Stress and Type 2 Diabetes: A Review of How Stress Contributes to the Development of Type 2 Diabetes

Shona J. Kelly and Mubarak Ismail

Center for Health and Social Care Research, Sheffield Hallam University, Sheffield S10 2BP, United Kingdom; email: s.Kelly@shu.ac.uk

Annu. Rev. Public Health 2015. 36:441–62

First published online as a Review in Advance on January 12, 2015

The *Annual Review of Public Health* is online at publhealth.annualreviews.org

This article's doi: 10.1146/annurev-publhealth-031914-122921

Keywords

physiologic stress response, socioeconomic status, health inequalities, prospective studies

Abstract

Current policy and research around type 2 diabetes (T2D) interventions largely invoke a behavioral model. We suggest that activation of the physiologic stress response (PSR) from chronic exposure to stressors, low socioeconomic status (SES), severe mental health problems, or aggressive behavior increases the risk of T2D. This article is a comprehensive review of the literature on the link between T2D and psychosocial factors focusing on prospective studies of the risk for developing diabetes. The review found an increased risk for T2D in people: exposed to stressful working conditions or traumatic events; with depression; with personality traits or mental health problems that put them in conflict with others; of low SES, either currently or in childhood; and in racial/ethnic minority populations, independent of current SES. This review suggests that T2D prevention research would be more effective if (*a*) the PSR to psychosocial factors (especially social disparities) was recognized and (*b*) intervention programs evaluated reduction in social disparities as part of a comprehensive approach.

INTRODUCTION

T2D: type 2 diabetes

PSR: physiologic stress response

CVD: cardiovascular disease

SES: socioeconomic status

Type 2 diabetes (T2D) is a group of conditions characterized by a background of insulin insensitivity and a failure of pancreatic insulin secretion to compensate for this; it is diagnosed clinically by elevated plasma glucose levels, which are frequently found in association with obesity and other metabolic abnormalities such as dyslipidemia as well as endothelial and cardiovascular dysfunction. The causes of T2D are attributed to lifestyle or genetics, both of which have been invoked to varying degrees to explain ethnic disparities in disease prevalence and outcomes (e.g., 60).

There is a solid body of literature showing the importance of conventional (nonpsychosocial) risk factors for T2D. However, in spite of interventions based on these conventional risk factors, the incidence of diabetes continues to rise. We propose that chronic activation of the physiologic stress response (PSR) increases the risk of developing T2D. The amount of literature examining this relationship remains limited and, conceptually, the link remains largely unrecognized; this is surprising when one considers the large amount of stress-related literature in diabetes management (e.g., 30, 80). However, focusing greater attention on the role of chronic stress factors in the development of T2D could afford researchers and clinicians greater insights and potential new avenues for intervention.

The prevalence of T2D, like that of cardiovascular disease (CVD), increases substantially with decreasing social position. In the case of CVD, a solid body of research evidence indicates that neither genetic factors nor lifestyle can fully explain socioeconomic status (SES) gradients and ethnic disparities in the disease prevalence within a country (e.g., 52, 53) or explain differences between countries (e.g., 73, 100). Moreover, although CVD and T2D share many risk factors, only for CVD is there much research on the role that stress-related exposure plays in the development of the disease. Although there is some debate of the mechanisms by which difficult life circumstances (associated for example to low SES) might affect health, the most prominent theories propose mechanisms such as cumulative exposure to stressors (allostatic load) (57), perceived lack of control (48), and stress-related consequences arising from unfavorable social comparisons (98). Much of the research describes the mechanisms as related to "stress," but the terminology is inconsistent (17).

This article reviews the evidence concerning psychosocial factors and the development of T2D, outlines possible mechanisms, and makes recommendations for future research and policy directions. It begins with a clarification of the terminology of stress, as this plays an important role throughout the review.

Stress Terminology

Stress is widely regarded (1) as an important cause of ill-health and is frequently cited as an important contributor to socioeconomic gradients in health (14, 96). A central problem is the terminology used in research. For example, the term "stress" has been used to describe "the stimuli that produce a certain state, the subjective feelings of discomfort in this state and the responses that occur in an organism in this state" (93); as Cohen and colleagues describe it, stress may have environmental, psychological and biological roles in the development of ill-health (16). In this article, the term "stressor" refers to objective events or circumstances that are generally agreed to be stressful (e.g., traumatic life events); "distress" refers to subjective feelings of discomfort; and PSR refers to the physiological responses that occur within an organism that is exposed to stressors. Here we are particularly focused on the PSR and whether it provides a testable hypothesis to link psychosocial risk factors with the development of T2D.

The Stress Mechanism Hypothesis

As in the case of CVD, the original models for the development of T2D were largely behavioral and posited that, in particular, poor diet and lack of physical activity were primarily responsible for the disease. The development of CVD, however, has been shown to be independently associated with a variety of stress-related factors, including control (i.e., feelings of control of one's life), hostility, and traumatic life events (e.g., 27, 73). Such stress-related factors, which have been demonstrated to be important for the development of CVD, may also be important for the development of T2D.

SAM: sympathetic adrenomedullary system

HPA: hypothalamic pituitary adrenal (axis)

PTSD: post-traumatic stress disorder

One could plausibly argue that stress-related risk factors act via behavioral risk factors, and indeed most of the literature reviewed here uses this explanation. However, as discussed below, most of the studies in this review controlled the statistical analyses for many or most of the behavioral risk factors and still found an effect from stress-related factors. For example, some studies have shown that risk is considerably greater for those of low socioeconomic (50) or racial minority status (71), suggesting pathways that go above and beyond the behavioral.

The immediate PSR is not thought to be the problem affecting health; rather, chronic activation of the PSR is thought to be the key. The role of the PSR is to maintain physiologic homeostasis; it consists of an interrelated response from the sympathetic adrenomedullary system (SAM) and the hypothalamic pituitary adrenal axis (HPA). Initially, the SAM releases epinephrine and norepinephrine; if the stressor is sustained, the HPA comes into play. The development of abdominal obesity, an important risk factor for diabetes, is a key step in the evolution of the condition.

In the early 1990s, Bjorntorp and Rosmond proposed that "neuroendocrine responses to stress-related pressures" might increase the accumulation of abdominal fat (10). Their final model proposed that the HPA axis is reprogrammed with chronic stress exposure (74, 75). The key is that the stressor exposure must be of sufficient magnitude or duration to reprogram the HPA axis.

With the current recognition that T2D is an inflammatory disease, the hypothesized mechanism can shift from a behavioral model to a model of repeated episodes of acute or chronic PSR, which induce a chronic inflammatory process that produces inflammatory diseases (11, 23). Animal models have shown that stressor exposure precedes the development of chronic subclinical inflammation. The animals develop central obesity, insulin resistance, dyslipidemia, hypertension, and depression; and they go on to develop T2D, metabolic syndrome, and coronary artery disease (11). In humans, prospective work has shown that increased levels of inflammatory markers predict the development of T2D (19, 24), and even subclinical elevations have been shown to predict the development of T2D in the Atherosclerosis Risk in Communities (ARIC) study cohort (24, 77), particularly in the first three years (77).

Cross-sectional studies have shown that people with T2D, compared with those who do not have T2D, have poorer general mental health (3), are more likely to be depressed (45, 78), to be alcohol dependent (40), and to have post-traumatic stress disorder (PTSD) (36). Type 2 diabetics report more chronic stressors (41), greater work distress (3), and exposure to a greater number of stressful life events (3). There is a socioeconomic gradient in T2D such that the lower the SES, the greater the prevalence of T2D (e.g., 39). Above and beyond the SES effect, disadvantaged minority populations are generally at greater risk of developing T2D (e.g., 51, 92). The majority of these cross-sectional analyses controlled for the behavioral risk factors for T2D such as obesity, family history, poor diet, and lack of physical activity. However, cross-sectional studies cannot be used to determine the direction of causality or temporal sequence. It might be, for example, that coping with T2D could make people depressed and less likely to maintain necessary health behaviors such as adhering to their diet. They may also tend to view the world negatively and to be more affected by, and likely to report, stressors. Thus, where possible, the remainder of

this review will focus on longitudinal studies that begin with healthy subjects who are exposed to stressors or report distress and follow them over time to assess their risk of developing T2D.

BMI: body mass index

METHODOLOGY

The Nature of the Review and Classification Process for the Literature

A search of "stress" and "T2D" in Medline produces more than 1,000 results, most of which are concerned with diabetes management. Because our interest was in prospective studies, we initiated the search process by identifying longitudinal studies; therefore, a search of "longitudinal" or "prospective" and "diabetes" was our starting point. This highlighted that diabetes was rarely mentioned in the title or abstract but was one of many health conditions listed in the tables within the document. An additional strategy was to create a list of stress-related risk factors from the CVD literature to be used in a further series of literature searches for this article.

An extensive review, covering the entire time period available in the databases, was conducted in Ovid Medline, EbscoPsycArticles, Ebsco Psychology & Behavioral Sciences Collection, EbscoPsycINFO, Proquest Social Sciences Journals, Proquest Psychology Journals, and Sociological Abstracts from Cambridge Scientific Abstracts. We combined T2D with: depression, schizophrenia, type A behavior, psychosis, life events, stress(or), work/occupational stress, burnout, anger, distress, anxiety, education, income, occupation, poverty, and mental health.

The initial database search produced 930 titles, of which 39 articles (covering 32 cohorts) were relevant. We excluded duplicates, studies not having a longitudinal design, or research on people who already had diabetes. With the exception of research on depression, for which we also found systematic reviews although not all papers are included here, the articles presented here were all that we found and were not selected based on our hypothesis.

We reviewed the articles in detail and extracted the following information: cohort name, country, size of study population, percent female, genders combined or split in analysis, length of follow-up, method used to determine the diabetic status, and other factors included in the analysis.

The stress-related factors were classified into four broad categories: (*a*) subjective and objective exposure to stressors, (*b*) mental health, (*c*) aggressive behavior and conflict, and (*d*) living at the bottom of the social status hierarchy.

RESULTS

Length of follow-up varied from 1 to 60 years, and the majority of studies had very large sample sizes (see **Table 1**). The majority of cohorts were developed for a purpose other than predicting the development of T2D. When the information was available, depending on the data source, the analyses included the known clinical and behavioral risk factors in the final statistical models (see **Table 2**). Most of the behavioral risk factors were included as control variables and the relationships were not reported. In the few studies that reported them, however, the findings were similar to those seen in cross-sectional studies: An increasing risk for the development of T2D was associated with increasing age (62), body mass index (BMI) (47), and waist girth (28), and risk was greater in people with hypertension (80) and limited physical activity (83) and in smokers (44).

Subjective and Objective Exposure to Stressors

Self-reported feelings of stress and/or exposure to stressful life events or circumstances are often cited as significant factors in precipitating health problems (e.g., 91). Using the terminology we

Table 1 Summary of the longitudinal studies included in this review[a]

Study population	Publication year	Country	N	Follow-up time in years	T2D[b]	Chronic stressors
1958 Birth Cohort (89)	2007	UK	7,518	45	Clinical or self-report	Childhood SES
1958 Birth Cohort (90)	2008	UK	7,784	45	Clinical or self-report	Poor parenting
Alameda County (54)	2005	USA	3,293 F 2,854 M	34	Self-report	Education, income, occupational prestige
Alameda County (55)	2008	USA	3,157 F 2,756 M	34	Self-report	Education, income, occupational prestige, childhood SES
Atherosclerosis Risk in Communities (34)	2004	USA	15,972	6	Clinical	Vital exhaustion
AusDiab—Australian Diabetes, Obesity & Lifestyle Study (99)	2010	Australia	4,405	5	Clinical	Education, income, occupational prestige
Australian Women's Health Survey (83)	2006	Australia	8,896 F	3	Self-report	General mental health, perceived stress, life events, poor social networks, education
Baltimore Epidemiologic Catchment Area Study (59)	2008	USA	1,070	23	Self-report	Clinically defined depression
Cardiovascular Health Study (12)	2007	USA	4,681	10	Clinical	Depression
Danish Database Linkage Study (65)	2005	Denmark	314,807 F 314,807 M	18	Medical records	Life events
English Longitudinal Study of Aging (20)	2006	UK	919	4	Clinical or self-report	General mental health
English Longitudinal Study of Aging (88)	2012	UK	8,578 F 8,578 M	4	Self-report	Income
Finnish Diabetes Prevention Study (69)]	2011	Finland	1,593 F 789 M	1	Clinical	Education, income, occupational prestige
Gifu Prefectural Center for Health Check & Health Promotion (63)	2006	Japan	5,130 M	8.4	Clinical	Work stress
Gifu Prefectural Center for Health Check & Health Promotion (63)	2006	Japan	13,537 M	7.4	Clinical	Occupational prestige
Healthy Women Study (68)	2007	USA	432 F	15	Metabolic syndrome	Depressive symptoms, trait anger, trait anxiety, Framingham tension score, perceived stress, life events
Helsinki Birth Cohort (4)	2009	Finland	2,003	37–50	Clinical	Early traumatic life experience

(*Continued*)

Table 1 (*Continued*)

Study population	Publication year	Country	N	Follow-up time in years	T2D[b]	Chronic stressors
Japan Public Health Center-Based Prospective Study (42)	2009	Japan	55,826 F	10	Self-report	Type A personality, perceived stress
Massachusetts Male Aging Study (81)	2000	USA	1,095 M	8	Self-report	Depression/distress/ anxiety, other mental health conditions
Medical Practice Database (94)	2004	Netherlands	34,818 F 33,186 M	25	Clinical	Depression/distress/ anxiety
Medical Practice Database (56)	2005	USA	357	8	Clinical	Schizophrenia
Multiethnic Study of Atherosclerosis (33)	2008	USA	5,201	5	Clinical	Depression
National Comorbidity Survey (37)	2004	USA	4,251 F 3,847 M	retrospective	Self-report	Childhood abuse
NHEFS-NHANES I Death Follow-up (13)	2003	USA	6,190	M = 15.6	Medical records or self-report	Depression/distress/ anxiety, education
NHEFS-NHANES I Death Follow-up (72)	2005	USA	6,825 F 4,244 M	M = 10	Clinical	SES
Nurses' Health Study (8)	2004	USA	72,178 F	4	Clinical	Depression
Nurses' Health Study (50)	2007	USA	100,330 F	16	Clinical	Childhood, partner and life-course SES
Nurses' Health Study (70)	2010	USA	67,853 F	16	Clinical	Lifetime abuse
Occupational Health Cohort (58)	2006	Israel	677	3.6	Self-report	Burnout
Occupational Health Cohort (44)	1999	Japan	2,764 M	8	Clinical	Depression/distress/ anxiety
Occupational Health Cohort (43)	1999	Japan	2,194 M	8	Clinical	Work stress, work conditions, education
Occupational Health Cohort (62)	2005	Japan	3,106 M	8	Clinical	Work conditions
Occupational Health Cohort (85)	2006	Japan	5,629 M	10	Clinical	Work conditions
Still Working Study (46)	2008	Finland	5,827 M	18	Clinical	Sense of coherence
Stockholm Diabetes Prevention Program (25)	2008	Sweden	3,100 F 2,127 M	8–10	Clinical	Depression/distress/ anxiety
Study of Women's Health Across the Nation (28)	2004	USA	2,662 F	3	Clinical	Depression/distress/ anxiety
Vasterbotten Intervention Program (64)	2007	Sweden	1,070	23	Self-report	Depression/distress/ anxiety, education

(*Continued*)

Table 1 (*Continued*)

Study population	Publication year	Country	N	Follow-up time in years	T2D[b]	Chronic stressors
Whitehall II (47)	2004	UK	2,680 F 5,950 M	Median = 10.5	Clinical	General mental health, depression/distress/anxiety, work stress, life events, occupational prestige, material limitations
Whitehall II (38)	2009	UK	5,895 F	11.6	Clinical	Work stress
Whitehall II (82)	2012	UK	7,237	14.2	Clinical	Occupational prestige
Women's Health Study (35)	2006	USA	11,615	6	Clinical	Anger trait

[a]Abbreviations: F, females; M, males; SES, socioeconomic status; T2D, type 2 diabetes.
[b]Source of T2D information: clinical = diagnosis from laboratory measures and/or use of diabetes medication; medical records = from hospital/medical records.

described earlier, the literature examining the role of stress in the development of T2D may be categorized based on whether it emphasizes distress or stressors.

Two longitudinal studies have examined the relationship between T2D incidence and self-reported mental stress (distress) level. One, following only women, found no relationship after controlling for general mental health (83), whereas the other found an association only in males (42). Because people's ability to accurately describe their personal stress burden has been questioned (76), some researchers prefer to rely on more objective measures, such as inventories of life events that are generally acknowledged as traumatic or life altering. Finnish researchers followed people who were child evacuees during World War II (4) and found an increased risk for developing T2D in midlife even after controlling for age, gender, and SES. The United Kingdom Whitehall II Study asked participants about life events such as death of a friend or relative, marital problems, or accidents over the previous 12 months and found a nonsignificantly increased risk of T2D in multivariate models that included other stressors and risk factors for T2D (47). Moderate and severe childhood abuse has been shown to increase the risk for T2D in a dose-response fashion even after controlling for the conventional risk factors (70). The US National Comorbidity Study has also demonstrated a relationship between childhood neglect and midlife diabetes onset (37) after controlling for age, gender, ethnicity, and SES.

Stressful work conditions, objectively determined from questions about specific stressful characteristics of work, have been linked to an increased risk of subsequent CVD; however, there have been few attempts to extend this work to T2D. The Japanese have used their system of annual medical check-ups in large occupational cohorts to look at several aspects of work that are presumed to be stressful (43, 44, 62, 85). For example, these routinely collected data have shown an elevated risk for the development of T2D in those who worked extensive overtime (62) and those who found the introduction of new technology stressful (43). In both studies the associations remained after controlling for an extensive list of behavioral risk factors for T2D (43). In the overtime study, the researchers also found a nonsignificantly increased risk of T2D in shift workers compared with white-collar (nonshift) workers (62), which may be due to either shift work itself or to the social position associated with it within the occupational hierarchy. Alternating shift work, along with age, BMI, liver enzymes, and lack of exercise, was associated with a greater risk of T2D in another Japanese occupational cohort (85). A study of the British Civil Service (38) found a doubling of the risk for diabetes in women but not in men exposed to job strain (a measure of work stress).

Table 2 Summary of stress factors and other factors included in the longitudinal studies in this review[a]

Study population	Chronic stressor	Demographic and socioeconomic	Medical and physical	Behavioral	Other
1958 Birth Cohort (89)	Childhood SES	Gender	BMI, waist girth, family history of T2D, birth weight, other neonatal		
1958 Birth Cohort (90)	Poor parenting	Gender, education, childhood SES	BMI, waist girth, family history of T2D, diabetes medication	Alcohol, smoking, physical activity	
Alameda County (54)	Education, income, occupational prestige	Age, ethnicity, marital status, type of health insurance	BMI, waist girth, hypertension, regular access to physician	Alcohol, smoking, physical activity	Depression
Alameda County (55)	Education, income, occupational prestige, childhood SES	Age, ethnicity, marital status, type of health insurance	BMI, height, waist girth, hypertension, regular access to physician	Alcohol, smoking, physical activity	Depression
Atherosclerosis Risk in Communities (34)	Vital exhaustion	Gender, age, ethnicity, education	BMI, waist girth/WHR, hypertension, lipids	Diet, smoking, physical activity	Geographic location
AusDiab—Australian Diabetes, Obesity & Lifestyle Study (99)	Education, income, occupational prestige	Gender, age	Waist girth/WHR, hypertension, lipids	Smoking, physical activity	
Australian Women's Health Survey (83)	General mental health, perceived stress, life events, poor social networks, education	Marital status	BMI, hypertension, menopausal status/HRT, physician visits	Diet, alcohol, physical activity	Geographic location
Baltimore Epidemiologic Catchment Area Study (59)	Depression, education	Gender, age, ethnicity	BMI, family history of T2D, regular access to physician, antidepressant use	Diet, alcohol, smoking, physical activity	Poor social networks
Cardiovascular Health Study (12)	Depression	Gender, age, ethnicity, marital status, education	BMI, CRP	Alcohol, smoking, physical activity	
Danish Database Linkage Study (65)	Life events	Age, education			Geographic location
English Longitudinal Study of Aging (20)	General mental health	Gender, age, income	BMI, hypertension, glucose, insulin		Geographic location
English Longitudinal Study of Aging (88)	Income	Age, ethnicity, marital status, education, occupational prestige, material limitations	BMI	Alcohol, smoking, physical activity	

Finnish Diabetes Prevention Study (69)	Education, occupational prestige	Age	Hypertension, lipids, BMI, waist girth		
Gifu Prefectural Center for Health Check & Health Promotion (63)	Work stress	Age, education	BMI	Alcohol, smoking, physical activity	
Gifu Prefectural Center for Health Check & Health Promotion (63)	Occupational prestige	Age, education	BMI	Alcohol, smoking	
Healthy Women Study (68)	Depressive symptoms, trait anger, trait anxiety, Framingham tension score, perceived stress, life events	Age, education	Menopausal status/HRT	Physical activity, alcohol, smoking	
Helsinki Birth Cohort (4)	Early traumatic life experience	Age, gender, education, childhood SES			
Japan Public Health Center-Based Prospective Study (42)	Type A personality, perceived stress	Age	BMI, hypertension, family history of T2D	Alcohol, smoking, physical activity, coffee, sleep	
Massachusetts Male Aging Study (81)	Depressive symptoms, other mental health conditions	Age	BMI, hypertension, sex hormone levels	Alcohol, physical activity	
Medical Practice Database (94)	Depression	Age, education, type of insurance			
Medical Practice Database (56)	Schizophrenia, affective psychosis	Gender, age, ethnicity	Other chronic health conditions	Smoking	
Multiethnic Study of Atherosclerosis (33)	Depression	Gender, age, ethnicity, education, income	BMI, lipids, insulin, inflammatory markers, hypertension	Diet, alcohol, smoking, physical activity	Geographic location
National Comorbidity Survey (37)	Childhood abuse	Age, ethnicity, marital status, education, income			Depression or anxiety disorder
NHEFS - NHANES I Death Followup (13)	Depressive symptoms, education	Gender, age, ethnicity	BMI	Alcohol, smoking, physical activity	
NHEFS - NHANES I Death Followup (72)	Education, occupational prestige, poverty index	Age, ethnicity	BMI	Diet, alcohol, smoking, physical activity	

(*Continued*)

Table 2 (*Continued*)

Study population	Chronic stressor	Demographic and socioeconomic	Medical and physical	Behavioral	Other
Nurses' Health Study (8)	Depression	Age	BMI, hypertension, family history of T2D, menopausal status/HRT	Alcohol, smoking, physical activity	
Nurses' Health Study (50)	Childhood, partner and life-course SES	Age, ethnicity	BMI, hypertension, family history of T2D, menopausal status/HRT, birth weight, breastfed	Diet, alcohol, smoking, physical activity	
Nurses' Health Study (70)	Lifetime abuse	Age, ethnicity, parents' education	BMI, age 5 somatotype, family history of T2D	Smoking, alcohol	
Occupational Health Cohort (58)	Burnout	Gender, age, education	BMI, hypertension	Alcohol, smoking, physical activity	
Occupational Health Cohort (44)	Depressive symptoms	Age	BMI, family history of T2D, other chronic health problem	Alcohol, smoking, physical activity	
Occupational Health Cohort (43)	Work stress and work conditions	Age, education, occupational prestige	BMI, family history of T2D	Alcohol, smoking, physical activity	
Occupational Health Cohort (62)	Work conditions	Age	BMI, family history of T2D	Alcohol, smoking, physical activity	
Occupational Health Cohort (85)	Work conditions	Age	Hypertension, BMI, lipids	Alcohol, smoking, physical activity	
Still Working Study (46)	Sense of coherence	Age, marital status, education		Alcohol, smoking, physical activity	Self-reported health, distress
Stockholm Diabetes Prevention Program (25)	Depression/distress/anxiety	Age, occupational prestige	BMI, family history of T2D	Smoking, physical activity	
Study of Women's Health Across the Nation (28)	Depression/distress/anxiety	Age, ethnicity, education	BMI, waist girth, glucose, insulin, antidepressant use	Physical activity	
Vasterbotten Intervention Program (64)	Work stress, education, social support	Gender, age, ethnicity, marital	BMI		

Whitehall II (47)	General mental health, work social support, depression, work stress, life events, occupational prestige, material limitations	Age, ethnicity	BMI, height, hypertension, family history of T2D	Smoking, physical activity	
Whitehall II (38)	Work stress	Age, gender, occupational prestige	BMI, height, hypertension, lipids, CRP, family history of T2D	Diet, alcohol, smoking, physical activity	Traumatic life events
Whitehall II (82)	Occupational prestige	Gender, age, ethnicity	BMI, hypertension, lipids	Diet, alcohol, smoking, physical activity	
Women's Health Study (35)	Anger trait	Gender, age, ethnicity, education	BMI, WHR, insulin, glucose, lipids, hypertension	Diet, smoking, physical activity	Geographic location

[a]Abbreviations: BMI, body mass index; CRP, C-reactive protein; HRT hormone replacement therapy; SES, socioeconomic status; T2D, type 2 diabetes; WHR, waist to hip ratio.

This echoes one of the key features of the impact of occupational stressors on the development of CVD: the different responses in men and women, with associations that sometimes operate in opposite directions (e.g., 14). Much of the gender differences have been attributed to differences in social support at work. For example, in Sweden, T2D research using a nested case-control study design found that low emotional support increased the impact of job strain on T2D development in women but not in men (64), even though men and women reported similar levels of emotional support.

A recent neuroscience review concluded that stressful life events that involve social rejection are more likely to precipitate depression with downstream PSR (79). Moreover, the effects of traumatic life events can be long-lasting. A Danish database linkage study found that parents who experienced the death of a child were at increased risk of developing diabetes for up to 18 years after the bereavement (65).

Overall, objective measures of stressor exposure are associated with a greater risk of developing T2D, but gender differences may occur. The limited amount of research into distress (perceived stress) does not suggest a greater risk for those perceiving their lives as more stressful.

Mental Health and the Development of Type 2 Diabetes

We posit that severe, rather than minor, mental health problems are a chronic stressor. It is well established that depression and T2D are comorbid conditions with a bidirectional relationship (9). Three systematic reviews (5, 18, 45) have found an overall small, but statistically significant increase of the risk to develop T2D in people with depression, with the latest study reporting an overall risk estimate of 1.17 (CI: 1.05, 1.29). Because we think the mental health condition has to be severe enough to activate the PSR, we reexamined the nature of the mental health measure within this literature. See **Table 3**.

It is interesting to note that in one of these reviews (45) the quality of the T2D diagnosis was evaluated, but the quality of the depression diagnosis was not. Examining the papers cited in the reviews and others published since then, we noted that the more clinically robust the instrument used to classify the depression was, the more likely the study was to find a significant association between T2D and a previous diagnosis of depression (59, 94) or depressive symptoms (28, 33, 44, 81). The studies defining depression on the basis of depressive symptoms collected within a general mental health scale were less likely to find a statistically significant elevated risk (8, 47), although some did (13, 25). These findings need to be reproduced in a full systematic review.

Interactions with SES and gender were noted in these studies of depression. Two studies found an interaction with education (13, 59), such that individuals with low education and depression were at greater risk for the development of T2D than both those with more education and depression and those with neither risk factor. Again, two studies also found gender differences, reporting an association of T2D with depression in males but not in females (25, 94).

Vital exhaustion and burnout are two conditions that share many features with depression. Vital exhaustion (VE) and burnout syndrome include, amongst other criteria, (*a*) feelings of excessive fatigue and lack of energy, (*b*) increased irritability, and (*c*) feelings of demoralization (7). American researchers found a significantly increased risk of T2D in the top, as compared with the bottom, quartile of the VE scale (34); and Israeli workers who met the criteria for burnout were at increased risk for developing diabetes over the subsequent 3 to 5 years (58).

Do mild nonspecific mental health problems (everyday strains) increase the risk of diabetes, or do only severe problems increase the risk? The research findings are mixed. Of three studies that have prospectively examined whether poor scores on general mental health scales [Short Form-36 Questionnaire (SF-36) and the General Health Questionnaire (GHQ)] predict an increase

Table 3 Associations between mental health measures (ranked from most to least robust) and risk of developing T2D[a]

Study population (reference)	MH measure	Findings	Controlled for conventional factors?
Baltimore Epidemiologic Catchment Area Study (59)	Diagnostic interview schedule	sig ↑	Yes
Medical Practice Database (94)	Medical records	sig ↑ only in M <50 years old	Some
Study of Women's Health Across the Nation (28)	CES-D	sig ↑	Yes
Multiethnic Study of Atherosclerosis (33)	CES-D	sig ↑	Yes
Massachusetts Male Aging Study (81)	CES-D	sig ↑	Yes
Occupational Health Cohort (44)	Zung self-rating depression scale	sig ↑	Yes
Healthy Women Study (68)	Beck depression inventory	sig ↑	Yes
Atherosclerosis Risk in Communities (34)	Vital exhaustion	sig ↑	Yes
Occupational Health Cohort (58)	Burnout	sig ↑	Yes
Cardiovascular Health Study (12)	Depressive symptoms	sig ↑ in least educated only	Yes
Whitehall II (47)	GHQ + depression subscale[b]	ns	Yes
Nurses' Health Study (8)	Depressive symptoms from SF-36	ns ↑	Yes
Stockholm Diabetes Prevention Program (25)	Psychological distress	F: ns; M: sig ↑	Yes
Australian Women's Health Survey (83)	SF-36 mental health	sig ↑	Yes
English Longitudinal Study of Aging (20)	SF-36 mental health	ns	Yes

[a]Abbreviations and symbols: CES-D, Centre for Epidemiologic Studies Depression (scale); F, females; GHQ, General Health Questionnaire; M, males; MH, mental health,; ns, not statistically significant; SF-36, Short Form-36 Questionnaire; sig, statistically significant; T2D, type 2 diabetes; ↑, increasing score associated with increasing risk of diabetes.
[b]Created by factor analyzing the GHQ.

in the development of T2D, two report a nonsignificant increase (20, 47) and one reports a statistically significant increase (83). These studies were large and the analyses included many of the conventional medical risk factors for T2D; therefore, they should have been able to identify an association if one were present.

There is very little longitudinal research prospectively examining the association between positive mental health and disease, possibly because there are considerably fewer measures of positive mental health. A high sense of coherence (SOC), which is a measure of a positive orientation towards life (6), has been associated with lower mortality from all causes, CVD, and cancer (84). A low SOC score (poorer mental health) has also been associated with an increased incidence of T2D in Finnish men over a period of 17 years (46).

In summary, there is sufficient evidence from prospective studies to conclude that depression leads to T2D, with only a small risk of the reverse (T2D increasing the risk for depression) (33). In addition, our review suggests that mild mental health problems are less likely to be associated with an increase in T2D risk than more severe mental health problems. The relationship between positive mental health measures and T2D development needs more investigation.

Aggressive Behavior and Conflict with Others

Aggressive behavior and higher levels of anger in experiences of conflict are positively correlated with the development of CVD (15). With a few exceptions, research has not recognized a similar

relationship for T2D, although T2D is considered a comorbid condition in patients diagnosed with affective psychoses. We take the perspective that angry and aggressive behavior puts people in conflict with others and is likely to chronically activate the PSR.

Two mental health conditions that often put patients in conflict with others are schizophrenia and affective psychoses. Using a retrospective review of primary care medical records, McDermott and colleagues identified schizophrenia or affective psychoses diagnosed by a psychiatrist or psychologist and examined their subsequent comorbid physical health conditions (56). They found a nonsignificant increase in T2D for schizophrenics and a statistically significant increase in T2D in patients diagnosed with affective psychoses after controlling for age, race, gender, smoking, obesity, hypertension, and depression. The authors also noted that the patients suffering from affective psychoses were more likely to develop T2D earlier in their lives.

The type A behavior pattern—typical of people who are dominating, hostile, aggressive, and impatient, and therefore often in conflict with other people—is hypothesized to activate the PSR. Japanese researchers found that the risk of T2D increased with increasing levels of type A behavior in women but not in men (42). Similarly, in a group of middle-aged and older men, the Massachusetts Male Aging Study failed to find a relationship between dominance (from a subscale of the Jackson Personality Research Form E) and the subsequent development of T2D (81). The ARIC study found no overall relationship between trait anger (measured with the Spielberger Trait Anger Scale) and the onset of T2D; however, those in the top tertile of scores were 34% more likely to develop T2D than those in the lowest tertile (35).

In summary, the hypothesis that these conditions and personality traits put people in conflict with others and are thus stressful is not widely recognized, there is little research about it, and the theory needs to be confirmed by a systematic research agenda.

Effects of Position in the Social Status Hierarchy

It is well established that living in poor economic circumstances affects people's health, but it is only within the past few decades that we have come to recognize that there is a social gradient in health such that even middle-class people have more diseases and shorter life expectancies than do people just a step higher in the social hierarchy (97). SES is the most studied measure of social position; in developed countries, it is typically measured as education, income, and/or occupational prestige.

It has been shown that the prevalence of health-adverse behaviors increases with decreasing social position (3, 49, 99), and it has also been shown that the latter is associated with increasing exposure to stressors such as poor social circumstances and psychological challenges (97). For example, Canadian data have shown that self-reported chronic stressors ranging from marital issues to neighborhood, job, financial, and life stressors were all more common as income decreased (66). Monden and colleagues have also demonstrated that people with lower education reported significantly more stressful work factors (61).

It has repeatedly been demonstrated in cross-sectional studies that T2D rates increase with decreasing socioeconomic position (e.g., 21, 39); but it has also been argued, without clear evidence, that having T2D affects a person's ability to maintain a high social standing. There is a need for longitudinal studies demonstrating that having T2D changes a person's SES to support this view.

Most of the longitudinal studies in this review only included SES as an adjustment variable, and its relationship with T2D was not reported. A recently published systematic review of 23 longitudinal studies (2) examined the relationship between SES and T2D incidence. It found that the risk was significantly greater in the lowest compared with the highest SES group, although the risk varied somewhat depending on the specific measure of SES that was used: occupational prestige (RR = 1.31; 95% CI = 1.09, 1.57), education level (RR = 1.41; 95% CI = 1.28, 1.55),

or income (RR = 1.40; 95% CI = 1.04, 1.88). Subgroup analysis found higher risks in women than men, and when medical records were used to determine diabetic status, risk was greater than when self-reports were used. The overall SES of an area has also been shown to have an additional impact on the risk of T2D in a Scottish study (26).

The higher T2D prevalence in ethnic minority populations is usually attributed to a poorer lifestyle (e.g., 92) and lower SES. However, some studies have reported greater risk for minorities that have higher education and income (e.g., 31), and there has been a call to focus more on the stress-related risks of minorities rather than just on their health behaviors (51).

The thrifty-gene hypothesis suggests that some ethnic groups with a history of famine have developed a gene that increases their risk of diabetes in a nonfamine environment. This hypothetical gene would allow them to fatten more quickly in times of food abundance, but in modern society this prepares them for a food scarcity that no longer occurs. This hypothesis continues to be invoked to explain high rates of T2D in minority populations (e.g., 67), in spite of other researchers' finding that low SES explains most of the relationship in some populations (51) and the fact that many populations at risk have no history of famine or starvation (e.g., Pacific Islanders).

SES in childhood has also been linked to the development of T2D in midlife. A recent systematic review of the effects of early childhood SES has found evidence that childhood neglect, trauma, or deprivation increases the future risk of T2D (87). For example, using data from the 1958 birth cohort, researchers sought to distinguish the effect on T2D risk of: (*a*) stressful emotional childhood adversities or experience of neglect; (*b*) other childhood factors, such as material disadvantage; (*c*) adult health behaviors (smoking, alcohol consumption, diet, and physical activity); and (*d*) adult SES. In multivariate analysis, only poor-quality parenting associated with neglect and early childhood adversity was significantly associated with the development of T2D (90).

As has been seen in other sections, gender differences exist, and the interaction between birth and current SES may be more important in one gender than in the other. For example, the Alameda County Study found that childhood SES was a risk factor for adult T2D in women but not in men after adjusting for a wide array of behavioral risk factors (55), and the Nurses' Health Study found an increased risk of T2D only for women whose father was "blue or lower white collar." Also relevant was the finding, in two US studies, of an interaction between depression and low social status (13, 59); the studies found an increased risk of developing T2D only in people with both depression and low social status after controlling for behavioral risk factors.

The fact that SES has been shown to interact with depression and to differ in relevance by gender suggests that SES needs to be more carefully considered in the analysis and not be included merely as an adjustment variable. Each measure of SES (education, income, and occupational prestige) could provide different pathways/mechanisms to connect stressful conditions with the development of T2D, and measures of SES should be included in any analysis of risk factors for the development of T2D.

As a result of this review, we propose a new model of how exposure to chronic stressors increases the risk of developing T2D (see **Figure 1**).

DISCUSSION

This review has explored the association between T2D and psychosocial factors focusing on prospective studies of the risk for developing diabetes/T2D. It has identified a wide array of stress-related circumstances that were associated with T2D in longitudinal studies. Even after controlling for conventional risk factors, an increased risk for T2D is seen in people: exposed to stressful working conditions or traumatic life events; with depression; with personality traits or mental health problems that put them in conflict with others (such as those with type A personality

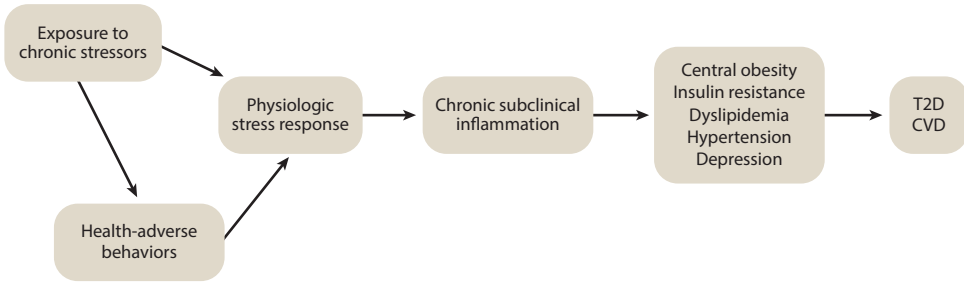

Figure 1

Model of stress mechanism hypothesis for the development of T2D. Abbreviations: CVD, cardiovascular disease; T2D, type 2 diabetes.

or schizophrenia); of low SES, either currently or during childhood; and in minority populations, independent of current SES. The amount of research available to support these hypotheses varies considerably, with most of the literature focusing on mental health conditions and SES, and only a minority of writings looking at aggressive behavior and stessor exposure. Moreover, the most significant finding is the lack of recognition of a direct pathway for stress to contribute to T2D development in addition to a behavioral pathway.

The hypothesized PSR mechanism is supported in the literature. Inflammatory marker levels (an indicator of PSR) have also been demonstrated to increase with decreasing SES (86) and to be greater in minority populations (95), suggesting a common mechanism for all these social hierarchy stressors.

Our hypothesis that severe mental health problems are a chronic stressor is supported by the finding that inflammatory markers are increased in major depressive disorder (32), and social rejection, social isolation, and interpersonal stress have all been shown to activate the PSR (79). Only two of the studies in this review measured inflammatory factor levels (12, 33); neither of them reported the individual effect of inflammatory factor levels on the risk of diabetes, because both studies were concerned with the effect of depression on the development of diabetes. Published reviews have suggested a PSR model to explain the link between depression and diabetes, but the reviewers report that there is little research to support this model (22), and the role of antipsychotic medication on glucose metabolism is unclear (29). We also note that mental health patients might be more clinically scrutinized and more likely to receive a diagnosis of diabetes earlier in their lives.

For the most part, these studies have been conducted with large study populations and most analyses adjusted for other risk factors for T2D; however, many of them relied on self-reports of both T2D and the stress-related measure. Self-reports are considered less reliable than objective measures. As such, biochemical confirmation of diabetic status and robust measures of depression (rather than depressive symptoms) would present a stronger argument. Still, one would have to argue that both the T2D and the stress-related measure were consistently misreported in the same direction for this to bias the results in any one particular direction. More likely, misreporting reduces the possibility of finding an association when one actually exists by increasing the overall error in all components.

If we accept this working hypothesis, the results of much of the research reviewed here could be reported differently and would attribute risks to the environment as well as to the individual. Black and colleagues' explanation for very high rates of T2D in minority populations is an example of the new way of thinking about the etiology of T2D. The authors concluded that "a significant relationship between internalized racism and glucose intolerance might be mediated through

abdominal fat" (11). By combining pathways prescribed by the traditional behavioral model with activation of the PSR by stress-related factors, Black and colleagues made a plausible conjecture that is increasingly supported by empirical evidence from other research (see **Figure 1**):

1. Stress-related factors influence PSR activation, which is highly correlated with increased abdominal adiposity.
2. Visceral fat is highly correlated with inflammation and glucose intolerance, both of which are correlates of T2D.

Future Research and Policy Implications

This review has shown that relatively little attention has been paid to the role that stress-related factors may play in the development of T2D. We feel that a research model that integrates the behavioral model with stress-related factors needs to become the standard. Considerable evidence supports the routine integration of stress-related factors with models of the effects of behavioral factors. Furthermore, the nature of stress-related factors to be incorporated into causal models relates specifically to negative stressors that are intensive and sustained. For example, in the studies we reviewed, mild distress was less likely to be identified as a risk factor for T2D than major depressive disorder. The health and research communities need to recognize that chronic stressor exposure (such as living in poverty) has a health impact that goes beyond the supposedly bad behavior of some people and that a pathway may operate via the direct activation of the PSR. This is entirely consistent with the WHO priority area "Tackling Social Determinants of Health," which forms part of the organization's general program of work for the period 2014–2019.

The incorporation of stress-related factors also needs to become a priority area of diabetes research and support charities. Current T2D interventions that are trying to reduce incidence and prevalence (e.g., **http://www.idf.org/node/2137**) still largely invoke a behavioral model (e.g., **http://www.diabetes.org.uk/About_us/What-we-say/**). If diabetes organizations understood the effect of stress-related factors, they could join in with the social determinants of health agenda and lobby governments to change the social and economic conditions that lead to avoidable health inequities. Given the number of people with T2D, there is the possibility of a powerful lobby for change.

CONCLUSION

This review provides consistent evidence to support the hypothesis that stress-related factors are a cause of T2D independent of behavioral factors. This review suggests that T2D prevention research would be more effective if (*a*) the PSR response to psychosocial factors (especially social disparities) was recognized and (*b*) intervention programs evaluated reduction in social disparities as part of a comprehensive approach. Research in this area could be advanced by reframing the research questions for existing datasets or designing new longitudinal studies.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

ACKNOWLEDGMENTS

We thank Peter Allmark for reviewing and proofreading this paper. The first author thanks the considerable number of people who over the past decade have critiqued and debated this

hypothesis with her. This includes staff at the Center for Health & Social Care Research, Ahmed Khair, Heather Orpana, Clyde Hertzman, Pamela Lyon, Mark Daniel, Matt Harren, Anne Taylor, Gary Wittert, Peter Lekkas, Leonie Segal, Karen Collins, and Deb Jack. Apologies if anyone has been inadvertently missed.

LITERATURE CITED

1. Acheson D. 1998. *Independent Inquiry into Inequalities in Health*. London: The Stationary Office
2. Agardh E, Allebeck P, Hallqvist J, Moradi T, Sidorchuk A. 2011. Type 2 diabetes incidence and socio-economic position: a systematic review and meta-analysis. *Int. J. Epidemiol.* 40:804–18
3. Agardh EE, Ahlbom A, Andersson T, Efendic S, Grill V, et al. 2004. Explanations of socioeconomic differences in excess risk of type 2 diabetes in Swedish men and women. *Diabetes Care* 27:716–21
4. Alastalo H, Raikkonen K, Pesonen A-K, Osmond C, Barker DJP, et al. 2009. Cardiovascular health of Finnish war evacuees 60 years later. *Ann. Med.* 41:66–72
5. Anderson RJ, Clouse RE, Freedland KE, Lustman PJ. 2001. The prevalence of comorbid depression in adults with diabetes: a meta-analysis. *Diabetes Care* 24:1069–78
6. Antonovsky A. 1987. *Unraveling the Mystery of Health: How People Manage Stress and Stay Well.* San Francisco: Jossey-Bass
7. Appels A. 1990. Mental precursors of myocardial infarction. *Br. J. Psychiatry* 156:465–71
8. Arroyo C, Hu FB, Ryan LM, Kawachi I, Colditz GA, et al. 2004. Depressive symptoms and risk of type 2 diabetes in women. *Diabetes Care* 27:129–33
9. Atlantis E, Goldney RD, Wittert GA. 2009. Obesity and depression or anxiety. *Br. Med. J.* 339:b3868
10. Bjorntorp P. 1991. Visceral fat accumulation: the missing link between psychosocial factors and cardiovascular disease? *J. Intern. Med.* 230:195–201
11. Black PH. 2003. The inflammatory response is an integral part of the stress response: implications for atherosclerosis, insulin resistance, type II diabetes and metabolic syndrome. *Brain Behav. Immun.* 17:350–64
12. Carnethon MR, Biggs ML, Barzilay JI, Smith NL, Vaccarino V, et al. 2007. Longitudinal association between depressive symptoms and incident type 2 diabetes mellitus in older adults: the cardiovascular health study. *Arch. Intern. Med.* 167:802–7
13. Carnethon MR, Kinder LS, Fair JM, Stafford RS, Fortmann SP. 2003. Symptoms of depression as a risk factor for incident diabetes: findings from the National Health and Nutrition Examination Epidemiologic Follow-up Study, 1971–1992. *Am. J. Epidemiol.* 158:416–23
14. Chandola T, Kuper H, Singh-Manoux A, Bartley M, Marmot M. 2004. The effect of control at home on CHD events in the Whitehall II study: gender differences in psychosocial domestic pathways to social inequalities in CHD. *Soc. Sci. Med.* 58:1501–9
15. Chida Y, Steptoe A. 2009. The association of anger and hostility with future coronary heart disease: a meta-analytic review of prospective evidence. *J. Am. Coll. Cardiol.* 53:936–46
16. Cohen S, Kessler RC, Gordon LU. 1995. Strategies for measuring stress in studies of psychiatric and physical disorders. In *Measuring Stress: A Guide for Health and Social Scientists*, ed. S Cohen, RC Kessler, LU Gordon, pp. 3–28. Oxford: Oxford Univ. Press.
17. Contrada RJ, Baum A, eds. 2011. *The Handbook of Stress Science: Biology, Psychology and Health*. New York: Springer
18. Cosgrove MP, Sargeant LA, Griffin SJ. 2008. Does depression increase the risk of developing type 2 diabetes? *Occup. Med.* 58:7–14
19. Dandona P, Aljada A, Bandyopadhyay A. 2004. Inflammation: the link between insulin resistance, obesity and diabetes. *Trends Immunol.* 25:4–7
20. Daniels MC, Goldberg J, Jacobsen C, Welty TK. 2006. Is psychological distress a risk factor for the incidence of diabetes among American Indians? The Strong Heart Study. *J. Appl. Gerontol.* 25:60S–72S
21. Demakakos P, Nazroo J, Breeze E, Marmot M. 2008. Socioeconomic status and health: the role of subjective social status. *Soc. Sci. Med.* 67:330–40
22. Dinan TG. 2004. Stress and the genesis of diabetes mellitus in schizophrenia. *Br. J. Psychiatry* 184:S72–75

23. Donath MY, Shoelson SE. 2011. Type 2 diabetes as an inflammatory disease. *Nat. Rev. Immunol.* 11:98–107
24. Duncan BB, Schmidt MI, Pankow JS, Ballantyne CM, Couper D, et al. 2003. Low-grade systemic inflammation and the development of type 2 diabetes: the Atherosclerosis Risk in Communities study. *Diabetes* 52:1799–805
25. Eriksson AK, Ekbom A, Granath F, Hilding A, Efendic S, Ostenson CG. 2008. Psychological distress and risk of pre-diabetes and type 2 diabetes in a prospective study of Swedish middle-aged men and women. *Diabet. Med.* 25:834–42
26. Evans JMM, Newton RW, Ruta DA, MacDonald TM, Morris AD. 2000. Socio-economic status, obesity and prevalence of type 1 and type 2 diabetes mellitus. *Diabet. Med.* 17:478–80
27. Everson-Rose SA, Lewis TT. 2005. Psychosocial factors and cardiovascular diseases. *Annu. Rev. Public Health* 26:469–500
28. Everson-Rose SA, Meyer PM, Powell LH, Pandey D, Torrens JI, et al. 2004. Depressive symptoms, insulin resistance, and risk of diabetes in women at midlife. *Diabetes Care* 27:2856–62
29. Expert Group. 2004. "Schizophrenia and diabetes 2003" expert consensus meeting, Dublin, 3–4 October 2003: consensus summary. *Br. J. Psychiatr. Suppl.* 184:S112–14
30. Fisher EB, Thorpe CT, McEvoy DeVellis B, Devellis RF. 2007. Health coping, negative emotions, and diabetes management: a systematic review and appraisal. *Diab. Educ.* 33:1080–103
31. Gaillard TR, Schuster DP, Bossetti BM, Green PA, Osei K. 1997. Do sociodemographic and economic status predict risks for type II diabetes in African Americans? *Diabetes Educ.* 23:294–300
32. Gibb J, Audet M-C, Hayley S, Anisman H. 2009. Neurochemical and behavioral responses to inflammatory immune stressors. *Front. Biosci.* 1:275–95
33. Golden SH, Lazo M, Carnethon M, Bertoni AG, Schreiner PJ, et al. 2008. Examining a bidirectional association between depressive symptoms and diabetes. *J. Am. Med. Assoc.* 299:2751–59
34. Golden SH, Williams JE, Ford DE, Yeh HC, Sanford CP, et al. 2004. Depressive symptoms and the risk of type 2 diabetes: the Atherosclerosis Risk in Communities study. *Diabetes Care* 27:429–35
35. Golden SH, Williams JE, Ford DE, Yeh HC, Sanford CP, et al. 2006. Anger temperament is modestly associated with the risk of type 2 diabetes mellitus: the Atherosclerosis Risk in Communities study. *Psychoneuroendocrinology* 31:325–32
36. Goodwin RD, Davidson JR. 2005. Self-reported diabetes and posttraumatic stress disorder among adults in the community. *Prevent. Med.* 40:570–74
37. Goodwin RD, Stein MB. 2004. Association between childhood trauma and physical disorders among adults in the United States. *Psychol. Med.* 34:509–20
38. Heraclides A, Chandola T, Witte DR, Brunner EJ, Heraclides A, et al. 2009. Psychosocial stress at work doubles the risk of type 2 diabetes in middle-aged women: evidence from the Whitehall II study. *Diabetes Care* 32:2230–35
39. Icks A, Moebus S, Feuersenger A, Haastert B, Jockel K-H, Giani G. 2007. Diabetes prevalence and association with social status: widening of a social gradient? German national health surveys 1990–1992 and 1998. *Diabetes Res. Clin. Pract.* 78:293–97
40. Jiang L, Beals J, Whitsell NR, Roubideaux Y, Manson SM, AI-SUPERPFP Team. 2007. Association between diabetes and mental disorders in two American Indian reservation communities. *Diabetes Care* 30:2228–29
41. Jiang L, Beals J, Whitsell NR, Roubideaux Y, Manson SM, AI-SUPERPFP Team. 2008. Stress burden and diabetes in two American Indian reservation communities. *Diabetes Care* 31:427–29
42. Kato M, Noda M, Inoue M, Kadowaki T, Tsugane S, JPHC Study Group. 2009. Psychological factors, coffee and risk of diabetes mellitus among middle-aged Japanese: a population-based prospective study in the JPHC study cohort. *Endocr. J.* 56:459–68
43. Kawakami N, Araki S, Takatsuka N, Shimizu H, Ishibashi H. 1999. Overtime, psychosocial working conditions, and occurrence of non-insulin dependent diabetes mellitus in Japanese men. *J. Epidemiol. Community Health* 53:359–63
44. Kawakami N, Takatsuka N, Shimizu H, Ishibashi H. 1999. Depressive symptoms and occurrence of type 2 diabetes among Japanese men. *Diabetes Care* 22:1071–76

45. Knol MJ, Twisk JW, Beekman AT, Heine RJ, Snoek FJ, et al. 2006. Depression as a risk factor for the onset of type 2 diabetes mellitus: a meta-analysis. *Diabetologia* 49:837–45
46. Kouvonen AM, Vaananen A, Woods SA, Heponiemi T, Koskinen A, Toppinen-Tanner S. 2008. Sense of coherence and diabetes: a prospective occupational cohort study. *BMC Public Health* 8:46
47. Kumari M, Head J, Marmot M. 2004. Prospective study of social and other risk factors for incidence of type 2 diabetes in the Whitehall II study. *Arch. Intern. Med.* 164:1873–80
48. Kunz-Ebrecht SR, Kirschbaum C, Marmot M, Steptoe A. 2004. Differences in cortisol awakening response on work days and weekends in women and men from the Whitehall II cohort. *Psychoneuroendocrinology* 29:516–28
49. Lantz PM, House JS, Lepkowski JM, Williams DR, Mero RP, Chen J. 1998. Socioeconomic factors, health behaviours, and mortality. *J. Am. Med. Assoc.* 279:1703–8
50. Lidfeldt J, Hu FB, Manson JE, Kawachi I, Li TY. 2007. A prospective study of childhood and adult socioeconomic status and incidence of type 2 diabetes in women. *Am. J. Epidemiol.* 165:882–89
51. Link CL, McKinlay JB. 2009. Disparities in the prevalence of diabetes: Is it race/ethnicity or socioeconomic status? Results from the Boston Area Community Health (BACH) survey. *Ethn. Dis.* 19:288–92
52. Marmot M, Shipley M, Brunner E, Hemingway H. 2001. Relative contribution of early life and adult socioeconomic factors to adult morbidity in the Whitehall II study. *J. Epidemiol. Community Health* 55:310–17
53. Marmot MG, Kogevinas M, Elston MA. 1991. Socioeconomic status and disease. In *Health Promotion Research: Towards a New Social Epidemiology*, ed. B Badura, I Kickbusch, pp. 113–46. Copenhagen, Den.: World Health Organ. Reg. Off. Eur.
54. Maty SC, Everson-Rose SA, Haan MN, Raghunathan TE, Kaplan GA. 2005. Education, income, occupation, and the 34-year incidence (1965–99) of type 2 diabetes in the Alameda County Study. *Int. J. Epidemiol.* 34:1274–81
55. Maty SC, Lynch JW, Raghunathan TE, Kaplan GA, Maty SC, et al. 2008. Childhood socioeconomic position, gender, adult body mass index, and incidence of type 2 diabetes mellitus over 34 years in the Alameda County Study. *Am. J. Public Health* 98:1486–94
56. McDermott S, Moran R, Platt T, Isaac T, Wood H, Dasari S. 2005. Heart disease, schizophrenia, and affective psychoses: epidemiology of risk in primary care. *Community Ment. Health J.* 41:747–55
57. McEwen BS. 1998. Stress, adaption, and disease: allostasis and allostatic load. *Ann. N. Y. Acad. Sci.* 840:33–44
58. Melamed S, Shirom A, Toker S, Shapira I. 2006. Burnout and risk of type 2 diabetes: a prospective study of apparently healthy employed persons. *Psychosom. Med.* 68:863–69
59. Mezuk B, Eaton WW, Golden SH, Ding Y. 2008. The influence of educational attainment on depression and risk of type 2 diabetes. *Am. J. Public Health* 98:1480–85
60. Misra A, Ganda OP. 2007. Migration and its impact on adiposity and type 2 diabetes. *Nutrition* 23:696–708
61. Monden CWS. 2005. Current and lifetime exposure to working conditions: Do they explain educational differences in subjective health? *Soc. Sci. Med.* 60:2465–76
62. Morikawa Y, Nagagawa H, Miura K, Soyama Y, Ishizaki M, et al. 2005. Shift work and the risk of diabetes mellitus among Japanese male factory workers. *Scan. J. Work Environ. Health* 31:179–83
63. Nagaya T, Yoshida H, Takahashi H, Kawai M. 2006. Policemen and firefighters have increased risk for type-2 diabetes mellitus probably due to their large body mass index: a follow-up study in Japanese men. *Am. J. Indus. Med.* 49:30–35
64. Norberg M, Stenlund H, Lindah B, Andersson C, Eriksson JW, Weinehall L. 2007. Work stress and low emotional support is associated with increased risk of future type 2 diabetes in women. *Diabetes Res. Clin. Prac.* 76:368–77
65. Olsen J, Li J, Precht DH. 2005. Hospitalization because of diabetes and bereavement: a national cohort study of parents who lost a child. *Diabet. Med.* 22:1338–42
66. Orpana HM, Lemyre L, Kelly SJ. 2007. Do stressors explain the association between income and changes in self-rated health? A longitudinal analysis of the National Population Health Survey. *Int. J. Behav. Med.* 14:40–47

67. Procopiou M, Philippe J. 2005. The metabolic syndrome and type 2 diabetes: epidemiological figures and country specificities. *Cerebrovasc. Dis.* 20:2–8
68. Raikkonen K, Matthews KA, Kuller LH. 2007. Depressive symptoms and stressful life events predict metabolic syndrome among middle-aged women: a comparison of World Health Organization, Adult Treatment Panel III, and International Diabetes Foundation definitions. *Diabetes Care* 30:872–77
69. Rautio N, Jokelainen J, Oksa H, Saaristo T, Peltonen M, et al. 2011. Socioeconomic position and effectiveness of lifestyle intervention in prevention of type 2 diabetes: one-year follow-up of the FIN-D2D project. *Scand. J. Public Health* 39:561–70
70. Rich-Edwards JW, Spiegelman D, Lividoti Hibert E, Jun H-J, James Todd T, et al. 2010. Abuse in childhood and adolescence as a predictor of type 2 diabetes in adult women. *Am. J. Prev. Med.* 39:529–36
71. Robbins JM, Vaccarino V, Zhang H, Kasl SV. 2001. Socioeconomic status and type 2 diabetes in African American and non-Hispanic white women and men: evidence from the Third National Health and Nutrition Examination Survey. *Am. J. Public Health* 91:76–83
72. Robbins JM, Vaccarino V, Zhang H, Kasl SV. 2005. Socioeconomic status and diagnosed diabetes incidence. *Diabetes Res. Clin. Pract.* 68:230–36
73. Rosengren A, Hawken S, Ounpuu S, Sliwa K, Zubaid M, et al. 2004. Association of psychosocial risk factors with risk of acute myocardial infarction in 11,119 cases and 13,648 controls from 52 countries (the INTERHEART study): case-control study. *Lancet* 364:953–62
74. Rosmond R, Bjorntorp P. 2000. The hypothalamic-pituitary-adrenal axis activity as a predictor of cardiovascular disease, type 2 diabetes and stroke. *J. Int. Med.* 247:188–97
75. Rosmond R, Wallerius S, Wanger P, Martin L, Holm G, Bjorntorp P. 2003. A 5-year follow-up study of disease incidence in men with an abnormal hormone pattern. *J. Intern. Med.* 254:386–90
76. Salminen JK, Saarijarvi S, Aarela E, Toikka T, Kauhanen J. 1999. Prevalence of alexithymia and its association with sociodemographic variables in the general population of Finland. *J. Psychosom. Res.* 46:75–82
77. Schmidt MI, Duncan BB, Sharrett AR, Lindberg G, Savage PJ, et al. 1999. Markers of inflammation and prediction of diabetes mellitus in adults (Atherosclerosis Risk in Communities study): a cohort study. *Lancet* 353:1649–52
78. Scott KM, Von Korff M, Alonso J, Angermeyer MC, Bromet E, et al. 2009. Mental-physical co-morbidity and its relationship with disability: results from the World Mental Health Surveys. *Psychol. Med.* 39:33–43
79. Slavich GM, O'Donovan A, Epel ES, Kemeny ME. 2010. Black sheep get the blues: a psychobiological model of social rejection and depression. *Neurosci. Biobehav. Rev.* 35:39–45
80. Soo H. 2009. Stress management training in diabetes mellitus. *J. Health Psychol.* 14:933–43
81. Stellato RK, Feldman HA, Hamdy O, Horton ES, McKinlay JB. 2000. Testosterone, sex hormone-binding globulin and the development of type 2 diabetes in middle-aged men: prospective results from the Massachusetts male aging study. *Diabetes Care* 23:490–94
82. Strighini S, Tabak AG, Akbaraly TN, Sabia S, Shipley MJ, et al. 2012. Contribution of modifiable risk factors to social inequalities in type 2 diabetes: prospective Whitehall II cohort study. *Br. Med. J.* 345:e5452
83. Strodl E, Kenardy J. 2006. Psychosocial and non-psychosocial risk factors for the new diagnosis of diabetes in elderly women. *Diabetes Res. Clin. Pract.* 74:57–65
84. Surtees P, Wainwright N, Luben R, Khaw KT, Day N. 2003. Sense of coherence and mortality in men and women in the EPIC-Norfolk United Kingdom Prospective Cohort Study. *Am. J. Epidemiol.* 158:1202–9
85. Suwazono Y, Sakata K, Okubo Y, Harada H, Oishi M, et al. 2006. Long-term longitudinal study on the relationship between alternating shift work and the onset of diabetes mellitus in male Japanese workers. *J. Occup. Environ. Med.* 48:455–61
86. Tabassum F, Kumari M, Rumley A, Lowe G, Power C, Strachan DP. 2008. Effects of socioeconomic position on inflammatory and hemostatic markers: a life-course analysis in the 1958 British birth cohort. *Am. J. Epidemiol.* 167:1332–41
87. Tamayo T, Christian H, Rathmann W. 2010. Impact of early psychosocial factors (childhood socioeconomic factors and adversities) on future risk of type 2 diabetes, metabolic disturbances and obesity: a systematic review. *BMC Public Health* 10:525

88. Tanaka T, Gjonca E, Gulliford MC. 2012. Income, wealth and risk of diabetes among older adults: cohort study using the English Longitudinal Study of Ageing. *Eur. J. Public Health* 22:310–17
89. Thomas C, Hypponen E, Power C. 2007. Prenatal exposures and glucose metabolism in adulthood. *Diabetes Care* 30:918–24
90. Thomas C, Hypponen E, Power C. 2008. Obesity and type 2 diabetes risk in midadult life: the role of childhood adversity. *Pediatrics* 121:e1240–49
91. Turner RJ, Avison WR. 2003. Status variations in stress exposure: implications for the interpretation of research on race, socioeconomic status, and gender. *J. Health Soc. Behav.* 44:488–505
92. Ujcic-Voortman JK, Schram MT, Jacobs-van der Bruggen MA, Verhoeff AP, Baan CA. 2009. Diabetes prevalence and risk factors among ethnic minorities. *Eur. J. Public Health* 19:511–15
93. Ursin H. 1991. Psychobiology of stress and attachment: the biobehavioural view. In *Health Promotion Research: Towards a New Social Epidemiology*, ed. B Badura, I Kickbusch, pp. 173–86. Copenhagen, Den.: World Health Organ. Reg. Off. Eur.
94. van den Akker M, Schuurman A, Metsemakers J, Buntinx F. 2004. Is depression related to subsequent diabetes mellitus? *Acta Psychiatr. Scand.* 110:178–83
95. Wang Z, Rowley K, Best J, McDermott R, Taylor M, O'Dea K. 2007. Hemostatic factors in Australian aboriginal and Torres Strait islander populations. *Metab. Clin. Exp.* 56:269–65
96. Wilkinson R. 1996. *Unhealthy Societies: The Afflictions of Inequality*. London: Routledge
97. Wilkinson R, Marmot M. 2003. *The Solid Facts*. Copenhagen, Den.: World Health Organ. Reg. Off. Eur.
98. Wilkinson RG. 2005. *The Impact of Inequality: How to Make Sick Societies Healthier*. London: New Press/Routledge
99. Williams ED, Tapp RJ, Magliano DJ, Shaw JE, Zimmet PZ, Oldenburg BF. 2010. Health behaviours, socioeconomic status and diabetes incidence: the Australian Diabetes Obesity and Lifestyle Study (AusDiab). *Diabetologia* 53:2538–45
100. World Health Organ. MONICA Proj. 1994. Ecological analysis of the association between mortality and major risk factors of cardiovascular disease. *Int. J. Epidemiol.* 23:505–16