Depression, neighborhood deprivation and risk of type 2 diabetes

Mezuk, Briana; Chaikiat, Åsa; Li, Xinjun; Sundquist, Jan; Kendler, Kenneth S.; Sundquist, Kristina

Published in:
Health and Place

DOI:
10.1016/j.healthplace.2013.05.004

2013

Depression, neighborhood deprivation and risk of type 2 diabetes

For submission to *Health and Place*

Word count (text only): 3448

Tables: 3

Figures: 1

ABSTRACT

Neighborhood characteristics have been associated with both depression and diabetes, but to date little attention has been paid to whether the association between depression and diabetes varies across different types of neighborhoods. This prospective study examined the relationship between depression, neighborhood deprivation, and risk of type 2 diabetes among 336,340 adults from a national-representative sample of primary care centers in Sweden (2001 – 2007). Multi-level logistic regression models were used to assess associations between depression and risk of type 2 diabetes across affluent and deprived neighborhoods. After accounting for demographic, individual-level socioeconomic, and health characteristics, depression was significantly associated with risk of diabetes (odds ratio (OR): 1.10, 95% confidence interval (CI): 1.06 – 1.14), as was neighborhood deprivation (OR for high vs. low deprivation: 1.66, 95% CI: 1.22 – 1.34). The interaction term between depression and neighborhood deprivation was non-significant, indicating that the relationship between depression and diabetes risk is similar across levels of neighborhood socioeconomic deprivation.

MeSH Keywords: depression, type 2 diabetes mellitus, residence characteristics, multi-level analysis, prospective study

INTRODUCTION

Major depression and type 2 diabetes mellitus are the first and eighth leading causes of disability-adjusted life years lost among high-income countries, and are projected to be in the top ten causes of disability-adjusted life years lost worldwide by 2030 (World Health Organization, 2008). A key characteristic of depression in mid- and late-life is comorbidity with medical illness (Katz, 1996). Epidemiologic and clinical studies have established that depression often co-occurs with type 2 diabetes (Katon, 2008)' and it is now acknowledged that this relationship is likely bi-directional (Pan et al., 2011, Pan et al., 2010, Campayo et al., 2010, Frasure-Smith et al., 2000, Mezuk et al., 2008a, Golden et al., 2008). Depression is associated with both risk of type 2 diabetes (Mezuk et al., 2008a), and poor clinical prognosis among those with diabetes (Pan et al., 2011, Lin et al., 2009, de Groot et al., 2001). However, research to date has not extensively examined whether depression may interact with other risk factors for type 2 diabetes, in particular contextual environmental characteristics.

There is a growing appreciation of the role that contextual environmental factors (e.g., “neighborhood” factors) have on mental and physical health (Shih et al., 2011, Dubowitz et al., 2011, Kim 2008, Xue et al., 2005, Kershaw et al., 2011). Neighborhoods have both physical and social attributes that may influence health. Physical attributes include access to goods and services, greenspace, and availability of alcohol and tobacco outlets; social attributes include community unemployment, segregation, social capital, civic participation, and crime (Diez Roux and Mair, 2010). Because place of residence is strongly patterned by social position, neighborhood characteristics may be important contributors to health disparities.(Diez Roux and Mair, 2010). Contextual environmental factors may influence mental and physical health by placing constraints on (or promoting) health-related behaviors (e.g., smoking, alcohol use, diet, physical activity), or through acting as a source of (or buffer against) stressors (Diez Roux and Mair, 2010). A handful of studies have prospectively examined contextual environmental characteristics and risk of depression or type 2 diabetes, with mixed results (Kim, 2008, Diez

Roux and Mair, 2010). Lofors and Sundquist (2007) reported that high neighborhood deprivation was associated with 20% increased risk of in-patient hospitalization for major depression relative to more affluent neighborhoods(Lofors and Sundquist, 2007), and Crump et al. (2011) reported that individuals in high deprivation neighborhoods were 15% more likely to be prescribed antidepressants than those in affluent neighborhoods(Crump et al., 2011). Galea et al. (2007) reported that individuals living in the poorest neighborhoods had twice the risk of major depression relative to affluent neighborhoods (Galea et al., 2007). However, other reports have not found a significant association between the contextual environment and risk of major depression or elevated depressive symptoms (Yen and Kaplan, 1999, Schootman et al., 2007a, Wight et al., 2009) Regarding diabetes, Auchincloss and colleagues found that living in a neighborhood with better resources for physical activity and healthy foods was associated with lower prevalence of insulin resistance (Auchincloss et al., 2008), and a 38% lower incidence of type 2 diabetes (Auchincloss et al., 2009). Other characteristics of the built environment, such as housing quality, have also been associated with risk of type 2 diabetes (Schootman et al., 2007b, Cox et al., 2007). Neighborhood deprivation and attributes of the physical environment have also been positively associated with conditions related to diabetes, particularly obesity (Mujahid et al., 2008).

Despite the epidemiologic evidence supporting major depression and depressive symptoms as a risk factor for type 2 diabetes, and the apparent association between neighborhood characteristics and these health conditions, thus far no studies have examined whether neighborhood context modifies the association between depression and risk of type 2 diabetes. Two studies have examined whether the relationship between depression and diabetes varies by individual-level indicators of socioeconomic status (Mezuk et al., 2008b, Carnethon et al., 2003), and both found that the risk of type 2 diabetes associated with depression was greatest among those with the lowest educational attainment. Not only are individuals with low educational attainment more likely to experience depression (Lorant et al.

2003), they may be less likely to have positive resources (socially or financially) to cope with a depressive episode when it occurs (Krueger and Chang, 2008). Because of their lower socioeconomic status, individuals with depression may also be more likely to live in and be exposed to environmental contexts that increase diabetes risk, such as high concentration of fast food restaurants, alcohol outlets, and tobacco shops. These contexts simultaneously promote opportunities to engage in unhealthy stress-coping behaviors (e.g., diets high in fats and sugar, smoking) and limit opportunities to engage in healthy behaviors that reduce diabetes risk through limited access to healthy foods and outdoor recreational activities (Auchincloss et al., 2008, Auchincloss et al., 2009). Over time, this may lead to an accumulation of poor health outcomes associated with depression among persons living in socially disadvantaged communities.

The aims of this study are to: (a) determine the prospective relationship between major depression, neighborhood deprivation, and type 2 diabetes, and (b) evaluate whether the relationship between major depression and risk of type 2 diabetes is moderated by contextual environmental characteristics.

METHODS

Sample

Data used in this study were retrieved from a research database, located at the Center for Primary Health Care Research at Lund University in Malmö Sweden (Lofors and Sundquist, 2007, Sundquist et al., 2011, Sundquist, Malmstrom and Johansson, 1999). Complete medical record data were obtained from a nationally-representative sample of 75 primary healthcare centers beginning in January 1, 2001. These records were then linked to national inpatient (available from 1964), outpatient (available from 2001), and prescription drug (available from 2005) registries, provided to by the National Board of Health and Welfare. Additional linkages were carried out to national census data to obtain individual socioeconomic status, occupation, and geographical region of residence. All linkages were performed by the use of an individual national identification number that is assigned to each person in Sweden for their lifetime, which was replaced by a serial number for analysis in order to provide anonymity. The quality and validity of electronic medical records from primary care in Sweden is high (Nilsson, Ahlfeldt and Strender, 2003, Grimsmo et al., 2001).

The sample is restricted to individuals aged 30 and older by January 1, 2001 followed until onset of type 2 diabetes, death, or censoring at the end of the study period at December 31, 2007. In order to ensure that all cases of type 2 diabetes were new cases, individuals were excluded if they had a diagnosis of type 2 diabetes in the first 18 months of follow-up (from 1/1/01 to 6/30/02). Individuals were also excluded from analysis if they had an in-patient, out-patient or primary care diagnosis of type 1 diabetes, schizophrenia, bipolar disorder, stroke, or dementia between January 1, 1995 and June 30, 2002.

Measures

Major Depression

Major depression was defined as a clinical diagnosis from either primary care, in-patient, or out-patient registries (ICD-10 code F32) from January 1, 2001 to the end of follow-up on December 31, 2007. Only cases of major depression that occurred at least 6 months prior to clinical diagnosis of type 2 diabetes were included. A four-level variable of depression severity was created based on healthcare setting: 0 = never had a diagnosis of depression in any healthcare setting, 1 = diagnosis of depression in primary healthcare setting only, 2 = diagnosis of depression in an outpatient setting at least once (may have also had diagnoses in primary care, but not inpatient settings), and 3 = diagnosis of depression in an inpatient setting at least once (may have also had diagnoses in primary care and outpatient settings). This variable was collapsed into a binary indicator (never had a diagnosis of depression versus had a diagnosis of depression at least once in any healthcare setting) for additional analysis. As described below, in the main models only depression diagnosed in primary care was considered because the vast majority of depression cases came from this setting.

Type 2 diabetes

Diabetes was defined as the first clinical diagnosis of type 2 diabetes from either the primary care, inpatient, or outpatient registries (International Classification of Diseases (ICD) – 10 codes E11, E13, and E14), or use of anti-diabetes medication as recorded in the primary care or national prescription registries (prescription codes A10A and A10B). Prescription data were derived from the primary care prescription records from January 1, 2001 to December 31, 2004, and from the national prescription registry thereafter, which began in January 1, 2005. Only incident cases of type 2 diabetes that occurred on or after July 1, 2002, and which occurred at least 6 months after the first clinical diagnosis of major depression, were included.

Comorbidities and family history

Presence of hypertension (ICD-10 codes I10 – I159) was derived from the primary care, outpatient, and inpatient registries. Analyses additionally accounting for heart disease (ischemic heart disease (ICD-10 codes I20 – I25) and other heart disease (ICD-10 codes I30-I52)) were similar to those presented here (data not shown). Family history of depression was assessed as diagnosis of depression (ICD-10 code F32) in either biological parent from 1/1/01 – 12/31/07 from the primary care, outpatient, and inpatient registries. Family history of type 2 diabetes was assessed as diagnosis of diabetes (ICD-10 codes E11, E13, and E14) in either biological parent from 1/1/01 – 12/31/07 from the primary care, outpatient, and inpatient registries.

Other individual-level variables

Age, gender, family income, educational attainment, and immigration status were obtained from national registries. Family income was based on the annual family income divided by the number of people in the family, (i.e. individual family income per capita) as calculated by Statistics Sweden, the Swedish Government-owned statistics bureau. The income parameter also takes into consideration the ages of people in the family and uses a weighted system whereby small children were given lower weights than adolescents and adults. This variable was then categorized into quartiles for analysis. Educational attainment was categorizes as completion of compulsory school or less (≤9 years), practical high school or some theoretical high school (10 – 11 years), and completion of theoretical high school or college (>12 years). Immigration status was collapsed into six categorizes based on the most common immigrant groups in Sweden: (a) native-born, (b) born in Finland; (c) born in Western Europe or North America (i.e., Denmark, UK, France, Italy, Germany, US, etc.); (d) born in Eastern Europe (i.e., Bosnia-Herzegovina, Yugoslavia, Czechoslovakia, Poland, Romania, Russia, etc.); (5) born in the Middle eastern (i.e., Turkey, Lebanon, Iran, Iraq, Morocco, North Africa, etc.); and (d) all other nativities.

Neighborhood deprivation

The home addresses of all Swedish adults have been geocoded to small geographic units that have boundaries defined by homogeneous types of buildings. These neighborhood areas, called Small Area Market Statistics (SAMS), have an average of 1,000 people (2,000 in the Stockholm area) and were used as proxies for neighborhoods, as described previously (Sundquist, Malmstrom & Johansson 2004). The total number of SAMS included in the present study was 4,770.

A summary measure was used to characterize neighborhood-level deprivation at baseline in 2001. We identified deprivation indicators used by past studies to characterize neighborhood environments and then used a principal components analysis to select deprivation indicators in the Swedish national database. The following four variables were selected for those aged 25 –

64: (a) low educational status (<10 years of formal education); (b) low income (income from all sources, including that from interest and dividends, defined as less than 50% of individual median income); (c) unemployment (not employed, excluding full-time students, those completing compulsory military service, and early retirees); and (d) social welfare assistance (Statistics Sweden, 2003). Each of the four variables loaded on the first principal component with similar loadings (+.47 to +.53) and explained 52% of the variation between these variables. A z-score was calculated for each SAMS neighborhood. The z-scores, weighted by the coefficients for the eigenvectors, were then summed to create the index (Gilthorpe 1995). The index was categorized into three groups: below one standard deviation (SD) from the mean (low deprivation), above one SD from the mean (high deprivation), and within one SD of the mean (moderate deprivation). Higher scores reflect more deprived neighborhoods. Using this categorization, 1,193 neighborhoods were categorized as low deprivation (34.6% of the study population), 2,784 categorized as moderate (42.9% of the study population), and 793 categorized as high deprivation (22.5% of the study population) (**Supplemental Table 1**). The correlation between the individual-level indicators of SES and neighborhood deprivation was modest, but in the expected direction (r^2 = -0.29 and -.12 for family income and education, respectively).

Statistical Analysis

After excluding prevalent cases of type 2 diabetes as described above, the study follow-up period started on January 1, 2001 and proceeded until date of type 2 diabetes diagnosis, or death, emigration or the end of the study period on December 31, 2007 for those who did not develop diabetes. Initially, age-standardized incidence rates of type 2 diabetes were calculated by direct age standardization using 5-year age groups according to depression status and neighborhood deprivation (Inskip et al., 1983).

First, discrete-time Cox proportional hazards models were used to estimate the relative hazard of type 2 diabetes associated with major depression, neighborhood deprivation, and their interaction, adjusting for individual-level covariates. The estimates of the hazard ratio, an approximate of the relative risk, account for the influence of incomplete information from censored observations because they reflect the changing risk set over the follow-up period. The hazard ratios indicate risk of the type 2 diabetes associated with a covariate at time *t+1*, given that diabetes had not occurred at or prior to time *t* (Selvin, 2004). The proportional hazards model does not specify the baseline hazard function, but requires that the hazard functions are proportional for all survival times. The assumptions of the survival model were evaluated with Schoenfeld residual plots.

Next, random intercept multilevel logistic regression models were used to account for the clustering of individuals within neighborhoods, and to estimate the variance in diabetes risk that is attributable to neighborhood characteristics. This approach was used to estimate the intraclass correlation coefficient (ICC), the proportion of variance in the outcome attributable to differences between individuals in different neighborhoods (or classes) as opposed to differences between individuals within the same neighborhood (Snijders and Bosker, 1999, Bryk and Raudenbush, 1992). The ICC ranges from 0 to 1; values close to 1 indicate that individuals within the same neighborhood are more highly correlated than individuals in different neighborhoods. Multilevel proportional hazards models were not used because of convergence issues given the large number of observations; however, multilevel logistic models are a good approximation of Cox models in instances such as ours, that is, when the sample size is large, the incidence of the outcome is low, the risk ratio is not large and the follow-up period is relatively short (Callas , Pastides and Homer, 1998).

This study was approved by the Institutional Review Board at the Centre for Primary Health Care Research at Lund University. Analyses were conducted using SAS (version 9.2;

SAS Institute, Cary, NC, USA) and MLwiN, version 2.02 1, and all p-values refer to two-tailed tests.

RESULTS

Among 336,340 adults aged 30 and older who did not have diabetes at baseline, there were 27,894 incident cases of type 2 diabetes over the 7 year follow-up period, which corresponds to a cumulative incidence of 8.2% (**Table 1**). The majority (N = 19,942, 71.5%) of diabetes cases were detected in primary care or by use of anti-diabetic medications rather than in inpatient or outpatient settings. Type 2 diabetes risk was positively associated with level of neighborhood deprivation, with age-standardized incidence ranging from 62.9/1,000 person-years for low deprivation areas to 115.6/1,000 person years for high deprivation areas. Approximately one in four (23.7%) persons had ever received a diagnosis of major depression, the vast majority of which occurred in primary care only (95.5%).

As shown by **Table 2**, the incidence of type 2 diabetes was higher among those who had a lifetime history of major depression relative to those who had never been diagnosed with depression (92.9/1,000 person-years vs. 79.9/1,000 person-years, respectively). This relationship persisted across age groups, but was most pronounced at younger ages, and held across levels of neighborhood deprivation. As neighborhood deprivation increased, the incidence of type 2 diabetes also increased, for all age groups and for those with and without a history of major depression. The incidence of type 2 diabetes among those with major depression was almost twice as high in the high deprivation neighborhoods as the low deprivation areas (127.5/1,000 person years vs. 69.3/1,000 person years). There was no evidence that the relationship between major depression and diabetes risk varied as a function of depression severity, indexed by treatment setting; overall, persons who had received a diagnosis of major depression in a psychiatric inpatient or outpatient settings had very similar incidence of type 2 diabetes as those who were only diagnosed in primary care settings

(93.2/1,000 person-years for inpatient vs. 92.3/1,000 person-years for outpatient vs. 92.9/1000 person-years for primary care). Therefore the remaining analyses report only on major depression diagnosed in primary care settings, which accounted for 95% of cases. The influence of depression on risk of type 2 diabetes increased across levels of neighborhood deprivation in an additive manner; among individuals diagnosed with major depression in primary care, the risk of type 2 diabetes approximately doubled moving from low to high deprivation areas (69.5/1,000 person-years in low deprivation to 127.4/1,000 person-years in high deprivation areas).

In multilevel logistic regression models, major depression was associated with a 10% increase in the risk of type 2 diabetes (95% CI: 1.06 – 1.14) after accounting for demographic characteristics, family history, and medical comorbidities (**Table 3**). Neighborhood deprivation accounted for 51% of the variance in diabetes risk (ICC = 0.017) in unadjusted models. In fully-adjusted models the ICC remained small (0.013), indicating that the majority of variance in type 2 diabetes risk derives from within-neighborhood rather than between neighborhood differences. After accounting for neighborhood deprivation the individual indicators of SES (education and family income) were not strongly associated with diabetes risk.

As shown by **Figure 1**, the relationship between major depression and onset of type 2 diabetes was not influenced by neighborhood deprivation (β: 0.01, 95% CI: -0.06 – 0.06, P= 0.573), indicating that the association between major depression and subsequent diabetes was similar across neighborhood context. In order to confirm that this non-significant interaction was not an artifact of scale, we repeated this analysis using a scale of raw probability rather than log-hazards and the results were consistent (data not shown). These results indicate that depression and neighborhood deprivation do not interact synergistically to increase risk of diabetes; the combined effect of these risk factors is consistent with an additive model on both the multiplicative and probability scales.

DISCUSSION

The primary finding from this study is that major depression is associated with a modest increased risk of developing type 2 diabetes, and that this relationship is not moderated by neighborhood-level deprivation. Even in low deprivation areas, depression was associated with increased risk of developing type 2 diabetes over the 7-year follow-up period; this elevated risk was similar across all levels of neighborhood SES. Although there was no evidence that the effect of depression on diabetes risk was exacerbated by neighborhood deprivation (e.g., there was no evidence of a synergistic interaction), because both depression and diabetes were more common in these areas, the attributable risk of type 2 diabetes due to depression was greatest in high deprivation neighborhoods. For example, among those in high deprivation areas the attributable risk ($\text{Diabetes Incidence}_{\text{Depression}}$ – $\text{Diabetes Incidence}_{\text{Never Depression}}$) = 16.4, but in the low deprivation areas the attributable risk was only 8.2. This indicates that in order to have the most impact on public health, efforts to reduce the medical comorbidity of depression should focus on individuals living in high deprivation areas (Gary Webb et al., 2011, Anderson et al., 2007). Our findings also indicate that individual indicators of SES (education and income) are not strongly related to type 2 diabetes risk after accounting for neighborhood SES, which highlights the role that contextual factors may play in development of this condition.

There was no evidence that the risk of type 2 diabetes varied by severity of major depression, at least as indexed by treatment setting. Other studies have also failed to find evidence that severe depression predicts diabetes more so than less severe (Campayo et al., 2010). It may be that the measure of depression severity used in this study (treatment setting) was too crude to detect clinically-meaningful differences in depressive symptomology. Because major depression is under-detected, particularly in primary care settings (Harman, Veazie and Lyness, 2006), it may also be that in order for a case to have been identified by a clinician at all it was significantly impairing; depression cases in clinical settings are more severe than general community settings. It is also possible that other indicators of depressive symptomology, such as age of onset or duration, have implications for type 2 diabetes risk.

The risk of diabetes associated with depression reported here, on the order of 10%, is more modest than many previous studies (e.g., a recent meta-analysis reported an average relative risk of diabetes associated with depression of 1.60 (95% Confidence Interval: 1.37 – 1.88) (Mezuk et al., 2008a). The difference between our estimate and prior work may also reflect the reliance on clinical records for diagnosed major depression which likely lead to misclassifcation of mild or moderate cases undetected by a clinician, and this misclassification would have diluted the effect estimate; that is, our estimate is likely conservative. We also note that in *post-hoc* analysis we examined the interaction between depression and the individual-level indicators of education and income on the risk of diabetes; within every level of these indicators depression was positively associated with diabetes risk. There was no interaction between depression and income (P=0.657), but for education the interaction suggested that the risk of diabetes associated with depression was strongest among those with the highest level of education (P<0.01). This is in the opposite direction of previous studies in US samples (Carnethon et al. 2003; Mezuk et al. 2008b), and points to the need to examine factors such as education and social welfare policies that may have contributed to this difference.

These findings should be interpreted in light of study limitations. All cases of major depression and type 2 diabetes were clinically-identified, which is not synonymous with true prevalence (particularly for depression). Although major depression is under-detected in primary care (Harman, Veazie and Lyness, 2006), in the past decade there has been a push to increase detection in Sweden general practice (Hansson, Bodlund and Chotai, 2008) and the discordance between primary care and clinical interviews is generally one of specific diagnosis (e.g., major depression versus dysthymia) rather than whether or not psychopathology is present at all (Tiemens, VonKorff and Lin, 1999). Also, the quality and validity of electronic medical records from primary care in Sweden is high (Nilsson, Ahlfeldt and Strender, 2003, Grimsmo et al., 2001), and the relative availability of primary and psychiatric care in Sweden should increase detection of major depression relative to places such as the United States. Also, we did not have information on potential behavioral mediators of the depression-diabetes relationship, including smoking, diet, body mass index, and physical activity; however other reports have indicated that the relationship between depression and risk of type 2 diabetes persists after accounting for these factors (Mezuk et al., 2008a, Mezuk et al., 2008b, Knol et al., 2006). We did not account for antidepressant medication use in these analyses. Because of concerns regarding confounding by indication (Knol et al., 2009), methods beyond regression models that explicitly account for selection effects (e.g., propensity score techniques) are necessary to assess whether antidepressants are associated with type 2 diabetes risk above and beyond depressive symptomology (Glynn, Schneeweiss and Stürmer, 2006, Rubin, 2004). Finally, because of the modest ICC (.013) we had limited statistical power to identify the influence of factors at this level. Approximately 27% of participants moved at some point during the study period (they may have remained within the same SAMS, however), and this mobility was not accounted for in our models. Therefore, there may be residual confounding by neighborhood characteristics. This study also has a number of strengths. It represents the largest population-based, prospective study to date of the relationship between major depression and incidence of type 2 diabetes, had a relatively long follow-up period, used clinical diagnoses that are unaffected by recall bias, and is the first to the authors' knowledge to examine whether neighborhood socioeconomic characteristics modify this relationship.

The worldwide prevalence of diabetes has increased substantially over the past 20 years, and this increase is projected to continue (World Health Organization, 2008, Centers for Disease Control and Prevention, 2011). This epidemic underscores the urgency of understanding the relationship between depression and diabetes, including how individual-level and neighborhood-level risk factors interact, to identify modifiable risk factors for this comorbidity and develop public health interventions that reflect this complexity to reduce social disparities in health. These results add to a growing body of research aimed at understanding the role of contextual environmental factors on health.

REFERENCES

Anderson, D., Horton, C., O'Toole, M.L., Brownson, C.A., Fazzone, P., Fisher, E.B., 2007. Treating Diabetes and Depression Integrating Depression Care With Diabetes Care in Real-World Settings: Lessons From the Robert Wood Johnson Foundation Diabetes Initiative. Diabetes Spectrum 20, 10-16.

Auchincloss, A.H., Diez Roux, A.V., Mujahid, M.S., Shen, M., Bertoni, A.G., Carnethon, M.R., 2009. Neighborhood resources for physical activity and healthy foods and incidence of type 2 diabetes mellitus: the Multi-Ethnic study of Atherosclerosis. Archives of Internal Medicine 169, 1698-1704.

Auchincloss, A.H., Diez Roux, A.V., Brown, D.G., Erdmann, C.A., Bertoni, A.G., 2008. Neighborhood resources of physical activity and healthy foods and their association with insulin resistance. Epidemiology 19, 146-157.

Bryk, A.S., Raudenbush, S.W., 1992. Hierarchical Linear Models: Applications and Data Analysis Methods. SAGE, Thousand Oaks CA.

Callas, P.W., Pastides, H., Homer, D.W. 1998. Empirical comparisons of proportional hazards, Poisson, and logistic regression modeling of occupational cohort data. AmericanJournal of Indian Medicine 33, 33-47.

Campayo, A., de Jonge, P., Roy, J.F., Saz, P., de la Cámara, C., Quintanilla, M.A., Marcos, G., Santabárbara, J., Lobo, A., 2010. Depressive disorder and incident diabetes mellitus: the effect of characteristics of depression. American Journal of Psychiatry 167, 580-588.

Carnethon, M., Kinder, L., Fair, J., Stafford, R., Fortmann, S., 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. American Journal of Epidemiology 158, 416-423.

Centers for Disease Control and Prevention. 2011. National Diabetes Factsheet: General information and national estimates on diabetes in the United States 2010. US Department of Health and Human Services, Atlanta, GA.

Cox, M., Boyle, P.J., Davey, P.G., Feng, Z., Morris, A.D., 2007. Locality deprivation and Type 2 diabetes incidence: a local test of relative inequalities. Social Science & Medicine 65, 1953-1964.

Crump, C., Sundquist, K., Sundquist, J., Winkleby, M.A., 2011. Neighborhood Deprivation and Psychiatric Medication Prescription: A Swedish National Multilevel Study. Annals of Epidemiology 21, 231-237.

de Groot, M., Anderson, R., Freedland, K., Clouse, R., Lustman, P., 2001. Association of depression and diabetes complications: A meta-analysis. Psychosomatic Medicine 63, 619-630.

Diez Roux, A.V. & Mair, C., 2010. Neighborhoods and Health. Annals of the New York Academy of Medicine 1186, 125-145.

Dubowitz, T., Ghosh-Dastidar, M., Eibner, C., Slaughter, M.E., Fernandes, M., Whitsel, E.A., Bird, C.E., Jewell, A., Margolis, K.L., Li, W., Michael, Y.L., Shih, R.A., Manson, J.E., Escarce, J.J., 2011. The Women's Health Initiative: The Food Environment, Neighborhood Socioeconomic Status, BMI, and Blood Pressure. Obesity 20, 862-871.

Frasure-Smith, N., Lesperance, F., Gravel, G., Masson, A., Juneau, M., Talajic, M., Bourassa, M., 2000. Social support, depression, and mortality during the first year after myocardial infarction. Circulation 101, 1919-1924.

Galea, S., Ahern, J., Nandi, A., Tracy, M., Beard, J., Vlahov, D., 2007. Urban Neighborhood Poverty and the Incidence of Depression in a Population-Based Cohort Study. Annals of Epidemiology 17, 171-179.

Gary Webb, T., Baptiste Roberts, K., Pham, L., Wesche Thobaben, J., Patricio, J., Pi Sunyer, F.X., Brown, A., Jones Corneille, L., Brancati, F., 2011. Neighborhood socioeconomic status, depression, and health status in the Look AHEAD (Action for Health in Diabetes) study. BMC Public Health 11, 349-349.

Gilthorpe, M.S. 1995. The importance of normalisation in the construction of deprivation indices. Journal of Epidemiol Community Health 49, S45-S50.

Glynn, R.J., Schneeweiss, S., Stürmer, T. 2006. Indications for Propensity Scores and Review of Their Use in Pharmacoepidemiology. Basic and Clinical Pharmacology and Toxicology 98, 253-259.

Golden, S.H., Lazo, M., Carnethon, M., Bertoni, A.G., Schreiner, P.J., Diez Roux, A.V., Lee, H.B., Lyketsos, C., 2008. Examining a bidirectional association between depressive symptoms and diabetes. JAMA 299, 2751-2759.

Grimsmo, A., Hagman, E., Faik, E., Matthiessen, L., Njlsson, T., 2001. Patients, diagnoses and processes in general practice in the Nordic countries. An attempt to make data from computerised medical records available for comparable statistics. Scandinavian Journal of Primary Health Care 19, 76-82.

Hansson, M., Bodlund, O., Chotai, J., 2008. Patient education and group counselling to improve the treatment of depression in primary care: A randomized controlled trial. Journal of Affective Disorders 105, 235-240.

Harman, J.S., Veazie, P.J., Lyness, J.M., 2006. Primary care physician office visits for depression by older Americans. Journal of General Internal Medicine 9, 926-930.

Inskip, H., Beral, V., Fraser, P., Haskey, J. 1983. Methods for age-adjustment of rates. Statistics in Medicine 2, 455-466.

Katon, W.J. 2008. The comorbidity of diabetes mellitus and depression. American Journal of Medicine 121, S8-S15.

Katz, I.R., 1996. On the inseparability of mental and physical health in aged persons. American Journal of Geriatric Psychiatry 4, 1-16.

Kershaw, K.N., Diez Roux, A.V., Burgard, S.A., Lisabeth, L.D., Mujahid, M.S., Schulz, A.J., 2011. Metropolitan-level racial residential segregation and black-white disparities in hypertension. American Journal of Epidemiology 174, 537-545.

Kim, D., 2008. Blues from the neighborhood? Neighborhood characteristics and depression. Epidemiologic Reviews 30, 101-117.

Knol, M.J., Geerlings, M.I., Grobbee, D.E., Egberts, A.C.G., Heerdink, E.R., 2009. Antidepressant use before and after initiation of diabetes mellitus treatment. Diabetologia 52, 425-432.

Knol, M.J., Twisk, J.W.R., Beekman, A.T.F., Heine, R.J., Snoek, F.J., Pouwer, F., 2006. Depression as a risk factor for the onset of type 2 diabetes mellitus. A meta-analysis. Diabetologia 49, 837-845.

Krueger, P.M. & Chang, V.W., 2008. Being poor and coping with stress: health behaviors and the risk of death. American Journal of Public Health 98, 889-96.

Lin, E.H., Heckbert, S.R., Rutter, C.M., Katon, W.J., Ciechanowski, P., Ludman, E.J., Oliver, M., Young, B.A., McCulloch, D.K., Von Korff, M., 2009. Depression and increased mortality in diabetes: unexpected causes of death. Annals of Family Medicine 7, 414-421.

Lofors, J. & Sundquist, K., 2007. Low-linking social capital as a predictor of mental disorders: A cohort study of 4.5 million Swedes. Social Science & Medicine 64, 21-34.

Lorant, V., Delige, D., Eaton, W., Robert, A., Philippot, P., Ansseau, M., 2003. Socioeconomic inequalities in depression: a meta-analysis. American Journal of Epidemiology 157, 98-112.

Mezuk, B., Eaton, W.W., Albrecht, S., Golden, S.H. 2008b. Depression and type 2 diabetes over the lifespan: A meta-analysis. Diabetes Care 31, 2383-2390.

Mezuk, B., Eaton, W.W., Golden, S.H., Ding, Y., 2008a. The influence of educational attainment on depression and risk of type 2 diabetes. American Journal of Public Health 98, 1480-1485.

Mujahid, M.S., Diez Roux, A.V., Shen, M., Gowda, D., Sanchez, B., Shea, S., Jacobs, D.R., Jackson, S.A., 2008. Relation between neighborhood environments and obesity in the Multi-Ethnic Study of Atherosclerosis. American Journal of Epidemiology 167, 1349-1357.

Nilsson, G., Ahlfeldt, H., Strender, L., 2003. Textual content, health problems and diagnostic codes in electronic patient records in general practice. Scandinavian Journal of Primary Health Care 21, 33-36.

Pan, A., Lucas, M., Sun, Q., van Dam, R.M., Franco, O.H., Manson, J.E., Willett, W.C., Ascherio, A., Hu, F.B., 2010. Bidirectional association between depression and type 2 diabetes mellitus in women. Archives of Internal Medicine 170, 1184-1191.

Pan, A., Lucas, M., Sun, Q., van Dam, R.M., Franco, O.H., Willett, W.C., Manson, J.E., Rexrode, K.M., Ascherio, A., Hu, F.B., 2011. Increased mortality risk in women with depression and diabetes mellitus. Archives of General Psychiatry 68, 42-50.

Rubin, D.B., 2004. On principles for modeling propensity scores in medical research. Pharmacoepidemiology and Drug Safety 13, 855-857.

Schootman, M., Andresen, E.M., Wolinsky, F.D., Malmstrom, T.K., Miller, J.P., Miller, D.K., 2007a. Neighbourhood environment and the incidence of depressive symptoms among middle-aged African Americans. Journal of Epidemiology and Community Health 61, 527-532.

Schootman, M., Andresen, E.M., Wolinsky, F.D., Malmstrom, T.K., Miller, J.P., Yan, Y., Miller, D.K., 2007b. The Effect of Adverse Housing and Neighborhood Conditions on the Development of Diabetes Mellitus among Middle-aged African Americans. American Journal of Epidemiology 166, 379-387.

Selvin, S., 2004. Statistical analysis of epidemiologic data. 3rd ed. Oxford University Press, New York.

Shih, R.A., Ghosh-Dastidar, B., Margolis, K.L., Slaughter, M.E., Jewell, A., Bird, C.E., Eibner, C., Denburg, N.L., Ockene, J., Messina, C.R., Espeland, M.A. 2011. Neighborhood socioeconomic status and cognitive function in women. American Journal of Public Health 101, 1721-1728.

Snijders, T.A.B. & Bosker, R.J., 1999. Multilevel analysis: An introduction to basic and advanced multilevel modeling. Sage Publications., Thousand Oaks, CA.

Statistics Sweden. 2003. Market profiles from Statistik Sweden—SAMS. Available: http://www.scb.se/templatesStatisticsSweden.

Sundquist, K., Chaikiat, A., Leon, V.R., Johansson, S.E., Sundquist, J., 2011. Country of birth, socioeconomic factors, and risk factor control in patients with type 2 diabetes: A Swedish study from 25 primary health-care centres. Diabetes and Metabolism Research and Reviews 27, 244-254.

Sundquist, J., Malmstrom, M., Johansson, S.E., 1999. Cardiovascular risk factors and the neighbourhood environment: a multilevel analysis. International Journal of Epidemiolology 28, 841-5.

Sundquist, K., Malmstrm, M., Johansson, S., 2004. Neighbourhood deprivation and incidence of coronary heart disease: a multilevel study of 2.6 million women and men in Sweden. Journal of Epidemiology and Community Health 58, 71-77.

Tiemens, B.G., VonKorff, M., Lin, E.H.B. 1999. Diagnosis of depression by primary care physicians versus a structured diagnostic interview: Understanding discordance. General Hospital Psychiatry 21, 87-96.

Wight, R.G., Cummings, J.R., Karlamangla, A.S., Aneshensel, C.S., 2009. Urban Neighborhood Context and Change in Depressive Symptoms in Late Life. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences 64B, 247-251.

World Health Organization., 2008. Global burden of disease: 2004 update. World Health Organization Technical Report, Geneva, Switzerland .

Xue, Y., Leventhal, T., Brooks-Gunn, J., Earles, F.J., 2005. Neighborhood residence and mental health problems of 5- to 11-year-olds. Archives of General Psychiatry 62, 554-563.

Yen, I.H. & Kaplan, G.A. 1999. Poverty area residence and changes in depression and perceived health status: evidence from the Alameda County Study. International Journal of Epidemiology 28, 90-94.

Figure 1: Plot of Survival Time to Type 2 Diabetes by Major Depression Status and Neighborhood Deprivation: 2001 – 2007

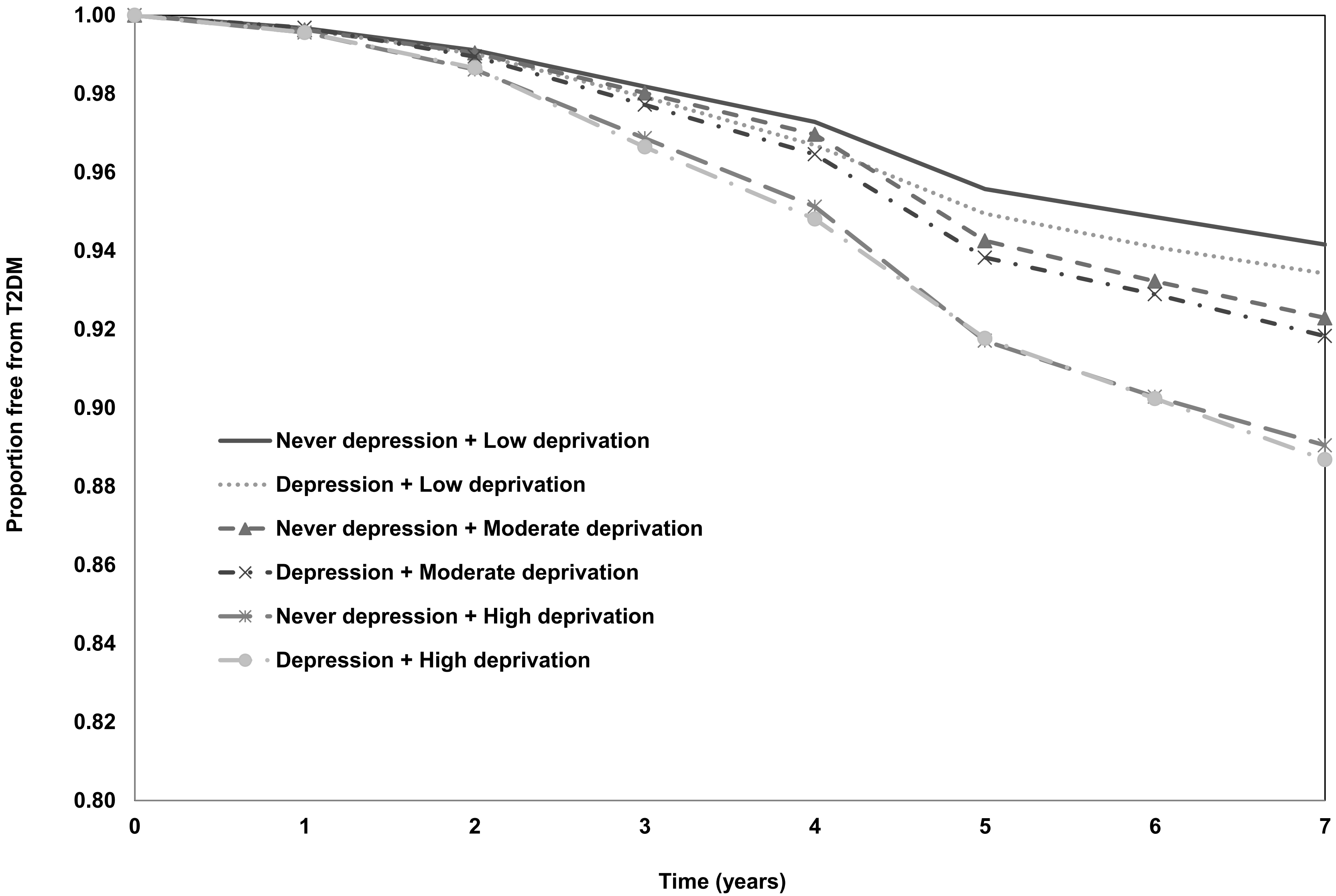

Table 1. Population Characteristics and Age-Standardized Incidence of Type 2 Diabetes by Level of Neighborhood Deprivation: 2001 – 2007

	Study population (N)	Distribution (%)	Type 2 diabetes events (N)	Incidence of type 2 diabetes by level of neighborhood deprivation*		
				Low	Moderate	High
Total population	336,340			116,370	144,175	75,795
Type 2 diabetes			27,894	62.8	82.0	115.6
Gender						
Men	142,672	42.4	14,625	83.5	102.8	133.2
Females	193,668	57.6	13,269	47.1	66.7	101.7
Age (years)						
30-39	83,390	24.8	1,519	9.8	15.1	35.1
40-49	72,574	21.6	3,612	30.5	47.0	82.9
50-59	72,631	21.6	7,458	77.4	99.0	154.9
60-69	50,655	15.1	7,494	120.5	144.2	201.3
>=70	57,090	17.0	7,811	116.6	132.5	176.2
Country of origin						
Sweden	267,589	79.6	20,293	59.8	78.5	92.8
Finland	15,644	4.7	1,586	69.8	91.7	109.2
Western countries	3,935	1.2	368	60.8	76.6	109.6
Eastern European countries	4,436	1.3	535	109.9	120.1	144.9
Middle Eastern countries	18,169	5.4	2,362	157.2	159.5	185.1
Others	26,567	7.9	2,750	86.3	100.1	144.7
Educational attainment						
≤ 9 years	72,169	21.5	7,922	74.1	92.2	131.8
10–11 years	93,775	27.9	6,915	70.7	83.8	109.8
≥ 12 years	170,396	50.7	13,057	60.5	83.6	117.6
Family income						
Quartile 1 (Low income)	84,175	25.0	7,689	79.4	92.3	135.5
Quartile 2	84,186	25.0	7,639	68.7	87.6	113.7
Quartile 3	83,998	25.0	6,884	64.3	82.0	100.2
Quartile 4 (High income)	83,981	25.0	5,682	54.1	68.4	95.7
Major depression						
Never major depression	256,482	76.3	20,524	61.1	79.6	111.1
Inpatient admission	1,383	0.4	122	72.4	98.1	101.4
Outpatient admission	2,485	0.7	182	58.5	86.9	143.7
Primary care	75,990	22.6	7,066	69.5	89.7	127.4
Type 2 diabetes						
Never type 2 diabetes	308,446	91.7				
Inpatient/outpatient admission	7,952	2.4	7,952	21.4	21.0	32.1

Primary care/Antidiabetics Rx	19,942	5.9	19,942	41.4	61.0	83.5
Family history and comorbidities						
Family history of depression	2,561	0.8	102	47.6	57.3	38.4
Family history of type 2 diabetes	19,645	5.8	1,362	78.0	91.0	108.3
Hypertension	30,079	8.9	6,479	158.4	177.9	239.5

Incidence rate per 1,000 person-years.

Table 2. Age-Specific and Age-Standardized Incidence of Type 2 Diabetes by Depression Status and Neighborhood Deprivation

Age group, year	Overall		Low deprivation		Moderate deprivation		High deprivation	
	Never major depression	Lifetime major depression	Never major depression	Lifetime major depression	Never major depression	Lifetime major depression	Never major depression	Lifetime major depression
30 – 39	15.3	28.2	8.5	15.6	12.5	23.6	30.6	47.5
40 – 49	45.2	63.1	27.5	41.4	44.6	53.8	75.9	98.3
50 – 59	98.8	115.2	77.1	78.3	94.2	113.9	150.3	167.0
60 – 69	145.4	158.3	117.6	133.4	142.3	151.6	199.1	209.8
≥70	136.1	138.9	115.4	119.9	132.9	131.5	173.3	184.8
All ages	79.9	92.9	61.1	69.3	79.6	89.6	111.1	127.5

Incidence rate per 1,000 person-years.

Table 3. Relative risk of Type 2 Diabetes from 2001 – 2007: Results from Multi-level Logistic Regression Analyses

	Model 1			Model 2			Model 3		
	OR	95% CI		OR	95% CI		OR	95% CI	
Depression *(ref. Never)*	1.07	1.04	1.11	1.07	1.03	1.11	1.11	1.07	1.15
Neighborhood deprivation *(ref. Low)*									
Moderate				1.35	1.28	1.41	1.28	1.23	1.35
High				1.84	1.73	1.96	1.67	1.57	1.77
Age *(years)*							1.05	1.05	1.05
Gender to men *(ref. Women)*							1.71	1.67	1.76
Country of origin *(ref. Sweden)*									
Finland							1.32	1.24	1.39
Western countries							1.15	1.03	1.28
Eastern European countries							1.73	1.57	1.92
Middle Eastern countries							2.19	2.07	2.33
Others							1.60	1.53	1.68
Education attainment *(ref. ≥ 12 yrs)*									
Compulsory school or less (≤9 years)							0.69	0.67	0.72
Practical high school or some theoretical high school (10–11 years)							1.09	1.06	1.13
Family income *(ref. Highest quartile)*									
Middle-high income							1.10	1.06	1.14
Middle-low income							1.07	1.02	1.11
Low income							1.04	1.00	1.08
Family history and comorbidities *(ref. Not present)*									
Family history of depression							0.85	0.69	1.04
Family history of type 2 diabetes							1.73	1.63	1.84
Hypertension							2.54	2.46	2.63
Variance (S.E.)	*0.119 (0.009)*			*0.056 (0.005)*			*0.044 (0.004)*		
Explained variance (%)	*-4*			*51*			*61*		
Intra class correlation	0.035			0.017			0.013		

Abbreviations:OR: Odds ratio. SE: Standard error. CI: Confidence interval.