each skinfold type was divided into five groups of increasing size. Two skinfold types were then paired - either ulnar and triceps or ulnar and subscapular. The subjects with the lowest value for both innate (ulnar) and acquired (subscapular or triceps) fat would be coded 1.1. An individual with the highest values in both of these fat

Table 8

Correlation Coefficients for Three Skinfold Sites and Related Variables

Subscapular	Hemoglobin	Osmolarity	Sodium	Potassium
Males (Number)	0.31* (41)	-0.02 (53)	-0.15 (53)	0.05 (53)
Females	0.02 (34)	0.23 (36)	-0.46**	-0.06 (38)
Triceps				
Males	-0.01 (41)	0.01 (53)	0.10 (53)	-0.01 (53)
Females	0.11 (35)	0.19 (37)	-0.35** (39)	0.02 (39)
Ulnar				
Males	-0.05 (41)	0.04 (53)	0.02 (53)	0.24* (53)
Females	0.05 (35)	0.10 (37)	-0.39** (39)	-0.05 (39)

* = p less than .05
** = p less than .01

Table 8. (continued)

Correlation Coefficients for Three Skinfold Sites and Related Variables

	Hematocrits	Cholesterol	Triglycerides	Age
Subscapular				
Males (Number)	0.14 (28)	0.19 (53)	0.10 (48)	0.28* (53)
Females	0.08 (22)	0.48** (38)	-0.03 (38)	0.54** (38)
Triceps				
Males	0.02 (28)	-0.07 (53)	-0.15 (48)	-0.05 (53)
Females	-0.02 (22)	0.39** (39)	0.01 (39)	0.54** (39)
Ulnar				
Males	0.14 (28)	-0.01 (53)	0.01 (48)	-0.03 (53)
Females	-0.01 (22)	0.40** (39)	-0.01 (39)	0.37** (39)

types would be given the value 5,5. These values were then used to create five levels of acquired weight gain (25 categories in all).

Relationships between several of the variables and the above categories are given in tables 9 and 10. "Elevated" values are denoted with asterisks to provide a general indication of the skinfold categories where the highest values are observed. Cholesterol and triglyceride levels are arbitrarily designated as being elevated if they fall above 200 mg%, since there appears to be a break in the values immediately before 200 mg%, and values above 200 mg are additionally more similar to mean values observed in other Polynesian populations (Basset et al, 1966; Hunter, 1962). A general idea of elevated sodium values is provided by indicating values above 132 mEq/l as elevated. This value is approximately one standard deviation above the population mean. Elevated blood pressures are identified according to the World Health Organization (1959) standards for identifying hypertension (165 mmHg systolic and 95 mmHg diastolic blood pressure).

The higest values for systolic and diastolic pressures were found in the upper one-half of the acquired weight categories (generally 12 to 25). The highest cholestrol and triglyceride values were also seen in the upper one-half of the categories. The upper one-half of the categories would tend to indicate higher innate obesity.

Since age is known to be related to body fat, its effects were removed through an analysis of covariance. After the effects of age were removed for the subscapular categories, innate obesity was found to have an effect on both systolic (p less than 0.01) and diastolic (p less than 0.05) pressures. In both cases, higher pressures were found in the individuals of higher innate obesity. Identical relationships were observed when analyzing the categories constructed on the basis of the triceps skinfold. After controlling for age, innate obesity appeared to have no influence on sodium or serum lipid levels.

In terms of acquired fat, the categories identified more individuals with elevated blood pressures than elevated serum lipids. For categories based on either the subscapular or triceps skinfolds, there are more males than females at the level of least acquired weight gain. Conversely, there are more females than males in the two highest levels of acquired weight gain.

Analysis of covariance was also performed to examine the effects of acquired weight on other variables. For the subscapular skinfold categories, age (p less than 0.05) and acquired weight (p less than 0.05) were found to have a significant effect on sodium levels. Acquired weight had an effect such that the lower sodium values were in the highest acquired weight individuals, after adjusting for age. Negative correlations had been previously observed in certain cases between sodium and weight, subscapular skinfolds and

Table 9

Mean Values for Acquired Weight Categories Based on the Subscapular Skinfold

Cat.	Sodium (mEq/l)				Cholesterol (mg%)		Triglycerides (mg%)	
	N	M	N	F				
1	13	130.5	1	*133.8	153.2	204.9	108.3	39.4
2	7	128.3	4	131.4	168.1	160.9	98.4	62.0
3	2	137.4	2	126.6	161.5	*233.6	60.4	124.0
4	0	--	1	131.3	--	148.1	--	199.9
5	0	--	0	--	--	--	--	--
6	7	*132.2	2	130.9	155.7	113.9	80.7	54.6
7	6	126.9	9	129.9	177.3	137.8	72.1	104.9
8	5	126.3	1	128.8	194.6	*213.1	147.8	47.4
9	1	128.0	0	--	180.3	--	188.8	--
10	1	130.5	0	--	185.2	--	63.0	--
11	0	--	1	*132.3	--	175.8	--	34.5
12	2	129.0	2	129.2	173.3	144.0	50.7	59.0
13	3	128.6	5	128.6	*240.4	144.9	*266.0	101.1
14	0	--	1	128.0	--	189.5	--	72.2
15	0	--	2	138.9	--	186.2	--	55.4
16	0	--	1	131.3	--	*237.7	--	174.1
17	0	--	1	128.5	--	*237.0	--	*275.3
18	0	--	0	--	--	--	--	--
19	0	--	2	129.3	--	156.8	--	90.0
20	1	131.5	2	127.6	142.9	194.2	136.9	87.4
21	0	--	0	--	--	--	--	--
22	2	130.5	1	128.5	161.0	180.3	72.6	110.9
23	0	--	0	--	--	--	--	--
24	1	127.5	0	--	150.0	--	91.1	--
25	3	129.4	2	125.9	176.9	*236.1	109.7	76.1

Cat. = category
N = number of subjects
M = males
F = females
* = elevated values, see text for explanation

Table 9. (Continued)

Mean Values for Acquired Weight
Categories Based on the Subscapular Skinfold

Systolic Pressure (mmHg)		Diastolic Pressure (mmHg)		Age (Years)	
M	F	M	F	M	F
125.8	118.0	81.2	86.0	20.2	20.5
126.8	116.0	86.8	75.5	37.2	18.0
145.0	112.0	*95.0	68.0	43.6	39.3
--	140.0	--	80.0	--	55.3
--	--	--	--	--	--
125.5	111.0	84.8	74.0	21.5	15.6
150.0	110.7	93.6	74.2	37.7	18.8
135.6	130.0	90.0	92.0	42.2	28.8
*170.0	--	90.0	--	51.2	--
130.0	--	90.0	--	44.6	--
--	122.0	--	80.0	--	21.5
134.0	118.0	89.0	74.0	34.1	19.5
154.7	132.8	*111.3	85.2	45.8	29.8
--	126.0	--	84.0	--	53.2
--	122.0	--	85.0	--	33.8
--	142.0	--	*110.0	--	57.7
--	*184.0	--	*120.0	--	58.8
--	--	--	--	--	--
--	142.0	--	*99.0	--	38.6
*170.0	149.0	92.0	88.0	16.3	38.2
--	--	--	--	--	--
124.0	124.0	86.0	86.0	16.7	14.7
--	--	--	--	--	--
*235.0	--	--	--	24.3	--
130.0	*195.5	90.0	90.0	40.0	42.0

Table 10

Mean Values for Acquired Weight Categories Based on the Triceps Skinfold

Cat.	Sodium (mEq/l)				Cholesterol (mg%)		Triglycerides (mg%)	
	N	M	N	F	M	F	M	F
1	8	129.9	1	125.8	156.9	*250.0	139.4	124.4
2	13	129.3	4	131.4	161.2	176.2	81.1	54.2
3	1	128.0	3	130.9	139.8	169.7	47.8	131.5
4	0	--	0	--	--	--	--	--
5	0	--	0	--	--	--	--	--
6	2	*132.3	0	--	*260.2	--	129.6	--
7	11	128.4	6	130.8	169.5	139.2	82.2	125.4
8	4	126.7	5	130.2	157.5	142.6	81.4	52.3
9	1	129.3	1	123.5	150.0	133.1	95.9	87.4
10	2	131.6	0	--	163.9	--	128.1	--
11	0	--	0	--	--	--	--	--
12	1	126.5	3	130.3	*251.7	154.6	*367.5	50.9
13	4	129.3	3	127.6	*204.0	132.9	133.0	102.9
14	0	--	3	128.7	--	177.9	--	55.7
15	0	--	2	129.9	--	176.9	--	106.3
16	0	--	0	--	--	--	--	--
17	0	--	0	--	--	--	--	--
18	0	--	0	--	--	--	--	--
19	0	--	1	128.5	--	*237.0	--	*275.3
20	1	131.5	5	129.0	142.9	188.0	136.9	105.8
21	1	131.5	0	--	169.2	--	194.1	--
22	1	127.5	0	--	150.0	--	91.1	--
23	0	--	0	--	--	--	--	--
24	0	--	0	--	--	--	--	--
25	4	129.4	3	126.8	170.8	*217.5	70.1	87.7

Cat. = category
N = number of subjects
M = males
F = females
* = elevated values, see text for explanation

Table 10. (Continued)

Mean Values for Acquired Weight Categories Based on the Triceps Skinfold

Systolic Pressure (mmHg)		Diastolic Pressure (mmHg)		Age (Years)	
M	F	M	F	M	F
127.2	--	82.8	--	20.5	44.9
127.7	113.0	84.5	75.0	30.4	18.0
136.0	127.3	94.0	78.7	52.0	36.6
--	--	--	--	--	--
--	--	--	--	--	--
123.0	--	89.0	--	30.6	--
144.4	115.7	90.9	74.3	38.9	18.8
131.0	112.0	88.5	78.0	40.2	19.9
126.0	94.0	--	72.0	27.8	16.7
140.0	--	80.0	--	34.6	--
--	--	--	--	--	--
*160.0	119.3	*120.0	76.0	36.9	20.2
143.0	119.3	* 98.0	76.0	42.2	27.6
--	122.0	--	84.7	--	33.1
--	155.0	--	99.0	--	44.0
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	*184.0	--	20.0	--	58.8
*170.0	144.8	92.0	96.8	16.3	42.3
--	--	--	--	41.1	--
*235.0	--	--	--	24.3	--
--	--	--	--	--	--
--	--	--	--	--	--
127.0	*171.7	88.0	88.0	28.1	32.9

triceps skinfolds. For the triceps categories, age had an insignificant effect on triglyceride levels, while acquired weight showed a significant effect (p less than 0.05). The lower triglyceride values were seen among the higher acquired weight individuals. However, these results should be viewed with caution, as the nonfasting triglyceride levels may not be truly representative of this population. After controlling for age, acquired weight appeared to have no significant influence on blood pressures or cholesterol levels.

SUMMARY

In summary, weights, skinfolds and blood pressures are elevated in the subject population. Hematocrits and hemoglobin are also somewhat elevated. Conversely, serum cholesterol and sodium levels are lower than would be expected. Similarities are seen in trends for weights, blood pressures and cholesterols, with values generally decreasing in the forties and seventies for males and in the fifties for females. Furthermore, weights and blood pressures appear more similar to those of other acculturated rather than unacculturated Polynesians.

On the basis of acquired weight categories, it is possible to identify some individuals having high levels of acquired weight, elevated blood pressures and serum lipids. Moreover, females are shown to outnumber males at the higher acquired weight levels. However, elevated blood pressures and lipid levels tend to cluster in the upper one-half of the categories, suggesting that higher innate obesity is also an important factor.

DISCUSSION

INTRODUCTION

The Samoan migrants in this study are characterized by excessive body fat and high blood pressures. The adverse effects resulting from obesity and elevated blood pressures have been well documented. Weights (Miall, Bell and Lovell, 1968), skinfold values (Albrink and Meigs, 1964, 1965; Montoye, Epstein and Kjelsberg, 1966; Kannel and Dawber, 1973) and weight indexes (Sive et al, 1970; Miall, Bell and Lovell, 1968; Gordon and Kannel, 1973; Kannel and Dawber, 1973) have been used to predict high risk individuals, especially those having cardiovascular disease. However, in this study, minimal additional information was gained by using Quetelet's index. The preferred method of identifying high risk individuals, and the one which appears to provide a more precise descrimination, is the development of acquired weight categories based on skinfolds (Albrink and Meigs, 1964).

ACQUIRED WEIGHT CATEGORIES

Although the total sample size is relatively small, categorizing acquired weight gain appears useful in predicting levels of cholesterol, triglycerides and blood pressures, as proposed in the first hypothesis. Evaluating the results of this small samples seems justified in view of the large number of individuals contained in the 30-59 age range, where peaks in blood pressures, weights and cholesterol for both males and females are found. Therefore, these ages would appear to be critical for examination of elevated values. However, it would be valuable to see whether the results could be improved with a larger sample. In this small sample though, it was possible to determine individuals with the highest acquired weights, as determined by the subscapular or triceps skinfolds, as well as individuals having elevated blood pressures and serum lipids. The clustering of individuals having elevated cholesterol and blood pressures in the upper one-half of the acquired weight categories seems to support the concept of higher innate obesity, as developed by Albrink and Meigs (1964).

From visual inspection (tables 9 and 10), the acquired weight categories appear to show a greater relationship to elevated blood pressures than to serum lipids, with higher blood pressures appearing in several of the high acquired weight individuals. The majority of values classified as definite hypertension - above 160 mmHg systolic or 95 mmHg diastolic - (World Health Organization, 1959) - are found in the upper one-half of the acquired weight categories. The categories were most successful in determining elevated blood pressures and cholesterols among those high acquired weight subjects also having higher innate obesity. They were not as effective, however, for those individuals of lower innate obesity, In other words, the categories were most effective when both original body size and acquired weight were larger. An increased sample size may help to increase the descriminatory powers of the categories at levels of lower innate obesity.

It appears that the subscapular acquired weight categories may be more sensitive descriminators of serum lipid levels than are the triceps categories. Although a similar total number of elevated blood pressures, cholesterols and triglycerides were observed for the total sample, when using either the triceps or subscapular based acquired weight categories, the number of elevated values was higher for females than for males when employing the subscapular skinfold, with most of the disproportion being in the cholesterol levels. The method of constructing the acquired weight categories was based on that used by Albrink and Meigs (1964), who when researching serum lipids obtained the best results with the subscapular skinfold. This may be additional support for the adequacy of the subscapular categories versus that of the triceps categories as discriminators of lipid levels. The adequacy of the acquired weight categories to identify elevated triglyceride values in this population may reflect the fact that serum samples were obtained from nonfasting subjects, and the greater amount of serum triglycerides which follow a meal becomes a confounding factor.

Statistical evaluation of the relationship between acquired weight categories, blood pressures and the seriological variables was disappointing. Acquired weight, as determined by the subscapular skinfold, showed a significant relationship only to sodium values (p less than 0.05), while acquired weight, as determined by the triceps skinfold categories, had a significant effect on triglyceride levels (p less than 0.05). Conversely, blood pressures were affected by the amount of innate obesity as determined by the skinfold categories. Innate obesity determined on the basis of either the subscapular or triceps skinfolds showed a relationship to systolic pressure (p less than 0.01) and to diastolic pressure (p less than 0.05). As previously mentioned, the results might have differed with a larger sample.

It is notable, though, that an elevated value in one variable is often accompanied by a high value in one or more other variables. Thus, in categories 1, 13, 16, 17 and 25 for acquired weight determined by the subscapular skinfold and among categories 6, 12, 13, 19 and 25 for acquired weight based on the triceps skinfold, levels of cholesterol, blood pressure and triglycerides tended to be elevated, although not necessarily in each instance. Such a combination of elevated values may constitute a health risk. For example, Kannel and Dawber (1973) proposed that elevated blood pressure assumed greater importance when accompanied by such conditions as abnormal blood lipids, higher hemoglobin values and obesity. Thus, the acquired weight categories may be useful in identifying individuals manifesting an elevated value for one or more variables.

SERUM SODIUM VALUES

An unexpected result of this study was that of the relationship between serum sodium concentration and the other variables. While higher values for serum lipids and blood pressure were found in the upper one-half of the acquired weight categories, the higher sodium values showed a tendency to appear in the lower one-half of the categories. This pattern of distribution was also supported by negative correlations between sodium, blood pressures and weights (see tables 4 and 6).

While some significant correlations may be expected to result by chance, the pattern of negative correlation coefficients for sodium is consistent. There were, for example, significant negative correlations between sodium and weight, Quetelet's index and blood pressure among males, and sodium and the subscapular, triceps and ulnar skinfolds among females. At first inspection, these findings appear contrary to those expected for sodium in this particular obese population, since other studies indicate that high blood pressure accompanies high sodium intake (Prior et al, 1968; Dahl, 1961; Tobian, 1975). However, according to Linquette et al (1969), abnormal sodium retention may not be a manifestation of noncomplicated obesity. Their study reported sodium values of 136.8 mEq/l for obese males and 140 mEq/l for obese females. Therefore, sodium values are not abnormally elevated in their obese subjects. Additionally, the average serum sodium values of 129.24 mEq for males and 129.54 mEq for females, as determined in the present sample, fall below the lower limit of normal ranges for serum sodium (136-145 mEq/l $\pm$ 3 mEq) reported by Randall (1973).

A possible explanation for the above results may be provided by the renin-angiotensin-aldosterone system, which affects sodium reabsorption by the distal tubules of the kidney (Vander, 1975). For example, if there is a deficiency in the amount of aldosterone production or some change in aldosterone control in fat and lean people, extra sodium would be excreted and the plasma level would be reduced. The lower-than-normal level would be sensed in the kidney, and renin production would be stimulated. As a result of the deficient aldosterone, the sodium level would not normalize, but because of increased renin, there would be an increased level of angiotensin present. Angiotensin, as a vasoconstrictor, would increase peripheral resistance, resulting in an increase in pressure. If this condition persisted, the increased resistance, along with that contributed by the elevated hematocrits of this population (table 1), would contribute to higher blood pressures. Kannel and Dawber (1973) also discussed the influence of hematocrit levels on the dynamics of blood flow and the additional significant correlation they found between hemoglobin values and blood pressures. This relationship was stronger between hemoglobin and diastolic pressure and therefore, they proposed a relationship to peripheral resistance. Diastolic pressure reflects the amount of pressure present in the vascular tree at its lowest level before the heart contracts. An elevated hemoglobin level would increase blood viscosity and thus increase resistance, which would then be reflected in the diastolic pressure. Positive significant correlations between diastolic pressure and hemoglobin for both sexes were also found in the present sample. Thus, hematocrit, hemoglobin and angiotensin levels may be combining in this population to increase peripheral resistance and raise blood pressure. Further investigation would appear desireable in order to determine if this is a phenomenon of the total Samoan migrant population on Oahu as well as to obtain additional dietary information, particularly on sodium intake, and biochemical assays of renin, aldosterone and urinary sodium levels.

SEXUAL DIFFERENCES IN BODY FAT

As indicated in the second hypothesis, women did show a higher degree of acquired weight than did men. In terms of innate obesity, as determined by the acquired weight categories based on the subscapular skinfold (table 9), men outnumber women, 42 to 20, until category 10. From catagories 11 to 25, women outnumber men, 20 to 12. A similar pattern emerges for the categories based on the triceps skinfold (table 10). Up to category 10, there are more males than females (42 versus 20). Above category 10, there are 12 males versus 20 females. In general, females also tend to be in larger numbers among the highest acquired weight categories. There are more men than women in the lowest level of acquired weight gain and more women than men in the two highest levels of acquired weight. These findings tend to be supported by the pattern of weight gain and increase in skinfold values exhibited by the females. Females seem to manifest a longer, steadier period of weight gain than do males (figure 4). This pattern is also reflected in the steady rise in subscapular and triceps skinfolds until age 49 among females (table 7). Thus, women appear to be gaining higher amounts of adipose tissue, and at a steadier rate, than are males.

This pattern of a sexual difference in body fat is similar to that reported in other studies of Polynesians. Among Atiu-Mitiaro subjects (Hunter, 1962) females had greater arm circumferences, weight/height^2 indexes and skinfolds than did males. New Zealand Maori females also exhibited larger skinfold values than did males (Prior, 1974).

AGE TRENDS OF OBESITY, BLOOD PRESSURE AND SERUM LIPIDS

As proposed in the third hypothesis, similar age trends were observed for weights, skinfolds, blood pressures and serum lipids (see tables 2, 3, 5 and 7 and figures 1 through 4). Among female skinfold values, there was a decline for both the subscapular and triceps site in the 50-59 age group, which appears to be duplicating the plateau seen in female weights after age 49. During this same time period, mean systolic pressure declines five millimeters of mercury, and mean diastolic pressure declines two millimeters of mercury. Cholesterol values also decline approximately six milligrams percent. Among males, the subscapular skinfold exhibits a large decline in the 50-59 and 70-79 age groups, while the triceps skinfold shows a large decline in the 70-79 age group. Male weights decrease in the 40-49 and 70-79 year age groups. Blood pressures follow this pattern, declining 9.4 mmHg and 33.5 mmHg systolic and 5.25 mmHg and 27.5 mmHg diastolic, respectively. Cholesterol values also decrease in the 50-59 and 70-79 year age groups. However, female trends appear to parallel each other a little more faithfully than do those in the males.

Trends in weight gain may be reflected in the acquired weight categories. As seen in tables 9 and 10, the highest mean ages are generally not located in the highest acquired weight categories. However, there appear to be higher mean ages for females in higher acquired weight categories than there are for males. One explanation for this could be that the males with high acquired weights are disappearing from the population at younger ages than are the females.

As previously discussed, weight gain has been implicated as a risk factor in several diseases as well as associated with increases in blood pressure and serum lipids.

The finding that the highest mean ages in this sample generally do not appear in the highest acquired weight categories may indicate that those individuals of higher acquired weight may be disappearing from the population at earlier ages than those individuals of lower acquired weight. Age trends observed in blood pressure and cholesterol levels also suggest that the numbers of individuals having elevated values may be reduced at certain ages. Therefore, high risk individuals, or those with elevated weights, blood pressures and cholesterol levels may be suffering health risks and dying earlier than those individuals having lower values.

Montoye, Epstein and Kjelsberg (1965) proposed that among the Tecumseh population, the decrease in relative weight among older subjects may be due to the men of that era being leaner or, alternatively, that the lean men may have survived. When comparing weights and skinfolds, they found that while some of the decline may be due to a decrease in muscle tissue, those who survived were in general more lean.

As previously discussed, increases in some risk factors along with gain in weight have been noted as promoting cardiovascular difficulties. Kannel and Dawber (1973) reported that blood pressure rose with increased weight and skinfold values. They proposed that elevated blood pressure assumes greater importance when accompanied by such conditions as abnormal blood lipids, higher hemoglobin values and obesity.

Gordon and Kannel (1973) also found weight gain to be associated with a rise in blood pressure and cholesterol when weight gain after age 25 was related to coronary events. Ashley and Kannel (1974) reported that change in weight appears to have an important influence on cholesterol and systolic blood pressure, two atherogenic variables. By employing a formula, they estimated that each 10% increase in relative weight may possibly result in a 30% increase in incidence of coronary heart disease, the effect being slightly less among women and older subjects. Albrink, Meigs and Granoff (1963) suggested that if high triglycerides may be predictive of coronary artery disease, their documentation of rise in triglycerides with weight gain may implicate weight gain in adult life as being more important in development of this disease than obesity itself.

In the present sample, numerous positive correlation coefficients are seen between the measures of weight, the biochemical variables and the blood pressures. A relationship between obesity and blood pressure was also reported in the larger sample of Oahu Samoans (Hanna and Baker, 1978) and among Samoans living in both Samoa and Hawaii (McGarvey and Baker, 1978).

Thus, in this sample, similarities are seen in trends for weight, blood pressure and cholesterol. As previously discussed, change in weight has been implicated in changes of blood pressure and serum lipids. This relationship is also suggested by trends in the present sample. In addition, the similar decline in values at certain ages of weight, blood pressure and cholesterol may suggest a health risk, since the adverse effects of excess weight gain, elevated blood pressures and elevated serum lipids may be operating.

COMPARISONS TO OTHER POLYNESIAN GROUPS

Blood pressures, weights and the biochemical assays in general tend to confirm the hypothesis that the Samoan migrants living on Oahu are similar to other acculturated Polynesians in terms of these variables. Weights are high, even somewhat higher than those observed in the larger Oahu sample (Hanna and Baker, 1978). Male and female weights are also elevated above those of Rarotongans (Hunter, 1962) another acculturated group, and male weights are also somewhat elevated over those of Hawaiian males (Healey et al, 1966; Basset et al, 1966).

Although somewhat elevated at certain ages, the blood pressure values obtained in this study are also close to those observed among Rarotongans (Hunter, 1962), Hawaiian males (Basset et al, 1966) and New Zealand Maoris (Prior, 1974). In addition, blood pressures in the present sample were found to increase with age. A pattern of increase in pressure with age similar to that shown in this sample has been observed among Rarotongans (Hunter, 1962), New Zealand Maoris (Prior, 1974) and Tokelauans (Prior et al, 1974). This phenomenon was also documented among the Framingham subjects (Kannel and Dawber, 1973), which may suggest that blood pressures increase with age when individuals are in contact with a more Westernized lifestyle and its associated stresses and inducements toward obesity. In contrast, blood pressures among Puka Pukans (Prior, 1974), who are more isolated atoll dwellers, do not increase with age and are lower than those of Rarotongans.

As previously mentioned, the subjects in the present study were a part of the study of Oahu Samoans conducted by Hanna and Baker (1978). The present subjects, except for a few individuals in the 10-19 age group, were from the Laie area on the North Shore of Oahu. Hanna and Baker found that subjects in this area had a rurally oriented lifestyle, with most individuals working within the region. They also reported higher blood pressures in this area than in Honolulu. However the same pattern of continual increase in pressure with age found in the present sample was not observed in their larger sample. In the larger sample, male blood pressures tended to plateau after a peak in the twenties. In the present sample, there was a second peak in male blood pressure in the fifties. Also, age had a significant positive correlation to blood pressure in both sexes, and in addition, blood pressures of both males and females tended to reach higher levels than in the larger sample.

A possible explanation for the differences between the two samples may be that the present sample was small and localized. The present subjects were only a small sample of the North Shore group, and such factors as familial relationships or individuals having originated from similar areas in Samoan may be involved. Previously, McGarvey and Baker (1978) found a relationship between blood pressure and place of birth in Samoa, such that those from the more acculturated areas had higher blood pressures.

For the larger Oahu sample, Hanna and Baker (1978) proposed that weight and trunk length were related to blood pressure among males, and weight, biacromial and biiliocristal diameters were related to blood pressure among females. Among both sexes in the present sample, weight showed a significant relationship to blood pressure, and biacromial diameter was significantly related to diastolic pressure. Hanna and Baker suggested that periods of weight gain in their sample corresponded to increases in blood pressures, and also noted that the size of the upper body, a major site of fat deposition in adults, also appeared related to blood pressure. Thus, the addition of adipose tissue appears related to blood pressure, and the relationship between blood pressure, weights and biacromial diameter are also seen in the present sample.

In summary, both weights and blood pressures in this study are elevated and somewhat above those recorded for other acculturated Polynesian groups. The elevation of blood pressures that increase with age appears to follow the pattern exhibited by other groups of Polynesians living in Westernized areas, but not of a larger sample of Samoans in

Hawaii.

CHOLESTEROL LEVELS

As interesting contrast to the elevated blood pressures is seen in cholesterol levels. As previously noted, cholesterol values in this study are lower than those reported for several other acculturated Polynesians and also much lower than Caucasian values. Furthermore, the cholesterol levels are lower than those seen in less acculturated coconut-eating Polynesians (Hunter, 1962).

It is possible that there were errors in the analytic technique, for example, multiple freezings of the samples. Although Hunter (1962) and Basset et al (1966) also used frozen samples, repetition of freezing could present a problem. Incorrect calibration of the machines may also be involved. Therefore, further cholesterol determinations of Samoan migrants would appear desireable. Yet, if all the values are consistantly low, the largest values would represent the highest values for this group and thus could be evaluated for relationship to weights and blood pressures.

If the observed levels are representative, dietary patterns may be involved. That dietary habits may influence cholesterol levels has been proposed by several investigators, including Keyes et al (1958). Their study demonstrated a progressive increase in cholesterol levels from Japanese in Japan, to Japanese in Hawaii and Los Angeles, and Caucasians in Minnesota. Cholesterol values for Japanese men in Hawaii averaged 76 mg% higher than those of Japanese men in Kyushu, Japan. A parallel increase in dietary fat was also noted, and it was concluded that the low cholesterol levels observed in Japan resulted from low levels of dietary fat. It was also proposed that as populations increase fat consumption, the intake of meat and dairy fats are also increased. The rise in cholesterol, therefore, may be attributable to increased intake of saturated fats.

A more recent study of Polynesians by Hunter (1962) implicated saturated coconut fat as contributing to the high cholesterol levels observed among subjects of Atiu-Mitiaro. When compared to Rarotongans, the Atiu-Mitiaro islanders had high levels of cholesterol even though they ate less animal fat. Thus, saturated fats are again implicated as raising cholesterol levels. Among Niihau Hawaiian males, Basset et al (1966) noted that cholesterol levels were not excessively high for the group. They suggested that the levels may be lower than those seen in comparable groups of Caucasians because of the lower percentage of fat calories and higher polyunsaturated-to-saturated fat ratio in the Niihau diet.

Contrary evidence was provided by Prior (1974), who found new Zealand Maoris to be more obese than New Zealand Europeans, while exhibiting much lower cholesterol levels. Prior could find no dietary explanation for this phenomenon. Furthermore, among Puka Pukan atoll dwellers, cholesterol levels were found to be lower than those among Rarotongans, although considerably more coconut-derived fat was consumed on Puka Puka. Conversely, among the atoll-dwelling Tokelauans, cholesterol levels were higher than among Puka Pukans and more similar to Maoris. In addition, Tokelauans consumed more coconut fat than did Maoris (Prior et al, 1974).

Therefore, the low cholesterol levels observed in this sample may be due to errors in methodology, or if correct, may be reflecting diet. The levels appear more similar to those seen among acculturated Polynesians than either unacculturated Polynesians or Caucasians. Perhaps the Samoan diet on Oahu does not contain the high amounts of coconut fat consumed by nonacculturated Polynesians on Atiu-Mitiaro or the higher amounts of meat and dairy fats which are expected in Western Caucasian diets. Since the relationships between serum cholesterol level and dietary composition are not firmly established, additional cholesterol determinations and dietary study of this population would be desireable.

An alternative to a dietary explanation of cholesterol levels may be to consider weight and weight gain. Relative weight has been associated with cholesterol levels (Garcia-Palmieri et al, 1972), and Montoye, Epstein and Kjelsberg (1966) found a relationship between cholesterol and skinfolds. Gordon and Kannel (1973) reported a relationship between weight gain and rise in cholesterol, while on the other hand, Waxler and Craig (1964) observed cholesterol levels in female obese subjects to be similar to those in control subjects of normal weight. Furthermore, Albrink, Meigs and Granoff (1963) reported that triglyceride levels appeared to be more strongly related to obesity than were cholesterol levels, although cholesterol levels did show a certain relationship.

If change in weight is an important factor in determining cholesterol levels, Oahu Samoans may not have yet gained enough weight over their innate body size to cause an increase in cholesterol levels. An alternative proposal was offered by Basset et al (1966), who observed a decline in relative weight and cholesterol at older ages in Hawaiians, which suggested that some of the individuals with the highest cholesterol levels may be dying at an early age. They surmized that high cholesterol values for this group (although lower than Caucasian values) may be above the normal limit for their particular group.

Further evidence for a genetic component is provided from a study of the Masai (Biss et al, 1971). The average serum cholesterol value for this population, whose members consume large amounts of animal fat, was only 135.4 mg%. It was concluded that a negative feedback system of suppression of endogenous cholesterol synthesis was operating after ingesting large amounts of cholesterol.

Thus, if the above explanations are valid, this Samoan group on Oahu, being composed of large, obese people may have not yet reached the level of weight gain at which they would manifest hypercholestemia. Alternatively, for some inherent reason their cholesterol levels may not reach the higher values recorded in Caucasians, yet the highest levels in this group may be above "normal" for this particular population.

RELATIONSHIPS TO YEARS OF RESIDENCE IN HAWAII

The final hypothesis proposes that cholesterol, blood pressure and weight will show positive relationships with years of residence in Hawaii. However, after controlling for age, no significant positive relationship was found between the number of years lived in Hawaii and cholesterol, blood pressure or weight. In addition, in the larger sample of Oahu Samoans studied by Hanna and Baker (1978), higher systolic pressures were observed in the newest migrants. Therefore, it appears that a future longitudinal study would be desireable since there may not as yet have been sufficient time for the effects of life in Hawaii and the influences from the more Westernized environment to manifest themselves.

Under normal circumstances, it would be expected that certain adverse effects would manifest themselves in the new environment. These could be either physical or psychological, as proposed by Cassel (1975) and Henry and Cassel (1969). For example, Garcia-Palmieri et al (1972) found serum triglycerides, cholesterol and relative weights to be significantly higher in an urban group of subjects than in rural subjects who were more physically active. Hyperglycemia, hypercholestemia and obesity were also about twice as frequent among urban subjects. Kannel and Dawber (1973) believe that there is much to suggest that hypertension is a disease of industrialization and urbanization, and they list obesity, lack of exercise and improper diet as being some of the major risk factors.

As previously mentioned, in the present sample, blood pressures are elevated and increase with age as in the case of several other Westernized Polynesians. Perhaps certain factors operating in the more urbanized environments of these Polynesian peoples, such as stress and changes in diet and activity patterns, are contributing to this rise. However, the length of residence in Hawaii may not as yet have been of sufficient time for statistically significant correlations to appear.

SUMMARY

In conclusion, elevated blood pressures and serum lipids are found among individuals of higher weight and also higher acquired weight. Women tend to gain more adipose tissue than do men during a longer, steadier period of increase. Individuals having higher weights, serum lipids and blood pressures may be declining from the population at certain ages (women at ages 50-59 and men at ages 40-49 and 70-79). Blood pressures and weights are similar to those observed in other acculturated Polynesians, while both

cholesterol and sodium levels are lower than was anticipated.

Thus, although the number of years of residence in Hawaii was not a statistically significant factor, the effects of migration on this group may include an elevation of blood pressure and weights, which also tend to increase with age. This would be expected since other acculturated Polynesians, such as the New Zealand Maoris (Prior, 1974) and the Rarotongans (Hunter, 1962), also exhibit elevated blood pressures and weights that increase with age. The higher weights, in combination with higher blood pressures, may be predisposing this population to increase in cardiovascular diseases and other health problems. Thus, migration may be aggrevating or causing new stresses for the body, which are sustained, and may result in an increase in values of risk factors, such as blood pressure.

SUMMARY AND CONCLUSIONS

Obesity was common in the group of Samoan migrants studied in this thesis. Blood pressures tended to be elevated and generally increased with age. Both weights and blood pressures were more similar to those observed among other acculturated Polynesian groups than among unacculturated groups. This contrasts with a larger sample of Oahu Samoans studied by Hanna and Baker (1978) where increases in blood pressure with age were not observed. This difference may be explained by the small and localized nature of the present sample. Familial relationships or migration from similar areas may be involved. Blood pressures were found to be significantly related to weight and biacromial diameter, a finding which was also observed in the larger sample.

Plasma cholesterol and sodium levels were lower than anticipated. The low cholesterol levels may be due to dietary factors, such as lower saturated fat intake, to errors in methodology, or they may be reflecting lower innate levels. Observed low plasma sodium values may reflect a deficit in the renin-angiotensin-aldosterone system, which would result in lower levels of aldosterone and plasma sodium along with elevated angiotensin, a vasoconstrictor. Thus, elevated angiotensin, hemoglobin and hematocrit values may be operating in conjunction to raise blood pressure levels.

Blood pressures, cholesterols and weights appear to rise and decline at similar ages. The combination of high values in these variables may be producing a health risk that may be reflected in similar declines at certain ages.

Acquired weight categories based on the method of Albrink and Meigs (1965) were constructed by pairing values for the ulnar and triceps skinfolds and ulnar and subscapular skinfolds to determine the amount of acquired weight. Use of the acquired weight categories made possible the identification of individuals with elevated blood pressures and cholesterol levels. The clustering of elevated values in the upper one-half of the categories may indicate that higher innate obesity is also having an effect on blood pressures and serum lipids. In addition, use of the acquired weight categories for identification of individuals with higher serum lipids and blood pressures was more successful among those individuals having both higher innate and acquired obesity. A larger sample size, however, would probably be helpful in refining the categories and increasing their usefulness.

Females in this sample tended to attain higher levels of acquired weight than did males. This is apparent in contrasting the lowest and two highest acquired weight levels. There were more males than females in the lowest level, while there were more females than males in the two highest acquired weight levels. There were also longer, steadier rises in female weights and skinfolds than in males.

Generally, female weights become higher than those of the males in the forties, and female skinfolds become higher in the thirties. Possibly differences in diet and physical activity between the sexes may be playing a role.

Although blood pressures and weights of these Samoan migrants were similar to those of other acculturated Polynesians, upon controlling for age, the number of years of residence in Hawaii did not show a significant relationship to these factors. This could possibly be due to the subjects having not as yet lived in the more urbanized environment long enough for sufficient effects to occur. A longitudinal study of the group after it has been exposed to the Oahu environment for a longer period of time may alter this finding. However, since it was found that blood pressures and weights were elevated and increased with age, it is suggested that environmental factors may be promoting these increases and perhaps contributing to cardiovascular disease and other health problems.

In summary, the subject population is characterized by obesity and elevated blood pressures. These conditions are similar to those seen in other acculturated Polynesians. Elevated blood pressures and obesity may be possible consequences of migration for this group and might be expected to produce health problems. The acquired weight categories were helpful in identifying individuals with elevated blood pressures and serum lipids. However, the success of this approach would probably be increased with a larger sample.

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