Association Among Depression, Physical Functioning, and Hearing and Vision Impairment in Adults With Diabetes

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Abstract

Objective. Individuals with diabetes may be at an increased risk for depression given the potential diabetes-induced link between sensory impairment, physical functioning, and depression. As a result, the purposes of this study were *1*) to examine the association between sensory impairment and depression among adults of all ages with diabetes, *2*) to examine whether dual sensory impairment and physical functioning are independently associated with depression, and *3*) to examine the association between physical functioning and sensory impairment.

Design and Methods. Data from the 2005–2006 National Health and Nutrition Examination Survey were used in the present study and, after exclusions, 567 participants (18–85 years of age) with evidence of diabetes constituted the analytic sample. Sensory impairment (vision and hearing), physical functioning, and depression were reported from questionnaires.

Results. After controlling for age, sex, race/ethnicity, comorbidity index, smoking, BMI, physical activity, and glycemic control, dual sensory impairment (odds ratio [OR] 7.48, 95% CI 2.09–26.71) and physical dysfunction (unable to perform activities; OR 3.21, 95% CI 1.28–8.08) were associated with increased depression symptoms. After adjustments, participants who were unable to perform activities had a 1.73 (95% CI 0.94–3.19, $P = 0.07$), 2.78 (0.78–9.87, $P = 0.11$), and 2.21 (0.50–9.68, $P = 0.29$) nonsignificant greater odds, respectively, of having hearing, vision, and dual sensory impairment than participants who were able to perform activities.

Conclusion. Adults with diabetes who have dual sensory impairment and physical functioning limitations are more likely to report depression symptoms. This highlights the importance of preventing and improving sensory impairments, physical functioning, and depression among adults with diabetes.

Diabetes is associated with sensory impairment, including both vision and hearing impairment,[1,2] with the underlying mechanisms occurring through unfavorable glucose-induced changes in inflammation, microvasculature, and sensory nerves.[3,4] Studies also have shown that individuals with diabetes are at an increased risk for depression,[5] which is not surprising given the psychological and emotional problems linked with sensory impairment and diabetes.[6,7] Notably, diabetes may also be linked with depression through other mechanisms such as elevated inflammation[8] or through lifestyle factors such as physical activity and smoking.[9]

The majority of studies examining the association between sensory impairment and depression have examined this relationship for single-sensory impairment alone (i.e., hearing or vision impairment).[10,11] Fewer studies have examined the association between dual sensory impairment (i.e., having both hearing and vision impairment) and depression.[10,11] Those that have usually

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restricted the sample to older adults (despite the fact that sensory impairment does not always start during the late adult years)[12,13] and did not always employ multivariate analyses to control for potential confounding variables.[11] Furthermore, we have a limited understanding of the association between dual sensory impairment and depression among adults with diabetes.

In addition to the link between sensory impairment and diabetes, individuals with diabetes may have considerable functional impairment, through changes in health status and mobility.[14] Although sensory impairment may influence depression, physical functioning has also been linked to depression symptoms.[15] We currently have a dearth of studies examining the concurrent independent effects of dual sensory impairment and physical functioning on depression symptoms.

Providing some insight into this, McDonnall[16] employed a longitudinal study to examine the association between physical status and depression among older adults with and without dual sensory loss. Physical status was assessed using three measures, including physical activity, physical condition, and BMI. All three physical status measures were associated with depression symptoms for individuals who had or who developed dual sensory loss.

The primary aims of this study were to increase our knowledge base in this area of research by *1*) examining the association between single and dual sensory impairment and depression among adults of all ages with diabetes while controlling for potential confounding variables and *2*) examining whether dual sensory impairment and physical functioning are independently associated with depression. A secondary purpose of this study was to examine the association between physical functioning and sensory impairment because, in the general population, studies have shown that those with sensory impairment have less functional independence.[17–19]

Study Methods

Design and participants

For this study, we used data from the 2005–2006 National Health and Nutrition Examination Survey (NHANES).[20] Briefly, NHANES employs a representative sample of noninstitutionalized U.S. civilians selected by a complex, multistage probability design. Participants were interviewed in their homes and subsequently examined in mobile examination centers (MECs) across numerous U.S. geographical locations. The study was approved by the National Center for Health Statistics ethics review board, with informed consent obtained from all participants before data collection. The final sample for the present study included 567 adult NHANES participants between 18 and 85 years of age after excluding participants who did not have diabetes or had missing data for the study variables.

Assessment of diabetes status

Administered in participants' homes, the NHANES included several questions related to diabetes. Participants were asked if they had ever been told by a doctor or health professional that they had or have diabetes or sugar diabetes and if they are now taking insulin. A subsample of NHANES participants was examined in a morning fasting session. Fasting glucose was measured from a blood sample, and participants with a fasting glucose level ≥ 126 mg/dl were considered to have diabetes. Finally, participants were also considered to have evidence of diabetes if they had an A1C value ≥ 6.5%.

Measurement of depression status

At the MECs, participants completed the Patient Health Questionnaire-9 (PHQ-9)[21] during the computer-assisted personal interview. The PHQ-9 depression scale consists of the nine diagnostic criteria for depressive disorders as listed in the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders*.[22] Sample items ask participants how often in the past 2 weeks they have been bothered by "feeling down, depressed, or hopeless," "feeling tired or having little energy," and "trouble concentrating on things, such as reading the newspaper or watching television."

For each question, participants responded using a 4-point Likert scale, with responses including not at all (0), several days (1), more than half the days (2), and nearly every day (3). Items were summed, with higher scores indicating greater severity of depression. As a measure of severity, the PHQ-9 can range from 0 to 27 because each of the nine items can be scored from 0 to 3. For the analyses presented herein, we defined depression status as follows: less than moderate depression (0–9) and moderate to severe depression (≥ 10).

The PHQ-9 has demonstrated evidence of reliability, with Cronbach's alpha ranging from 0.86 to 0.89 and a 48-hour test-retest correlation coefficient of 0.84.[21] Additionally, this cut-point of ≥ 10 has demonstrated evidence of validity, with a sensitivity of 88% and a specificity of 88% for clinical depression.[21] In the present sample, internal consistency of this questionnaire, as measured by Cronbach's alpha, was 0.84.

Measurement of hearing and vision impairment

In the 2005–2006 NHANES sample, participants self-reported hearing and vision functioning. For hearing assessment, participants were asked whether their hearing was excellent, good, a little trouble, moderate trouble, a lot of trouble, or deaf. The hearing variable was dichotomized into excellent or good hearing and a little or more hearing trouble. For vision assessment, participants were asked whether their eyesight, with glasses or contact lenses if worn, was excellent, good, fair, poor, or very poor. The vision variable was characterized as excellent, good or fair, and poor or worse vision. Participants with a little or more hearing trouble and poor or worse vision were classified as having dual sensory impairment. A categorical impairment variable was created with four groups including *1*) excellent or good hearing and excellent, good, or fair vision; *2*) a little or more hearing trouble; *3*) poor or worse vision; and *4*) dual

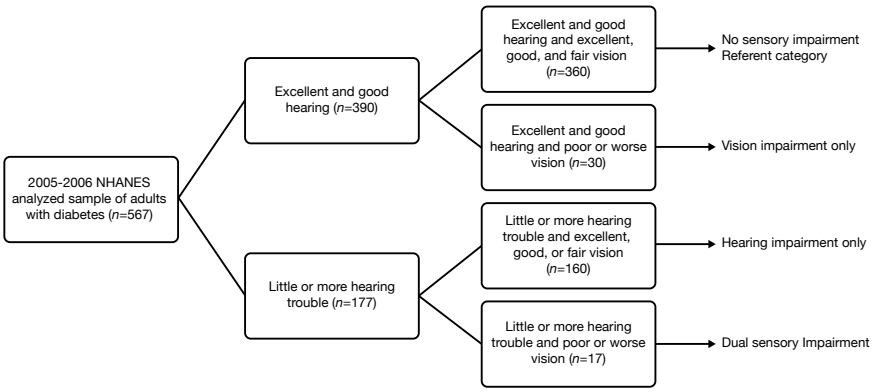

Figure 1. Classification of sensory impairment among adults with diabetes, NHANES 2005–2006.

sensory impairment. Note that the second and third categories were mutually exclusive in that participants classified as having a little or more hearing trouble did not have poor or worse vision, and those with poor or worse vision did not have a little or more hearing trouble (Figure 1).

Measurement of physical functioning

During a home interview and using the computer-assisted personal interviewing system, participants were asked several questions related to their physical functioning. To provide an assessment of physical functioning, participants were asked: "Because of a health problem, do you have difficulty walking without using any special equipment?" Response options were "yes" and "no." Participants were also asked how much difficulty they had walking for a quarter of a mile; walking up 10 steps without resting; stooping, crouching, or kneeling; lifting or carrying something as heavy as 10 lb; doing chores around the house; preparing meals; walking from one room to another on the same level; standing up from an armless straight chair; getting in or out of bed; eating, such as holding a fork, cutting food, or drinking from a glass; dressing, including tying shoes, working zippers, and fastening buttons; standing or being on their feet for ~ 2 hours; reaching up overhead; using their fingers to grasp or handle small objects; going out for activities such as shopping, movies, or sporting events; participating in social activities; and pushing or pulling large objects such as a living room chair. Response options for these questions included "no difficulty," "some difficulty," "much difficulty," and "unable to do this activity."

With respect to physical functioning classification, participants were classified as "able to do activities" (i.e., they reported having no difficulty or some difficulty), "having much difficulty doing activities," and "unable to do activities." Participants were classified as "having much difficulty" if they said they had much difficulty for any of the above physical functioning questions. Participants were classified as "unable to do activities" if they answered "yes" to the question "Do you have difficulty walking without using any special equipment?" or if they reported being unable to do any of the above physical functioning questions.

Measurement of covariates

To control for potential confounding variables, covariates were examined in the analytical models. Participants completed questionnaires providing data on age, sex, race/ethnicity, and physical activity levels (whether they engaged in any moderate- or vigorous-intensity physical activity in the past 30 days for at least 10 minutes). Additionally, a comorbidity index variable was created, which included the following chronic diseases/events: arthritis, coronary heart disease, heart attack, congestive heart failure, stroke, cancer, emphysema, chronic bronchitis, and elevated blood pressure (systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg). As a marker of active smoking status or as an index of environmental exposure to tobacco (i.e., passive smoking), serum cotinine was measured. Serum cotinine was measured by an isotope dilution high-performance liquid chromatography/atmospheric pressure chemical ionization tandem mass spectrometry. Other covariates included glycemic control as measured by A1C levels and BMI. During examination at the MECs, BMI was calculated from measured weight and height (weight in kilograms divided by the square of height in meters).

Data analysis

All analyses were performed using STATA (version 10.0, STATA Corp., College Station, Tex.). To provide demographic characteristics of the analyzed sample, means and standard errors were calculated for continuous variables, and proportions were calculated for categorical variables.

Mean depression scores across the impairment categorical variable and the physical functioning variable were calculated, and a one-way analysis of variance was used to test for a significant difference across groups. A χ^2 test was used to assess whether there was a difference in the proportion of individuals with depression across the impairment and physical functioning variables.

Two multivariate logistic regression models were computed. For both models, depression served as the outcome variable, with depression dichotomized into "less than moderate depression" (coded as 0) and "having moderate to severe depression symptoms" (coded as 1). The first multivariate logistic regression analysis was used to examine the association between the categorical impairment variable and depression while controlling for age, sex, race/ethnicity, comorbidity index, smoking, BMI, physical activity, and glycemic control. For the impairment categorical variable, "excellent or good hearing and excellent, good, or fair vision" served as the reference group. The second multivariate logistic regression was the same as the first model except the physical functioning variable was added to

the model. Statistical significance was established as a nominal alpha level of 0.05.

In addition to examining the direct association between single and dual sensory impairment on depression symptoms, additive and multiplicative interaction for hearing and vision impairment was assessed. As described by Kalilani and Atashili,[23] multiplicative interaction exists when the joint effect of the risk factors differs from the product of the effects of the individual factors; additive interaction exists when the joint effect of the risk factors differs from the sum of the effects of the individual factors.

Additive interaction was tested by calculating the relative excess risk due to interaction (RERI), the attributable proportion due to interaction (AP), and the synergy index (S), using the methods described by Andersson et al.[24] RERI is the excess risk due to interaction relative to the risk without exposure;[23] AP is considered the attributable proportion of the outcome (in this case, depression) which is due to the interaction among individuals with both exposures (i.e., both hearing and vision impairment);[23] and S is the ratio of the combined effect and the sum of the individual effects.[25] To calculate these parameters, a logistic regression was computed with depression serving as the outcome variable. The regression coefficients from the single sensory hearing and vision variables, along with the dual sensory impairment variable, were entered into the Microsoft Excel spreadsheet developed by Andersson et al.[24] Then, the covariance matrix of the coefficients of the logistic model was computed with the appropriate covariances from the covariance matrix entered into the spreadsheet to provide an estimate of RERI, AP, and S. Statistical significance was evaluated with 95% confidence intervals with AP and RERI > 0 and S > 1.0 indicating additive interaction. Multiplicative interaction was tested by including a cross-product term for vision and hearing along with the main effect terms for each in the regression model.

The secondary purpose of this study was to examine the association between physical functioning and sensory impairment. To address this potential association, a multinomial logistic regression was employed, with sensory impairment serving as the outcome variable. Covariates included age, sex, race/ethnicity, comorbidity index, smoking, BMI, physical activity, glycemic control, and depression.

To ensure that NHANES results are representative of the U.S. population, the National Center for Health Statistics provides sample weights to correct for differential selection probabilities and to adjust for non-coverage and non-response. Sample sizes for some of our analyses were insufficient (i.e., $n < 35$) to provide reliable population estimates. Thus, our analyses are unweighted and reflect associations in NHANES participants and are not intended to represent the entire U.S. population.

Study Results

Characteristics of the study participants with diabetes are displayed in Table 1. Mean depression scores and percentages or participants with depression symptoms across the four categories of impairment and physical functioning are shown in Table 2. For sensory impairment, participants with excellent or good hearing and excellent, good, or fair vision had the lowest mean depression score (2.8, 95% CI 2.4–3.2), with participants having dual sensory impairment exhibiting the highest depression score (7.4, 95% CI 3.5–11.3, $P < 0.0001$). Participants with excellent or good hearing and

Table 1. Means and Proportions for Characteristics of People With Diabetes in NHANES 2005–2006 (n = 567)

Variable	Mean/Proportion (Standard Error)
Demographic and biological variables	
Age (years) (range 18–85 years)	60.6 (0.6)
Sex (% male)	50.7 (2.1)
BMI (kg/m^2)	32.2 (0.3)
Race/ethnicity	
Mexican American (%)	24.3 (1.8)
Other Hispanic (%)	2.8 (0.6)
Non-Hispanic white (%)	38.9 (2.0)
Non-Hispanic black (%)	31.3 (1.9)
Other race (%)	2.4 (0.6)
Comorbidity Index	
0 comorbidities (%)	26.4 (1.8)
1 comorbidity (%)	34.5 (2.0)
2 comorbidities (%)	18.8 (1.6)
3 comorbidities (%)	10.7 (1.3)
4+ comorbidities (%)	9.4 (1.2)
Cotinine (ng/ml)	51.6 (5.4)
Those engaging in any moderate to vigorous physical activity within the past 30 days (%)	47.4 (2.0)
A1C (%)	7.3 (0.07)

continued on p. 10

Table 1. Means and Proportions for Characteristics of People With Diabetes in NHANES 2005–2006 (*n* = 567), *continued from p. 9*

Variable	Mean/Proportion (Standard Error)
Study variables	
Depression	3.4 (0.1)
Moderate to severe depression (%; *n* = 55)	9.7 (1.2)
Hearing	
Excellent (%; *n* = 184)	32.4 (1.9)
Good (%; *n* = 206)	36.3 (2.0)
A little trouble (%; *n* = 107)	18.8 (1.6)
Moderate trouble (%; *n* = 39)	6.8 (1.0)
A lot of trouble (%; *n* = 28)	4.9 (0.9)
Deaf (%; *n* = 3)	0.5 (0.3)
Vision	
Excellent (%; *n* = 123)	21.6 (1.7)
Good (%; *n* = 270)	47.6 (2.0)
Fair (%; *n* = 127)	22.3 (1.7)
Poor (%; *n* = 39)	6.8 (1.0)
Very poor (%; *n* = 8)	1.4 (0.4)
Impairment classification	
Excellent or good hearing and excellent, good, or fair vision (%; *n* = 360)	63.4 (2.0)
A little or more hearing trouble (%; *n* = 160)	28.2 (1.8)
Poor or worse vision (%; *n* = 30)	5.2 (0.9)
Dual sensory impairment (%; *n* = 17)	3.0 (0.7)
Physical functioning	
Able to do activities (%; *n* = 191)	45.4 (2.4)
Having much difficulty (%; *n* = 55)	13.0 (1.6)
Unable to do activities (%; *n* = 174)	41.4 (2.4)

excellent, good, or fair vision had the lowest prevalence of depression symptoms (6.9%, 95% CI 4.3–9.5%); participants with dual-sensory impairment had the highest prevalence (41.1%, 95% CI 17.0–65.3%, $P < 0.001$). For physical functioning, participants who were able to do activities had the lowest depression score (2.2, 95% CI 1.7–2.7), with participants who were unable to do activities having the highest depression score (5.7, 95% CI 4.8–6.5, $P < 0.0001$). Participants who were unable to do activities had a higher prevalence of depression (20.6%, 95% CI 14.6–26.7%) compared to participants who were able to do activities (5.7%, 95% CI 2.4–9.0%) and those having much difficulty (5.4%, 95% CI 0.0–11.5%).

The adjusted logistic regression analyses examining the association among depression, sensory impairment, and physical functioning are shown in Table 3. In the first model, and after controlling for age, sex, race/ethnicity, comorbidity index, smoking, BMI, physical activity, and glycemic control, those with dual sensory impairment (odds ratio [OR] 11.21, 95% CI 3.30–37.99) were 11.2 times more likely to have depression symptoms compared to those with excellent or good hearing and excellent, good, or fair vision. For model 2, in which physical functioning was added to the model, the association between dual sensory impairment and depression was attenuated but still significant (OR 7.48, 95% CI 2.09–26.71). Independent of sensory impairment, participants unable to do activities (OR 3.21, 95% CI 1.28–8.08) were 3.21 times more likely to have depression symptoms than participants who were able to perform various activities. Although dual sensory impairment and physical functioning were both independent predictors of depression, the strength of the association was greater for dual sensory impairment.

To determine whether there was additive or multiplicative interaction between hearing and vision impairments on depression, further analyses were performed. The RERI (6.79, 95% CI –6.0 to 19.5) and S (3.07, 95% CI 0.57–16.53) were not significant. However, the AP was significant at 0.61 (95% CI 0.07–1.15), suggesting that a significant proportion of depression can be attributed to the additive interaction between hearing and vision. The cross-product term for hearing and vision to evaluate multiplicative interaction was not significant when added to the final model along with the main effect terms ($P = 0.33$).

The secondary purpose of this study was to examine the association between physical functioning and sensory impairment (Table 4). Participants who were unable to perform activities had a 1.73 (95% CI 0.94–3.19, $P = 0.07$), 2.78 (0.78–9.87, $P = 0.11$), and 2.21 (0.50–9.68, $P = 0.29$) nonsignificant greater odds, respectively, of having hearing, vision, and dual sensory impairment

Table 2. Mean Depression Scores and Percentages of Participants With Moderate to Severe Depression Symptoms Across the Impairment and Physical Functioning Variables Among People With Diabetes in NHANES 2005–2006

Variable	Mean Depression (95% CI)	*P*	Depressed (% [95% CI])	*P*
Impairment variable		< 0.0001		< 0.001
Excellent or good hearing and excellent, good, or fair vision (*n* = 360)	2.8 (2.4–3.2)		6.9 (4.3–9.5)	
A little or more hearing trouble (*n* = 160)	3.9 (3.1–4.7)		10.0 (5.3–14.6)	
Poor or worse vision (*n* = 30)	4.5 (2.9–6.1)		23.3 (7.9–38.7)	
Dual sensory impairment (*n* = 17)	7.4 (3.5–11.3)		41.1 (17.0–65.3)	
Physical functioning variable		< 0.0001		< 0.001
Able to do activities (*n* = 191)	2.2 (1.7–2.7)		5.7 (2.4–9.0)	
Having much difficulty (*n* = 55)	2.9 (2.0–3.8)		5.4 (0.0–11.5)	
Unable to do activities (*n* = 174)	5.7 (4.8–6.5)		20.6 (14.6–26.7)	

than participants who were able to perform activities.

Discussion

The purposes of this study were threefold: *1*) to examine the association between sensory impairment and depression among adults of all ages with diabetes, *2*) to examine whether dual sensory impairment and physical functioning are independently associated with depression, and *3*) to examine the association between physical functioning and sensory impairment. The major finding of this study was that both dual sensory impairment and physical functioning were independently associated with depression. Furthermore, we showed that there is additive interaction between hearing and vision on the association with depression.

Most previous research has examined the influence of diabetes on sensory impairment,[26–28] the association between single sensory impairment (i.e., hearing or vision alone) and health outcomes (e.g., depression) in the general population[29,30] among those with diabetes,[31] or the association between dual sensory impairment and depression in nondiabetic populations.[32] The examination of the correlates of dual sensory impairment is a relatively new line of inquiry among those with diabetes.

Our findings contribute to the literature by demonstrating that adults with diabetes who have both vision and hearing impairments (i.e., dual sensory impairment) have an increased odds of depression and that these dual sensory impairments have an additive effect on the odds of depression. Additionally, this study showed that physical functioning was marginally associated with dual sensory impairment among adults with diabetes. Similarly, our findings also indicated that glycemic control was independently associated with sensory impairment, which supports other research demonstrating that poor glycemic control among adults with diabetes is independently associated with functional limitations.[33] The independent association among glycemic control, sensory impairment, and functional limitations underscores the importance of glycemic control and of counseling patients about its importance.

Along these lines, it is reasonable to suggest that glycemic control may also be independently linked to depression symptoms, particularly because glycemic control is linked to factors (e.g., inflammation,[8,34] functional impairment,[33] and self-efficacy[35]) that are associated with depression. For example, those with poorer glycemic control may have greater systemic inflammation[36] and functional impairment[33] and in turn may be at a greater risk for depression.[8,34,37] Moreover, Sacco and Bykowski[35] showed that glycemic control was indirectly associated with depression through diabetes adherence mastery (self-efficacy). Importantly, these findings only held true for adults with type 1 diabetes and not for those with type 2 diabetes.

In our study, glycemic control was not independently associated with depression symptoms. It was not possible to determine whether participants in the study had type 1 or type 2 diabetes. Given that type 2 diabetes is more common, however, it is plausible to suggest that a greater proportion of adults in this sample had type 2 diabetes, and if so, the null findings for this sample would support those reported by Sacco and Bykowski.[35] Our findings are also similar to those reported by McDonnall,[16] who showed that, among adults in the general population, physical status was associated with depression symptoms for individuals who had or who developed dual sensory loss.

To decrease the likelihood of developing depression, these findings underscore the importance of preventing sensory impairments and improving physical functioning among adults with diabetes.

Table 3. Association Among Depression (Dependent Variable), Impairment Classification Status, and Physical Functioning in People With Diabetes in NHANES 2005–2006

	Those Having Depression (OR [95% CI])	
Variables	**Model 1 (*n* = 514)**	**Model 2* (*n* = 375)**
Sensory impairment		
Excellent or good hearing and excellent, good, or fair vision	Referent	Referent
A little or more hearing trouble	1.14 (0.52–2.50)	0.73 (0.30–1.77)
Poor or worse vision	**4.13 (1.37–12.43)**	2.03 (0.55–7.47)
Dual sensory impairment	**11.21 (3.30–37.99)**	**7.48 (2.09–26.71)**
Covariates		
Age (years)	**0.96 (0.94–0.99)**	**0.93 (0.90–0.97)**
Sex		
Male	Referent	Referent
Female	1.25 (0.64–2.42)	1.08 (0.49–2.34)
Race/ethnicity		
Mexican American	Referent	
Non-Hispanic white	1.54 (0.62–3.83)	1.20 (0.41–3.51)
Non-Hispanic black	1.34 (0.51–3.48)	1.24 (0.42–3.61)
Other	0.54 (0.06–4.88)	0.48 (0.03–6.03)
Comorbidities		
0 comorbidities	Referent	Referent
1 comorbidity	2.56 (0.97–6.75)	2.39 (0.69–8.23)
2 comorbidities	1.61 (0.46–5.63)	1.23 (0.26–5.75)
3 comorbidities	2.49 (0.66–9.29)	1.66 (0.35–7.75)
4+ comorbidities	2.77 (0.69–11.03)	2.22 (0.44–11.08)
Smoking (ng/ml)	1.00 (0.99–1.00)	1.00 (0.99–1.00)
BMI (kg/m^2)	1.01 (0.96–1.05)	0.99 (0.94–1.04)
Physical activity		
Engaging in MVPA in past 30 days	Referent	Referent
Not engaging in MVPA in past 30 days	1.72 (0.85–3.49)	1.02 (0.44–2.37)
A1C (%)	0.94 (0.78–1.13)	0.92 (0.73–1.16)
Physical functioning		
Able to perform activities	NA	Referent
Having much difficulty	NA	0.94 (0.23–3.84)
Unable to perform activities	NA	**3.21 (1.28–8.08)**

**Physical functioning now added to the model.*
MVPA, moderate to vigorous physical activity; NA, not applicable. Bold indicates statistical significance (P < 0.05)

Table 4. Association Between Physical Functioning and Sensory Impairment in People With Diabetes in NHANES 2005–2006

	Sensory Impairment Classification (OR [95% CI])*		
Variables	**A little or more hearing trouble**	**Poor or worse vision**	**Dual sensory impairment**
Physical functioning			
Able to perform activities	Referent	Referent	Referent
Having much difficulty	1.76 (0.87–3.53)	1.25 (0.22–7.19)	0.80 (0.08–8.18)
Unable to perform activities	1.73 (0.94–3.19)	2.78 (0.78–9.87)	2.21 (0.50–9.68)
Covariates			
Age (years)	1.01 (0.99–1.04)	0.95 (0.90–1.00)	1.05 (0.98–1.12)
Sex			
Male	Referent	Referent	Referent
Female	0.74 (0.44–1.23)	1.02 (0.34–3.06)	0.62 (0.18–2.12)
Race/ethnicity			
Mexican American	Referent	Referent	Referent
Non-Hispanic white	1.14 (0.59–2.20)	0.23 (0.04–1.11)	1.72 (0.28–10.33)
Non-Hispanic black	0.86 (0.42–1.74)	0.87 (0.25–2.92)	1.36 (0.22–8.27)
Comorbidities			
0 comorbidities	Referent	Referent	Referent
1 comorbidity	1.00 (0.49–2.04)	2.82 (0.42–18.61)	0.49 (0.08–2.79)
2 comorbidities	0.71 (0.31–1.64)	6.47 (0.82–50.56)	0.58 (0.07–4.46)
3 comorbidities	1.64 (0.66–4.05)	7.53 (0.81–69.70)	0.80 (0.08–7.90)
4+ comorbidities	1.69 (0.65–4.40)	4.45 (0.40–49.44)	0.60 (0.06–5.75)
Smoking (ng/ml)	1.00 (0.99–1.00)	0.99 (0.99–1.00)	1.00 (0.99–1.00)
BMI (kg/m^2)	0.99 (0.96–1.03)	0.96 (0.90–1.04)	1.03 (0.95–1.12)
Physical activity			
Engaging in MVPA in past 30 days	Referent	Referent	Referent
Not engaging in MVPA in past 30 days	1.18 (0.71–1.97)	2.37 (0.72–7.72)	2.40 (0.56–10.16)
Depression	1.02 (0.96–1.08)	1.03 (0.92–1.15)	**1.13 (1.02–1.25)**
A1C (%)	1.03 (0.88–1.21)	1.18 (0.89–1.56)	**1.43 (1.04–1.97)**

**Excellent or good hearing and excellent, good, or fair vision served as referent group.*
MVPA, moderate to vigorous physical activity. Bold indicates statistical significance ($P < 0.05$*).*

Additionally, given the observed associations, interventions targeted at those who already experience dual sensory impairment may be needed to prevent or treat depression symptoms.

Given that some individuals with diabetes may be at risk for sensory impairment, physical dysfunction, and depression, effective preventive and rehabilitation programs are needed. Developing such programs is not an easy task, especially for adults with diabetes who suffer from these conditions.

It is not within the scope of this article to provide a detailed overview of programs for individuals suffering from these conditions. For a detailed review of rehabilitation measures for sensory impairment, readers are referred to the thorough review by Saunders and Echt.[10] Briefly, rehabilitation for individuals with dual sensory impairment should attempt to enhance communication by ensuring that the patient-provider

environment is optimized, providing redundancy, speaking clearly, providing clear written or Braille materials, and providing assistive devices.[10]

Common treatment for depression may include counseling, antidepressant medication (e.g., selective serotonin reuptake inhibitors,[38] which may also help to regulate blood glucose levels[39]), and regular participation in physical activity.[40] Physical therapy, regular participation in home or fitness center–based structured exercise programs, and lifestyle physical activity may also serve as effective strategies to improve physical functioning among adults with diabetes.[41–43]

Based on our findings, clinicians should screen for physical functioning and depression in patients with diabetes and especially in those with hearing or vision impairments. Clinicians could use some of the described strategies in their practice to help prevent and improve depression symptoms, sensory impairment, and physical functioning. Additionally, implementation of said strategies in rehabilitation programs specializing in care for adults with diabetes may improve health outcomes, including physical functioning and psychological well-being, in this population.

Limitations of this study include the cross-sectional design, which precludes any ability to establish temporal sequence and determine causation. Also, sensory impairment and physical functioning were assessed using nonobjective measures. And finally, relatively few participants (n = 17) in the sample had dual sensory impairment. Notwithstanding these limitations, major findings of this study indicate that, among adults with diabetes, dual sensory impairment and severe physical dysfunction (i.e., individuals unable to perform various activities of daily living) are independently associated with depression.

The authors encourage future studies using a prospective design to provide evidence of cause and effect. If feasible, objectively measuring hearing and vision impairment is encouraged because it may reduce any sensory impairment misclassification that may occur with a self-report methodology. Also, larger studies are needed to ensure a sufficient sample size for those with dual sensory impairment. Finally, identification and evaluation of strategies for prevention and reduction of depression among adults with diabetes is warranted.

In summary, our results suggest that people with diabetes who have more than one sensory impairment are more likely to be depressed and may be more likely to have physical functioning limitations. This highlights the importance of preventing and improving sensory impairments, depression, and physical functioning among adults with diabetes. Additionally, and as indicated by the American Association of Diabetes Educators,[44] clinicians are encouraged to screen for signs and symptoms of depression among people with diabetes.

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