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Diabetes Locus of Control and Depression in Older Adults with Type 1 and Type 2 Diabetes: The Study of Longevity in Diabetes

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Diabetes Locus of Control and Depression in Older Adults with Type 1 and Type 2 Diabetes: The Study of Longevity in Diabetes

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Abstract:

Objective: To determine if diabetes locus of control (dLOC) is associated with depression in older adults with type 1 and type 2 diabetes and whether this association differs by diabetes type.

Methods: Data for the current study were obtained from The Study of Longevity in Diabetes (SOLID), a prospective cohort study of aging and diabetes. SOLID participants aged 60 and older with type 1 diabetes (T1D), type 2 diabetes (T2D), and without diabetes were recruited from members of Kaiser Permanente Northern California (KPNC). For the current study, we excluded all of participants without diabetes since the primary exposure, diabetes locus of control (dLOC), was not applicable in this population. This resulted in a final analytic sample of 1053 (n=805 with T1D and n=248 with T2D). Cross sectional associations between dLOC and depression (ascertained using the 15-item Geriatric Depression Scale [GDS]) were estimated using covariate adjusted linear and logistic regression models.

Results: Overall, the mean dLOC score was higher in individuals with T1D (mean=7.4, SD=3.2) than in those with T2D (mean=5.8, SD=3.4; p value<0.0001), indicating those participants with T1D had a more internal locus of control than those with T2D. Overall, 13.9% of participants had GDS scores indicating depression. The prevalence of depression did not differ by diabetes type (13.7% in T1D, 14.6% in T2D; p value=0.71). In fully adjusted regression analyses, a one-unit increase in dLOC (i.e. more internal dLOC) was associated with a lower depression score (β=-0.11; 95% CI: -0.15, -0.06) and lower odds of having depression (OR=0.91; 95% CI: 0.85, 0.96).

Conclusion: In adults over 60 with either type 1 or type 2 diabetes, we found that higher dLOC scores were associated with lower depressive symptoms. Individuals with T1D had higher dLOC scores than individuals with T2D, indicating stronger internal dLOC in those with T1D. The association between mean depression score and dLOC did not differ by diabetes type.

Introduction

Diabetes Mellitus (hereafter “diabetes”) is a chronic metabolic disease that impairs the body’s ability to process blood glucose. Diabetes results from a deficiency in insulin secretion, an inability to process insulin properly, or a combination of both.[1] This affects how the body turns food into energy. When food is consumed, the body breaks it down into glucose and other components, releasing glucose into the blood stream. When this happens, the level of blood glucose rises, and the pancreas is signaled to release insulin. The insulin then lets the blood sugar into the cells to use as energy. Since individuals with diabetes either cannot make enough insulin or have trouble using insulin, excess glucose in the blood stream is common.[2] Gradually this causes long-term damage to organs, such as the heart, kidneys and eyes, blood vessels and nerves. Compared to those without diabetes, individuals with diabetes have double the risk of stroke or heart disease.[3] People with diabetes also have high rates of chronic kidney disease and nerve damage (which can lead to complications such as foot ulcers and amputations).[3] Hearing loss, vision loss, and poor mental health are also common health complications amongst people with diabetes.[3]

Type 1 diabetes (T1D), previously known as insulin-dependent diabetes or juvenile onset diabetes, is an autoimmune disease that results from destruction of beta cells in the pancreas, which stops the body from making insulin.[1] Individuals eventually become completely dependent on insulin for survival. T1D accounts for about 5% of people who have diabetes.[1] It is usually diagnosed in children, teens, and young adults; late onset T1D is very rare but can occur.[1]

Type 2 diabetes (T2D), previously known as non-insulin dependent diabetes or adult-onset diabetes, is a chronic disease in which the body is not able to properly use insulin.[1] T2D accounts for about 95% of all diabetes prevalence.[1] Risk factors for T2D are well-established and include increasing age, poor diet, lack of physical activity, and high body weight, among others.[2]

Among older adults, incidence and prevalence of diabetes are increasing dramatically. While most of this phenomenon is due to T2D, data suggest that T1D also contributes.[23] Although T1D is normally diagnosed in children and young adolescents, about 25 percent of individuals are diagnosed as adults.[22] Further, it is estimated that about 10 percent of adults who are originally diagnosed with T2D are later found to have pancreatic autoantibodies associated with T1D.[22] The incidence of T1D is increasing 2-5 percent per year worldwide.[4] In addition to the increasing incidence, life expectancy for individuals with T1D has been improving in recent decades. A 1975 study of individuals with T1D in the US, estimated that life expectancy was reduced by 27 years compared to those without diabetes.[4] A more recent analysis from the Pittsburgh Epidemiology of Diabetes Complications Study found life expectancy at birth for those diagnosed with T1D in 1965–1980 was 15 years greater than participants diagnosed in 1950–1964 (68.8 [95% CI 64.7–72.8] vs. 53.4 [50.8–56.0] years, respectively) ($p<0.0001$).[4] Another study from Scotland estimated that at the age of 20, loss of residual life expectancy for men was 11 years and 13 years for women compared with the general population without T1D.[5] These improvements in life expectancy in T1D are largely attributed to improvements in treatment, diabetes education, and advances in technology.[6] In addition to the growing population of older

adults with T1D, the prevalence of T2D in older adults is increasing as well. It is estimated that 20 percent of the elderly population will develop T2D by the age of 75.[22,23] It is important for older adults to consider age-related changes when it comes to managing their diabetes. It is also necessary that treatment plans change to adapt with problems that accompany aging, such as hearing, vision, cognition, depression, chronic pain and mobility, to help minimize hypoglycemia and hyperglycemia to maximize the quality of life in older diabetic individuals.[22,23,24] As the population of older adults with T1D or T2D grows, there is an increasing need for further research to understand the needs of this unique population as they face both aging-related health concerns and diabetes simultaneously.

Studies have shown that as individuals age, insulin resistance increases and glucose tolerance decreases making diabetes harder to control.[23,24] It is extremely important for the elderly to monitor blood glucose numbers, limit simple carbohydrates in their diet, and make sure they are taking the correct insulin dosage. However, these disease management strategies can become difficult as the individual ages and experiences cognitive decline and other aging-related illnesses, such as impaired vision and functional abilities.[23,24]

Elderly individuals who are taking multiple medications that may directly cause low blood glucose or interact with drugs used to treat diabetes are highly prone to hypoglycemia.[24] Elderly individuals are also known to have impaired glucose counter regulation.[24] This is a condition where certain hormones that typically help protect against low blood glucose levels are less likely to be released. It also contributes to the reduction of symptoms that normally appear at the onset of a hypoglycemic episode such as

sweating, trembling, dizziness and headaches. Thus, aging individuals should create individualized diabetes management and treatment plans.[24]

When developing management plans for older adults with diabetes it is important to know the age at diagnosis of diabetes, because with increased duration and severity of illness comes the potential to have more diabetes related complications.[24]

With both T1D and T2D the therapeutic goal is to control blood sugar (glucose) levels in a healthy range, without going too low or too high.[3] It can often be a very difficult task for young and older individuals alike. Managing heathy blood sugar does not just mean watching what you eat. There are other key factors that play an important role in managing diabetes such as stress, weight, activity level, sleep quality, and finances.[3]

Due to the many factors that contribute to the management of diabetes, there is no one size fits all prescription. It is very individualized and can change day to day. Maintaining good glucose management is a multistep process. Strategies that contribute to healthy glucose levels are to adhere consistently to anti-diabetes medicines, monitor blood glucose and blood pressure numbers, eat well-balanced meals at regular times and not skip meals, exercise, participate in stress relief activities and get the proper rest. Incorporating these regimens will help people with diabetes (T1D or T2D) keep their blood sugar in the target range.[3]

Diabetes technology has contributed a great deal to managing diabetes efficiently and effectively. Glucose levels must be checked before and after every meal and sometimes require checks in between meals. Continuous glucose monitoring devices have made this vital task a lot more convenient. This piece of technology allows the patient to apply a sensor to their body that checks their glucose levels many times per

day. The sensor is applied to the arm, thigh, or abdomen. It allows the ease of checking blood glucose levels while driving, exercising and before and after all meals, without interrupting daily activities by having to draw blood from the finger and place on a strip.[7]

Another piece of innovative technology in diabetes is the insulin pump. While some patients only need one daily injection, some need multiple. These patients may benefit more from continuous subcutaneous insulin injection. In patients with T1D, studies have shown the insulin pump increases glycemic control and contributes to a decreased risk in all-cause mortality.[5] Unfortunately, however, these devices are not fully covered by most insurance companies. The cost of day-to-day insulin is expensive and is continuously increasing, so getting this technology is not an option for many diabetics, not due to the cost of the technology but due to the cost of the insulin.

Due to the complex nature of diabetes self-management, and the stresses of the disease itself, many individuals with diabetes experience “diabetes distress”, an emotional state where individuals experience feelings such as stress or denial from living with diabetes, burnout, and/or depression, which are often linked to poor health outcomes, such as poor glycemic control.[8] Reported rates of depression (13%−27%) and suicidality (8%) amongst adolescents with T1D are higher than the general adolescent population.[9] In adults, the prevalence of depression is three times higher in individuals with T1D and twice as high in individuals with T2D compared to the general population.[10] The American Diabetes Association recommends psychosocial evaluation (eg, assessment of symptoms of diabetes distress, depression, anxiety, and queries about life circumstances that can affect physical and psychological health outcomes well-being) as part of comprehensive care, and the US Preventive Services Task Force suggests regular

screening for depression for all people with diabetes when adequate systems are in place to ensure accurate diagnosis and follow-up treatment.[10]

Locus of Control

The locus of control theory is often used to describe self-management behavior in chronic illnesses. The concept of locus of control denotes a context of outer- or inner-directed behavior in various situations faced by patients in daily life. Individuals who firmly believe in their ability to cope with anything that might happen to them are regarded as having an *internal* locus of control. Conversely, placing responsibilities outside the self (fate, health professionals, friends, family members) is considered an *external* locus of control.[11] As such, the locus of control is hypothesized to have a central importance in driving emotional reactions and behavior patterns. For example, a person with a more internal locus of control believes they have more control over their health, which may in fact lead to improved personal health.

Among individuals with diabetes, a number of studies have reported that those with a more internal locus of control have better adherence to their diabetes self-care regimen than individuals with a more external locus of control. [9,12,13] In children with T1D, there is an association between locus of control, attitude towards their diabetes, and HbA1c levels such that children with a high internal locus of control had lower Hba1c levels.[14] Additionally, children with a low internal locus of control and a positive attitude had lower HbA1c levels than children who had a low internal locus of control and a negative attitude.[14]

In addition to a consistent association between locus of control and diabetes self-care, studies have reported associations between locus of control and depression,

though the majority of these studies are examine dLOC and depression only among individuals with T2D or examine locus of control (broadly, not diabetes-specific) among individuals without diabetes. A study conducted among Chinese university students without diabetes to determine the joint effects of locus of control and self-esteem found that locus of control and self-esteem were both significantly, and independently, associated with depression.[15] Studies that focused on the relationship between dLOC of control and depression have generally found that that external locus of control was associated with increased depression.[15] It is also reported that a higher internal locus of control not only for diabetes but also other chronic illnesses, was negatively associated with depressive symptoms.[16] Locus of control may therefore directly affect not only an individual's emotional state but also an individual's mental health through self-esteem.[11] Those with an internal locus of control felt they could control their behaviors and future events, which was associated with higher self-esteem and improved mental health.[17]

In the context of these prior studies, locus of control could be viewed as a underlying personality construct and therefore not highly modifiable. However, research suggests that locus of control can be modified and used to help individuals respond to circumstances.[18,19] For example, interventions that have been done in nursing home populations have reported that increasing an individual's perceived control over their environment is associated with improved physical health, psychological health, and cognitive functioning and increased longevity.[20,21,22]

Depression

Diabetes — both T1D and T2D — is associated with increased risk of developing depression. Depression is common in late life, affecting nearly 16% of the 31 million

Americans aged 65 and older, with clinically significant depressive symptoms reported by 13% of adults aged 80 and older.[23] Major depression is reported in 5-16% of community dwelling older adults, 10-12% of hospitalized older adults, and up to 54% of residents during the first year living in a nursing home.[24] Depression is more common in those with multiple chronic conditions. Although depression is often reversible with prompt recognition and appropriate treatment, if left untreated, depression may result in the onset of physical, cognitive, functional, and social impairment, as well as decreased quality of life, delayed recovery from medical illness and surgery, increased health care utilization, and suicide.[25]

Though the relationship between diabetes and depression isn't fully understood, managing diabetes can be stressful and lead to symptoms of depression. Additionally, diabetes can cause complications and health problems that may worsen symptoms of depression.[16] Depression can reduce the ability to make healthy lifestyle decisions, and may result in increased unhealthy eating, less exercise, and smoking, all of which are risk factors for worsening diabetes. Depression also affects ability to perform tasks, communicate, and think clearly. This can interfere with an individual’s ability to successfully manage diabetes. Thus, preventing depression in patients with diabetes could have beneficial effects for diabetes management.[26]

To determine if locus of control could serve as a modifiable target for reducing depression risk in the older adult population with type 1 and type 2 diabetes, we conducted a secondary analysis of data from The Study of Longevity in Diabetes (SOLID) using a cross-sectional study design.

Methods

Study Design and Data

Data for the current study were obtained from The Study of Longevity in Diabetes (SOLID), a prospective cohort study of aging and diabetes.[27] SOLID participants aged 60 and older were recruited from members of Kaiser Permanente Northern California (KPNC). First, individuals with T1D were identified using ICD-9 and ICD-10 diagnosis codes extracted from their electronic medical record. If individuals were prescribed insulin and more than 75% of their diabetes-related diagnosis codes were for T1D, they were classified as having T1D. A total of 805 out of 2,113 eligible members aged 60 and older with T1D were enrolled and completed baseline interviews. Enrolled participants were comparable to participants who were eligible but did not enroll with the exception that enrolled participants were more likely to be non-Hispanic White (Supp Table 2). Enrolled participants with T1D were then used to guide recruitment of two comparator groups: people with T2D and people without either T1D or T2D. Individuals with T1D were frequency matched to potential participants with T2D and non-diabetic controls. Individuals with diagnostic codes related to both types of diabetes were classified as having T2D if at least 75% of diagnostic codes related to diabetes were for T2D. Matching was performed on the following factors: sex, age (grouped as: 60-64, 65-69, 70-74, 75-79, 80-84, 85-89, 90+), race, and education. This study was approved by the KPNC Institutional Review board and all individuals enrolled in the study provided informed consent. No IRB approval was needed for this secondary analysis of the de-identified SOLID data.

Analytic Sample

For the current study, we excluded all control participants (n=258) because the primary exposure, dLOC, was not measured in this population since they do not have diabetes. This resulted in a final analytic sample of 1053 (n=805 with T1D and n=248 with T2D).

Diabetes Locus of Control (dLOC)

For this study, the exposure of interest is diabetes locus of control (dLOC). dLOC was self-reported by participants through a mailed questionnaire.[28] Individuals ranked their level of agreement (strongly disagree, disagree, agree, strongly agree) based on 6 statements that depict internal or external locus of control. The three statements that internal locus of control was measured by are: “Taking care of my diabetes is a high priority for me right now”, “What I do has a big effect on my health,” and “I can avoid complications of diabetes.” The three statements that were used to measure external locus of control include: “I have many more important things in my life than diabetes to take care of now,” “Good blood sugars will be what they will be,” and “Good blood sugar control is a matter of luck”.

Supplemental Table 1

		Strongly disagree	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
Internal	“Taking care of my diabetes is a high priority for me right now”	1	2	3	4	5
	“What I do has a big effect on my health”	1	2	3	4	5

	"I can avoid complications of diabetes"	1	2	3	4	5
External	"I have many more important things in my life than diabetes to take care of now"	-1	-2	-3	-4	-5
	"Good blood sugars will be what they will be"	-1	-2	-3	-4	-5
	"Good blood sugar control is a matter of luck"	-1	-2	-3	-4	-5

Diabetes Locus of Control summary score was calculated as the total of all 6 items. Possible scores ranged from –15 to 15. Lower scores represent a belief in the more external influence of diabetes management and higher scores represent a more internal control of diabetes.

Depression

Depression was measured using the 15-item Geriatric Depression Scale (GDS-15).[25] It is a basic screening measure for depression in older adults. Item responses indicating presence of a depressive symptom are assigned one point each, then all items are summed. A GDS-15 score > 5 points is suggestive of depression.[28] For the current analysis, we examined GDS-15 both as a numeric outcome and as a dichotomous outcome using a cutoff of >5.

Covariates

We created a directed acyclic graph (DAG; using DAGitty.net) to identify the minimally sufficient adjustment set of confounders needed to obtain the most unbiased estimate of the association between dLOC and depression (Figure 1).[29] Based on the DAG, data elements were extracted from KPNC and SOLID. Age at baseline interview was calculated using date of baseline interview and date of birth. Sex was obtained from KPNC records. Race/ethnicity was self-reported and categorized into African American, Asian, White Hispanic, More than one race/Other, and unknown. Educational attainment was self-reported as highest degree obtained and categorized as less than a college degree or college degree or greater. Sleep was assessed using the Pittsburg Sleep Quality Index (PSQI). The PSQI measures seven areas of sleep over the past month to differentiate between 'good and 'poor' quality sleep. Global PSQI scores range from 0 to 21 with higher scores indicating worse sleep quality. The PSQI was used as a continuous covariate. Income was self-reported and categorized into <$10,000 a year, $10,000-$14,999, $15,000 -$19,999, $20,000-$39,999, $40,000-$59,999, $60,000-$99,999, $100,000-$199,999 and $200,000+. The Comorbidity scale was a sum (0 for no, 1 for yes) calculated based on self-reported history of a physician's diagnosis of the following conditions: heart attack, stroke, coronary bypass, retinopathy, nephropathy, neuropathy. Age at diagnosis was self-reported and categorized into: < than 10 years old, 10-14, 15-19, 20-29, 30-39, 40-49, 50-59, 60-69 and 70+. Social support was measured using an 8-item scale capturing instrumental support from the NIH Toolbox Adult Social Relationship Scales.[30] Response options ranged from 0 (never)-4 (always) and were summed.

Statistical Analysis

First, we examined the distribution of baseline characteristics of the study population, overall and by diabetes type. Baseline characteristics were compared by diabetes type using one-way ANOVA for continuous variables (age, sleep, stress) and chi-squared tests for categorical variables. Next, we examined mean standardized scores for dLOC (internal/external) by diabetes type and examined the distribution of responses to each dLOC item by diabetes type. We, then, examined the mean depression score by diabetes type and calculated the percent of participants that met the criteria for depression using the Geriatric Depression Scale (using GDS>5 as cutoff). We used a series of linear regression models (with varying levels of confounder adjustment) to examine the cross-sectional association between dLOC and depression score (continuous). Model 1 adjusted for age at baseline, age at diabetes diagnosis, and sex; Model 2 additionally adjusted for education, income, and comorbidities; and, Model 3 additionally adjusted for sleep and social support. As a sensitivity analysis we examined potential interaction between dLOC and diabetes type to determine if the association between dLOC and depression differed between diabetes type. We used logistic regression models to examine the association of dLOC and the presence of depression (binary, >5 GDS). We then stratified the regression models by type of diabetes to determine if diabetes type modifies the association between dLOC and depression. All analyses were performed using SAS 9.4®.

Results:

In this sample of 1053 older adults with diabetes (n=805 with type 1 diabetes; n=248 with type 2 diabetes), the mean age at baseline was 67.6 years (SD 6.5; Table

1). Participants were predominately white (85%) and majority had obtained at least a college degree (62%). The majority of participants had an annual income >$40,000. On average, participants had 1 comorbidity (SD 1.28). The two most common comorbidities were retinopathy (37%) and neuropathy (39%). Individuals with T1D were more likely to have retinopathy (45%) or neuropathy (43%), while individuals with T2D were more likely to just have neuropathy (26%).

Participants had an average dLOC of 7.0, representing a more internal locus of control, with a minimum observed score of −6 and a maximum score of 13 (possible range of −15 to 15). Overall dLOC score was higher in individuals with type 1 diabetes (mean=7.4, SD=3.2) than in those with type 2 diabetes (mean=5.8, SD=3.4; p-value=<0.0001) meaning they have a more internal locus of control than participants with type 2 diabetes. Distributions of dLOC responses are presented in Figure 2.

Overall, 13.9% of participants had GDS-15 scores at or above the cutoff for depression. Prevalence of depression did not differ by diabetes type (13.7% in T1D, 14.6% in T2D; p value=0.71). The mean GDS-15 score in our sample was 2.27 (SD=3.51); this also did not differ by type of diabetes (T1D mean = 2.23, T2D mean=2.42; p= 0.30).

In minimally adjusted linear regression models (Model 1 adjusted for age, sex, age at diabetes diagnosis) we found a one-unit increase in dLOC (i.e. more internal locus of control) is associated with a lower depression score (i.e. less depression symptoms on the GDS; β=-0.16 ; 95% CI: -0.21, -0.11; Table 2). In models additionally adjusting for education, income, and prevalent comorbidities at baseline (Model 2) and additionally adjusting for sleep and social support (Model 3, fully adjusted for

confounding) the association between dLOC and depression was attenuated but remained statistically significant (Model 2: β=-0.12 ; 95% CI: -0.17, -0.07; Model 3: β=-0.11 ; 95% CI: -0.15, -0.06). In a sensitivity analysis, we found no evidence of statistically significant interactions between dLOC and diabetes type (all p-values greater than .20; supplemental table 1).

In minimally adjusted logistic regression models (Model 1 adjusted for sex, age, and age at diabetes diagnosis), a one-unit increase in dLOC is associated with lower odds of having depression (OR=0.87, 95% CI: 0.82, 0.92; Table 3). In models additionally adjusting for education, income, and prevalent comorbidities at baseline (Model 2) and additionally adjusting for sleep and social support (Model 3, fully adjusted for confounding) the association between dLOC and depression was slightly attenuated but remained statistically significant (OR=0.91; 95% CI: 0.85, 0.96).

Discussion:

In this study we assessed the association between dLOC and its association with depression among a large sample of older adults with type 1 and type 2 diabetes. We further examined if the association between dLOC and depression was modified by type of diabetes. We found that higher dLOC scores (i.e. more internal locus of contol) were associated with fewer depressive symptoms. Individuals with type 1 diabetes had higher dLOC score than those with type 2 diabetes, indicating a more internal locus of control. We did not observe an association between mean depression score or depressive symptoms and diabetes type.

As life expectancy increases for individuals with type 1 diabetes, the need for further research on managing diabetes and age-related diseases simultaneously

becomes more crucial. Individuals with both type 1 and type 2 diabetes have an increased risk of developing depression. Though the relationship between diabetes and depression isn't fully understood, the rigors of managing diabetes can be stressful and may lead to symptoms of depression. Additionally, diabetes can cause complications and health problems that may worsen symptoms of depression. Depression can lead to poor lifestyle decisions, such as unhealthy eating, less exercise, smoking and weight gain — all of which are risk factors for diabetes. Further, depression affects the ability to perform tasks, communicate and think clearly which can interfere with the ability to successfully manage diabetes.

Our findings of a significant association between dLOC and depression supports prior findings from other studies. Numerous studies report an association between internal locus of control and a decreased risk in depression; however, the majority of prior studies were conducted in populations with type 2 diabetes. Whether or not this extended to older adults with type 1 diabetes was unknown. Conversely, our finding that individuals with type 1 diabetes had a more internal locus of control than those with type 2 diabetes contradicts findings from a previous study that investigated dLOC in type 1 and type 2 diabetes.[28] This study reported that patients with type 1 diabetes had lower internal control, increased fatalism, and increased reliance upon others compared to those with type 2 diabetes.[28] In our study we found individuals with type 1 diabetes had more internal locus of control than those with type 2 diabetes. The previous study had a smaller sample size of 83 patients, and only 27 of them had type 1 diabetes. Individuals with type 1 diabetes in their study were younger (mean age was 36), where in our study the average age was 65. It is known from other studies that younger individuals with

diabetes are more likely to have a lower internal locus of control.[9] This was the only study to our knowledge that compared locus of control of patients with type 1 and type 2 diabetes.

Strengths and Limitations

The strengths of this study include the ability to examine aging and depression in a large cohort of older adults with type 1 diabetes and type 2 diabetes. Additionally, the use of validated measures for dLOC and depression were important strengths. Limitations of this study include generalizability of study population. This study consisted of predominately wealthy, highly educated, white individuals who lived in northern California. Being wealthy and highly educated would allow access to resources and technology that would contribute to managing diabetes successfully, which could have contributed to a higher internal locus of control. Although, people with T1D are living longer, many do not live to be over the age of 60.[23,24] Thus, it is unlikely that this study sample is broadly representative of all older adults with T1D. In this study, we used the GDS-15 to measure depression. There are other measures of depression that could have been used such as the Beck Depression scale.[31] We selected the GDS, however, as it was developed specifically for use in older adults. We did not have blood lab values, so we do not know how well dLOC associates with diabetes self-care in this study population. This study used cross-sectional data that included only baseline data from individuals with diabetes from the ongoing SOLID study. We could not determine changes in dLOC or depression over time and how that may have affected the association. Finally, much of the data was obtained through self-report, which is subject to self-report bias or recall bias.

With the increased risk of depression in individuals with diabetes and a lack of research in older adults with type 1 diabetes, our study identified a potentially modifiable factor that can be targeted to reduce risk of depression among older adults with type 1 and type 2 diabetes. If we were to focus on increasing the locus of control in patients with diabetes, this could possibly help decrease their risk of depression. Internal locus of control is an indicator that an individual feels as if they have a grasp on their disease and they are in control. Individuals with a more external locus of control feel they have less control over their diabetes. Understanding the reasons why individuals with external locus of control feel unable to control their diabetes may help identify specific tools to improve their dLOC.

Future studies can focus on the association between diabetes management and locus of control. Longitudinal studies are also needed to better understand the directionality of this association; it is possible that depression actually leads to lower locus of control or that the association is bidirectional. Future studies could also include more diverse study sample, examining whether or not our findings are consistent in populations with diverse race/ethnicity and access to healthcare.

Conclusion:

This study examined the association between dLOC and depression in older adults with type 1 and type 2 diabetes and tested if this association was modified by diabetes type. In conclusion, we found that dLOC was associated with depression. Individuals with an internal locus of control had lower scores on the Geriatric Depression Scale and were less likely to experience depressive symptoms than individuals with a more external locus of control. Individuals with type 1 diabetes had

higher internal locus of control than individuals with type 2 diabetes. Further research is needed to examine how dLOC can be targeted to help prevent depression in older adults with diabetes.

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Appendix:

Table 1 Characteristics of study participants from SOLID

Characteristic	***Overall***	***T1D***	***T2D***	***p-value***
	(n=1053)	**(n=805)**	**(n=248)**	
Age, mean (SD)	67.6 (6.5)	67.2 (6.3)	68.8 (7.1)	0.001
Sex, n (%)				
Female	534(50.71)	409(50.81)	125(50.40)	0.9114
Male	519(49.29)	396(49.19)	123(49.60)	
Race/ethnicity, n (%)				
African American	22(2.09)	22(2.73)	0	<.0001
Asian	22(2.09)	21(2.61)	1(0.40)	
Caucasian	895(85.0)	686(85.22)	209(84.27)	
Hispanic	65(6.17)	29(3.60)	36(14.52)	
Mix/Other	44(4.18)	42(5.22)	2(0.81)	
Unknown	5(0.47)	5(0.62)	0	
College education, n (%)				
Less Than College Degree	402(38.40)	304(38.05)	98(39.52)	0.0189
College Degree or Greater	645(61.60)	495(61.95)	150(60.48)	
Pittsburg Sleep Quality Index*, mean (SD)				
Continuous	8.2(2.8)	8.2 (2.8)	8.3 (2.6)	0.6769
Income, n (%)				
<$10,000 a year	12(1.23)	7(0.94)	5(2.16)	0.12224
10,000-14999	19(1.95)	12(1.61	7(3.02)	
15,000-19,999	26(2.66)	17(2.28	9(3.88)	
20,000-39,999	120(12.30)	84(8.61)	36(15.52)	
40,000-59,999	160(16.39)	126(16.94)	34(14.66)	
60,000-99,999	296(30.33)	223(29.97)	73(31.47)	
100,000-199,999	272(27.87)	217(29.17)	55(23.71)	
200,000 +	67(6.86)	54(7.26)	13(5.60)	
Comorbidity Score, mean (SD)***	1.12(1.28)	1.28(133)	0.62(0.92)	
Heart attack, n (%)	126(12.44)	102(13.20)	24(10.00)	0.1901
Stroke, n (%)	94(9.31)	71(9.23)	23(9.54)	0.8848
Coronary bypass, n (%)	132(12.82)	110(13.99)	22(9.02)	0.0421
Retinopathy, n (%)	362(37.05	342(45.48)	20(8.89)	<0.0001
Nephropathy, n (%)	66(7.30)	64(9.32)	2(0.92)	<0.0001
Neuropathy, n (%)	387(38.74)	325(42.65)	62(26.16)	<0.0001
Age at Diagnosis, n (%)				

<10 years old	65 (6.34)	65 (8.32)	0	<0.0001
10-14 years old	103 (10.04)	203(13.19)	0	
15-19 years old	103 (10.04)	102(13.06)	1(0.41)	
20-29 years old	186 (18.13)	184(23.56)	2(0.82)	
30-39 years old	161 (15.69)	144(18.44)	17(6.94)	
40-49 years old	146 (14.23)	104(13.32)	42(17.14)	
50-59 years old	143 (13.94)	57(7.30)	86(35.10)	
60-69 years old	95 (9.26)	18(2.30)	77(31.43)	
70+ years	23(2.24)	3(0.29)	20(8.16)	
Social Support*, mean (SD)***	20.2(8.8)	20.2(8.9)	20.2(8.5)	.99

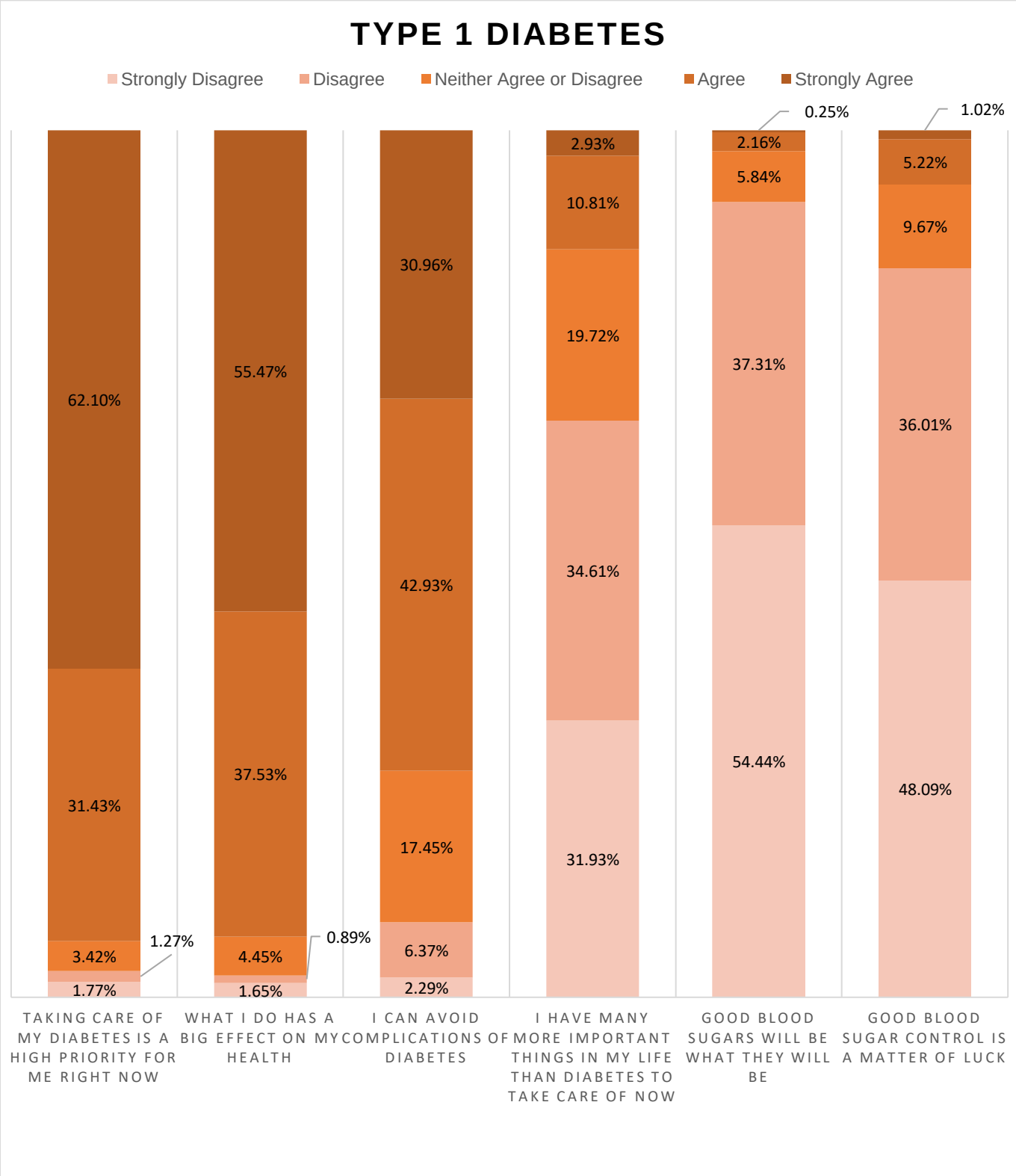
*p-value calculated using ANOVA for continuous variables (age, sleep, stress,) and chi-square test for categorical variables.

** **Pittsburg Sleep Quality Index** – scores **range from 0 to 21 with higher scores indicating worse sleep quality.**

***Comorbidity score calculated based** self-reported history of a physician's diagnosis of **the following conditions:** retinopathy, nephropathy, neuropathy, stroke/cerebrovascular event, heart attack, coronary bypass.

****Social Support** was measured using an 8-item scale capturing instrumental support from the NIH Toolbox Adult Social Relationship Scales.[31] Response options ranged from 0 (never)-4 (always) and were summed.

Figure 2. Distribution of diabetes locus of control by diabetes type



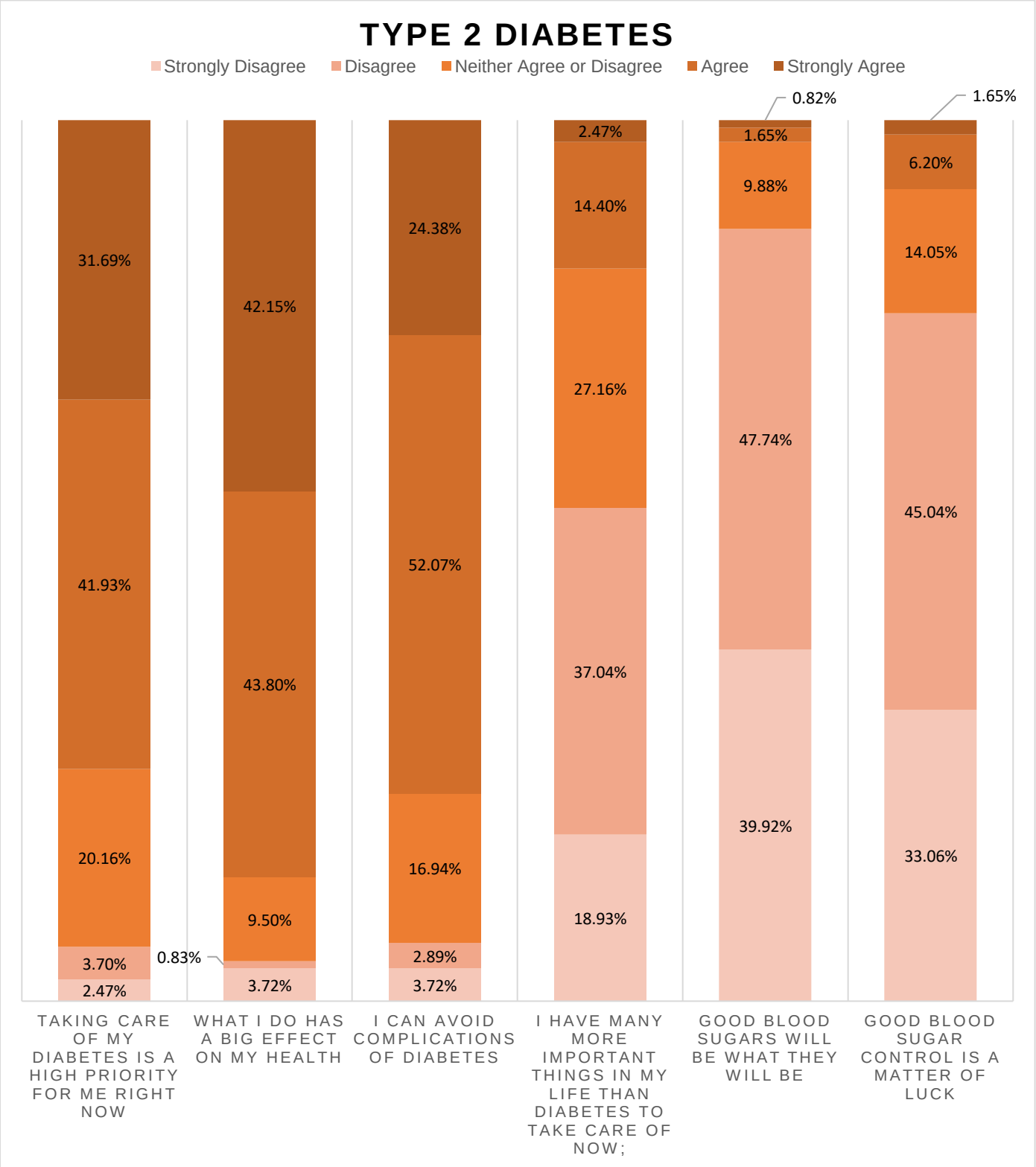

TYPE 2 DIABETES
Strongly Disagree
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
31.69%
41.93%
20.16%
3.70%
2.47%
0.83%
42.15%
43.80%
9.50%
3.72%
24.38%
52.07%
16.94%
2.89%
3.72%
2.47%
14.40%
27.16%
37.04%
18.93%
0.82%
1.65%
9.88%
47.74%
39.92%
1.65%
6.20%
14.05%
45.04%
33.06%
TAKING CARE OF MY DIABETES IS A HIGH PRIORITY FOR ME RIGHT NOW
WHAT I DO HAS A BIG EFFECT ON MY HEALTH
I CAN AVOID COMPLICATIONS OF DIABETES
I HAVE MANY MORE IMPORTANT THINGS IN MY LIFE THAN DIABETES TO TAKE CARE OF NOW;
GOOD BLOOD SUGARS WILL BE WHAT THEY WILL BE
GOOD BLOOD SUGAR CONTROL IS A MATTER OF LUCK

Table 2. The association between diabetes locus of control and continuous depression score

	β (95%CI)
Model 1: Adjusted for diabetes type, *sex, age and age at diabetes diagnosis*	-0.16 (-0.21, -0.11)
Model 2: Model 1 + additional adjustment for education, income, comorbidities	-0.12 (-0.17, -0.07)
Model 3: Model 2 + additional adjustment for sleep and social support	-0.11 (-0.15, -0.06)

Table 3. The association between diabetes locus of control and presence of depression

	OR (95%CI)
Model 1: Adjusted for diabetes type, sex, age and age at diabetes diagnosis	0.87(0.82, 0.92)
Model 2: Model 1 + additional adjustment for education, income, comorbidities	0.91(0.85, 0.96)
Model 3: Model 2 + additional adjustment for sleep and social support	0.91(0.85, 0.96)

Supplemental Table 2. Association between diabetes locus of control and depression stratified by diabetes type

	Type 1 diabetes β (95% CI)	*Type 2 diabetes β (95% CI)*	*p-value for LOC*diabetes type*
Model 1: Adjusted for sex, age and age at diabetes diagnosis	-0.18 (-0.23, -0.13)	-0.12 (-0.21, -0.03)	0.40
Model 2: Model 1 + additional adjustment for education, income, comorbidities	-0.15 (-0.20, -0.09)	-0.08 (-0.17,0.01)	0.26
Model 3: Model 2 + additional adjustment for sleep and social support	-0.12 (-0.18, -0.07)	-0.06 (-0.14, -0.02)	0.33

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