Published in final edited form as:

J Diabetes Complications. 2018 January ; 32(1): 75–82. doi:10.1016/j.jdiacomp.2016.06.026.

Type 2 Diabetes, depressive symptoms and disability over a 15-year follow-up period in older Mexican Americans living in the Southwestern United States

Jennifer J. Salinas^{*,a}, Jennifer M. Reingle Gonzalez^b, and Soham Al Snih^c

^a Department of Epidemiology, Human Genetics, Environmental Sciences, University of Texas Health Science Center at Houston School of Public Health, United States; Address: 1101 N. Campbell St. El Paso, TX 79902 U.S.A

^b Department of Epidemiology, Human Genetics, Environmental Sciences, University of Texas Health Science Center at Houston School of Public Health, United States; Address: 6011 Harry Hines Blvd., Suite V8.112 Dallas, TX 75390 U.S.A

^c Division of Rehabilitation Sciences, School of Health Professions, Internal Medicine, Division of Geriatrics, Sealy Center on Aging Rebecca Sealy Bldg 5.112A, 301 University Blvd. Rt. 0177, Galveston, Texas 77555

Abstract

AIMS—To evaluate how depression and diabetes severity impacts disability progression among Mexican Americans over a 15-year period.

METHODS—We used seven waves of the Hispanic Established Population for the Epidemiologic Study of the Elderly (H-EPESE). Primary disability outcomes included the Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) scales. Explanatory variables included time since diagnosis with diabetes (no type 2 diabetes, 1-10, 11-20, 21+), an indicator of disease severity, and depression. Longitudinal generalized estimating equation models were used to estimate the relationship between time since diabetes diagnosis, depressive symptoms and ADL and IADL disability progression over a 15-year time period.

RESULTS—Years since diabetes diagnosis was associated with more rapid ADL and IADL disability progression compared to those without type 2 diabetes. Depression accelerated the disabling process in participants who were diagnosed with diabetes 11 years or more years ago.

CONCLUSIONS—Longer duration of diabetes and greater symptoms of depression increases vulnerability for disability among older Mexican American adults.

Keywords

Mexican American; diabetes; disability; Hispanic; depression

*Corresponding Author: Jennifer Salinas, PhD, University of Texas Health Science Center at Houston School of Public Health, Department of Epidemiology, Human Genetics, Environmental Sciences, 1101 N. Campbell St., El Paso, TX 79902, phone: (915) 747-8505, Jennifer.J.Salinas@uth.tmc.edu, jennifer.reingle@utsouthwestern.edu, soalsnih@utmb.edu

Conflicts of Interest: None

1.0 Introduction

Hispanics have elevated rates of type 2 diabetes compared to any other non-Hispanic racial group, and Mexican Americans bear the greatest burden of type 2 diabetes among Hispanics overall (Centers for Disease Control and Prevention [CDC] 2014a). According to the CDC, 10% of Mexican Americans have been diagnosed with type 2 diabetes compared to 6% of non-Hispanic Whites (CDC 2014b). Mexican Americans disproportionately suffer from type 2 diabetes-related complications, including disability, diabetic retinopathy, and end stage renal disease (Dhamoon et al., 2014; Pugh et al., 1988) with little change in this trend over the past few decades (Beard et al., 2009). To quantify this burden of type 2 diabetes among Mexican Americans, more than 50% have some form of type 2 diabetes-related disability (Beard et al., 2009) including diabetic retinopathy (37%), renal disease (17%), cardiovascular disease (28%), circulatory disease (40%), and as many as 80% of Mexican Americans with diabetes have at least one functional limitation. Timely intervention programs that aim to delay or prevent onset of disability in Mexican Americans are needed. For example, expansion of programs like SONRISA in Arizona (Reinschmidt and Chong, 2007) designed to train Mexican Americans to manage their type 2 diabetes and associated mental health issues could mitigate the repercussions of a growing population with an increased burden of type 2 diabetes and comorbid disability.

The longer a person lives with a type 2 diabetes diagnosis, the more likely they are to develop a disabling condition – such as stroke, neuropathy, hip fractures, visual impairments or amputation – that leads to mortality, functional limitations and disability (Al Snih et al., 2005; Varma et al, Los Angeles Latino Eye Study Group 2010). Despite this relationship, most population-based studies continue to use measures of self-reported type 2 diabetes status, current biological measures of fasting blood glucose, or HbA1c, without taking into consideration the length of time since diagnosis (Afaible-Munsuz et al., 2013; Palmer et al., 2012; Afaible-Munsuz, et al., 2014). Length of time since diagnosis of type 2 diabetes reflects the damage caused by long-term elevated blood sugar (Otiniano et al., 2012) and insulin resistance (Lorenzo et al., 2012; Xiang et al., 2013). Moreover, there is now growing evidence that the longer a person lives with type 2 diabetes, the greater the incidence of depression and other mental health conditions (Ell et al., 2015; Shah et al., 2015).

Depression is commonly comorbid with type 2 diabetes in Mexican Americans. Depressive symptoms may manifest as a result of the type 2 diabetes diagnosis, difficulties with diabetes management, declining health status and physical functioning (Glassy et al., 2010; Ford et al., 2014). Estimates suggest that 31% of Mexican Americans with type 2 diabetes had at least some depressive symptomology, while 11% of diabetes patients meet diagnostic criteria for major depressive disorder (Anderson et al., 2001; Black et al., 2003). Mexican Americans with type 2 diabetes have twice the odds of depression compared to non-diabetic Mexican American adults (Anderson et al., 2001). Adults with co-morbid type 2 diabetes and clinical depression have higher levels of the biomarker hemoglobin A1c and are less medically compliant with their diabetes treatment (Shah et al., 2015). Moreover, comorbid type 2 diabetes and depression is associated with increased fall risk in older adults (Tchalla et al., 2014) and disability (Schmitz et al., 2011). Still, few studies have examined the

relationship between years since diagnosis of type 2 diabetes, severity of depressive symptoms and the progression of disability longitudinally in the Mexican American population.

Given that Mexican Americans have a higher prevalence of uncontrolled type 2 diabetes, type 2 diabetes-related disability and a high burden of depressive symptoms than most race/ethnic groups, this study will extend previous research by evaluating the relationship between the number of years in which a person has been suffering from type 2 diabetes (a proxy of disease severity) and two measures of disability progression (activities of daily living [ADL] and instrumental activities of daily living [IADL]). We will also determine whether this relationship varies as a function of depressive symptomology. While studies have evaluated the relationship between diabetes and depression (Anderson et al., 2001) or diabetes, depression and disability cross-sectionally (Mishra et al., 2015; Ell et al., 2015), few studies have assessed how the established pattern progression of disability in those with diabetes could be compounded by the severity of depression symptoms over time (Black 1999; Styne et al., 2015).

Additionally, most studies have used the ADL measure as the primary indicator of disability, without considering how diabetes impacts the progression of IADL, such as money management or driving independently, which are often the first signs of loss of independence in older adults. Most studies that have investigated this relationship have not included Mexican Americans or Hispanics in general (Styner et al., 2015; de Souza Moreira et al., 2015). Further, while previous studies have not taken into account the length of time that an individual has had the diagnosis, which could impact the rate of disability progression through biological processes associated with the disease (e.g. small vessel disease, stroke, peripheral vascular disease). These biological processes could be compounded by perceived disease burden and depressive symptoms, thus leading to earlier onset and more rapid escalation of disability (Sharkey et al., 2006; Lange and Piette, 2005). In light of these previous findings, we will also evaluate whether the relationship between duration of time with diabetes diagnosis and progression of disability varies as a function of severity of depressive symptomology. Specifically, we expect that the relationship between years since type 2 diabetes diagnosis and disability progression over time will be moderated by depression severity.

2.0 Subjects, Materials, and Methods

2.1 Data

The Hispanic Established Population for the Epidemiologic Study of the Elderly (H-EPESE) is a cohort study of older (65+ years) Mexican American adults living in the Southwest United States (U.S.) collected between 1993/94 and 2012/13 (Markides et al., 1997). The initial purpose of the H-EPESE was to document the aging process among Mexican Americans, the largest Hispanic population in the U.S. The sample was selected using a probability design to represent older Mexican American adults living in Texas, Arizona, California, Colorado, and New Mexico. Baseline data were collected between 1993-1994, and seven subsequent waves (1995/96, 1998/99, 2000/01, 2003/04, 2005/06, 2007/08, 2010/11, and 2012/13) were collected over a 20-year follow-up period. For this study, we

used the first 7 waves of data, since the 2012/13 wave was not yet available to the authors for analysis. Given this large representative sample and multiple follow-up data collection points, the H-EPESE provides a unique opportunity to assess longitudinal relationships between type 2 diabetes, disability and depression in a high-risk population of older adults. While average age of diabetes diagnosis in Hispanics in the U.S. was 45.5 in 1997 (the most proximate year available to when the H-EPESE data was collected) (CDC, 2015), the average years since diagnosis in this sample is 12.9. Given the age distribution of our sample, the majority of participants in the H-EPESE had diabetes for about a decade, suggesting that the majority of the sample were likely diagnosed after the age of 50. While there is the possibility that because of the age range of H-EPESE participants, we could have systematically omitted those who were diagnosed earlier than 55 and had diabetes for less than a decade since our sample begins at age 65 those potential participants would have been missed.

After excluding cases for missing data on depression symptomology at baseline, our final sample for this analysis was 2,823 of the total 3,050 (93%). To identify missing data patterns that could bias our results, we conducted an analysis to determine to what extent participants with missing baseline data on depressive symptomology differed from those with complete data. Those of older age and female gender were significantly more likely to have missing data on depression at baseline. We adjusted for both of these variables in our analysis to reduce potential bias.

2.2 Measures

2.2.1 Type 2 Diabetes Status—Type 2 diabetes status was measured using self-reported physician diagnosis of type 2 diabetes. At baseline, 672 participants self-reported having been diagnosed with type 2 diabetes by a physician. Diagram 1 presents the number of participants and percentage of the original sample that we retained in each wave.

2.2.2 Years Since Diagnosis—Using self-reported age at diagnosis data, the number of years since diagnosis was calculated. Because this distribution was not approximately normal, we categorized this variable to represent *years since type 2 diabetes diagnosis*. These four categories included: 0 = no type 2 diabetes, 1 = 1- 10 years since diagnosis, 2 = 11-20 years since diagnosis, 3 = 21+ years since diagnosis. Greater time since diagnosis is reflective of disease severity (Al Snih et al., 2005; Varma et al., Azen, Los Angeles Latino Eye Study Group 2010).

2.2.3 Depression—Depressive symptoms during the previous week were measured using the Center for Epidemiologic Studies Depression Scale (CES-D) with scores ranging from 0 (no depressive symptoms) to 60 (Radloff, 1977). The Center for Epidemiologic Studies-Depression (CES-D) has high reliability at detecting high depressive symptoms among Hispanics with chronic diseases, including type 2 diabetes (Ell et al., 2015; Glassy et al., 2010; Ell et al., 2011). Using established cutpoints (Black et al., 2003), we created three categories representing no depressive symptoms (0 CES-D score), minor depressive symptoms (1-15 CES-D score) or significant depressive symptomology (16+ CES-D score).

2.3.4 Outcome: Disability

Self-Reported Disability: The seven-item Katz Activities of Daily Living (ADL's) scale and the eight-item Instrumental Activities of Daily Living (IADL's) scale were used to ascertain disability status (Katz et al., 1963; Lawton and Brody, 1969). The ADL scale measured participant's ability to care for themselves, with indicators such as bathing, dressing, grooming, feeding and toileting. The total number of indicators was summed to create an index of no disability (0) to seven (7) with higher scores indicative of greater disability. The IADL scale measured participants' ability to shop for themselves, pay bills, prepare meals, take medications, do housework and drive or take the bus. Participants were asked if they need help with any self-care activity listed above, and they responded "yes" or "no" to each activity. A summative score was created with a higher score indicative of greater disability. Responses were summed within scales and retained as time-varying continuous variables for regression analysis.

2.3.5 Covariates included age at baseline (65-74; 75-85; and 86 or older), gender, marital status (married, separated, divorced, widowed, or never married) at baseline, and total number of years of formal education completed (0 years; 1-6 years; 7+ years). Cut-points for years of education were created based on the frequency distributions with the majority of the sample having no greater than 6 years of formal schooling (74%) and less than 10% graduating from high school. Because previous studies using the H-EPESE dataset suggest that older adults commonly suffer from other conditions in addition to diabetes (Fillenbaum, Pieper, Cohen, Cornoni-Huntley and Guralnik 2000; Otiniano, Du, Ottenbacher, and Markides 2003), we controlled for self-reported past experience of a heart attack, stroke, cancer or hypertension in all multivariate models.

2.3 Analytical Methods

Descriptive Analyses—All measures were examined for normality and descriptive data was examined to identify outliers. Chi-square tests and analyses of variance were performed to assess associations between type 2 diabetes and CES-D categories at baseline with disability. We assessed potential bias due to attrition in participants with type 2 diabetes due to mortality by assessing the probability that participants would survive to subsequent waves of follow-up by duration of time since diagnosis with type 2 diabetes. Our analysis indicated that although participants with type 2 diabetes at baseline died earlier than those who did not have the disease, there were not significant differences in the likelihood of survival according to the exposure of interest (years with type 2 diabetes). Figure 1 shows the survival curve stratified by type 2 diabetes status for the sample. These findings are consistent with existing evidence that survival rates of persons with type 2 diabetes are highly dependent upon diabetes and comorbidity control, rather than the amount of time with the disease (Leal et al., 2009). Therefore, we do not expect that any systematic bias in years with type 2 diabetes was introduced due to earlier mortality.

We conducted a test for collinearity between age and years since diabetes diagnosis. This analysis yielded significant results, therefore we opted to include one model that includes age as a contrast to subsequent models without the age-adjustment. The removal of age in

the GEE regression did affect the significance of the effect size of years since diabetes diagnosis significantly.

Inferential Analyses—Bivariate and multivariate generalized estimating equation (GEE) regression models were used to assess the relationship between years since type 2 diabetes diagnosis, depression and progression of disability for each outcome (ADL and IADL disability indicators). Four stepwise regression models were fit: a model 1) adjusting for age and other demographic characteristics, 2) adjusting for demographic characteristics without age, 3) adjusting for demographics without age and comorbidities, and 4) adjusting for demographics without age, including comorbidities and an interaction terms. Multiplicative interaction terms were added to each model to test for any potential modification of the relationship between type 2 diabetes and disability as a function of depressive symptomology. Given the well-establish relationship between diabetes and the progression of disability in older Mexican Americans (Glassy et al., 2010; Ford et al., 2014), we tested the strength of the relationship between diabetes and disability at different levels of depressive symptoms, rather than determining the presence or absence of a relationship between diabetes and disability based on depression status (Baron & Kenney 1986). All analyses were conducted using Stata 13 SE (Stata Corp 2013).

3.0 Results

Table 1 presents baseline characteristics of the H-EPESE sample by disability measure at baseline. The majority of the sample was between 65 and 74 years old (67.3%) and female (57.6%). Most participants had 1-6 years of education (56.3%) and were married (55.5%). Overall, about 17% of the sample had type 2 diabetes and nearly half of those with type 2 diabetes were diagnosed less than 10 years ago. Two-thirds of the sample had mild depressive symptoms (1-16 CES-D score) category and 21.2% were moderately/severely depressed (16 or more CES-D score). Most participants reported less than one ADL disability (.53; $sd = 1.6$) and 2.06 ($sd = 2.9$) IADL disabilities. Female participants had higher IADL (2.32 vs. 1.71, $p = .000$) disability than males (Table 1), however there were no gender differences in ADL status. Participants who were widowed or never married had greater average ADL (widowed $mean = .718$, $p = .000$; never married $mean = .686$, $p = .046$) and IADL (widowed $mean = 2.86$, $p = .000$; never married $mean = 2.27$, $p = .007$) disability compared to married participants.

The overall number of years since type 2 diabetes diagnosis was associated with differential baseline ADL and IADL status *except* for participants who were living with type 2 diabetes for 10 years or less at baseline (Table 1). Specifically, participants with 11-20 years and 21 years or more since type 2 diabetes diagnosis had significantly higher average ADL disability than those without a type 2 diabetes diagnosis (11-20 years $mean = .685$, $p = .049$; 21+ years $mean = 1.36$, $p = .000$). All participants with type 2 diabetes had significantly greater average IADL disability at baseline than for those without type 2 diabetes (0-10 years $mean = 2.35$, $p = .005$; 11-20 years $mean = 2.61$, $p = .001$; 21+ years $mean = 3.63$, $p = .000$).

After adjusting for age and other demographic characteristics in model 1, years since type 2 diabetes diagnosis categories had differential trajectories, with 21 or more years having the greatest increase in ADL and IADL disability over the 15-year follow-up period (Table 2). Compared to participants without type 2 diabetes, those who were diagnosed with type 2 diabetes 10 years ago or less had an average increase of .275 ($p < .001$) units of ADL disability and .734 ($p < .001$) units of IADL disability compared to participants without type 2 diabetes over the 15-year follow-up period. Participants who have had a diagnosis of type 2 diabetes for 11-20 years had an increase of .470 ($p < .001$) units of ADL disability and .831 ($p < .001$) units of IADL disability. Finally, participants diagnosed with type 2 diabetes 21 or more years ago had an average increase of .792 ($p < .001$) units of ADL disability and 1.40 ($p < .001$) units of IADL disability.

In model 3, age was removed from the model as a sensitivity test due to potential collinearity and controls for heart attack, hypertension, cancer and past stroke were retained. Years since diagnosis continues to be significantly related to disability progression. However, the effect size for participants diagnosed with diabetes 10 years ago or less was attenuated for ADL [.275 ($p=.000$) versus .178 ($p=.016$)] and IADL [.734 ($p=.000$) versus .477 ($p=.000$)] when compared to model 2. Despite relationships observed for past heart attack [ADL .344 ($p=.000$); IADL .616 ($p=.000$)] and for past stroke [ADL .976 ($p=.000$); IADL 1.35 ($p=.000$)], this adjustment does not impact the effect size for years since diabetes diagnosis.

The interaction model (Model 4, Table 2) yielded significant interaction effects related to ADL disability. A significant interaction effect was observed between diagnosis of type 2 diabetes 11-20 years ago and moderate/severe depression (.673, $p = .044$) on ADL disability. Specifically, while the average increase in ADL progression over time for participants with diabetes 11-20 years without depression was .470 units, those participants with diabetes for the same amount of time and moderate/severe depression was .953 units. In addition, participants diagnosed with type 2 diabetes 21 or more years ago and moderate/severe depression had an average decline of 1.82 ADL units over time, which is nearly double than those who have had type 2 diabetes 21 or more years without depression (.792). In other words, the effect of having diabetes for two or more decades on the progression of ADL disability during the follow-up period of this study was greatest in those with moderate/severe depression. No significant interaction effects were observed for the IADL disability measure.

4.0 Discussion

The purpose of this study was to determine if years since diagnosis of type 2 diabetes was differentially associated with progress of ADL and IADL disability and if depression moderated this relationship in older Mexican Americans with type 2 diabetes during a 15-year follow-up period. Results from this study indicated that years since diagnosis of type 2 diabetes at baseline was monotonically associated with a more dramatic increase in ADL and IADL disability over the 15-year follow-up period of this study, after controlling for demographic and comorbidity covariates. In addition, depression moderated this relationship among participants who had type 2 diabetes for 21 or more years for ADL disability only. In other words, both depressive symptoms and years with diabetes were significantly and

independently related to disability progression longitudinally. However, participants who had diabetes for 21 or more years and moderate/severe depression had the greatest increase in ADL disability, but not IADL disability over the follow-up period.

Results suggest that years since type 2 diabetes diagnosis was differentially associated with ADL and IADL disability progression over the 15-year follow-up period. This association became stronger as the time since type 2 diabetes diagnosis increased. For example, participants diagnosed with type 2 diabetes more than 20 years ago had greatest increases in ADL and IADL disability over the 15-year follow-up period. Furthermore, this relationship was not impacted by other common diabetes comorbidities, including having experienced a heart attack, stroke, cancer or hypertension.

A small number of recent studies have used years since diagnosis of type 2 diabetes as an important indicator of the severity of type 2 diabetes and to distinguish more recently diagnosed from those with long-term exposure to the disease (Ell et al., 2015). There is also research that suggests that longer duration of type 2 diabetes is an indicator of more severe disease (Seth et al., 2015) and a risk factor for other chronic conditions (Salinas-Martínez et al., 2014; Onitilo et al., 2014). While these findings are consistent with previous studies, the results from our study support the notion that this relationship exists among Mexican Americans, a historically under-researched group that experiences substantial burden of disease and is typically medically underserved (Salinas et al., 2015).

This study also builds upon the extant literature as previous studies have focused only on ADL disabilities (Ell et al., 2015; Black et al., 2003) and not IADL disabilities. Our study therefore provides evidence that in older Mexican Americans, diabetes is associated not only with functional limitations such as grooming and bathing, but also instrumental activities such as managing money and driving which could have a large impact on independent living. Moreover, our findings indicate that the effect of time since diagnosis on the progression of disability is independent of other common comorbidities that are common in this population.

Our findings also suggest that the relationship between type 2 diabetes and ADL disability varied by depression status, but not IADL after controlling for comorbidities. Depression is well established as a predictor of type 2 diabetes control (De la Roca-Chiapas et al., 2013). There is evidence to suggest that the relationship between type 2 diabetes and depression on glucose control is time dependent, and longer duration of both conditions raises the risk of uncontrolled type 2 diabetes (Georgiades et al., 2007). Limited evidence to date suggests that comorbid type 2 diabetes and depression is associated with lower functional status in clinic-based samples (Ciechanowski et al., 2003). Findings from our study are consistent with this limited body of literature generally and with previous research using three waves of the H-EPESE dataset specifically, which showed significant interaction effects between type 2 diabetes status and depression on self-reported disability using ADL status (Black et al., 2003). The current study expands upon previous findings by Black and colleagues (Black 1999; Black et al., 2003) by adding a longer follow-up period, including IADL functioning and evaluating years since types 2 diabetes diagnoses as our primary independent variable (Black et al., 2003).

Importantly, our findings indicate that the role of moderate/severe depression on ADL functional decline is critical among persons who have had type 2 diabetes for more than twenty years. Depression did not have the same effect on IADL disability after accounting for comorbid conditions. Our current knowledge on this relationship in the Hispanic population, and Mexican Americans specifically, is limited despite the elevated risk of diabetes and disability observed in this population. Therefore, this study adds to the literature by documenting the extent to which comorbid depression modifies the progression into disability and loss of independence in persons with diabetes for long periods of time.

Early identification of depressive symptoms in a clinic setting, particularly for those patients with long-term type 2 diabetes may help to delay disability, thereby maintaining functional independence for patients with type 2 diabetes. Patients with long-term type 2 diabetes should be screened routinely for depression during annual exams (Ell et al., 2011; Abrams et al., 2015). However, evidence still suggests that depression is often undiagnosed or unrecognized among Hispanics due to cultural and linguistic barriers between health professionals and patients, despite its high prevalence (Dilsaver and Akiskal, 2005). Moreover, high uninsurance rates among Hispanics creates added barriers to time screening of both mental and physical health conditions (Salinas et al., 2015). The potential for prevention at the primary care level is vast (Huang et al., 2012, de Groot et al., 2012), as simple screenings during regular office visits could prevent or delay loss of independence or earlier nursing home placements and mortality.

While these findings contribute to our knowledge of the interplay between type 2 diabetes, depression and the progression of disability among Mexican Americans, there are a number of limitations that need to be acknowledged. First, although the H-EPESE data is characterized by a long-term follow-up period and a large-scaled sampling effort across the southwestern U.S., it is only representative of older Mexican Americans living in this area. Therefore, these findings should be replicated across other Hispanic national groups and persons diagnosed with diabetes at younger ages. Since diabetes is commonly diagnosed when one is between 40 and 50 years of age, there may be differential effects of depression on disability progression in persons with diabetes in this age range. Second, while the use of years of diagnosis has enabled us to consider how not just the status of having type 2 diabetes but the potential progression that may occur with longer time living with the disease, we relied on self-reported data as clinical measures (i.e. HbA1c, fasting blood glucose) were unavailable. Moreover, survey measures may be subject to recall bias, as participants may not remember how many years exactly since they have been diagnosed with type 2 diabetes. Finally, while the CES-D has been used in numerous studies and is highly reliable, it is not a diagnostic tool, but rather briefly screens for symptoms consistent with depression. About 7% of our sample did not have complete data for the CES-D and differential completion of this tool was explained by age and gender. These patterns may have biased our findings, as participants who were more likely to be clinically depressed may have been less likely to complete the CES-D.

In light of these weaknesses, this study has notable strengths. First, data were collected from a large cohort of Mexican American adults, and measures were stable over time. This is a unique strength that allowed us to assess how depression impacted disability status as the

cohort aged. Additionally, we were able to distinguish duration with type 2 diabetes as a diagnosis and determined that time with the disease is an important distinction to make when considering the disablement process due to physiological processes associated with the disease (Otiniano et al., 2012; Lorenzo et al., 2012; Xiang et al., 2013). Moreover, there is now growing evidence that the longer a person lives with type 2 diabetes, the greater the incidence of depression and other mental health conditions (Ell et al., 2015; Shah et al., 2015). Therefore, the findings from this study are novel and demonstrate that type 2 diabetes is associated with both progression and onset of disability, with more severe increases in disability for Mexican Americans who have had type 2 diabetes for longer periods of time. This finding was consistent regardless of disability measurement tool, highlighting the robust relationships observed. Future research should further explore a possible mediated relationship between duration with type 2 diabetes, depression, and disability, as it is possible that a portion of the variation in disability is explained through changes in depression status.

4.1 Conclusion

Comorbid depression in persons with diabetes for 20 or more years may have more rapid progression into ADL disability than those with diabetes the same amount of time without depression.

Acknowledgements

The authors would like to thank the study participants and staff who have contributed two decades of their lives to this important study.

Funding: This study was supported in part by grants R01-AG017638, R01-AG010939, R03-AG029959, and P30-AG024832 from the National Institute on Aging.

References

- Abrams RC, Boné B, Reid MC, Adelman RD, Breckman R, Goralewicz R, Palombo M, Stern A, Shengelia R, Teresi J. Psychiatric assessment and screening for the elderly in primary care: design, implementation, and preliminary results. *Journal of Geriatrics*. 2015 PubMed PMID: 25954771. PubMed Central PMCID: PMC4420197.
- Afable-Munsuz A, Gregorich SE, Markides KS, Pérez-Stable EJ. Diabetes risk in older Mexican Americans: effects of language acculturation, generation and socioeconomic status. *Cross Cultural Gerontology*. 2013; 28:359–373. PubMed PMID: 23990075. Pubmed Central PMCID: PMC3804224.
- Afable-Munsuz A, Mayeda ER, Pérez-Stable EJ, Haan MN. Immigrant generation and diabetes risk among Mexican Americans: the Sacramento area Latino study on aging. *American Journal of Public Health*. 2014; 104:S234–250. PubMed PMID: 24899459. PubMed Central PMCID: PMC4396826. [PubMed: 24899459]
- Al Snih S, Fisher MN, Raji MA, Markides KS, Ostir GV, Goodwin JS. Diabetes mellitus and incidence of lower body disability among older Mexican Americans. *Journal of Gerontology A Biological Science Medical Science*. 2005; 60(9):1152–1156. PubMed PMID: 16183955. PubMed Central PMCID: PMC1853254.
- Anderson RJ, Freedland KE, Clouse RE, Lustman PJ. The Prevalence of Comorbid Depression in Adults With Diabetes: A meta-analysis. *Diabetes Care*. 2001; 24:1069–1078. PubMed PMID: 11375373. [PubMed: 11375373]
- Beard HA, Gerst K, Ghatrif MA, Markides KS, Samper-Ternent R. Trends in diabetes prevalence and diabetes-related complications in older Mexican Americans from 1993-1994 to 2004-2005.

Diabetes Care. 2009; 32:2212–2217. PubMed PMID: 19755626. PubMed Central PMCID: PMC2782979. [PubMed: 19755626]

Black SA. Increased health burden associated with comorbid depression in older diabetic Mexican Americans. Results from the Hispanic Established Population for the Epidemiologic Study of the Elderly survey. Diabetes Care. 1999; 22(1):56–64. PubMed PMID: 10333904. [PubMed: 10333904]

Black SA, Markides KS, Ray LA. Depression Predicts Increased Incidence of Adverse Health Outcomes in Older Mexican Americans With Type 2 Diabetes. Diabetes Care. 2003; 26:2822–2828. PubMed PMID: 14514586. [PubMed: 14514586]

Centers for Disease Control. Age-Adjusted Rate per 100 of Civilian, Noninstitutionalized Population with Diagnosed Diabetes, Hispanics, United States, 1997–2011. 2014a. Retried 6-24-15 from <http://www.cdc.gov/diabetes/statistics/prev/national/figbyhispanic.htm>

Centers for Disease Control. Age-Adjusted Rate per 100 of Civilian, Noninstitutionalized Population with Diagnosed Diabetes, by Race, United States, 1980–2011. 2014b. Retrieved 6-24-14 from <http://www.cdc.gov/diabetes/statistics/prev/national/figbyrace.htm>

Centers for Disease Control. Median Age at Diagnosis of Diabetes Among Adult Incident Cases Aged 18–79 Years, by Race/Ethnicity, United States, 1997–2011. 2015. Retrieved 4-27-16 from <http://www.cdc.gov/diabetes/statistics/age/fig4.htm>

Ciechanowski PS, Katon WJ, Russo JE, Hirsch IB. The relationship of depressive symptoms to symptom reporting, self-care and glucose control in diabetes. General Hospital Psychiatry. 2003; 25:246–252. PubMed PMID: 12850656. [PubMed: 12850656]

de Groot M, Doyle T, Kushnick M, Shubrook J, Merrill J, Rabideau E, Schwartz F. Can lifestyle interventions do more than reduce diabetes risk? Treating depression in adults with type 2 diabetes with exercise and cognitive behavioral therapy. Current Diabetes Report. 2012; 2:157–166. PubMed PMID: 22350739. PubMed Central PMCID: PMC3314326.

De la Roca-Chiapas JM, Hernández-González M, Candelario M, Villafañá Mde L, Hernández E, Solorio S, Rivera A, Sosa M, Jasso J. Association between depression and higher glucose levels in middle-aged Mexican patients with diabetes. Revista de Investigación Clínica. 2013; 65:209–213. PubMed PMID: 23877807. [PubMed: 23877807]

de Souza Moreira B, Sampaio RF, Cavalcanti Furtado SR, Dias RC, Kirkwood RN. The Relationship between Diabetes Mellitus, Geriatric Syndromes, Physical Function, and Gait: A Review of the Literature. Current Diabetes Review. Jun 15.2015 PubMed PMID: 26073610.

Dhamoon MS, Moon YP, Paik MC, Sacco RL, Elkind MS. Diabetes predicts long-term disability in an elderly urban cohort: the Northern Manhattan Study. Annals of Epidemiology. 2014; 24:362–368. PubMed PMID: 24485410. PubMed Central PMCID: PMC4011963. [PubMed: 24485410]

Dilsaver SC, Akiskal HS. High rate of unrecognized bipolar mixed states among destitute Hispanic adolescents referred for "major depressive disorder". Journal of Affective Disorders. 2005; 84:179–186. PubMed PMID: 15708415. [PubMed: 15708415]

Ell K, Katon W, Xie B, Lee PJ, Kapetanovic S, Guterman J, Chou CP. One-year post-collaborative depression care trial outcomes among predominantly Hispanic diabetes safety net patients. General Hospital Psychiatry. 2011; 33:436–442. PubMed PMID: 21774987. PubMed Central PMCID: PMC3175272. [PubMed: 21774987]

Ell K, Katon W, Lee PJ, Guterman J, Wu S. Demographic, clinical and psychosocial factors identify a high-risk group for depression screening among predominantly Hispanic patients with Type 2 diabetes in safety net care. General Hospital Psychiatry. 2015; 37(5):414–419. PubMed PMID: 26059979. [PubMed: 26059979]

Fillenbaum GG, Pieper CF, Cohen HJ, Cornoni-Huntley JC, Guralnik JM. Comorbidity of five chronic health conditions in elderly community residents: determinants and impact on mortality. Journal of Gerontology A Biological Science and Medical Science. 2000; 55(2):M84–M89.

Ford AH, Flicker L, Hankey GJ, Yeap BB, Chubb SA, Golledge J, Almeida OP. Insulin Resistance and Depressive Symptoms in Older Men: The Health in Men Study. American Journal of Geriatric Psychiatry. 2014; 23(8):872–880. PubMed PMID: 25532417. [PubMed: 25532417]

Georgiades A, Zucker N, Friedman KE, Mosunic CJ, Applegate K, Lane JD, Feinglos MN, Surwit RS. Changes in depressive symptoms and glycemic control in diabetes mellitus. Psychosomatic Medicine. 2007; 69:235–241. PubMed PMID: 17420441. [PubMed: 17420441]

- Glassy CM, Lemus H, Cronan T, Glassy MS, Talavera GA. Relationship between depressive symptoms and cardiovascular risk factors among selected Latino patients at a community clinic. *Psychological Health Medicine*. 2010; 15:117–126. PubMed PMID: 20391229.
- Huang H, Russo J, Von Korff M, Ciechanowski P, Lin E, Ludman E, Katon W. The effect of changes in depressive symptoms on disability status in patients with diabetes. *Psychosomatics*. 2012; 53:21–29. PubMed PMID: 22221718. PubMed Central PMCID: PMC3254020. [PubMed: 22221718]
- Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe NM. The index of ADL: a standardized measure of biological and psychosocial function. *JAMA*. 1963; 21:941–949. PubMed PMID: 14044222.
- Lange LJ, Piette JD. Perceived health status and perceived diabetes control: psychological indicators and accuracy. *Journal of Psychosomatic Research*. 2005; 58(2):129–137. PubMed PMID: 15820840. [PubMed: 15820840]
- Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *Gerontologist*. 1969; 9:179–186. PubMed PMID: 5349366. [PubMed: 5349366]
- Leal J, Gray AM, Clarke PM. Development of life-expectancy tables for people with type 2 diabetes. *European Heart Journal*. 2009; 30:834–839. PubMed PMID: 19109355. PubMed Central PMCID: PMC2663724. [PubMed: 19109355]
- Lorenzo C, Lee R, Haffner SM. Impaired glucose tolerance and obesity as effect modifiers of ethnic disparities of the progression to diabetes: the San Antonio Heart Study. *Diabetes Care*. 2012; 35:2548–2552. PubMed PMID: 22923668. PubMed Central PMCID: PMC3507579. [PubMed: 22923668]
- Markides, KS., Rudkin, L., Angel, RJ., Espino, DV. Health status of Hispanic elderly in the United States. In: Martin, LG.Soldo, BJ., Foote, K., editors. *Racial and ethnic differences in later life health in the United States*. National Academy Press; Washington DC: 1997. p. 285-300.
- Mishra SR, Sharma A, Bhandari PM, Bhochhibhoya S, Thapa K. Depression and Health-Related Quality of Life among Patients with Type 2 Diabetes Mellitus: A Cross-Sectional Study in Nepal. *PLoS One*. 2015; 10(11):e0141385. PubMed PMID: 26599008. PubMed Central PMCID: PMC4658137. [PubMed: 26599008]
- Onitilo AA, Stankowski RV, Berg RL, Engel JM, Glurich I, Williams GM, Doi SA. Breast cancer incidence before and after diagnosis of type 2 diabetes mellitus in women: increased risk in the prediabetes phase. *European Journal of Cancer Prevention*. 23:76–83. PubMed PMID: 23571511.
- Otiniano ME, Du XL, Ottenbacher K, Markides KS. The effect of diabetes combined with stroke on disability, self-rated health, and mortality in older Mexican Americans: results from the Hispanic EPESE. *Archives of physical medicine and rehabilitation*. 2003; 84(5):725–730. [PubMed: 12736889]
- Otiniano ME, Al Snih S, Goodwin JS, Ray L, Al Ghatrif M, Markides KS. Factors associated with poor glycemic control in older Mexican American diabetics aged 75 years and older. *Journal of Diabetes Complications*. 2012; 26:181–186. PubMed PMID: 22520403. PubMed Central PMCID: PMC3521032.
- Palmer RF, Espino DV, Dergance JM, Becho J, Markides K. The role of physical activity and diabetes status as a moderator: functional disability among older Mexican Americans. *Age Ageing*. 2012; 41:752–758. PubMed PMID: 23052844. PubMed Central PMCID: PMC3577043. [PubMed: 23052844]
- Pugh JA, Stern MP, Haffner SM, Eifler CW, Zapata M. Excess incidence of treatment of end-stage renal disease in Mexican Americans. *American Journal of Epidemiology*. 1988; 127:135–144. PubMed PMID: 3276155. [PubMed: 3276155]
- Reinschmidt KM, Chong J. SONRISA: a curriculum toolbox for promotores to address mental health and diabetes. *Preventing Chronic Disease*. 2007; 4(4):A101. PubMed PMID: 17875245. PubMed Central PMCID: PMC2099266. [PubMed: 17875245]
- Salinas JJ, de Heer H, Lapeyrouse L, Heyman J, Balcazar H. Socioeconomic factors more powerful than acculturation as barriers to diabetes and cardiovascular disease screening in the Mexican origin population in El Paso, Texas. *Hispanic Health Care International*. 2015; 13(4) PubMed PMID: 26671560.
- Salinas-Martínez AM, Flores-Cortés LI, Cardona-Chavarría JM, Hernández-Gutiérrez B, Abundis A, Vázquez-Lara J, González-Guajardo EE. Prediabetes, diabetes, and risk of breast cancer: a case-

control study. Archives of Medical Research. 2014; 45:432–438. PubMed PMID: 24937172. [PubMed: 24937172]

Schmitz N, Messier L, Nitka D, Ivonova A, Garipey G, Wang JL, Malla A, Boyer R, Lesage A, Strychar I. Factors associated with disability and depressive symptoms among individuals with diabetes: A community study in Quebec. Psychosomatics. 2011; 52:167–177. PubMed PMID: 21397110. [PubMed: 21397110]

Seth P, Kaur H, Kaur M. Clinical Profile of Diabetic Ketoacidosis: A Prospective Study in a Tertiary Care Hospital. Journal of Clinical Diagnostic Research. 9:OC01–4. PubMed PMID: 26266145. PubMed Central PMCID: PMC4525534.

Shah BM, Mezzio DJ, Ho J, Ip EJ. Association of ABC (HbA1c, blood pressure, LDL-cholesterol) goal attainment with depression and health-related quality of life among adults with type 2 diabetes. Journal of Diabetes Complications. 2015; 29(6):794–800. PubMed PMID: 259768630.

Sharkey JR, Ory MG, Wang S. Double strain of severe obesity and depression on perception of increased diabetes burden among homebound older women. Journal of Nutrition for the Elderly. 2006; 26(1-2):123–130. PubMed PMID: 17890207. [PubMed: 17890207]

Stynen D, Jansen NW, Kant I. The impact of depression and diabetes mellitus on older workers' functioning. Journal of Psychosomatic Research. 2015; 79(6):604–613. PubMed PMID: 26362227. [PubMed: 26362227]

Stata Corp. STATA 13 SE. College Station, Texas: 2013.

Tchalla AE, Dufour AB, Trivison TG, Habtemariam D, Iloputaife I, Manor B, Lipsitz LA. Patterns, predictors, and outcomes of falls trajectories in older adults: the MOBILIZE Boston Study with 5 years of follow-up. PLoS One. 2014;9. PubMed PMID: 25184785. PubMed Central PMCID: PMC4153626.

Varma R, Choudhury F, Klein R, Chung J, Torres M, Azen SP, Los Angeles Latino Eye Study Group. Four-year incidence and progression of diabetic retinopathy and macular edema: the Los Angeles Latino Eye Study. American Journal of Ophthalmology. 149:752–761. PubMed PMID: 20149342. PubMed Central PMCID: PMC2905589.

Xiang AH, Takayanagi M, Black MH, Trigo E, Lawrence JM, Watanabe RM, Buchanan TA. Longitudinal changes in insulin sensitivity and beta cell function between women with and without a history of gestational diabetes mellitus. Diabetologia. 2013; 56:2753–2760. PubMed PMID: 24030069. PubMed Central PMCID: PMC4139094. [PubMed: 24030069]

Figure 1.
Percent survival to follow-up wave by number of years with diabetes.

Diagram 1.

Flow Chart of HEPSE participants by diabetes years since diagnosis vs. no diabetes.

Table 1Baseline Sample Characteristics stratified by Disability Measures-H-EPESE, N=2,823^a

	Total n (%)	ADL		IADL	
		<i>M (sd)</i>	<i>p-value</i>	<i>M (sd)</i>	<i>p-value</i>
Age					
65-74	2,053 (67.3)	.303 (1.2)	Ref	1.40 (2.4)	Ref
75-85	805 (26.4)	.770 (1.8)	<.001	2.90 (3.1)	<.001
86+	192 (6.3)	1.92 (2.6)	<.001	5.61 (3.4)	<.001
Gender					
Female	1,758 (57.6)	.558 (1.57)	.203	2.32 (2.9)	<.001
Male	1,292 (42.4)	.485 (1.56)	Ref	1.71 (2.8)	Ref
Years of Education					
None	517 (17.2)	.649 (1.7)	Ref	2.73 (3.1)	Ref
1-6	1,691 (56.3)	.511 (1.5)	.076	2.02 (2.8)	<.001
7 or more	794 (26.4)	.437 (1.4)	.016	1.63 (2.7)	<.001
Marital Status					
Married	1,693 (55.5)	.429 (1.46)	Ref	1.63 (2.7)	Ref
Separated	89 (2.9)	.371 (1.31)	.732	1.89 (2.8)	.393
Divorced	142 (4.7)	.324 (1.25)	.442	1.60 (2.2)	.254
Widowed	967 (31.7)	.718 (1.74)	<.001	2.86 (3.1)	<.001
Never Married	159 (5.2)	.686 (1.81)	.046	2.27 (3.0)	.005
Years Since Diabetes Diagnosis					
No Diabetes/0 years	2,370 (83.0)	.458 (1.47)	Ref	1.88 (2.8)	Ref
10 years or less	338 (8.6)	.583 (1.62)	.169	2.35 (3.0)	.005
11-20 years	198 (5.0)	.685 (1.78)	.049	2.61 (3.0)	<.001
21 years or more	136 (3.4)	1.36 (2.31)	<.001	3.63 (3.6)	<.001
CES-D					
None	446 (15.8)	.130 (.66)	Ref	1.03 (1.9)	Ref
1-16	1,779 (63.0)	.294 (1.1)	.014	1.62 (2.4)	<.001
17 or more	598 (21.2)	.773 (1.8)	<.001	2.95 (3.1)	<.001
Disability (mean ± S.D.)					
ADL	.53 (1.6)				
IADL	2.06 (2.9)				

Table 2

GEE population-average model regression analysis results for disability outcomes by baseline diabetes and depression status.

	ADL's				IADL's			
	Model 1 β (p-value)	Model 2 β (p-value)	Model 3 β (p-value)	Model 4 β (p-value)	Model 1 β (p-value)	Model 2 β (p-value)	Model 3 β (p-value)	Model 4 β (p-value)
Main Effects								
Years since diagnosis								
No diabetes	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
10 years or less	.275 (.000)	.178 (.016)	.149 (.043)	.333 (.076)	.734 (.000)	.477 (.000)	.410 (.002)	.428 (.207)
11-20 years	.470 (.000)	.443 (.000)	.370 (.000)	-.108 (.694)	.831 (.000)	.761 (.000)	.535 (.002)	.188 (.701)
21 years or more	.792 (.000)	.797 (.000)	.697 (.000)	.296 (.377)	1.40 (.000)	1.40 (.000)	1.06 (.000)	.519 (.391)
CES-D								
None	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
1-16	.156 (.010)	.211 (.001)	.196 (.002)	.198 (.004)	.439 (.000)	.590 (.000)	.480 (.000)	.530 (.000)
17 or more	.464 (.000)	.511 (.000)	.472 (.000)	.388 (.000)	1.28 (.000)	1.41 (.000)	1.20 (.000)	1.20 (.000)
Female	.226 (.000)	.157 (.002)	.198 (.072)	.199 (.000)	.661 (.000)	.472 (.000)	.565 (.000)	.568 (.000)
Years of Education	-.018 (.002)	-.029 (.000)	-.031 (.000)	-.031 (.000)	-.083 (.000)	-.112 (.000)	-.115 (.000)	-.115 (.000)
Marital Status								
Married	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Separated	.112 (.396)	.086 (.527)	.122 (.365)	.120 (.371)	.415 (.070)	.350 (.154)	.231 (.340)	.413 (.088)
Divorced	-.058 (.586)	.004 (.968)	.009 (.932)	.003 (.977)	-.242 (.194)	-.084 (.675)	-.110 (.573)	-.095 (.630)
Widowed	-.002 (.969)	.218 (.000)	.206 (.000)	.203 (.000)	.147 (.124)	.743 (.000)	.696 (.000)	.702 (.000)
Never Married	.077 (.477)	.185 (.099)	.199 (.072)	.185 (.093)	.118 (.530)	.402 (.046)	.376 (.058)	.381 (.055)
Age	.057 (.000)				.152 (.000)			
Comorbidities								
Past Heart Attack			.340 (.000)	.344 (.000)			.616 (.000)	.728 (.000)
Hypertension			-.042 (.371)	-.041 (.385)			.130 (.129)	.064 (.452)
Cancer			-.059 (.586)	-.052 (.628)			.023 (.904)	-.008 (.968)
Past Stroke			.976 (.000)	.974 (.000)			1.35 (.000)	1.61 (.000)
Interaction Effects								
Diabetes 0 years or less*CESD 1-16				-.252 (.227)				-.198 (.599)

	ADL's				IADL's			
	Model 1 β (p-value)	Model 2 β (p-value)	Model 3 β (p-value)	Model 4 β (p-value)	Model 1 β (p-value)	Model 2 β (p-value)	Model 3 β (p-value)	Model 4 β (p-value)
Diabetes 10 years or less* CESD17+			-.098 (.690)					.472 (.287)
Diabetes 11-20 years* CESD 1-16			.502 (.095)					.482 (.370)
11-20 years*17+			.673 (.044)					.459 (.443)
21 years or more*1-16			.148 (.684)					.654 (.321)
21 years or more*17+			1.14 (.004)					1.01 (.161)
Wald χ^2	447.1 (.000)	208.5 (.000)	335.3 (.000)	358.8 (.000)	1108.1 (.000)	500.3 (.000)	562.8 (.000)	643.1 (.000)