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REVIEW ARTICLE

Diabetes and stress: an anthropological review for study of modernizing populations in the US-Mexico border region

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ABSTRACT

Introduction: Diabetes is a growing worldwide problem, characterized by considerable ethnic variation and being particularly common in modernizing populations. Modernization is accompanied by a variety of stressful sociocultural changes that are believed to increase the risk of diabetes. Unfortunately, there is little accurate knowledge about impact of stress on the risk of diabetes in the US–Mexico border area.

Methods: Literature searches were performed in PubMed and Google Scholar to identify anthropological studies on stress and diabetes. Snowball and opportunistic sampling were used to expand the identified literature. In total, 30 anthropological studies were identified concerning the role of stress and modernization on diabetes among Indigenous peoples. This article reviews the available information regarding stress and diabetes in different populations from various anthropological perspectives.

Results: Four different concepts of stress were indentified: physiological, psychological, psychosocial and nutritional stress. Unlike physiological and nutritional theories of diabetes, psychological and psychosocial theories of stress and disease lack etiological specificity. No study addressed all four concepts of stress and few studies addressed more than two concepts. Most studies concerned nutritional stress and the developmental origins of diabetes. Most studies were conducted on the Pima Indians of Arizona and Mexico. All four stress concepts have some evidence as determinants of diabetes.

Conclusion: These theoretical concepts and ethnographic results can provide the basis for developing comprehensive research protocols and public health intervention targeted at diabetes. A comprehensive view of stress can potentially explain the high prevalence of diabetes in developing countries and among Indigenous peoples. These results can be used to inform public health interventions aimed at reducing diabetes in the US–Mexico border region or similar areas, help identify at-risk individuals, and guide health education and promotion.

Keywords: acculturation, activity patterns, developmental origins of disease, diabetes mellitus, dietary change, economic development, health disparities, lifestyle incongruence, modernization, nutritional stress, psychosocial stress, risk factors, stress hormones, US-Mexico Border.

Introduction

Diabetes as a worldwide epidemic

Type II diabetes mellitus (T2DM) has become a worldwide epidemic. From an estimated 2.8% global prevalence (171 million persons) in 2000, its prevalence rose to 347 million cases in 2008[1] and is expected to rise up 5.3% (438 million cases) by 2030[2,3]. Once thought to be related to affluence and development, countries in the process of economic development now face the largest burden from diabetes[2,4]. Diabetes poses an enormous public health burden, accounting for 11.6% of global health spending and 6.8% of global all-cause mortality[5]. Undiagnosed diabetes, more serious in developing countries with limited surveillance resources and more extensive rural areas with reduced healthcare access, worsens the burden[6]. Undiagnosed diabetes was 3.5 times more prevalent in low socio-economic status groups than in high[7]. Income-related health disparities are particularly important in developing countries or Indigenous populations. Diabetes prevalence is exhibits considerable ethnic disparities[4,8]. Diagnosed diabetes among US Hispanics and non-Hispanic Blacks was twice the rate of non-Hispanic Whites[6,9]. Similarly, total diabetes was higher among Hispanic than non-Hispanic White populations in 46 states, with undiagnosed diabetes higher among Hispanics in all 50 states[10].

Many anthropologists have been concerned with the high prevalence of diabetes among Indigenous peoples worldwide[11-14]. Yet prior to the 20th century, diabetes was virtually unknown among Indigenous peoples[11-13,15]. The dramatic rise occurred within the span of several decades: Australian Aborigines in 1932, Pima Indians between 1937 and 1954, and American Indian and First Nations peoples in the 1940s[11-13,15-18]. By 1987, most Indigenous populations had diabetes prevalence and diabetes mortality rates several times higher than comparable Caucasian populations[11,12].

Diabetes is a complex multi-factorial disorder[19], with genetic[19] and environmental[11,12,20,21] determinants. Anthropologists have often tended to favor one or the other side, biomedical or cultural, as the predominant explanation. Medical anthropologists are concerned with the subjective lived experience of people with diabetes and the ways bodily illnesses reflect sociocultural power relationships[4,22,23]. However, biological anthropologists have often favored unidentified 'thrifty genotype' genetic susceptibilities among Indigenous peoples to explain their high prevalence of diabetes[11,12,24,25].

Statistical evidence from genome-wide association studies has implicated numerous regions in elevated diabetes risk[26]. However, independent replication rates are very low and causal variants remain unknown[26,27]. The rapid (<2-3 generations) emergence of diabetes does seem incongruous with a common genetic etiology for 300 million Indigenous people in thousands of cultures across the globe[28,29].

The drastic rise in diabetes prevalence among Indigenous peoples in the 20th century seems more likely to be explained by known social factors than unknown genetic risks[19,22,28,30,31]. An understanding of culturally constructed models of diabetes causality is necessary for designing effective public health interventions[32,33]. And an exclusive focus on subjective experience risks overlooking known biomedical determinants of diabetes[22]. A middle way is suggested that incorporates both biological and cultural stress and stressors in diabetes etiology[22,34].

This article is a review of the anthropological literature on the prevalence and incidence of diabetes in modernizing populations from an anthropological perspective. This review focuses on the role of psychosocial stress, broadly conceived as modifiable behavioral or social determinants, in environments characterized by modernization and economic development.

Definitions and measures of stress

The human stress response stems from the body's reaction to physical, biotic, and/or sociocultural stimuli resulting in the need to appraise adaptive activity[34]. Contemporary stress research derives from Hans Selye, who recognized that stress has both adaptive and destructive effects and proposed to measure stress by hormones that maintain or disturb physiological homeostasis[35]. Stressors included both internal (nervous tension) and external (infectious) factors, and could cause both specific (affecting particular bodily systems) and non-specific (whole-body) responses[35]. Stressors could be bad (distress), which can lead to exhaustion and ill health, or good (eustress), which provides a healthy level of tension.

The vague definition of stress as wear and tear on the body, made it difficult to measure the effects of stress on health[35-38]. But the theoretic distinction between stress as a psychophysical state, and stressors as noxious environmental stimuli, allowed study of external social stressors, subjective mental or emotional states, and their relationship[36-38]. Since homeostasis was maintained by the neuroendocrine system, stress could be measured objectively by hormones of the hypothalamic-pituitary-adrenal (HPA) axis, and disturbed homeostasis could increase disease susceptibility[36,38]. Chronic stress resulted in fatigue, led to exhaustion, reduced resistance and increased ill health due to disturbed homeostasis and eventually caused disease or death[39]. This notion of allostasis contrasts to homeostasis and refers to an alternative but dysfunctional physiological set point induced by various stressors including aging and measured by various biomarkers[40,41].

The following operational definitions are used in this article:

- *Physiological stress* refers to the general adaptation response involving the HPA axis and is measured by levels of 'stress hormones' (adrenalin, norepinephrine, cortisol) that underlie the human body's adaptive response to external stimuli.
- *Psychological stress* refers to subjectively perceived mental or emotional states, as measured by various survey instruments, open-ended interviews or other self-reports.
- *Psychosocial stress* refers to objective measures of external sociocultural stressors associated with modernization or acculturation, including socioeconomic status, lifestyle incongruence (LI), urbanization, chronic (migration, trauma) or acute (familial or work-place conflicts) stressors, changes to traditional lifestyles (diet, physical activity) and environmental stressors (toxins, extreme weather events). These stressors are similar to the social determinants of health studied by public health practitioners[42].
- *Nutritional stress* refers to under-nutrition, over-nutrition or malnutrition, particularly in the perinatal period, as it pertains to Barker's theory of the developmental origins of chronic disease[20,25].

Methods

A literature review was performed in PubMed using the MeSH search terms 'diabetes' in [title] and 'stress' [text]. The initial search identified 3702 articles. A review of the 430 most recent (March 2009–March 2011) articles revealed that 74% of the articles concerned physiological stress

(Table 1). However, most of these (192 articles, or 60% of the category and 45% of the total) concerned oxidative stress and only 6 (1.8% of the category and 1.4% of the total) concerned the HPA axis or the physiological stress response. A review of these abstracts identified 83 articles of potential interest. Refinement of this literature search, by adding the terms 'anthropological' or 'anthropology' or 'ethnographic' or 'indigenous' in the text, reduced results to 35 articles. Of these, only 5 articles were of potential interest, 2 of which were used here[22,43]. A subsequent refinement added the search terms 'Hispanic' or 'Mexican-American' or 'Mexican' in the text and returned 3 articles, none of which were pertinent to this topic. These meager results indicated that a formal literature search using PubMed was inadequate to the task.

Due to these limitations, three additional procedures were incorporated to identify pertinent literature. First, similar searches were conducted on GoogleScholar: 'diabetes' and 'stress' in the title returned 2010 references, while 'diabetes' and 'anthropology' in the title returned 4 articles, one of which was used here[44]. Second, abstracts of the 83 PubMed articles were reviewed and the 2010 GoogleScholar references were browsed to determine their relevance to the research question. Third, it was quickly determined that a better method to identify pertinent historical and recent studies was to use a combination of snowball sampling from the bibliographies of found references[22,44,45], and opportunistic sampling from PubMed when retrieving known abstracts, to identify further substantive articles of interest.

Study limitations

The main study limitation identified was the inadequacy of search engine results using PubMed and GoogleScholar. While this approach can be a good starting point for systematic reviews of biomedical topics, it was inadequate to identify a sufficient number of references on the desired topic. Another limitation was the multi-dimensional and often incompatible definitions of stress used across a wide range of studies, which resulted in large numbers of irrelevant hits in both Pubmed and GoogleScholar. Finally, the number of studies identified that address T2DM as related to stress in ethnic populations or anthropological perspectives was limited.

Theories about stress and chronic disease

Psychosocial stress and chronic disease: The very diversity of studies on stress and diabetes (Table 1) suggested a need to better characterize and categorize the nature of stress and help ensure better comparability among studies[46]. Two major theoretical perspectives on chronic diseases and stress were identified: psychosocial stress (sociocultural and psychological) and biomedical stress (physiological or hormonal and nutritional). Theories on stress and chronic disease distinguish between subjectively perceived stress (a private mental or emotional state), external factors that induce stress (sociocultural stressors),physiological changes involving the HPA axis that underlie behavioral responses to stressors, and nutritional stress[2,21,36-38]. Psychosocial stress can be psychological (subjective psycho-emotional states) or sociocultural (social support, financial issues, chronic familial or workplace conflict, acute traumatic events). Psychological stress, as subjective psycho-emotional states (anxiety, depression) can be inferred from verbal reports, written questionnaires or open-ended interviews. The impact of stress can vary depending on personality, interpretation, social support and coping style[36,37,47-49]. The sociocultural context and cultural meaning of events can influence how psychosocial stressors are interpreted[47,49,50]. Psychological stress can affect health status by increasing behavioral risk factors, such as tobacco or alcohol consumption[51,52].

Physiological stress can be measured by levels of stress hormones (adrenalin, norepinephrine and cortisol)[51]. Persistent elevation of stress hormones in people exposed to social situations normatively described as 'stressful' (including spousal loss, workload and migration) suggested a connection between subjective psycho-emotional states and their social causes[51]. Stress hormones can increase diabetes risk by stimulating release of glucose or insulin and lead to obesity and hyperinsulinemia[11,51].

Table 1: Multiple definitions of stress identified in PubMed search ('diabetes'[title] AND 'stress'[all fields]), by count and percentage.

Definition of Stress	*n* (%)
Psychosocial	28 (6.5)
Psychological	46 (10.7)
Physiological	319 (74.2)
Nutritional	3 (0.7)
Mechanical	9 (2.1)
Undetermined/irrelevant	25 (5.8)
Total	430 (100)

Stressors themselves can be chronic (everyday stress) or acute (migration, traumatic life events), and either sociocultural (including environmental) or nutritional in nature[2,46,47]. Excessive chronic stress can eventually lead to emotional, physical, and behavioral breakdown[39]. Social stressors included crowding, occupational mobility, social isolation, family breakdown, migration, urbanization and economic development[36-38]. Acute stressors are traumatic events that demand psychological, behavioral or social readjustment, such as migration, divorce or job loss[48,49]. Chronic stressors derived from discord related to routine social roles, including family, job, marriage or money[48,49]. Specific psychosocial stressors were related to health outcomes in modernization[49,50]. It has been argued that the stress of modernization differs from both acculturation (Western education, speaking English) and biomedical risk factors (diet, obesity, physical activity)[48-50,53]. Specifically, lifestyle incongruence is the disjunction between people's desired socioeconomic status and their actual attainment and can lead to chronic disease[48,49]. Lifestyle incongruence is primarily a theory of consumption during modernization[9,49,50].

These theoretical developments provided a research focus for studies of stress and diabetes and indicated a need to measure a variety of stress processes or social stressors[37,38]. In Cassell's theory, social stressors produce non-specific effects on health[36-38]. This lack of etiological specificity meant that there are no 'stress diseases' but only altered incidences of routine diseases due to stress[36-38]. Consequently, all disease outcomes (rather than particular diseases of interest) must be studied to characterize the effects of exposure to social stressors[37].

Nutritional stress and chronic disease: Nutritional stress is another stress theory related to modernization. The developmental origins of chronic disease postulates that perinatal malnutrition leads to chronic disease in adulthood. Fetuses adapt *in utero* to their nutritional milieu, as determined by maternal condition and diet during pregnancy and previous nutritional experience[54,55]. The fetus responds to under-nutrition by altering changing hormone production, tissue sensitivity to hormones, and growth rates. The result is reduced fetal growth rates, low birth weight (LBW), stunting, reduced rates of postnatal growth, and altered organ/body weight ratios[55]. The timing of malnutrition can impact different organs differently, depending on critical growth periods affected[55]. Therefore, unlike psychosocial stress, nutritional stress can induce etiological specificity.

The developmental origins model proposed that diabetes can be a long-term consequence of the hormonal changes induced by maternal malnutrition[20,21]. This model proposed that early-life malnutrition led to decreased fetal insulin, insulin-like growth factors and glucose which control fetal growth, thus leading to reduced fetal growth rates and permanently altered insulin and glucose metabolism[20,55]. The thrifty phenotype hypothesis posits fetal and early life malnutrition impose nutritional thrift upon the individual, leading to impaired pancreas development and increased susceptibility to T2DM[20,21]. Low birth weight also induces pre-diabetic traits of high blood glucose and insulin, insulin resistance, and impaired beta cell function[30,56-59]. Subsequent childhood over-nutrition resulted in accelerated childhood growth insulin resistance, glucose intolerance, obesity and T2DM diabetes in later life[20,21,60]. Offspring glucose and insulin levels were associated with low maternal BMI independently of offspring birth weight[55,60]. The developmental origins model postulates that prenatal nutritional stress permanently altered physiological and metabolic pathways. Subsequent nutritional stress, including obesity and nutritionally poor diets, can lead to T2DM in mid-life[61].

Epidemiological studies have suggested that adult non-communicable chronic diseases have a host of determinants, from genetic and adult lifestyle factors to environmental factors acting in early life[62]. In summary, psychosocial stress in conjunction with nutritional deficits can potentially explain the diabetes epidemic in modernizing countries and among Indigenous peoples worldwide.

Results

Anthropological literature on modernization, stress and diabetes

Theories of psychosocial and nutritional stress and their impact on chronic disease are related to anthropological studies of modernization. Modernization is the process of economic and sociocultural change, by which traditional cultures industrialize and develop a capitalist economy characterized by division of labor, reduced importance of kinship, and changes in traditional lifestyles[48,63,64]. Modernization is related to increased chronic disease morbidity and mortality and is a major focus of contemporary medical anthropology[48,65-67]. The unique contribution of anthropological studies is that the global diabetes epidemic strongly impacts modernizing populations[5,67] and occurs during the nutritional transition[68,69] involving reduced physical activity, increased obesity and diets rich in processed carbohydrates[1,20,70].

The real challenge in anthropological studies of diabetes is how to operationalize 'modernization'. Drastic lifestyle changes involving nutrition, activity patterns, residence, and psychosocial stress related to post-WWII modernization are related to diabetes among Indigenous peoples[11,71]. Urbanization is a composite variable for several aspects of modernization, including decreased physical activity, increased healthcare access, and differential access to Western foods[72]. Urbanization also correlates with access to wage-labor jobs and socioeconomic factors[47,50]. With some exceptions[18,43,73], data to compare diabetes incidence or prevalence between Westernized and traditional Indigenous peoples are sparse[12]. Anthropologists have operationalized the lifestyle changes associated with modernization by measuring activity patterns, acculturation scales, affluence and consumption, dietary changes and nutrition, urbanization and other psychosocial factors[11,18,71,73,74] (results in Table 2).

Psychological and physiological stress

Anthropological studies on subjective stress, though infrequent[51], have been conducted[74-77]. Levels of epinephrine were higher in Westernized urban Samoans than in Samoans having a more traditional lifestyle as rural agriculturalists, but norepinephrine levels did not differ[76,77]. Rural villagers had higher levels of life satisfaction and emotional stability compared with urban Samoans, thus correlating stress hormone levels to subjective stress[77]. A study of Mexican–American migrant farm-workers in Wisconsin demonstrated associations between dopamine β hydroxylase (DBH, a norepinephrine precursor), acute stressors (familial separation, migration), and diabetic status[78]. A longitudinal study of children and young adults in the Dominican Republic demonstrated that several measures of chronic and acute household insecurity, especially poor maternal care, were associated with cortisol levels[79].

Psychosocial stress

Overall lifestyle change: A generalized acculturation measure, including dietary change, anxiety and economic stress, was used to study cardiovascular disease (CVD) risk factors among rural Solomon Islands villagers[80]. Westernization was operationalized by a 12 point acculturation scale based on changes in culture (education, religion, access to Western medical care), diet (salt intake, Western foods), adult height (reflecting childhood nutrition) and economy (wage-labor jobs or swidden agriculturalists) changes[80]. They studied two risk factors for diabetes: obesity and hypertension. Acculturation was associated with hypertension, but not with obesity[80].

The relationship between modernization and diabetes was studied in American Samoa[81]. The measure of modernization captured different degrees of participation in modern life, as measured by location of residence (modern, intermediate or traditional) and characterized by different degrees of connectedness to westernized areas (central harbor, paved roads, isolated rural areas)[81]. These locations also corresponded to differences in language, education, occupation and blood pressure (BP)[81]. Activity levels were categorized by occupational information recorded on health certificates[81]. More westernized males and those with more sedentary life-styles had elevated CVD-related mortality[81]. The effects of modernization on diabetes risk was not directly assessed, but there was a significantly higher age-adjusted incidence of diabetes-related mortality among Samoans (32.2 deaths/100 000 population) relative to the US (13.4 deaths/100 000)[81].

Finally, 2 unspecified American Indian populations (Northern Plains, Southwest) were studied using a 25 item early-life traumatic events and a 30 item chronic stress instrument[43]. Results showed that diabetes in the Northern Plains population was associated with early-life trauma, while the Southwest population diabetes was associated with discrimination and community addiction problems[43].

Lifestyle incongruence: Lifestyle incongruence refers to a discrepancy between material consumption (lifestyle) and economic means[48]. The effects of LI on BP in Western Samoa were studied using a 21 point scale for lifestyle/material possessions and an 8 point occupational scale[82]. For men, LI was associated with elevated systolic BP. For women, diastolic BP was higher when occupational rank exceeded lifestyle, the opposite of LI[82]. In American Samoa, LI also varied by sex[83]. The effects of modernization versus status incongruence on hypertension were directly compared in a Mexican community[84]. The modernization model predicted that stress accumulated with the degree of modernization and increased chronic disease risk[84]. Modern traits included wage-labor, Western education, urban residence, reduced kinship support network, and adoption of modern attitudes, behaviors and values[84]. They also measured subjectively perceived stress (anxiety, depression, life-satisfaction, recent life events, social support, tension and worry)[85]. The alternative explanation was lifestyle incongruence[84,85]. Results showed that systolic and diastolic BP increased with increasing modernization but not with LI[84]. Among the Mississippi Choctaw tribe, LI was associated with elevated non-fasting plasma glucose[85], while psychological stress was associated with elevated diastolic BP[85]. These mixed results suggest that more research on the effects of LI and acculturation on diabetes is needed. Cultural factors may also modify the impact of lifestyle incongruence[53].

Dietary change: The effects of traditional diet and dietary change, often conceptualized biomedically as adoption of a high-fat, high-carbohydrate, low-fiber diet, have been studied as a risk factor for diabetes among Indigenous peoples[11,12,71]. An interesting anecdote about the impact of refined carbohydrates on diabetes came from India in 1907. The earliest reported cases of diabetes occurred in areas near the first industrial rice mills, which removed most of the bran fiber from the grain[71]. By contrast, areas that continued to use traditional home-pounding of rice, which left half the bran fiber, had lower incidence of diabetes[71].

Many traditional Australian Aboriginal, Pima Indians and Pacific islander foods protect against hyperglycemia by being digested more slowly than Western foods and result in lower levels of blood glucose and insulin[86-88]. Westernized diabetic Aborigines who temporarily (7 weeks) reverted to a traditional hunter-gatherer diet and lifestyle had improved blood glucose, insulin and triglycerides and reduced insulin resistance[89]. Pima Indians who ate a Western diet were 2.9 times more likely to develop diabetes, while those on a mixed diet were intermediate at 1.6 times more likely, compared with those eating a traditional diet[88]. Over-eating by non-diabetic Pima Indians increased plasma insulin[90]. Dietary changes among the Eastern Oklahoma Cherokee, including replacement of traditional beans, corn and squash with refined flours and a change from boiling or broiling to deep-frying, are thought responsible for the increase in diabetes prevalence, from 0% before 1941, to 13% in 1974[91]. Traditional methods for processing wheat, including parboiling and baking whole grains, resulted in lower glycemic response compared to bread baked with industrially milled flours[92]. Unhealthy dietary changes often result from greater availability and affordability of energy rich, nutrition poor foods[93]. The increase in nutritional risk factors is an important factor in the increasing prevalence of diabetes and other chronic diseases in developing countries[72].

The effects of acculturation and dietary factors on CVD risk factors were studied in Yaqui and Tepehuanos Indian communities in Mexico[52,94]. Diabetes was assessed as a CVD risk, along with obesity and triglycerides[52]. A 12 point acculturation scale was used and included language use, media exposure and social relations[95]. The Yaqui Indians were more acculturated than the Tepehuanos, who were subsistence farmers with a vegetarian diet until Western foods were introduced in 1998[94]. The Yaqui were more obese (48% vs 7% prevalence), had more hypertriglyceridemia (15% vs 43% prevalence), less LDL-cholesterol (34% vs 42% prevalence), and a remarkable 22-fold higher prevalence of diabetes (18.3% vs 0.8%) than the more traditional Tepehuanos[52]. Impaired fasting glucose was higher among the Yaqui (17%) than the Tepehuanos (5%)[52]. Neither total daily energy consumption nor total fiber intake differed between groups, but they did differ in the energy derived from saturated fats (1412 Kj/day Yaqui, 978 Kj/day Tepehuanos)[52]. The Yaquis' higher diabetes prevalence was attributed to their higher saturated fat consumption[52].

A 64 item food questionnaire was administered in 12 Yaqui communities at 2 time-points, 1994 (traditional vegetarian diet) and 2004 (Westernized diet) to assess total caloric intake and food proportions derived from protein, carbohydrates and saturated and unsaturated fats[96]. Traditional foods (green vegetables, bread, beans, potatoes and mixed-root tortillas, occasional meat) and Western foods (refined flours, canned foods, pasta, soft drinks, and 'junk' food) were compared[94]. In 10 years of follow up, dietary saturated fat doubled while unsaturated fats declined by 75%, fiber intake declined from 53 g/day to 49 g/day, and total caloric intake increased from 1476 KCal/day to 2100 KCal/day[94]. These dietary changes were associated with increased overweight/obesity (11% to 22%), hypertriglyceridemia (3% to 17%), impaired fasting glucose (6% to 15%), and decreased HDL (71% to 10%)[94]. Hypertension prevalence doubled from 2% to 4%, and metabolic syndrome increased from 0% to 10%, although diabetes prevalence did not change at 1%[52,94]. Acculturation among the Tepehuanos Indians was characterized by dietary changes involving increased consumption of calories and saturated fats, reduced fiber and was associated with an increased prevalence of risk factors[94].

Physical activity change: Decreased energy expenditure is primary feature of lifestyle change during modernization that can lead to obesity and diabetes[71]. Historically recent (>1930s) changes in activity patterns among Oklahoma Cherokee involved decreased walking and increased reliance on vehicular transportation and were associated in time with increased diabetes-related mortality (from 0 cases in 1941 to 26.2/100 000 in 1977), which was 63% higher than

Caucasian rates[91]. Most studies on the role of reduced physical activity as a diabetes risk factor concerned the Pima Indians. Questionnaires were used to estimate the amount of time spent in various activities[96]. Traditional Mexican Pimas had 23 h/wk of occupational physical activity, compared with 5 h/wk for more Westernized Arizona Pimas[96]. These differences corresponded to higher prevalence of diabetes among Arizona Pima (38.2%) than Mexican Pima (6.2%)[96]. A later study confirmed these results, with Arizona Pimas having physical activity of 3.1 h/wk (female) to 12.1 h/wk (male), compared with Mexican Pima females (22 h/wk) and males (32.9 h/wk)[97].

Prenatal nutritional stress

The only anthropological studies concerning the developmental origins of diabetes were conducted on the Pima Indians. Several large studies examined the relationship between known birth weights and serum glucose or insulin levels[98,99]. Diabetes prevalence and 2 hour fasting glucose concentration had a U-shaped relationship with birth weight[98,99]. The LBW Pima were more insulin resistant, after controlling for weight and height[98]. The highest adult prevalence of diabetes (52.4%) was found in the lowest one-third (<2500 g) and the highest one-third (>4500 g) of birth weights. High prevalence among high birth weight (HBW) babies was attributed to gestational diabetes[99]. The LBW babies were 3.8 times more likely to have diabetes as adults, compared with middle birth weight babies[99]. Only approximately 6% of Pima babies were LBW and there was no evidence of maternal nutritional stress during pregnancy, making Barker's developmental model an incomplete explanation of the high (≥40%) adult diabetes prevalence[99]. The high prevalence of diabetes among LBW babies was attributed to selective survival of diabetes-prone LBW infants through an unknown genetic mechanism[99]. In another study, HBW Pima babies exhibited a dose-response relationship between extent of bottle feeding with cow's milk and adult diabetes prevalence[100]. Diabetes at age 30–39 years had 20% prevalence among Pima babies exclusively breast fed for at least 2 months, 25% prevalence among the cohort with some breast feeding, and 30% prevalence among those exclusively bottle fed with cow's milk[100]. Perinatal nutritional stress associated with later-life diabetes seemed related to nutritional overload of cow milk bottle-feeding, or possibly a missing nutrient specific to breast milk which affected infant insulin sensitivity[100].

Discussion and Conclusions

A survey of the literature on stress and chronic disease identified four concepts of stress: physiological, psychological, psychosocial, and nutritional. To varying degrees, all are determinants of diabetes and should be studied in any comprehensive study. The anthropological survey demonstrated how studies of various anthropological populations undergoing modernization have operationalized stressors that influence diabetes risk. The remaining question of interest was how to measure modernization stressors in the US–Mexico border area, in order to study their influence on diabetes risk.

In fact, many of these stress concepts have empirical support in Hispanic populations. Hispanic youth with metabolic syndrome have higher serum cortisol than overweight healthy controls, as expected from physiological stress theory[101]. Acculturation measures in Hispanic populations are associated with reduced prevalence of breastfeeding[103], which is associated with increased risk of diabetes in adulthood[102], as suggested by the developmental origins model of diabetes[20,21]. Measures of modernization are associated with reduced dietary quality (decreased intake of fiber and fruit, and increased consumption of saturated fats and sugar) among diabetic Hispanics[104,105]. Hispanic household food insecurity is associated with increased consumption of poor-quality foods, including fats and sugar[106]. But no studies were found in the border area that addressed all four concepts of stress in diabetes etiology.

Table 2: Summary of ethnographic studies related to diabetes and stress[20,21,43,52,71,76-92,94,96-102]

Ref	Study design	Population	Age range	Sex	Type/s of stress	Measure of stress	Diabetes-related response	Outcome (+/-)
20	Review	Various	4-74 yr	M & F	Nutritional	LBW	Diabetes risk	+
21	Review	Various	Adult	M & F	Nutritional	LBW	Diabetes risk	+
43	X-section	2 American Indian tribes (Northern Plains, SW)	15-54 yr	M & F	Psychosocial	25-item acute stress & 30-item chronic stress	Diabetes	+ (Northern Plains/acute stress) & + (SW/chronic stress)
52	X-section	Yaqui & Tephanous Indians (Mexico)	20-65 yr	M & F	Psychosocial	Traditional/Westernized lifestyle	Diabetes (diagnosed & undiagnosed)	+
71	Anecdote	Colonial India	Adult	NS	Psychosocial	Dietary change (rice bran fiber)	Diabetes prevalence	+
76	X-section	Western Samoa	Young adults	M	Psychological, physiological	Traditional/Westernized lifestyle	Epinephrine & norepinephrine excretion	+
77	X-section	Western Samoa	Young adults	M	Psychological, physiological	Traditional/Westernized lifestyle	Systolic BP	-
78	X-section	Mexican-American migrants	43-54 yr	M & F	Psychological, physiological, psychosocial	Chronic & acute social stress, perceived stress, DBH	Diabetes	+ (acute, DBH), - (perceived)
79	Prospective cohort	Dominican Republic	2 mo-18 yr	M & F	Psychological, physiological	Household insecurity	Salivary cortisol	+
80	X-section	Solomon Islanders	Adult (≥15 yr)	M & F	Psychosocial	12-point Westernization scale	Htn, BMI	+ (htn), - (BMI)
81	Retrospective cohort	American Samoa	30+	M & F	Psychosocial	Residence (urban/intermediate/rural)	Diabetes-related mortality	+
82	X-section	Western Samoa	25-64 yr	M & F	Psychosocial	LI	BP	+ (males), - (females)
83	X-section	American Samoa	Adult	M & F	Psychosocial	LI	BP	+ (males), - (females)
84	X-section	Temascalcingo, Mexico	17-71 yr	M & F	Psychosocial	LI & modernization scales	BP	+(modernization), - (LI)
85	X-section	Mississippi Choctaw	≥21 yr	M & F	Psychological, psychosocial	LI & perceived stress scales	Blood glucose, Systolic BP	+ (LI &glucose) +(perceived stress & systolic BP)
86	Pre/post test	Healthy Caucasians	21-24 yr	M & F	Psychosocial	6 Traditional Pima foods	Serum glucose & insulin, in vitro starch digestibility	+
87	Pre/post test	Healthy Caucasians	24.4 yr	M & F	Psychosocial	37 Traditional foods	Serum glucose & insulin, in vitro starch digestibility	+
88	Prospective cohort	Pima Indians (AZ)	18-74 yr	M & F	Psychosocial	Diet (traditional/intermediate/Western)	Diabetes risk	+ (dose/response relationship of diet to odds of diabetes)
89	Pre/post test	Australian Aborigines	Adult (54 yr)	NS	Psychosocial	Traditional diet & activity	Fasting glucose, insulin, triglycerides	+
90	Pre/post test	Pima Indians (AZ)	Adult	NS	Psychosocial	Over-eating	Plasma insulin & glucose	+ (insulin), - (glucose)
91	Anecdote	East Oklahoma Cherokee	≥34 yr	NS	Psychosocial	Western diet & acculturation	Diabetes prevalence	+
92	Pre/post test	Diabetics & healthy controls	NS	M & F	Psychosocial	Traditional food processing	Glycemic index	+
94	X-section (consecutive)	Tepehuanos Indians	23-51 yr	M & F	Psychosocial	64-Item FFQ (food frequency questionnaire)	Fasting glucose; BMI; dietary LDL-c, fat, triglycerides	+ (All)

Table 2: Cont'd

Ref	Study design	Population	Age range	Sex	Type/s of stress	Measure of stress	Diabetes-related response	Outcome (+/-)
96	X-section	Pima Indians (Mexico & AZ)	NS	M & F	Psychosocial	Physical activity, diet, BMI	Diabetes prevalence	+ (All)
97	X-section	Pima Indians (Mexico, AZ) & non-Pima Mexicans	20-55 yr	M & F	Psychosocial	Physical activity, diet, BMI	Diabetes prevalence	+ (All)
98	Prospective cohort	Pima Indians (AZ)	5-29 yr	M & F	Nutritional	Birth weight	Serum glucose & insulin	+
99	Prospective cohort	Pima/Papagola (AZ)	20-39 yr	M & F	Nutritional	Birth weight	Diabetes prevalence	+ (diabetes associated with LBW & HBW)
100	Retrospective cohort	Pima/Papagola (AZ)	10-39 yr	M & F	Nutritional	Over-nutrition (breast- vs bottle-fed)	Diabetes prevalence	+
101	Prospective cohort	US Latino youth	8-13 yr	M & F	Psychosocial	Serum cortisol	Metabolic syndrome	+
103	Systematic review	Various	Infant to adult	M & F	Nutritional	Breast-feeding	Diabetes risk, serum glucose & insulin	+ (diabetes), - (glucose, insulin)

BP, Blood pressure; DBH, dopamine β hydroxylase; Htn, Hypertension; HBW, high birth weight; LDL-c, low density lipoprotein-c; LI, lifestyle incongruity; LBW, low birth weight ; Mo, months; NS, not specified; yr, year; X-section, cross-sectional; +/-, positive effect/negative effect.

Several suggestions can be made for best practice. Throughout, the importance is underscored of a comprehensive view of stress and use of multiple indicators[34,75]. If blood samples can be collected, diabetes can be directly inferred by fasting glucose levels using established WHO criteria. Tissue sampling would also allow measurement of stress hormones (salivary cortisol, serum epinephrine). If blood sampling is not feasible, diabetes prevalence could be estimated by self-reporting (having been told by a physician that they are diabetic). Furthermore, the few available studies indicate that 'stress hormones' do not always measure stress[76,77,79]. In that regard, it may be inadvisable to collect tissues at all. Biomedical risk factors should be measured, including diet (by 24 hour recall or food frequency questionnaires [FFQs]), physical activity levels (to assess work and leisure activity patterns)[104]. Surveys should address the presence of barriers and motivating factors for increased physical activity[107]. Obesity (BMI) can be measured using basic anthropometry (height and weight) in either clinical or field situations. Lifestyle incongruence can be inferred using Dressler's instrument[50]. Childhood nutritional stress can be estimated by parental recall[106], which is reliable up to 42 years later[102]. It can also be retrospectively estimated in adults by measurement of adult leg length (the difference between height and seated height)[108-110]. Acculturation can be measured by uni-dimensional scales, like the Short Acculturation Scale (SAS), which utilizes the single dimension of language use[95] Such uni-dimensional acculturation scales have been criticized because culture is more than language, culture change is not identical to stress, and changes in diet and physical activity do not fully explain the increased risk of chronic disease encountered during modernization[49,50,85,111]. Multidimensional scales, like the Acculturation Rating Scale for Mexican Americans-Revised (ARMSA II), also measure the attitudes, beliefs, values and behaviors that constitute the actual processes of cultural change, while still incorporating language and social factors like immigration status and length of residence[112-114].

Conclusion

In the authors' view, lifestyle changes, multidimensional acculturation scales, FFQs, subjective stress instruments[115], and anthropometry are needed to fully assess the impact of stress as a determinant of diabetes. This knowledge can be used to design more effective public health interventions and accurately target diabetes prevention efforts toward individuals at greatest risk of developing diabetes in the US–Mexico border area or similar modernizing populations.

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