DIABETES MANAGEMENT, PHYSICAL ACTIVITY, AND DEPRESSION: INVESTIGATING THE NEXUS

A Dissertation

by

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ABSTRACT

Introduction

Diabetes is a pressing health issue both globally and in the US. Diabetes requires individual and social efforts for its successful management. This dissertation investigates how individuals' physical activity (PA) surrounded by social contexts affect persons' risk of depression in diabetes. Additionally, it evaluates the impact of the Medicaid expansion on diabetes management.

Methods

A systematic review was conducted examining the association between depression and PA in type 2 diabetes from 2000 to 2018. Logistic regression was performed to examine for potential differences in reported depression associated with levels of PA across populations using the Behavioral Risk Factor Surveillance System (BRFSS). Additionally, this dissertation evaluated the impact of Medicaid expansion on diabetes management using the 2011 to 2016 BRFSS.

Results

A systematic review found a significant association between PA and reported depression. A logistic regression analysis demonstrated that those older than age 65 had a lower risk of depression when engaging in PA, than those younger than 45. There was evidence of ethnic differences in the risk of depression associated with PA while there was no difference associated with one's genders. The evaluation of the Medicaid expansion showed significant improvements in access to healthcare, diabetes

management, and health status in states that expanded Medicaid compared to those that did not.

Discussion

This systematic review reveals is a significant association between reported depression and PA in persons with diabetes, suggesting positive effects of PA in reducing depression. Guidelines for objective measurements for depression and PA are needed to strengthen the evidence for this association and its directionality. The positive effects of PA in reducing the risk of depression is more marked among older adults than among younger adults. Medicaid expansion had a significant impact on successful diabetes management. Among states with high diabetes rates, the positive impact was substantially higher in Medicaid-expansion states than Medicaid non-expansion states, suggesting health disparities between states.

Conclusion

The association between depression and PA is confirmed. Compared to younger adults, older adults may gain greater health benefits by adopting physically active lifestyles, while there was no gender difference. Diabetes management has substantially improved in Medicaid expansion states. However, non-Medicaid expansion states with higher rates of diabetes may be facing poorer health practices and outcomes compared to Medicaid expansion states, suggesting emerging health disparities between states.

DEDICATION

I dedicate this dissertation to my family.

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Thank you God, for your love and blessings throughout my life which belongs to you.

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Contributors

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1. INTRODUCTION

According to one estimate of worldwide diabetes prevalence, our global society will have about 300 million individuals with diabetes by 2025, a significant increase from 135 million in 1995.[1] When it comes to the U.S. population, diabetes prevalence is predicted to reach one in three adults by 2050.[2] This high prevalence of diabetes is attributed to a variety of individual and social factors, such as exposure to sedentary lifestyles, environmental and social barriers to physical activity, lack of access to healthcare, failure to adhere to diabetes management, and a variety of complications associated with other diseases. Given the complicated nature of the risk of diabetes as a pressing public health issue internationally and in the U.S., control and reduction in rates of diabetes will require a multi-faceted approach to reduce the burden of the disease through individual and social efforts.

Depression and physical activity (PA) play an important role in reported ability to successfully manage and control diabetes. [3, 4] Depression often is reported concurrently with diabetes [5] and is one of the known risk factors for diabetes development [6]. In contrast, PA is known to substantially reduce the risk of depression, suggesting that active involvement in PA could contribute to the reduction of depression and, as such, successful diabetes management. In order to explore this issue, this dissertation conducted a systematic review for evidence on the association between depression and PA in persons with type 2 diabetes. In addition, this review investigated any variation of the findings concerning the association by study characteristics given a wide range of instruments of measuring depression and PA that have appeared in the literature.

Though researchers have increasingly examined the association between depression and PA in persons with diabetes, a previous review suggested that the literature has paid little attention to different reported associations between depression and PA across diabetes population subgroups, as their focus has often been on a dose-response relationship between the two elements.[7] The narrow perspective that more PA can lead to better health outcomes may obscure or potentially cast shade on another critical viewpoint that PA reflects *both* individual identities and social contexts. While individuals' engagement in and the type of PA they prefer, (if any), are their own decisions, these judgments are the result of numerous factors surrounding individual, cultural and social contexts. Among most commonly studied factors are gender, race/ethnicity, and age reflecting varying personal characteristics, cultural background, social circumstances, and geographical location of residence. [8] These more obvious population characteristics may moderate the association between depression and PA. [9, 10] Surprisingly, there is scant knowledge of the possible different risks of depression associated with PA across population groups. Therefore, this dissertation investigated the association between depression and PA in persons with diabetes by gender, race/ethnicity, and age.

Individual health behaviors or lifestyles are shaped in a social context, where local, state or national cultural practices, infrastructure and architectural planning, health policies and regulations could be the basis for persons' health practices and outcomes.

When it comes to diabetes management, a comprehensive strategy encompasses clinical diabetes care by healthcare professionals, self-management activities, and goals towards achieving short-term health outcomes. While the existing literature stream has established a positive relationship between health insurance coverage and a variety of health indicators,[11] this evidence may now be somewhat dated due to the fact that, a substantial number of Americans with diabetes were previously reported to be uninsured.[12] With Medicaid expansion created under the Affordable Care Act (ACA), we observed that the U.S. healthcare system allowed a number of states to voluntarily and optionally expand Medicaid eligibility, which enabled uninsured individuals to become newly covered by Medicaid. This was monumental restructuring of the healthcare system in modern U.S. history by national undertaking of social responsibility for citizens' health. Given the Medicaid expansion is considered to benefit persons with diabetes in their diabetes management, it increasingly became more important and relevant to evaluate the various impacts of Medicaid expansion under the ACA. Therefore, this dissertation evaluated the impact of the Medicaid expansion on diabetes management after Medicaid expansion by comparing states that opted to enact Medicaid expansion with those states which declined to expand Medicaid.

Through a series of investigations in the context of diabetes, the aims of this dissertation are to provide evidence and policy observations and implications for both individuals with diabetes and to provide further evidence for policymakers in their efforts to find better ways for successful diabetes management and control.

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2. ASSOCIATION BETWEEN DEPRESSION AND PHYSICAL ACTIVITY IN TYPE 2 DIABETES, 2000-2018: A SYSTEMATIC REVIEW

2.1. Introduction

Worldwide prevalence of diabetes is expected to reach 300 million by 2025, a significant increase over three decades from a prevalence of 135 million in 1995.[1] The World Health Organization (2003) has suggested that by year 2030, 350 million people will be diagnosed with type 2 diabetes (T2DM), which accounts for 90–95% of all diabetes cases.[2] Individuals with T2DM frequently suffer from higher levels of depressive symptoms than the general population.[3] A meta-analysis published over a decade ago estimated that the prevalence of depression in people with T2DM is around 17.6%, which is about two times that of the general population.[4] The health impact of depression diagnosed as a comorbidity in persons with T2DM is substantial. Depression as a co-morbidity associated with T2DM is estimated to account for mortality rates 1.6–2.3 times higher than in T2DM without depression.[5] Depression is also diagnosed concurrently with a variety of diabetes-related complications, such as peripheral neuropathy, renal failure and lower-extremity amputation.[6,7]

Physical activity (PA) has been shown to reduce depression in the general population as known to have an antidepressant effect,[8,9] and many advocate regular exercise to help to alleviate depressive symptoms.[10,11,12] Although it is recommended that people get vigorous PA on a regular basis, even moderate doses of PA is shown to reduce the risk that someone will experience depressive symptoms.[13] Moreover, a lack of PA is a substantial risk factor for developing depression.[14] The literature has suggested that there is a significant relationship between depression and physical inactivity [15] and a two-fold risk of depression in inactive people compared to in those who engage in regular PA.[16]

Given the high prevalence of *both* depression and physical inactivity in persons with diabetes, [4,17,18] researchers have argued that the association between depression and PA in diabetes could vary from that in the general population [19] and that depression could be reduced with improved health outcomes by prescribing PA as an element of routine diabetes care. [20] Lysy, et al conducted a review of the literature on the association between depression and PA, concluding that there was a significant association in the context of T2DM. [21] Heijden et al found that studies on the effects of exercise reported conflicting findings regarding the existence of depression. [22] A more recent systematic review (2014) with studies conducted from 2000 to 2012 suggested a significant and negative association between depression and positive PA adherence in T2DM. [23] Previous reviews have included studies with a variety of different methodologies, except Heijden et al's study, which focused on randomized controlled trials. In addition, previous reviews searched multiple databases from three to seven to identify relevant articles.

Despite the contribution of previous literature reviews to the body of knowledge, reported literature reviews have not investigated or compared the way researchers have employed survey instruments to measure depression and PA and the potential effects this may have had on their findings. In fact, there are a variety of survey measurement options for evaluating the presence of PA *and* depression raising a host of questions about the types of instruments and their effect on the strength of association found for PA and depression. In addition, previous reviews did not report their quality assessment methodology in detail, although Sumlin et al's review [23] briefly discussed a few of their appraisal criteria.

Given this ambiguity in the reported literature, the aim of this study was to review evidence for the association between depression and PA in persons with reported T2DM. Our emphasis is on this association with respect to the survey measures used to assess depression and PA as well as the study designs and settings. This review set out to answer the following questions:

1. Which survey instruments have researchers used to measure PA and depression?
2. What were the settings and designs of these studies?
3. What was the association between depression and PA in T2DM given individual study characteristics?

2.2. Methods

This systematic review included studies based on eligibility criteria as follows;

- Population – persons diagnosed with T2DM
- Types of study – observational studies
- Findings – studies reporting an association between PA & depression
- Period - January 2000 through December 2018
- Publication status – no restriction
- Language - English

Searches were conducted in Medline (Ovid), Embase (Ovid), CINAHL (Ebsco), and PsycINFO (Ebsco) combining the concepts of diabetes, depression, and physical activity. See Table 1 for the Medline (Ovid) search, conducted on July 20, 2018 and January 8, 2019. The searches derived from other databases were translated from the Medline search and retrieved through December 31, 2018. The search protocol was registered in PROSPERO (http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42018104877).

Table 2.1 Medline (Ovid) search

1. DIABETES MELLITUS/ or exp DIABETES MELLITUS, TYPE 2/
2. diabet*.ti,ab.
3. or/1-2
4. exp DEPRESSION/
5. depression.ti,ab.
6. or/4-5
7. exp Exercise/
8. exp Physical Fitness/
9. exp SPORTS/
10. (exercise or sport*).ti,ab.
11. (physical adj2 (activit* or fitness)).ti,ab.
12. or/7-11
13. 3 and 6 and 12

2.2.1. Study selection

Two authors conducted the database review employing a two-stage screening procedure. First, each author scanned the titles and abstracts of studies to determine eligibility. Articles that might meet the inclusion criteria were retained for further review. In the second stage, investigators reviewed the full text of articles to determine whether they met the eligibility requirements. The discrepancy between reviewers was about 2% and a consensus was reached through discussion.

2.2.2. Data collection

A data extraction form was created in Microsoft Excel and was subsequently tested and refined by the authors. One investigator conducted data extraction and entered data into the table. Data included the author, setting, design, and results of the study. It also included the sample size, the age and gender of participants, the year and country in which the study was conducted, the measures authors used to assess PA and depression, and the follow-up procedure (for longitudinal studies). Another investigator independently assessed the extracted information. In the case of disagreement, a consensus was reached through discussion.

2.2.3. Quality assessment

Included articles were assessed for quality using critical appraisal tools from the Joanna Briggs Institute (JBI). [24] The JBI is a recognized tool for literature review extraction and has been provided or made publicly available (http://joannabriggs.org/research/critical-appraisal-tools.html). It includes an eight-item checklist for cross-sectional studies. The checklist for prospective studies includes 11 items, of which eight were applicable to the included studies. While the two study designs had some items in common, the prospective study checklist included additional items related to follow-up. Included studies were independently assessed by two authors. After the initial assessment, the authors discussed any disagreements in order to reach a consensus.

2.3. Results

2.3.1. Sample

The initial search identified 2,294 articles and an additional 24 articles were included as a result of searching references of the reviewed articles (Figure 2. 1). After removing 835 duplicates, we screened 1,347 articles by scanning titles and abstracts, which yielded 136 (5.9%) articles. A full-text review excluded 106 articles that did not meet eligibility criteria. In total, 30 articles (1.3%) met the criteria for this systematic review. [20, 25-53]

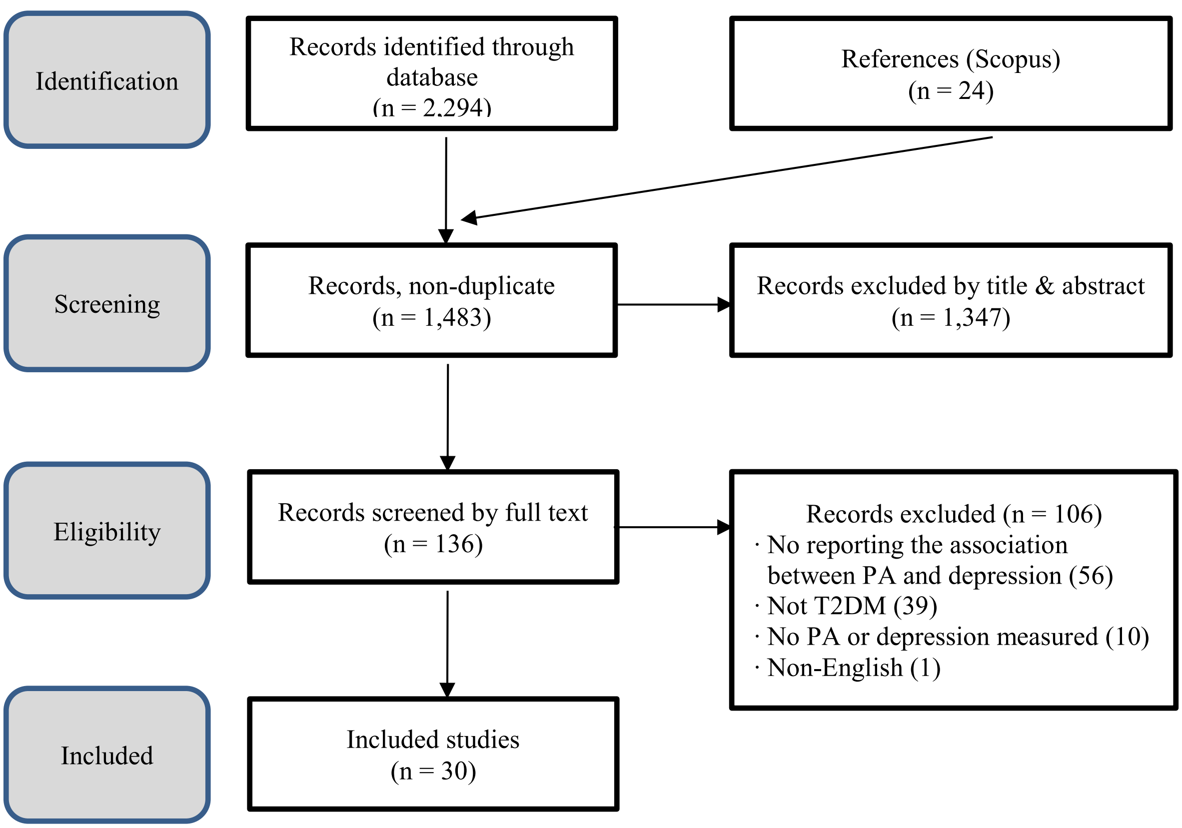

Figure 2.1 Flow diagram of a systematic review

Table 2.2 Characteristics of cross-sectional studies by year (n=22)

Author, year, country	Sample	Setting	Depression		Physical Activity (PA)			Results
			Instrument	Measure	Instrument	Measure	Scope	
Park et al 2004 [25] South Korea	N=168 Male 60% Mean age 49.5 (SD 9.2)	Clinical	CES-D	20 items	Study-specific	Regular PA/ Not	Leisure	OR= 1.10 (95%CI 1.03-1.18)
Vickers et al 2006 [26] US	N=207 Male 48.3% Mean age 63 (SD 12)	Clinical	CES-D	20 items	CHAMPS	Frequency of all exercise-related activities per week	Leisure/Non-leisure/work	Ratio Est.= 0.99 (p=0.22)
Fisher et al 2007 [27] US	N=506 Male 41.3% Mean=57.8 (SD 9.9)	Community	CES-D CIDI	20 items 9 items	IPAQ	Minutes of PA	Leisure/Non-leisure/work	β= -37.90 (p=<0.01) CES-D β= 35.86 (p>=0.05) CIDI
Gonzalez et al 2007 [28] US	N=879 Male 47% Mean age 66.2 (SD 12.4)	Clinical	HANDS	10 items	SDSCA	Days of at least 30 minutes PA last week	Leisure/Non-leisure	β= -0.17 (p=<0.001)
Gonzalez et al 2008 [29] US	N=848 Male 52.4% Mean age 66.2 (SD 12.4)	Clinical	HANDS	10 items	SDSCA	Days of at least 30 minutes PA last week	Leisure/Non-leisure	β= -0.42 (p=<0.001)
Koopmans et al 2009 [30] Netherland	N=2,646 Male ~= 50% Mean age 68	Clinical	EDS	10 items	Study-specific	Active/inactive	Leisure/Non-leisure	OR= 1.74 (95%CI 1.32-2.31)
Yang et al 2009 [31] China	N=148 Male 38.5% Mean age 66.4 (SD 10.8)	Community	ZSDS	20 items	Study-specific	Regular PA/Not	Leisure	β= -0.26 (P=0.00)
Bell et al 2010 [32] US	N=696 Male 50.7 Mean age 74.1	Community	CES-D	20 items	SDSCA	Days of at least 30 minutes PA last week	Leisure/Non-leisure	OR= 0.5 (95%CI 0.2-0.9)
Fisher et al 2010 [33] US	N=463 Male 49.5 Mean age 58.8 (SD 9.1)	Clinical	PHQ-8	8 items	CHAMPS	Frequency of all exercise-related activities per week	Leisure	β= -0.03 (p>0.05)

Table 2.2 Characteristics of cross-sectional studies by year (n=22) - Continued

Author, year, country	Sample	Setting	Depression Instrument	Depression Measure	Physical Activity (PA) Instrument	PA Measure	PA Scope	Results
Daniele et al 2013 [34] Brazil	N=200 Male 41% Mean age 52.7 (SD 5.6)	Clinical	BDI	21 items	IPAQ	Minutes of PA	Leisure/Non-leisure/work	β= 0.01 (p=0.66)
Walker et al 2014 [35] US	N=615 Male 61.6% Mean=61.3 (SD 10.9)	Clinical	PHQ-9	9 items	SDSCA	Days of at least 30 minutes PA last week	Leisure/Non-leisure	β= -0.15 (p=<0.05)
Kim et al 2015 [36] South Korea	N=311 Male 60.5% Mean age 58.7 (SD 11.7)	Clinical	CES-D	20 items	SDSCA	Days of at least 30 minutes PA last week	Leisure/Non-leisure	β= -0.112 (p=0.049)
Park et al 2015 [37] South Korea	N=753 Male 58.6% Mean age 55.5 (SD 8.2)	Community	BDI	21 items	Study-specific	Regular PA/Not	Leisure	OR= 1.46 (95%CI 0.96-2.23) for moderate (BDI>16) OR= 1.70 (95%CI 1.02-2.82) for severe (16<=BDI <24)
Smith al 2015 [38] Canada	N=2,028 Male 49.8% Mean age 60.5 (SD 8.4)	Community	PHQ-9	9 items	Study-specific	Days of at least 15 minutes of moderate to strenuous PA last month	Leisure	OR= 1.98 (95%CI 1.23-3.17)
Hernandez et al 2016 [39] US	N=250 Male 32% Mean age 53.2 (SD 12.3)	Clinical	PHQ-9	9 items	SDSCA	Days of at least 30 minutes PA last week	Leisure/Non-leisure	β= -0.042 (p<0.01)

Table 2.2 Characteristics of cross-sectional studies by year (n=22) - Continued

Author, year, country	Sample	Setting	Depression		Physical Activity (PA)			Results
			Instrument	Measure	Instrument	Measure	Scope	
Wang et al 2016 [40] US	N=2,182 Male 48.7% Age 30+	Community	PHQ-9	9 items	GPAQ	Meeting PA guidelines or not	Leisure/Non-leisure/work	OR= 0.4 (95%CI 0.2-0.7)
Johnson et al 2016 [41] Canada	N=2,040 Male 55% Mean age 64.4 (SD 10.6)	Community	PHQ-8	8 items	GLTEQ	Moderate-to-vigorous PA (score≥150 min) or no	Leisure	OR= 1.4 (95%CI 0.7-2.7) for any depressive symptom
Holmen et al 2016 [42] Norway	N=151 Male 59% Median age 58 (R 20-80)	Clinical	CES-D	20 items	Norwegian study HUNT3	Active/Inactive	Leisure	OR= 2.86 (95%CI 1.17-7.01)
Lee et all 2017 [43] Taiwan	N=696 Male 41.7% Mean age 68.2 (SD 9.5)	Clinical	CGDS-SF	15 items	Study-specific	Regular PA/Not	Leisure/Non-leisure	OR= 2.67 (95%CI 1.63-4.36)
Craike et al 2017 [44] Australia	N=705 Male 49.9% Mean age 58.9 (SD 8.3)	Community	PHQ-9	9 items	IPAQ	Low/moderate/high by MET minutes	Leisure/Non-leisure/work	n_p^2= 0.04, p<.001
Naicker et al 2017 [45] Norway	N=2,035 Male 51.1% Mean age 64.9	Community	CONOR-MHI	3 items	Study-specific	Regular PA/Not	Leisure	OR= 1.23 (95%CI 1.08-1.40) for men OR= 1.42 (95%CI 1.28-1.58) for women
Nanayakkara et al 2018 [46] Australia	N=2,552 Male 52.1% Mean age 63 (SD 13)	Clinical	BCD	4 items	NPAGA	Sufficient/Not	Leisure/Non-leisure	OR= 0.84 (95%CI 0.67-1.05)

Table 2.3 Characteristics of longitudinal studies by year (n=8)

Author, year, country	Sample	Setting	Depression		Physical Activity			Follow-up	Results
			Instrument	Measure	Instrument	Measure	Scope		
Gonzalez et al 2008 [20] US	N=208 Male 51% Mean age 65.5 (SD 11.6)	Clinical	HANDS	20 items	SDSCA	Days of at least 30 minutes PA last week	Leisure/ Non-leisure	9 months	β= -0.12 (p=0.046)
Aikens 2012 [47] US	N=253 Male 50% Mean age 57.3 (SD 8.3)	Clinical	PHQ-9	9 items	SDSCA	Days of at least 30 minutes PA last week	Leisure/ Non-leisure	6 months	β= -0.25 (p=0.001)
Messier et al 2013 [48] Canada	N=1,183 Male=46.4% Age range 18-80	Community	PHQ-9	9 items	Study-specific	Days of at least 15minutes PA last month	Leisure	1 year	OR=1.71 (95%CI 1.02-2.90)
Swardfager et al 2015 [49] Canada	N=624 Male 47% Mean age 55.6 (SD10.5)	Clinical	CES-D	20 items	Study-specific	Completion /Non-completion (12 weekly & 3 monthly exercise sessions for 6 months)	Exercise	6 months	HR = 1.67 (95%CI 1.13-2.48) for women HR = 1.23 (95%CI 0.73-2.01) for men
Palakodeti et al 2015 [50] US	N=6,853 Male 48.6% Mean age 60.2	Clinical	Study-specific	-	Study-specific	Meet recommendation (PA>150 per week)/Not	Leisure/ Non-leisure	6.2 months	OR = 0.77 (0.62-0.96)
Lin et al 2017 [51] Taiwan	N=13 Male 53.8% Mean age 48.2 (SD 4.1)	Clinical	BDI	21 items	Study-specific	Aerobic exercise training (3 sessions of 30 minutes exercise per week)	Exercise	12 weeks	β= -2.6 (p<0.001)
Ivanova et al 2017 [52] Canada	N=1,691 Male 50.9% Mean age 63.9 (SD 6.8)	Community	PHQ-9	9 items	Study-specific	Days of at least 15 minutes PA last month	Leisure	2 years	β = -.06 (p>.05)
Oh et al 2017 [53] US	N=387 Male 17.8% Age>=50 - 72.1%	Clinical	PHQ-9	9 items	SDSCA	Days of at least 30 minutes PA last week	Leisure/ Non-leisure	12 months	β= .09 (p<0.05)

2.3.2. Characteristics

In Tables 2.2 and 2.3, the characteristics of included studies are shown. Of 30 studies in this review, the summary statistics (Table 2.4) show that 22 were cross-sectional, [25-46] and eight were longitudinal. [20, 47-53] While 10 studies were conducted prior to 2011, [20, 25-33] 20 were conducted after that time. [34-53] There were 19 studies conducted in clinical settings [20, 25-26, 28-30, 33-36, 39, 42-43, 46-47, 49-51, 53] and 11 were community-based. [27, 31-32, 37-38, 40-41, 44-45, 48, 52] Included studies had sample sizes ranging from 13 [51] to 6,853. [50] The mean age of participants in the majority, 83.3% of studies was between 50 and 75. In longitudinal studies, the follow-up period ranged from 12 weeks [51] to 24 months. [52] Thirteen studies were conducted in the United States [20, 26-29, 32-33, 35, 39-40, 47, 50, 53] and the rest were conducted in a variety of countries worldwide. Studies used a range of ten standard instruments to measure depression and seven to measure PA; however, there were a considerable number of studies using individual study-specific measures for PA. [25, 30-31, 37-38, 43, 45, 48-52] The characteristics of included studies both before and after 2011 have been analyzed in Figure 2. 2, which could provide the propensity of adopting instruments in recent years as opposed to previous years. Before 2011, seven of 10 studies were conducted within clinical settings. After 2011, this figure was 12 out of 20. Before 2011, three of 10 studies were conducted in community settings [27, 31-32] and after 2011, this figure was eight out of 20. [37-38, 40-41, 44-45, 48, 52] Of those studies that were included before 2011, nine were cross-sectional, [25-33] while one was longitudinal. [20] However, 13 of the included studies after 2011 were cross-sectional, [34-46] while seven were longitudinal. [47-53]

Table 2.4 Frequency of sample studies by characteristics

		N	%			N	%
	Total	30	100		Total	30	100
Depression*				PA scope			
	PHQ-9 or PHQ-8	11	35.5		Leisure	10	33.3
	CES-D	7	22.6		L + N	13	43.3
	HAND	3	9.7		L + N + W	5	16.7
	BDI	3	9.7		Exercise training	2	6.7
	EDS	1	3.2	Setting			
	ZSDS	1	3.2		Clinical	19	63.3
	GDS	1	3.2		Community	11	36.7
	BCD	1	3.2	Design			
	CONOR-MHI	1	3.2		Cross-sectional	22	73.3
	CIDI	1	3.2		Longitudinal	8	26.7
	Study specific	1	3.2	county			
PA Instrument					US	13	43.3
	SDSCA	9	30.0		Canada	5	16.7
	IPAQ	2	6.7		Europe	3	10.0
	CHAMPS	3	10.0		South America	1	3.3
	GLTEQ	1	3.3		Asia-pacific	8	26.6
	HUNT3	1	3.3				
	NPAGA	1	3.3				
	GPAQ	1	3.3				
	Study specific	12	40.0				

Note: *Depression is 31 count in total as one study used two instruments. L + N indicates Leisure + Non-leisure activity and L + N + W indicates Leisure + Non-leisure + Work activity.

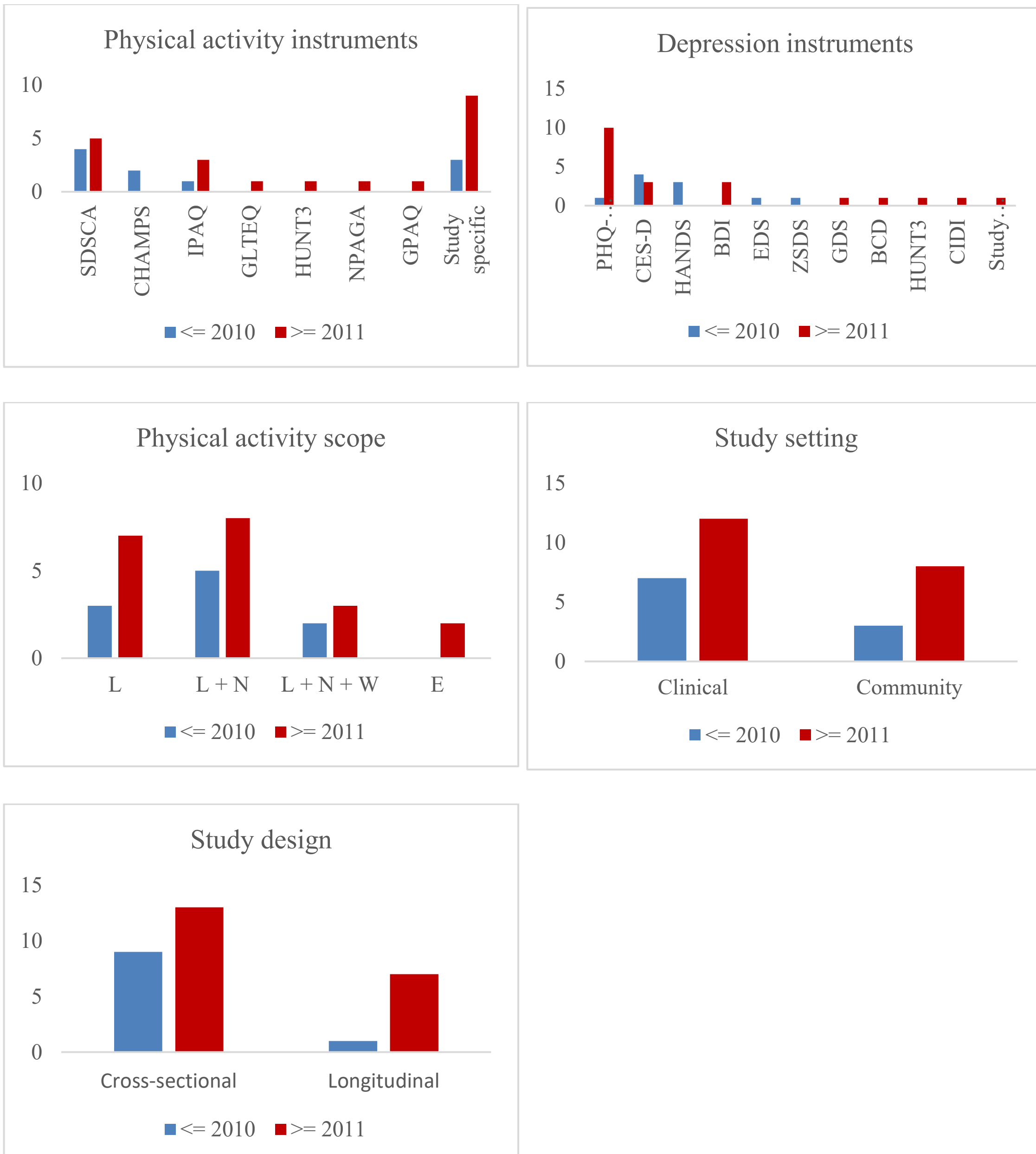

Figure 2.2 Frequency of sample studies by time periods

Note: In physical activity scope, L, N, W, and E indicates Leisure, Non-leisure, Work-related, and exercise training, respectively.

2.3.3. Depression

Studies included in this analyses were found to have utilized or adopted a wide variety of instruments to measure depression. These instruments have emerged only in recent decades. For example, the *Beck Depression Inventory* (BDI) [54] and the *Zung Self-Rating Depression Scale* (ZSDS) [55] were developed in the 1960s and validated in clinical and population studies, followed by the *Centers for Epidemiologic Studies-Depression* (CES-D), [56] *Geriatric Depression Scale* (GDS), [57] the *Edinburgh Depression Scale* (EDS), [58] and the *Composite International Diagnostic Interview* (CIDI) [59] in the 1970s and 1980s. Yet more instruments were developed during the 1990s, such as the *Patient Health Questionnaire-9* (PHQ-9), [60] the *Harvard National Depression Screening Day Scale* (HANDS), [61] the *Brief Case-Find for Depression* (BCD), [62] and the *Cohort of Norway Mental Health Index* (CONOR-MHI), [63] which have been validated in multiple settings. The most frequently used instruments were the PHQ-9 or PHQ-8 (n = 11) [33, 35, 38-41, 44, 47-48, 52-53] and the CES-D (n = 7) [25, 26, 27, 32, 36, 42, 49,] followed by the HANDS (n = 3) [20, 28-29] and the BDI (n = 3). [34, 37, 51] Before 2011, the CES-D (n = 4) [25-27, 32] and the HANDS (n = 3) [20, 28-29] were the most popular measures; together they accounted for 64% out of the 11 measures during that period. In contrast, from 2011, 10 out of 20 studies adopted the PHQ-9/PHQ-8. [35, 38-41, 44, 47-48, 52-53] This was a large increase from only one study prior to 2011. [33] The number of studies using the CES-D decreased from four out of 10, (40%), before 2011 [25-27, 32] to three out of 20, (15%), after. [36, 42, 49]

2.3.4. Physical Activity (PA)

Different PA measures were used in the studies included in this review. These included the *Godin Leisure-Time Exercise Questionnaire* (GLTEQ), [64] *Nord-Trøndelag Health* (HUNT), [65] and the *Summary of Diabetes Self-Care Activities Assessment* (SDSCA), [66, 67] which were introduced in the 1980s and validated in population studies. The *Community Healthy Activities Model Program for Senior*s (CHAMPS), [68] and *National Physical Activity Guidelines for Australians* (NPAGA), [69] and the *International Physical Activity Questionnaire* (IPAQ), [70] were developed during the 1990s, and the *Global Physical Activity Questionnaire* (GPAQ) was developed most recently. [71] Out of the 30 studies included in this systematic review, the most frequent instruments were individual study-specific measures (n = 12), [25, 30-31, 37-38, 43, 45, 48-52] followed by the SDSCA (n = 9) [20, 28-29, 32, 35-36, 39, 47, 53] and IPAQ (n = 3). [27, 34, 44] Prior to 2011, four studies used the SDSCA, [20, 8-29, 32] followed by individual study-specific measures (n = 3). [25, 30, 31] However, after 2011, study-specific measures were used in nine studies, [37-38, 43, 45, 48-52] followed by the SDSCA, which was used in five studies. [35-36, 39, 47, 53] Approaches by which PA was measured varied depending on the instrument used. Some tools measured both leisure and non-leisure activities (n = 13), [20, 28-30, 32, 35-36, 39, 43, 46-47, 50, 53] while some only measured leisure activities (n = 10). [25, 31, 33, 37-38, 41-42, 45, 48, 52] These studies accounted for 76.7% of those included. Other studies used a comprehensive measurement strategy, which included work-related activities in addition to leisure and non-leisure activities (n = 5) [26-27, 34, 40, 44] and some adopted exercise training (n = 2). [49, 51]

2.3.5. Association between depression and Physical Activity

Overall, five studies reported associations between depression and PA for subpopulations, which this review treated as separate associations, resulting in the identification of a total of 35 associations (Table 2.5).[27, 37, 41, 45, 49] Of these 35 results, 25 reported a significant association (71.4%). Significant associations were found in 15 clinical settings [20, 25, 28-30, 35-36, 39, 42-43, 47, 49-51, 53] and 10 community settings.[27, 31-32, 37-38, 40, 44-45, 48] However, there was no statistically significant difference in the findings of associations between study settings according to the Fisher's exact test ($p = 0.71$). In 18 out of 26 cross-sectional studies,[25, 27-32, 35-40, 42-45] and seven out of nine longitudinal studies,[20, 47, 48-51, 53] significant associations were found. The PHQ, CES-D, and other instruments showed a significant association in eight out of 12,[35, 38-40, 44, 47-48, 53] six out of eight,[27, 32, 36, 42, 49] and 11 out of 15 studies,[20, 28-31, 37, 43, 45, 50-51] respectively. Many of the studies that investigated leisure and non-leisure activities (12 out of 13),[20, 28-30, 32, 35-36, 39, 43, 47, 50, 53] exercise training (two out of three),[49, 51] and leisure activities (eight out of 13)[25, 31, 37-38, 42, 45, 48] found significant associations, while relatively fewer studies with a comprehensive measure found significant associations (three out of six).[27, 40, 44] A similar percentage of studies reported significant associations before (eight out of 11)[20, 25, 27-32] and after 2011 (17 out of 24).[20, 35-40, 42-45, 47-51, 53]

Among studies classified as high quality or high reliability as a result of quality assessment, meeting at least 80% of the assessment criteria, 18 out of 22 studies found a significant association,[25, 27-32, 35-40, 42-45, 48, 53] an increase to 81.8% from 71.4% of the overall sample (Table 2.6). Accordingly, across study characteristics, the percentage of studies that found a significant association was greater than those of the overall sample. As in the overall sample, the difference in the reported findings of associations among categories in study characteristics was statistically insignificant.

Table 2.5 Summary of association between physical activity and depression in T2DM by sample characteristics

		Frequency		%		P*
		No	Association	No	Association	
Overall		10	25	28.6	71.4	
Setting						0.71
	Clinical	5	15	25.0	75.0	
	Community	5	10	33.3	66.7	
Design						1.00
	Cross-sectional	8	18	30.8	69.2	
	Longitudinal	2	7	22.2	77.8	
Depression						1.00
	PHQ	4	8	33.3	66.7	
	CED-S	2	6	25.0	75.0	
	Other	4	11	26.7	73.3	
PA instrument						0.46
	Study specific	3	12	20.0	80.0	
	Validated	7	13	35.0	65.0	
PA scope						0.14
	Leisure	5	8	38.5	61.5	
	Leisure + Non-leisure	1	12	7.7	92.3	
	Leisure + Non-leisure + work	3	3	50.0	50.0	
	Exercise training	1	2	33.3	66.7	
Year						1.00
	<=2010	3	8	27.3	72.7	
	>=2011	7	17	29.2	70.8	

*Statistical significance is set at 5% level (Fisher's exact test)

Table 2.6 Summary of association between physical activity and depression in T2DM by sample characteristics using only studies assessed as high quality

		Frequency		%		P*
		No	Association	No	Association	
Overall		4	18	18.2	81.8	
Setting						0.59
	Clinical	1	9	10.0	90.0	
	Community	3	9	25.0	75.0	
Design						1.00
	Cross-sectional	4	16	20.0	80.0	
	Longitudinal	0	2	0.0	100.0	
Depression						0.63
	PHQ	2	6	25.0	75.0	
	CED-S	0	5	0.0	100.0	
	Other	2	7	22.2	77.8	
PA instrument						0.26
	Study specific	0	7	0.0	100.0	
	Validated	4	11	26.7	73.3	
PA scope						1.00
	Leisure	2	7	22.2	77.8	
	Leisure + Non-leisure	1	8	11.1	88.9	
	Leisure + Non-leisure + work	1	3	25.0	75.0	
	Exercise training	-	-			
Year						1.00
	<=2010	1	6	14.3	85.7	
	>=2011	3	12	20.0	80.0	

*Statistical significance is set at 5% level (Fisher's exact test)

2.3.6. Quality assessment

In studies with a cross-sectional design (n = 22), 21 measured independent [25-39, 41-46] and outcome variables [26-46] using instruments validated in previous studies (Figure 2. 3). Twenty studies used objective and standard criteria such as blood glucose or hemoglobin A1c levels to diagnose T2DM by clinicians. [25-31, 33-36, 38-46] In total, 20 studies identified confounding factors, such as demographic and socioeconomic status, 20 dealt with them, [25-26, 28-39, 41-46] and 18 used appropriate statistical methods to do so. [25-30, 32, 35, 37-46] However, seven of the included studies failed to clearly define inclusion/exclusion criteria as they often did not describe their eligibility criteria of study participants in detail.[26, 30, 33, 35, 37, 41, 44] While 18 studies described study subjects properly, [25, 27-29, 31-32, 34-46] others were not clear enough about the time of data collection or methods of recruiting participants. In addition, two studies failed to describe how they identified confounders, [33-34] one failed to describe an outcome variable (PA) sufficiently,[25] and four were vague about describing appropriate statistical methods. [31, 33-34, 36]

Of the eight longitudinal studies included in the study, seven measured both explanatory [20, 47-51, 53] and outcome variables [20, 47-49, 51-53] in a valid and reliable way (Figure 2. 4). All studies identified confounders and addressed those using appropriate statistical methods. However, prospective studies did not perform as well. Only four clearly described completeness or loss of follow-up, [48, 51-53] and three had a sufficient follow-up time. [48, 52-53] Only one study had a strategy to address study drop outs, [20] while seven studies were either unclear or did not mention any strategy.[47-53]

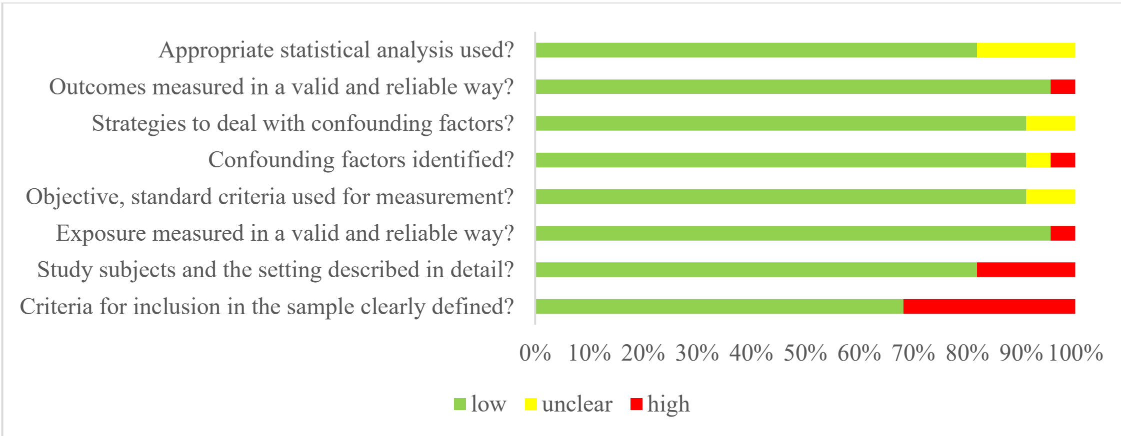

Figure 2.3 Critical appraisal of cross-sectional studies

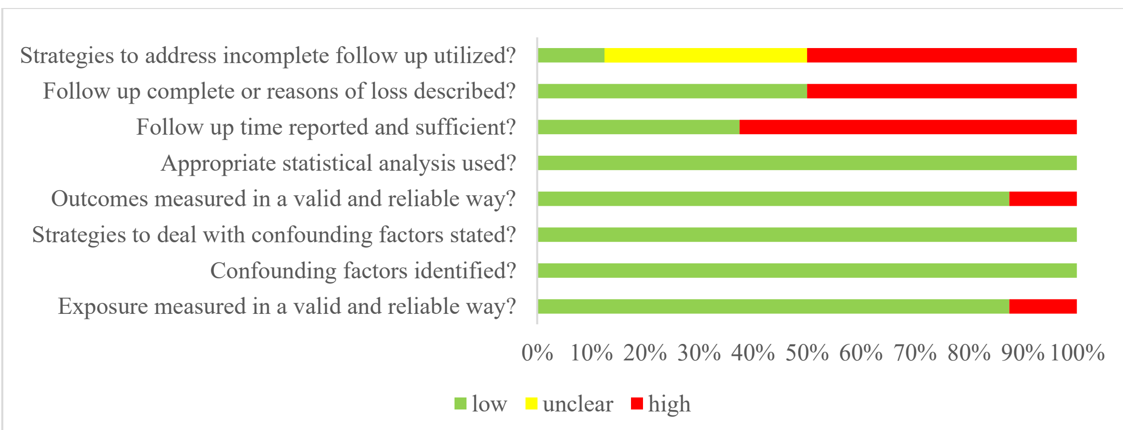

Figure 2.4 Critical appraisal of longitudinal studies

2.4. Discussion

This study systematically reviewed the literature to identify patterns in the associations found between depression and PA in patients with T2DM by looking at study settings, study designs, and the survey instrument tools used to measure depression and PA. The studies generated as a result of our selection criteria used various tools to measure depression and PA. Within the findings reviewed, 71% of the studies suggested a significant and inverse association between depression and PA in people with T2DM, which is consistent with the conclusions of previous reviews. [21, 23] Moreover, when considering only those assessed as highly reliable after quality assessment, about 82% reported a significant association. Despite some variation in the findings of studies by characteristics, a Fisher's exact test showed that it was not significant.

The PHQ survey instrument was used by the majority of studies to measure depression. The PHQ has been widely implemented in clinical and epidemiological studies, which might have influenced its popularity. [72, 73] Many studies adopted individual study-specific, measures for PA. This suggested a lack of standardized tools applicable to a range of contexts for measuring PA. [21, 74] Another issue when examining the effect of PA on health outcomes is its variability of the measurement scope [75, 76] as the majority of studies incorporated either leisure activities alone or both leisure and non-leisure activities. Only five studies adopted a comprehensive measurement that included leisure, non-leisure, and work-related activities, and half of these reported a significant association between PA and depression. This apparent emerging awareness of other factors suggests that more studies need to reflect the multi-dimensional nature of PA.

This systematic review likewise revealed that between 66.7% and 77.8% of studies found significant associations between PA and depression regardless of their settings and designs. The consistency of these findings suggested a robust association between depression and PA in persons with T2DM. However, many of the reviewed studies were cross-sectional, and further longitudinal studies are needed to strengthen this evidence. Literature on the relationship between depression and PA is still vague about directionality. [20] Well-designed prospective studies could help to improve the body of knowledge in this respect. Furthermore, as PA is a key lifestyle behavior that promotes health, [77] additional studies in the population in real-life settings may provide a more balanced view of the relationship.

Cross-sectional studies tended to be more reliable in meeting several items of the quality appraisal criteria. They tended to be more clear about how the authors identified and dealt with confounders and how they measured explanatory and outcome variables. However, approximately 32% (N = 7) of cross-sectional studies failed to define their inclusion criteria clearly, and some, (N = 4) did not describe study subjects sufficiently. Future studies should be specific about recruitment procedures and inclusion criteria. Many longitudinal studies demonstrated robust measurements of key independent and outcome variables. They also identified confounders and used appropriate statistical methods to deal with them. However, sufficient follow-up of participants was often missing, and this is critical in prospective studies. Many followed up after a few weeks or months, much less than one year later. [78] Many longitudinal studies also failed to explain the reason of loss clearly and how they addressed incomplete follow-up. Limitations in study quality may keep researchers from demonstrating robust findings or making conclusions about the association.

Lysy, et al noted a scarce literature stream for studies identifying variations in this association among populations with different characteristics. [21] Our review confirmed this finding as well. Future studies may be well-advised to focus on the questions raised here in order to respond to the specific health issues of population sub-groups.

2.5. Limitation

As with any study there are limitations in this systematic review. First, this review included only observational studies. Specifically, this was necessary because the focus of this review was to understand a variety of measurements of PA and depression and how they reached different findings given the broad range of different measurement types that have appeared in observational studies. Nevertheless, future studies would significantly expand our knowledge and understanding of the strength of the association between depression and level of PA, if they included all types of studies to see if there is any other pattern of measurements and findings. Second, although the literature validated PA and depression instruments, many relied on self-reports, which is viewed skeptically by some because of the danger of introducing the possibility of measurement error. A third noted limitation is that only five studies measured PA in a comprehensive way, such as leisure, non-leisure, and work-related activities. In the future, objective measurements accounting for a wide scope of PA could improve studies in this area, which could increase confidence in findings. Fourth, individual study-specific measures for PA accounted for the majority. Their high frequency might undermine the validity or reliability of the findings of this review.

Well-validated PA measurements are critical in examining the associations between PA and health outcomes. Public health policy specialists and researchers should, therefore, seriously consider setting standardized guidelines for measuring PA that are widely accepted. Fifth, a limited number of longitudinal studies (eight out of 30) were available, and many of them had relatively short follow-up periods. To better synthesize findings on the relationships studied in this review, more research with an extended follow-up time is necessary.

Despite these limitations, the present systematic review suggests that the association between depression and PA in diabetes is significant, although the direction appears ambiguous. It identified instruments for PA and depression and analyzed the association between them in the context of study characteristics, while addressing what is missing in the literature.

2.6. Conclusion

This systematic review showed that a significant number of studies used the PHQ-9 and PHQ-8 to measure depression and individual study-specific measures for PA. A majority of studies reported a significant association between depression and PA. The findings provide evidence for health benefits of PA on reducing depression in persons with diabetes, suggesting active engagement in PA for effective diabetes management. However, guidelines for objective measurements and well-designed prospective studies are needed to strengthen the evidence base for this association and its directionality. Furthermore, there is a growing need for studies examining variation in this association between populations with different characteristics. Future studies will contribute to the body of literature by addressing the limitations of existing studies and meeting the need for further evidence on this topic.

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3. DIFFERENCE IN THE RISK OF DEPRESSION ASSOCIATED WITH PHYSICAL ACTIVITY STATUS IN DIABETES: ACROSS AGE, GENDER, AND RACE/ETHNICITY

3.1. Introduction

The CDC's 2015 National Diabetes Statistics Report estimated that 9.4% of the US population (30.3 million people) have a diagnosis of diabetes. [1] The figure is much higher among adults aged 18 or older where the percent of adults diagnosed with diabetes is 12.2%. [2] Persons with diabetes often report co-occurring depression. As one of the major mental disorders in the US, depression is an important chronic health condition occurring as a comorbidity with diabetes. [3] Evidence suggests that people with diabetes are at a higher risk of reporting depressive symptoms than those without diabetes. [2, 4] In fact, estimated 20% to 40% of individuals with diabetes experienced depressive symptoms, [3, 5] Proper management at an early stage of depression is significant to prevent further progress of the disease.[6] The high prevalence of depression in persons *also* diagnosed with diabetes suggests that depression is a substantial health concern necessitating further scientific examination and analysis to understand health behaviors that contribute to effective diabetes management that also focuses on reducing depression.

While depression is a critical concern in the management of diabetes, physical activity (PA), a health behavior effective in reducing the risk of depression, may have an ameliorative effect on diabetes. Experimental studies have found that PA is an important factor in diabetes management, as it helps to control weight and blood pressure and improves glycemic levels. [7, 8, 9] In addition, a significant association between depression and PA in persons with diabetes has been reported in a number of cross-sectional [10, 11, 12] and longitudinal studies. [13, 14] Systematic reviews synthesizing existing evidence have concluded that an inverse association between depression and PA exists for persons with diabetes. [15, 16]

Though the association between depression and PA in diabetes has been widely examined, Lysy, et al. (2008) noted that there is a scarcity of studies that have investigated the risk of depression associated with PA across varying populations. [17] Research concerning PA has focused mainly on its quantitative or functional components— such as duration, frequency, and intensity—with an assumption of a dose-response relationship, namely that active involvement in PA leads to better health outcomes. [18] However, this narrow perspective on PA fails to take into account that the social benefits of PA reflect both individual identities and social contexts. [19] While individuals make decisions about engaging in PA and make choices about the types of PA, these decisions are the result of a number of factors in combination, including geographic locale, individual characteristics, social circumstances, and cultural background. Each of these factors could play a moderating role in the risk of depression associated with PA. [20, 21, 22] Recognizing both the individual and social-contextual perspectives toward PA invites consideration of how PA is related to the risks of depression across different groups.

First, we observe that the literature suggests that gender differences are consistently associated with participation in PA and reported symptoms of depression. Reported studies show that generally, women tend to be more sedentary than men, and they are about 6% to 10% less likely to engage in PA. [23, 24, 25] There is also a reported tendency towards a more inactive lifestyle among women and this has been observed to remain as a consistent pattern throughout their lifetimes. [26, 27] Lower rates of participation in PA among women compared to men could be driven by social expectations related to gender and personal motivation as well as preference. [28] Unfortunately, the literature also has reported that females more frequently suffer from depressive symptoms than males. [29, 30, 31] Understanding the negative association between PA and depression, it might be possible that women could improve mental health status through adopting a lifestyle with regular PA. In contrast, some investigators opined in an epidemiological study that women might need less PA than men to attain similar health outcomes as they would need less energy than men in PA. [32] Thus, divergent arguments arise surrounding the effect of PA on depression between genders, which strongly supports a formal empirical investigation to determine if the different views are supported by evidence.

The literature also suggests that PA participation varies across race/ethnicity. [33] Multiple studies have reported that leisure-time PA is significantly lower in non-white groups. [34, 35, 36] Williams and Collins (1995) argued that social position determines many life choices, preferences and experiences, including leisure activity. [37] Moreover, because each race/ethnicity has a particular set of social and cultural values which influence participation in and types of exercise, these values shape an individual's choice of PA. [20] Onge (2011) noted that race is an important determinant of social position, which is closely related to PA. [19]

Socioeconomic status is conceptualized as an individual's position in society, and is strongly associated with race and ethnicity. [38, 39] Researchers (2006) suggest that persons of low socioeconomic status and residents of areas with high minority concentrations have limited access to environments for PA, a condition associated with reduced PA. [40] Moreover, low-income communities are more likely to have higher risk of suffering physical injury or harm due to violence [41] and report compromised safety in their settings for outdoor PA, such as sidewalks and parks in poor condition and high risk areas, which is a significant barrier to PA in the community. [42]

Previous studies examining differences in reported depression by race/ethnicity show mixed results. Studies found that African Americans had a lower risk of depression than white Americans, [43, 44] while another study suggested that, because of unmet basic needs in their daily lives, racial/ethnic minorities were more exposed to major depression than the white population.[45] Given divergent individual and social factors across each racial and ethnic group, it is important to understand the different effects of PA on reported depression broken down by race or ethnicity. The literature reveals that the associations among race/ethnicity, depression, and PA status require additional study.

The benefits of PA have been well-documented in adults. Specifically, engagement in regular PA reduces the likelihood of chronic conditions and premature mortality. [46, 47] The U.S. Department of Health and Human Services (DHHS) official reports (2018) highlighted that substantial health benefits can be gained by adopting active lifestyles in adults including those above 65 years old and by engaging in even low-level of PA for those who used to be inactive.[48] The DHHS provided official recommendations for common PA guidelines that apply to all ages of adults accounting for intensity, duration, and frequency.[48] According to its criteria, being active means at least 150 to 300 minutes per week of moderate intensity PA equivalent to brisk walking or at least 75 to 150 minutes per week of rigorous-intensity PA equivalent to jogging or running.

When it comes to depression, prevalence defined by age groups is not consistent across studies: while one suggested that individuals 40 years or older show higher depression prevalence [49], another reported adults aged 18 to 25 years are suffering at a higher rate than those older.[50] Although the health benefits of PA are established through numerous studies [51, 52], the effect of different levels of PA on depression across diverse age groups has been less consideration. Understanding the association between PA status and depression among age groups would provide a practical implication for the adult population in PA participation as an effective health promotion strategy.

Despite different propensities to develop depression associated with PA across diverse populations, to the best of our knowledge, the literature has paid little attention to these questions. Therefore, this present study aims to examine the link between depression and PA by examining the association across genders, reported race/ethnicity, and age.

Conceptual framework

The aim of this current study is to examine the effect of PA on depression while controlling for population characteristics as potential confounders. Andersen (1995) provides a long-accepted, and frequently cited, behavioral model examining health behaviors as they affect health outcomes considering population characteristics, such as predisposing, enabling, and need factors that influence both health behaviors and health outcomes.[53] **Predisposing factors** are demographic and socio-cultural characteristics, such as age, gender, occupation, education, and race or ethnicity. **Enabling factors**, such as income, health insurance, and community health resources allow individuals to practice health behaviors. **Need factors** are health conditions that cause behavioral and lifestyle changes and the use of health services. In this study, sociodemographic factors represent predisposing and enabling factors and comorbidity denotes need factors. Based on the framework, the study adds interaction effects between PA and population characteristics, such as age, gender, and race/ethnicity (Figure 3. 1).

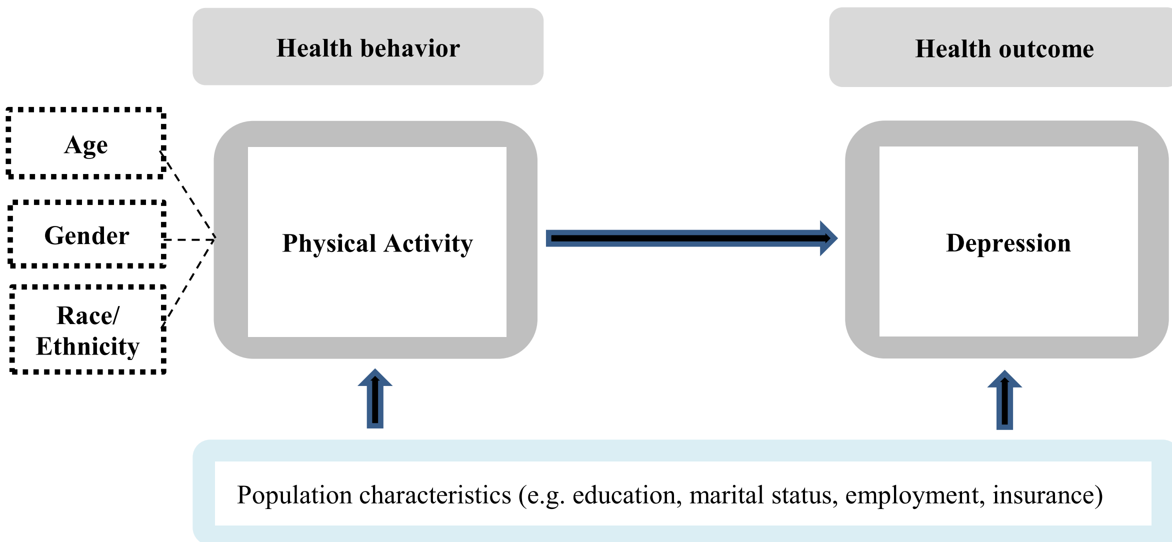

Figure 3.1 Conceptual framework

3.2. Methods

3.2.1. Data

The present study derived its data from the 2011 and 2015 Behavioral Risk Factor Surveillance System (BRFSS), a national-centric but with unique state add-on's and independently administered system of health surveys that has been verified as high in quality and reliability.[54] BRFSS, managed by the Centers for Disease Control and Prevention (CDC), is population data from all states, the District of Columbia, and United States territories. Conducted on landline and cellular phones, the survey focuses on non-institutionalized individuals aged 18 and older. Though the BRFSS collects data annually, we pooled cross-sectional datasets for just two years, 2011 and 2015, based on the availability of the dependent variables, questions necessary for the eight-item Patient Health Questionnaire (PHQ-8) measure. The present study identified the study sample according to inclusion criteria. First, it restricted the sample to only those states which had surveyed respondents for depressive symptoms. Second, it narrowed the sample down to those respondents within the included states who had reported being diagnosed with diabetes. The sampling process resulted in 5,950 observations from 7 states that include MS, NH, NM, ND, OK, TN, and WV.

3.2.2. Measurements

3.2.2.1. Dependent variable

In examining the relationship between depression and the status of PA among persons with diabetes, the outcome variable is self-reported depression. The PHQ-8 is a well-validated instrument for measuring depression in both clinical settings and epidemiological studies. [55, 56] The BRFSS included eight questions consistent with the PHQ-8, with four scales for each question and overall scoring from 0 to 24. To measure depression, the PHQ-8 include questions about days of respondents' psychological symptoms over the last two weeks: little interest or pleasure, depressed or hopeless, trouble falling asleep or too much sleeping, felt tired or litter energy, a poor appetite or too much eating, a failure or having let self or family down, trouble concentrating on things, and moving/speaking so slowly or being fidgety or restless. Scores from 0 to 4 indicated no depression, whereas scores equal to or above 5 indicated depression, mild to severe. [55] For sensitivity analysis, this study additionally set the cut points equal to or above 10 scores, considered at the advanced stage of and clinically significant depression. [55] The outcome scores were coded as a binary variable of depression or no depression.

3.2.2.2. Independent variable

Physical activity

PA status was a key independent variable. The 2018 exercise guidelines developed by the U.S. Department of Health and Human Services (DHHS) recommended a *sufficient* amount of moderate to vigorous leisure-time PA. [48] The guidelines set four levels of PA for adults: high, medium, low, and inactive. High activity involved more than 300 minutes of moderate-intensity physical activity per week; medium activity was 150 minutes to 300 minutes of moderate-intensity physical activity per week; and low activity was fewer than 150 minutes of moderate-intensity physical activity per week. Inactive status was defined as no activity beyond the baseline of light activities in daily life, such as walking and standing. The BRFSS PA questionnaire was consistent with the DHHS guidelines. In the present study, PA was categorized as active (highly active and active combined), moderately active, and inactive.

Sociodemographic factors

Demographics included gender, race/ethnicity, age, and marital status. Race/Ethnicity was categorized as white, Hispanic, African American, or ethnic minority consisted of such as Asian, American Indian/Alaskan Native, and Native Hawaiian or other Pacific Islander. Age was a categorical variable defined as younger than 45, 45-64, or older than 64. Marital status was coded as married/unmarried couples, divorced/widowed/separated, or never married. Smoking status, an identified risk factor for depression, [57, 58] was also coded in the current study, as non-smoker, former smoker, or current smoker.

Given that socioeconomic characteristics are established risk factors associated with depression, we also included education, employment, and health insurance status in our models. [59, 60, 61] Education level was categorized as less than high school graduation, high school graduation, some college or technical school education, and college graduation. Employment status had four categories: currently employed, homemaker/student, currently unemployed, and retired. Health insurance status was binary, either insured or uninsured.

Comorbidity

The literature suggests that people with chronic conditions have a higher risk of depression and are less likely to engage in PA. [62, 63] We concurrently created a chronic condition comorbidity indicator measure for asthma, cancer, angina or coronary heart disease, arthritis, obesity, and physical and mental disability as the sum of the total number of these conditions because these comorbidities contribute to the risk of depression and exacerbate tendency towards reduced physical activity.

3.2.3. Statistical analysis

This study first presents a descriptive analysis of characteristics for the study population. It also calculated proportions of the sample for key variables by depression status. Additionally, this study then calculated unadjusted depression rates by PA status and presented this information graphically to better understand the patterns of the relationship between PA and depression across population groups. In the multivariate analysis, the logistic regression procedure was performed to investigate the association between depression and PA status while controlling for covariates including the year indicator of the *Affordable Care Act* (ACA). Finally, this study reported on fully adjusted models, by adding interaction terms between PA and the elements of gender, race/ethnicity, and age to examine whether significant differences in the risk of depression could be associated with PA status of different populations or groups. As a sensitivity analysis, we performed an additional logistic regression with the PHQ-8 scores set at equal to or above 10. Our estimates were tested at the P = .05 significance level. All statistical analyses were conducted using the SAS 9.4 version (SAS Institute Inc., Cary, NC).

Our base model is as follows:

Base model:

$$\log(\frac{p}{1-p}) = \beta_0 + \beta_1 * PA + \beta_2 * age + \beta_3 * gender + \beta_4 * race/ethnicity + \gamma * X$$

*Model 1 (Interaction effect of PA*gender):*

$$\log(\frac{p}{1-p}) = \beta_0 + \beta_1 * PA + \beta_2 * age + \beta_3 * gender + \beta_4 * race/ethnicity + \beta_5 * PA * gender + \gamma * X$$

*Model 2 (Interaction effect of PA*race/ethnicity):*

$$\log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 * PA + \beta_2 * age + \beta_3 * gender + \beta_4 * race/ethnicity + \beta_5 * PA * ethnicity + \gamma * X$$

*Model 3 (Interaction effect of PA*age):*

$$\log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 * PA + \beta_2 * age + \beta_3 * gender + \beta_4 * race/ethnicity + \beta_5 * PA * age + \gamma * X$$

X – Covariates (insurance, employment, education, marital status, smoking, comorbidity, year)

P – Probability of the event (depression)

3.3. Results

In table 3.1, we see that 6.3% of the sample consisted of adults younger than 45, 40.3% were adults between 45 and 64, and 53.4% were older adults aged 65 or above. The proportion of females 57.9% was higher than that of males 42.1%. The majority of the respondents were white 71.1%, and most of the sample 94.4% was insured. High school graduates accounted for 35.2% of the sample, followed by those with some college education 25.6%, and college graduates 22.7%. Retired participants constituted 44.6% of the total, while 25.4% of the participants were employed. About half of the sample were married and about half had never been smokers. In terms of leisure-time PA, many of the sample were inactive 39.3% or active 35.6%. When considered by year, 2015 accounted for over two-thirds of the sample.

Table 3.1 Characteristics of the study sample

Variables	N 5,950	% or mean (s.d)
Age		
<45	377	6.3
45-64	2,395	40.3
65>=	3,178	53.4
Gender		
Male	2,503	42.1
Female	3,447	57.9
Race/Ethnicity		
White	4,233	71.1
Hispanic	505	8.5
Black	778	13.1
Other	364	6.1
Marital status		
Married	2,957	49.7
Divorced/Separated	2,441	41.0
Never married	539	9.1
Education		
< High school	967	16.3
High school	2,095	35.2
Some college	1,525	25.6
College	1,349	22.7
Employment		
Employed	1,510	25.4
Home/stud	350	5.9
Unemployed	1,417	23.8
Retired	2,655	44.6
Insurance		
No	318	5.3
Yes	5,618	94.4
Smoking		
Never	2,824	47.5
Former	2,122	36.7
Current	872	14.7
PA		
Inactive	2,337	39.3
Moderate	905	15.2
Active	2,118	35.6
Year		
2011	1,701	28.6
2015	4,249	71.4
Comorbidity	5,950	1.9 (1.3)
Depression		
No	3,914	65.8
Yes	1,837	30.9

In comparing the participants' characteristics by depression status in Table 3.2, the percentage of those in the age-range of 45 to 64 years categorized in the depression group was 50.6%, and the percentage of that range in the group without depression was 35.0%. Those aged 65 or older accounted for 43.0% and 58.9% of the participants for the group with and without depression, respectively. Among people with depression, 65.7% were females, while the figure was 53.6% in those without depression. The ethnic composition and percentage of insured were similar in the two groups, the one that reported depression and another that did not. However, the percentages of those who were college graduates, employed, married, and had never smoked tended to be higher in the non-depressed group than in the group with depression. In regard to PA, 56.1% of the sample with depression were inactive, while 28.4% were active. In contrast, 36.5% of the people without depression were inactive, while 46.1% were active. People with depression reported a higher number of comorbidity than those without (2.5 vs 1.6).

Table 3.2 Characteristics of the study sample by depression status

Variables	Depression		No Depression	
	N 1,837	% or mean (s.d)	N 3,914	% or mean (s.d)
Age				
<45	118	6.4	239	6.1
45-64	930	50.6	1,369	35.0
65>=	789	43.0	2,306	58.9
Gender				
Male	630	34.3	1,815	46.4
Female	1,207	65.7	2,099	53.6

Table 3.2 Characteristics of the study sample by depression status - Continued

Variables	Depression		No Depression	
	N 1,837	% or mean (s.d)	N 3,914	% or mean (s.d)
Race/Ethnicity				
White	1,296	71.2	2,785	72.1
Hispanic	177	9.7	318	8.2
Black	240	13.2	520	13.5
Other	108	5.9	239	6.2
Marital status				
Married	776	42.3	2,089	53.5
Divorced/Separated	881	48.0	1,475	37.8
Never married	177	9.7	340	8.7
Education				
< High school	389	21.2	545	14.0
High school	678	37.0	1,345	24.4
Some college	464	25.3	994	25.5
College	302	16.5	1,021	26.1
Employment				
Employed	336	18.3	1,137	29.2
Home/stud	118	6.4	224	5.7
Unemployed	763	41.6	578	14.8
Retired	619	33.7	1,958	50.2
Insurance				
No	115	6.3	192	4.9
Yes	1,718	93.7	3,712	95.1
Smoking				
Never	805	43.9	1,936	51.1
Former	630	34.4	1,422	37.6
Current	399	21.8	427	11.3
PA				
Inactive	998	56.1	1,235	36.5
Moderate	276	15.5	591	17.4
Active	506	28.4	1,562	46.1
Year				
2011	1,701	25.6	2,297	30.0
2015	4,249	74.4	478	70.0
Comorbidity	1,837	2.5 (1.2)	3,914	1.6 (1.2)

Figure 3.2 shows depression rates according to self-reported PA status of the different population groups. At all levels of PA, females tended to report higher rates of depression than males. Those in 45-64 accounted for the highest rates of depression at

each level of PA, while older adults tended to have consistently lower rates of depression than other age groups. For different ethnic groups, varying patterns of depression rates were observed according to PA status. For instance, among the “other” ethnic minority group including groups like Asian, Native Americans and Pacific islanders, the highest depression rate was evident at the inactive level, while the depression rate was about the lowest at levels considered active. Overall, across population groups, a lower depression rate was shown with being more active in the continuum of PA status.

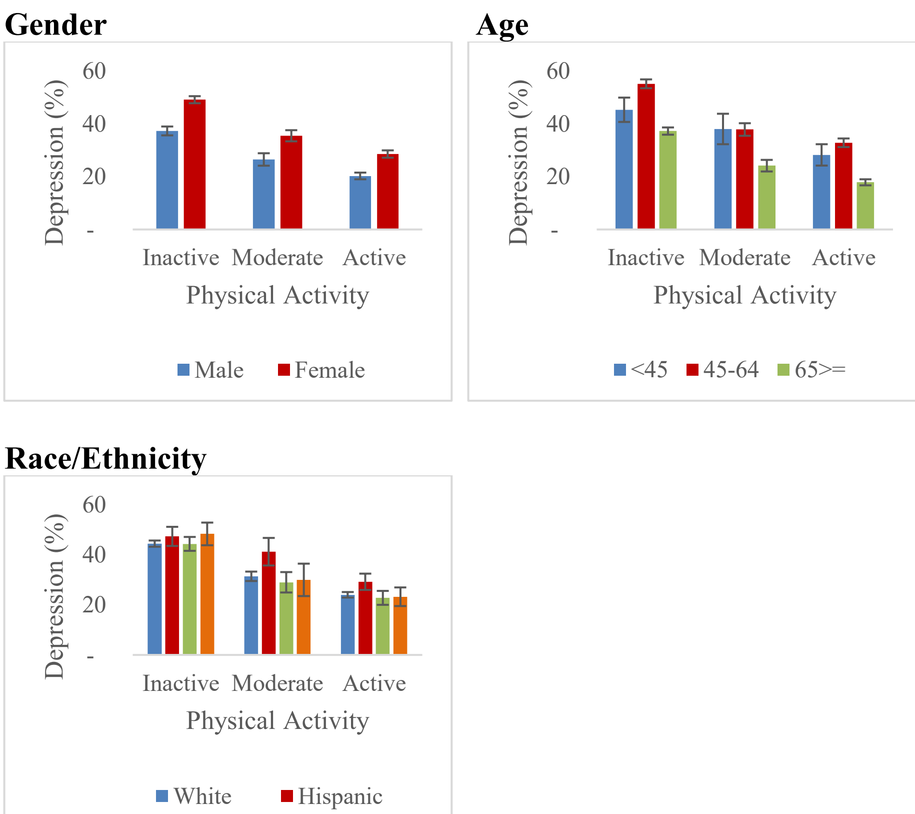

Figure 3.2 Depression rates by physical activity status in different gender, age, and race/ethnicity groups

In Table 3.3, we can see that when interactions between PA and gender, age, and race/ethnicity were not included in the logistic regression model, adults who were 65 years old or above (OR 0.57, 95% CI 0.43, 0.75) showed a significantly lower likelihood of depression compared to those below 45 years old. Females had a higher risk of depression than males (OR 1.48, 95% CI 1.22, 1.81). African American participants had a lower overall risk of depression than white participants (OR 0.68, 95% CI 0.55, 0.84), while Hispanics had a higher risk of depression (OR 1.18, 95% CI 1.02, 1.37). Compared to being physically inactive, being moderately active (OR 0.62, 95% CI 0.47, 0.81) or active (OR 0.53, 95% CI 0.46, 0.60) was associated with a significantly lower risk of depression.

When the interaction effects of PA with population characteristics such as gender, race/ethnicity, and age were added, no significant interaction between PA and genders was evident in Table 3.4. However, those in 65 or older (OR 0.59, 95% CI 0.36, 0.96) showed a more significant effect of reducing depression when active than those younger than 45. Compared to the white group, the group consisted of ethnic minorities experienced a stronger effect for the active PA level (OR 0.59, 95% CI 0.42, 0.84). The findings of the sensitivity analysis were fairly consistent with those of the main model for gender and age (Appendix A). However, though the minority group still showed reduced depression by being physically active compared to the white group, the estimate was not statistically significant, while the higher risk of depression in the Hispanic group than the white group turned to be statistically significant at moderately active.

Table 3.3 Association between depression and physical activity in persons with diabetes – no interaction model

Effect	OR (95% CI)
Age	
<45	-
45-64	1.03 (0.80, 1.32)
65>=	0.57 (0.43, 0.75)‡
Gender	
Male	-
Female	1.48 (1.22, 1.81)‡
Race/Ethnicity	
White	-
Hispanic	1.18 (1.02, 1.37)*
Black	0.68 (0.55, 0.84)‡
Other	0.99 (0.86, 1.15)
Marital status	
Married	-
Divorced/Separated	1.27 (1.15, 1.42)‡
Never married	1.07 (0.95, 1.21)
Education	
<high school	-
High school	0.82 (0.70, 0.98)*
Some college	0.76 (0.63, 0.91)†
College grad	0.64 (0.54, 0.75)‡
Employment	
Employed	-
Home/student	1.46 (0.97, 2.18)
Unemployed	2.25 (1.99, 2.53)‡
Retired	1.03 (0.89, 1.18)
Insurance	
No	-
Insured	0.89 (0.58, 1.38)
Smoking	
Never	-
Former	1.00 (0.83, 1.20)
Current	1.54 (1.20, 1.96)‡
PA	
Inactive	-
Moderate	0.62 (0.47, 0.81)‡
Active	0.53 (0.46, 0.60)‡
Year	
2011	-
2015	1.00 (0.95, 1.05)
Comorbidity	1.48 (1.42, 1.53)‡

*Notes: P<.05, †P<.01, ‡P<.001.

Table 3.4 Difference in the association between depression and physical activity in persons with diabetes across age, gender, and race/ethnicity

Effect	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Age			
<45	-	-	-
45-64	1.03 (0.80, 1.32)	1.03 (0.79,1.30)	1.45 (0.83, 2.52)
65>=	0.56 (0.43, 0.75)‡	0.56 (0.42, 0.74)‡	0.76 (0.46, 1.27)
Gender			
Male	-	-	-
Female	1.52 (1.23, 1.89)‡	1.48 (1.21, 1.81)‡	1.48 (1.22, 1.79)‡
Race/Ethnicity			
White	-	-	-
Hispanic	1.18 (1.03, 1.37)*	1.11 (0.90, 1.38)	1.16 (1.01, 1.34)*
Black	0.68 (0.55, 0.84)‡	0.71 (0.58, 0.89)†	0.65 (0.52, 0.81)‡
Other	0.99 (0.86, 1.14)	1.29 (0.88, 1.88)	0.98 (0.83, 1.15)
Marital status			
Married	-	-	-
Divorced/Separated	1.27 (1.15, 1.41)‡	1.27 (1.15, 1.41)‡	1.29 (1.16, 1.42)‡
Never married	1.07 (0.94, 1.22)	1.07 (0.95, 1.21)	1.10 (0.98, 1.23)
Education			
<high school	-	-	-
High school	0.82 (0.70, 0.97)*	0.83 (0.70, 0.98)*	0.83 (0.71, 0.97)*
Some college	0.74 (0.63, 0.92)†	0.76 (0.63, 0.92)†	0.77 (0.65, 0.92)†
College grad	0.64 (0.54, 0.75)‡	0.64 (0.55, 0.75)‡	0.65 (0.55, 0.77)‡
Employment			
Employed	-	-	-
Home/student	1.45 (0.96, 2.19)	1.46 (0.96, 2.23)	1.47 (0.99, 2.19)
Unemployed	2.25 (1.99, 2.54)‡	2.27 (2.01, 2.56)‡	2.23 (2.02, 2.46)‡
Retired	1.03 (0.90, 1.28)	1.03 (0.90, 1.18)	1.03 (0.90, 1.19)
Insurance			
No	-	-	-
Insured	0.89 (0.58, 1.38)	0.89 (0.58, 1.38)	0.92 (0.62, 1.35)
Smoking			
Never	-	-	-
Former	1.00 (0.83, 1.20)	1.00 (0.83, 1.20)	0.99 (0.82, 1.20)
Current	1.53 (1.20, 1.97)‡	1.54 (1.20, 1.98)‡	1.51 (1.18, 1.93)†
PA			
Inactive	-	-	-
Moderate	0.66 (0.54, 0.81)‡	0.64 (0.45, 0.91)*	0.91 (0.30, 2.78)
Active	0.53 (0.43, 0.66)‡	0.54 (0.47, 0.62)‡	0.85 (0.55, 1.34)
Year			
2011	-	-	-
2015	1.00 (0.95, 1.05)	1.00 (0.96, 1.04)	1.02 (0.97, 1.07)
Comorbidity	1.48 (1.42, 1.53)‡	1.48 (1.42, 1.53)‡	1.48 (1.43, 1.53)‡

Table 3.4 Difference in the association between depression and physical activity in persons with diabetes across age, gender, and race/ethnicity - Continued

Effect	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
PA*Gender			
Moderately active	-		
Male	-		
Female	0.90 (0.62, 1.30)		
Active			
Male	-		
Female	0.98 (0.66, 1.44)		
PA*Race/Ethnicity			
Moderately active			
White		-	
Hispanic		1.16 (0.64, 2.08)	
Black		0.83 (0.52, 1.33)	
Other		0.69 (0.22, 2.16)	
Active			
White		-	
Hispanic		1.07 (0.90, 1.27)	
Black		0.96 (0.78, 1.19)	
Other		0.59 (0.42, 0.84)†	
PA*Age			
Moderately active			
<45			-
45-64			0.72 (0.26, 2.03)
65>=			0.64 (0.25, 1.66)
Active			
<45			-
45-64			0.58 (0.33, 1.02)
65>=			0.60 (0.38, 0.96)*

*Notes: Model 1 adds an interaction between PA and gender. Model 2 adds an interaction between PA and race/ethnicity. Model 3 adds an interaction between PA and age. P<.05, †P<.01, ‡P<.001.

3.4. Discussion

The present study aimed to examine the associations between PA and depression across diverse population groups who reported having been diagnosed with diabetes. We found that the association between PA and depression was significant, suggesting a link between more PA and lower rates of depression, which confirmed what has been reported in the literature. [10, 11] When the interaction effects between PA and population characteristics were considered, the association between PA and depression was not statistically different between genders. However, there was evidence that PA had varying effects on depression among age and ethnic groups. Our findings suggest that PA may be more beneficial in combating depression among older adults than among younger adults and those who reported identity in an ethnic minority group as compared to whites. Among those with clinically significant depression, the findings are fairly consistent for age and gender. Though an ethnic minority group did show reduction of depression, it was no longer statistically significant.

Overall, higher levels of PA were associated with a lower risk of depression. Numerous previous studies investigating the health benefits of PA have concluded that PA is beneficial in preventing a range of chronic conditions and reducing all-cause mortality regardless of population characteristics.[64, 65] Even having a moderately active lifestyle promotes the health status of those who were formerly inactive.[48] The findings of the present study strengthen the evidence for a positive effect of PA on the health of people with diabetes. Although the benefits of PA have been well-documented, questions about whether PA varies in its effects on the risk of depression among population groups have arisen in the literature. As Lysy et al. (2008) noted,[17] for example, PA may vary in its effects on health outcomes of different racial or ethnic groups. However, previous studies have paid little attention to investigating different effects of PA on depression across diverse population groups. They focused primarily on the functional aspects of PA and its benefits did not take into consideration the social aspects that could also affect people's participation in PA, as well as the types and quality of PA, leading to different effects of PA on depression across populations. Thus, the significance of the present study is to investigate and to improve the understanding of the less explored questions, which contributes to establishing evidence about the different association between depression and PA across sub-populations in persons with diabetes.

First, gender is an important factor in both depression and reported PA. While national guidelines recommend equal amounts of PA for males and females, it is important to determine whether PA produces similarly beneficial effects on depression in both genders. It is necessary because evidence consistently indicates that females are more sedentary and show a higher depression rate than males.[24, 25] The gender gap to participate in exercise may be related to different motivations; [66] and even media coverage that dedicates more attention to the PA of men.[67] The idea of gender differences in PA may also be reinforced to some extent by the popular belief that these differences do in fact exist.[68] These personal characteristics and social perceptions may collectively affect the participation of females in PA. The current study found that females were at a higher risk of depression than males, which is consistent with previous findings, [29, 69] However, the comparison between genders when moderately active or active showed no significant difference. The findings reveal no evidence of gender difference in the risk of depression at each level of PA. This might suggest that females could improve their mental health by engaging in regular PA to the similar extent that males do.

Researchers suggest that ethnic groups could engage in various types of physical activities depending on social and cultural values surrounding them, which might differently affect health outcomes.[20] The findings of the present study may suggest that the ethnic minority group possibly obtain greater health gains in reducing depression by actively engaging in PA than their white counterparts do. The finding maybe a positive signal to the ethnic minority group given previous arguments that racial and ethnic minorities are at a greater risk of having psychological distress and substantially lower engagement in PA than other ethnic groups.[70, 71] The earlier suggestion could be related to the observation that ethnic minorities might have barriers to PA for both individual and environmental reasons, while suffering poor mental health. The greater positive effect of PA on reducing depression in ethnic minorities found in this study would encourage ethnic minorities to more actively engage in regular PA. However, when included only those with advanced depression, they did not show significant reduction of depression, while an increased risk of depression was found in the Hispanic group compared to the white group. Given the mixed findings and scarce knowledge base of ethnic differences, substantial studies are needed to improve the understanding in the associations. Furthermore, as the ethnic minorities are diverse, research on each segment of the populations about, such as preference, satisfaction, and types of PA is necessary to deepen the evidence base; further studies could strengthen this relationship.

Age is another key consideration for PA and depression. Studies have established that PA prevents a number of chronic conditions such as cancers, obesity, and cardiovascular diseases in the adult population.[46, 72] In particular, for older adults, PA reduces the risk of falls and the injuries associated with them.[73, 74] Regular PA participation also promotes mental health by reducing depressive symptoms.[75] The findings of this study reveal that older adults showed a relatively lower likelihood of depression than younger adults as they participate in regular PA. [76] Acknowledging that the severity of depression is much significant among older adults compared to younger adults, the findings could encourage older adults to participate in regular PA to promote their mental health.[5] One possible explanation might be that, given higher incidence of chronic conditions in older age groups,[77] PA would be an effective health behavior for preventing and managing a variety of diseases, such as cancers, arthritis, diabetes, obesity, and cardiovascular disease.[46] Another possible reason for the age difference might be that people gain additional benefits from PA besides those related to health; these benefits involve social interaction and engagement.[48] Researchers have reported that engaging in active social interaction can substantially reduce the risk of mental health conditions in older adults.[78] The present study's findings recommend that people as they are aging who engage in regular physical activity receive substantial public health gains and improve mental health. However, considerable investigation is needed to improve our understanding of the age differences in the association between depression and PA. Furthermore, in the face of an aging society, those younger than 65 years old have been less studied than older adults regarding PA and depression. The findings of the present study would invigorate further studies to understand the different effect of PA on depression in various age groups.

We acknowledge several limitations in this study. First, the BRFSS datasets included only leisure-time PA which was defined as PA during leisure-time in pursuit of improvement in physical performance and general health status. Although researchers have noted the significance of leisure-time PA in the investigation of the positive effect PA exerts on health outcomes, [79] well-designed surveys that reflect a wider scope of PA are needed to strengthen the analysis. Second, although the BRFSS is a national survey, our study included only a limited number of states due to the availability of the dependent variable. Collection of data from more states could enrich the analysis. Moreover, the generalizability of the findings may also be affected because of the number of states involved. Thus, it is necessary to be cautious when interpreting the findings. We also acknowledge as a limitation the use of self-reported survey data and the nature of retrospective questions, inherently present a recall bias or social desirability bias. In particular, people are less likely to disclose their depressive symptoms for a variety of reasons[80] and inaccurately report the levels of PA.[81] It is possible that, among those who did report depressive symptoms, these symptoms were underreported [80] and among respondents to the PA question, levels of PA were overreported.[81]

Despite these noted limitations, our study adds some important findings to the literature. First, the importance of PA as a means of promoting mental health by reducing the risk of depression is confirmed. More importantly, age and race/ethnicity are differently associated with the effects of PA on depression while gender is not, suggesting different effects of PA on depression between age groups and ethnicities but not between genders. In particular, the effects of PA on depression is more marked among older adults than among younger adults. The findings of the present study could inspire further studies on the relationship between PA and various population characteristics.

3.5. Conclusion

The control of depression is critical for persons with diabetes. Engagement in regular PA produces significant health benefits. Similar health benefits can be gained from PA regardless of gender. However, compared to younger adults, older adults may gain more health benefits in reducing the risk of depression by adopting physically active lifestyles. Despite some evidence of ethnic differences, more studies focusing on this association are needed.

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4. THE IMPACT OF MEDICAID EXPANSION ON DIABETES MANAGEMENT

4.1. Introduction

Diabetes has been a reported major chronic health condition in the US for decades. By 2050, it is estimated that 21% of the adult population will have diabetes, a considerable increase from 12% in 2015. [1] Diabetes causes significant health complications and enormous social costs, imposing substantial challenges to both public health practice and society overall. [2, 3, 4] According to recent estimates, the economic impact of diabetes is large and growing, with disease costs moving from US$174 billion in 2007 to over US$327 billion in 2017. [5] The burden of diabetes for American society requires serious actions to control diabetes and reduce its associated problems.

Diabetes prevention and control needs a strategic approach that includes multi-dimensional tactics rather than a simple intervention, given that diabetes is associated with a wide range of risk factors and complications, for which the combined roles of laypersons and health professionals are essential. [6] Glasgow (1995) proposes three stages of diabetes management including background context, cycle of care, and follow-up outcomes. The essence of the proposed diabetes management is that, surrounded by the social and environment contexts, patients who follow continuous cycle of care composed of health care, self-management behaviors, and short-term physiologic outcomes could have improved long-term health outcomes. [7]

A health professional's clinical care is a critical component of diabetes management. Clinical guidelines recommend that people with diabetes undergo routine check-ups for vital examinations and receive appropriate care. [8] Continuous interactions with healthcare providers are needed to facilitate timely examination of health status and maintain personalized diabetes management. The literature has shown that diabetic patients with periodic preventive procedures and interaction with providers are more likely than those without to experience better health outcomes and less likely to visit the emergency room. [9] Unfortunately, however, the literature reports that in 2009, 15% of individuals with diabetes, aged 18–64, lacked health insurance, potentially preventing their access to essential diabetes care provided by healthcare professionals. [10] Postponing or foregoing necessary care due to a lack of health insurance coverage can result in unintended consequences, such as aggravated conditions, unexpected complications, and escalated medical costs. [11, 12, 13]

Another vital component of diabetes management is self-management. The literature about chronic disease self-management emphasizes the patients' central role in managing their disease and its efficacy in improving their health outcomes and reducing healthcare utilization. [14, 15] Consistent monitoring of physiological indicators including self-blood glucose monitoring and regular foot checks are vital and effective for successful diabetes management. A suggested strategy to promote adherence to self-management entails consistent education and support to ensure that people with diabetes gain sufficient knowledge and skills. [16, 17] Among multiple resources that might be available in the community, healthcare professionals play a pivotal role in educating and supporting patients for effective self-management of their diabetes. [16]

Individuals' disease management activities occur in a broad sphere of support, including family and community-level support as well as social support through state and federal policies that frame social contexts in which individual and institutional behaviors are structured. [6] Andersen (1995) notes the importance of national-level policies and resources as they are recognized as the basis for improved access to healthcare and changes in people's behavioral patterns of using healthcare. [6] From the perspective of a federal-level policy, the US experienced a historical change in its healthcare system through the passage of the Affordable Care Act (ACA) in 2010, which was primarily intended to reduce uninsured rates, increase preventive care, and improve healthy behaviors. According to the Kaiser Family Foundation, in 2012, over 47 million nonelderly Americans were uninsured, [18] of whom the majority were low-income working adults. Considering the significant number of low-income Americans that had no coverage before the reform, the ACA could have reshaped the social context for healthcare and controlled chronic health issues like diabetes among people who would otherwise remain uninsured.

Under the ACA, its key provisions are anticipated to be beneficial for diabetes control as it incentivizes people with diabetes or pre-diabetes to receive essential services for preventing or managing the disease. [19] Among the reform's provisions, the core changes included an individual mandate for insurance coverage and the removal of pre-existing condition exclusions on coverage. The ACA also ensures preventive services for adults without additional costs, such as screenings for blood pressure, depression, type 2 diabetes, and obesity. [20] Another principal policy of the reform was the mandatory expansion of Medicaid to all individuals earning less than 138% of the federal poverty level across the country. However, with the 2012 Supreme Court decision in National Federation of Independent Business v Sebelius allowing individual states to decide on whether or not to opt in,[21] states optionally implemented the expansion in January 2014.[22] Burge et al. (2014) and Shi et al. (2015) acknowledged that the reform would have a positive impact on diabetes management by offering individuals with diabetes necessary care.[21, 23] Kaufman et al. (2015) found an increased number of patients who were newly diagnosed with diabetes in Medicaid expansion states compared with non-expansion states.[24] A more recent study focusing on persons with diabetes in clinical settings found improved health care access but no improvement in diabetes care provided by clinicians,[25] while another study found an increase in prescriptions filled in Medicaid expansion states.[26] However, previous studies covered a limited time period and focused on access and clinical care and was thus limited in scope regarding impact evaluation. Despite the possibly significant role of Medicaid expansion on diabetes control, the literature reveals scant knowledge about such an impact on diabetes management that accounts for both state's Medicaid expansion status and a time period of before and after the policy implementation.

Therefore, this study investigates the impacts of the Medicaid expansion on diabetes management among low-income adults with diabetes. In addition, as some states have higher diabetes rates than others, referred to as "diabetes belt" states by the Centers for disease Control and Prevention (CDC),[27] those states need substantial improvements in diabetes management to reduce the high burden of the disease. Thus, the present study compares the impacts of Medicaid expansion between expansion and non-expansion states while considering diabetes rates of the states.

4.2. Methods

4.2.1. Study design

The purpose of this study is to examine the impact of the Medicaid expansion on diabetes management. Difference-in-Differences (DID) modeling, a quasi-experimental method that evaluates the effects of policy implementation by comparing the changes in outcomes between the Medicaid expansion group and the non-Medicaid expansion group is used for our primary analysis.

4.2.2. Data

This research uses 2011–2016 data from the Behavioral Risk Factor Surveillance System (BRFSS), a nationally representative public database of self-reported responses to a telephone survey among non-institutionalized adults aged 18 or older. In 2011, the BRFSS started including a cellphone-based survey to improve the representativeness of the data. The 2011–2013 and the 2014–2016 periods cover the years prior to and after the Medicaid expansion implementation, respectively. The policy effects take time to occur and there is a need for investigating measurable changes after the Medicaid expansion. [28] Thus, the present study included 24 states plus the District of Columbia that expanded Medicaid, as of January 2014 and 19 states that remained non-expansion states until 2016 to evaluate the impacts of the Medicaid expansion. [29] About 95% of adults over 65 years old are covered by health insurance, including Medicare. [30] Given that the Medicaid expansion mainly targets low-income adults under 65 years old, those belonging to the 18–64 age range, with diabetes diagnoses and incomes below 138% of the federal poverty level (FPL), are included in this study. To identify the yearly federal poverty level, [31] the study uses 2011–2016 Federal Poverty Guidelines from the Office of the Assistant Secretary for Planning [32] and the Evaluation and Federal Register. [33] As the BRFSS categorizes income levels, a percentage of the FPL is calculated using the midpoint of each income category divided by the FPL of the corresponding year. [31] Additionally, as suggested by the literature examining state's Medicaid expansion, [31, 34] this study controls for state unemployment rates over the study year 2011-2016 from the Bureau of Labor Statistics. [35]

4.2.3. Measurements

4.2.3.1. Covariates

Primary covariate

It is the interaction term between the indicator variable of the Medicaid expansion (coded as 1 if the state implemented Medicaid expansion) and the indicator variable of the Medicaid expansion time period (coded as 1 if the time period is the post-Medicaid expansion).

Secondary covariates

Demographic and socioeconomic characteristics included age, gender, race/ethnicity, marital status, education, and employment. Age was a categorical variable as 18-34, 35-44, 45-54, and 55-64. Race/Ethnicity was classified as white, Hispanic, African American, or other that includes Asian, American Indian/Alaskan Native, and Native Hawaiian or other Pacific Islander, and any other ethnicities. Marital status was categorized as married/unmarried couples, divorced/widowed/separated, or never married. Education level was categorical as less than high school graduation, high school graduation, some college or technical school education, and college graduation. Employment status had four categories, such as currently employed, homemaker/student, currently unemployed, and retired. In addition, the study included comorbidity of chronic conditions: asthma, cancer, angina or coronary heart disease, arthritis, obesity, and physical and mental disability.

4.2.3.2. Outcome variables

This study identified a range of variables related to access to healthcare, diabetes care, diabetes self-management, and health status. Then, rather than examining the impact of Medicaid expansion by individual variables, a factor analysis was performed to evaluate the impact by factor variables that well reflect the identified variables. [36]

Outcome measures

The variables about access to healthcare include each respondent's current health insurance status and non-consultation with a doctor due to the cost involved in the past 12 months. The health insurance status measure was dichotomized as yes or no. The literature has determined financial affordability as the primary reason for people to forgo or postpone the necessary healthcare. [37, 38] Non-consultation with a doctor due to the cost involved was measured as having or not having such experience.

For diabetes care provided by healthcare professionals, survey respondents reported how often they visited a doctor for consultation over the past 12 months. In addition, participants reported how often they had feet checks in the past 12 months. The participants were also asked about the number of times in the past 12 months when their Hemoglobin A1c (HA1c) was checked by health professionals. [39]

To measure diabetes self-management, the study includes measures designed to account for self-blood sugar checks and self-feet checks, which are critical to diabetes management. [40] Participants reported the number of times they were self-checking their blood for glucose or sugar and how often they check their feet themselves daily or within a period of time.

The analysis also includes a composite measure designed to capture various aspects of overall health status. Considering the significant relationship between diabetes and mental health, mental health was measured, using a BRFSS question about how many days in the past 30 days the mental health was not good. Participants also reported how many days in the past 30 days their physical health status was not good. Both mental and physical health status was dichotomized as not good if participants reported any experience that mental or physical health was not good, otherwise as good. Furthermore, the self-rated general health status was measured. Excellent, very good, and good were combined as good; otherwise, the response was coded as not good.

Key outcome variables

The factor analysis produced three-factor variables whose eigenvalue is above one, widely recommended criteria in identifying factors.[41] The three factor variables were titled as self-reported access to health care, self-reported diabetes management, and self-reported health status. Self-reported access to health care reflected two variables, insurance rates and non-consultation with doctors due to costs. Self-reported diabetes management, another factor variable represented five variables, such as doctor visits for consultation, feet checks, Hemoglobin A1c (HA1c) checks, self-blood sugar checks, and self-feet checks. The third factor variable termed as self-reported health status reflected self-reported mental health, self-reported physical health, and self-reported general health. Factor-based scores were calculated by adding up the values of the identified variables by each factor to get key outcome variables.

4.2.4. Statistical analysis

This analysis begins with a baseline descriptive analysis of the characteristics of Medicaid expansion states and non-Medicaid expansion states before the Medicaid expansion using t-tests and chi-square tests.

Difference in Differences model

$$\boldsymbol{Y_{ist} = \beta_0 + \beta_1 * Post_t + \beta_2 * Expanded_s + \beta_3 * Post_t * Expanded_s + \gamma * X_{ist} + \delta * State_s + \vartheta * Year_t + \varepsilon_{ist}}$$

$\boldsymbol{\beta_3}$ = Change in the outcome variable associated with Medicaid expansion

$\boldsymbol{\beta_{ist}}$ = Covariates (age, gender, race/ethnicity, education, marital status, employment status, comorbidity, and state-year unemployment rate)

After descriptive analysis, this study examines unadjusted and adjusted effects in the outcome variables between Medicaid expansion states and non-Medicaid expansion states after the expansion. In the multivariate linear model, the coefficient of the interaction term represents the difference in the changes of the outcome variables in the

Medicaid expansion states compared with the non-Medicaid expansion states accounting for the pre- and the post-Medicaid expansion. The model includes covariates for age, gender, race/ethnicity, education, employment status, marital status, comorbidity, and state-year unemployment rate. The model also adjusts for state and quarter-year fixed effects. The estimation is based on robust standard errors, clustered at the state using the generalized estimating equations (GEE). A sensitivity analysis was conducted with expansion states excluding five states that already provided low-income adults expanded insurance coverage before 2014 Medicaid expansion and non-expansion states excluding one that provided expanded coverage to low-income adults under non-expansion status (Appendix B. 4).

Finally, the analysis concludes with a triple differences analysis (Difference in Difference in Differences) to compare the estimated changes between expansion and non-expansion states accounting for diabetes rates of the states. The CDC identified 15 states with high diabetes rates as a diabetes belt based on a county-level evaluation of diabetes rates with 2007 and 2008 data. [27] Its approach recognized counties with high diabetes rates and then categorized states based on county diabetes rates, suggesting that it does not necessarily reflect state-level diabetes rates. Motivated by the CDC, this study identified top 15 states with high diabetes populations among 50 states plus the District of Columbia based on the CDC's 2013 state-level diabetes rates to reflect the up-to-date figures of the states before the Medicaid expansion, whereas the rest of the states were grouped as a non-high diabetes group. All statistical analyses were performed using the SAS 9.4 version (SAS Institute Inc., Cary, NC).

4.3. Results

The baseline characteristics of the study sample by Medicaid expansion status are shown in Table 4.1. The age composition was similar in the two groups: one that expanded Medicaid and another that did not. The percentage of females in the non-expansion group was 57.9% (95% CI 55.6%, 60.1%) significantly higher than 53.4% (95% CI 50.8%, 56.0%) in the expansion group (p=0.024). African Americans accounted for 33.3% (95% CI 31.2%, 35.3%) in the non-expansion group, while they accounted for only 14.8% (95% CI 13.0%, 16.6%) in the expansion group. In contrast, the percentages of Hispanics were 7.7% (95% CI 6.4%, 9.1%) in the non-expansion group and 23.0% (95% CI 20.3%, 25.6%) in the expansion group, respectively. The comparison of the ethnic composition between the two groups was statistically significant (p = <.000). Divorced or separated constituted 35.6% (95% CI 33.6%, 37.7%) in the non-expansion group, while the figure was 32.4% (95% CI 30.3%, 34.5%) in the expansion group (p = <.000). In the non-expansion group, 61.3% (95% CI 59.2%, 63.5%) were unemployed, while the figure was 56.5% (95% CI 53.9%, 59.0%) in the expansion group (p = 0.006). In the unemployment rates of the states, the non-expansion group had 7.9 (SD 1.3) compared to the expansion group that had 7.6 (SD 1.4). Although some variations existed, education (p=0.080) and comorbidity (p=0.562) did not show a significant difference between the two groups.

Table 4.1 Baseline (2011-2013) characteristics of the study sample

	% (95% CI) or mean (s.d)				
	Non-expansion (n=6,138)		Expansion (n=6,230)		P-value
Age					0.601
18-34	335	11.0 (9.3, 12.8)	363	11.1 (9.2, 13.1)	
35-44	633	15.0 (13.3, 16.7)	746	17.0 (15.1, 18.8)	
45-54	1,756	32.6 (30.5, 34.8)	1,852	31.4 (29.0, 33.7)	
55-64	3,414	41.4 (39.3, 43.4)	3,269	40.5 (38.2, 42.9)	
Gender					0.024
Male	2,051	42.1 (39.9, 44.4)	2,321	46.6 (44.0, 49.2)	
Female	4,087	57.9 (55.6, 60.1)	3,909	53.4 (50.8, 56.0)	
Race/Ethnicity					<.000
White	3,238	51.6 (49.5, 53.7)	3,403	50.3 (48.0, 52.5)	
Hispanic	262	7.7 (6.4, 9.1)	1,019	23.0 (20.3, 25.6)	
African American	2,113	33.3 (31.2, 35.3)	851	14.8 (13.0, 16.6)	
other	379	5.1 (4.2, 6.1)	844	10.6 (9.3, 11.9)	
Education					0.080
<high school	1,527	34.2 (32.0, 36.4)	1,379	32.8 (30.1, 35.5)	
High school	2,383	35.0 (33.0, 37.1)	2,405	35.0 (32.7, 37.3)	
Some college	1,514	22.7 (21.0, 24.4)	1,648	24.3 (22.3, 26.2)	
College grad	671	7.2 (6.3, 8.0)	754	7.6 (6.6, 8.5)	
Marital status					<.000
Married	2,254	42.5 (40.4, 44.6)	2,390	43.4 (40.8, 45.9)	
Divorced/Separated	2,699	35.6 (33.6, 37.7)	2,516	32.4 (30.3, 34.5)	
Never married	1,154	21.5 (19.5, 23.5)	1,272	23.7 (21.4, 26.0)	
Employment					0.006
Employed	1,252	24.1 (22.0, 26.1)	1,426	27.4 (24.9, 29.8)	
Home/Student	367	6.4 (5.4, 7.3)	479	8.1 (6.8, 9.4)	
Unemployed	3,847	61.3 (59.2, 63.5)	3,614	56.5 (53.9, 59.0)	
Retired	619	7.2 (6.3, 8.0)	648	7.5 (6.5, 8.5)	
Comorbidity	6,138	2.0 (1.9, 2.0)	6,230	1.9 (1.8, 1.9)	0.562
Unemployment of states (s.d.)	6,138	7.9 (1.3)	6,230	7.6 (1.4)	<.000

The factor analysis found three outcome variables - self-reported access to health care, self-reported diabetes management, and self-reported health status. The baseline means of the key outcome variables are presented in Table 4.2. While self-reported access was significantly higher in the expansion group than in the non-expansion group (1.33 in non-expansion vs 1.42 in expansion, p=0.000), respectively. The differences between the two groups were not statistically significant for self-reported diabetes management (11.62 in non-expansion vs 11.08 in expansion, p = 0.150) and self-reported health status (1.11 in non-expansion vs 1.13 in expansion, p = 0.824).

Table 4.2 Baseline (2011-2013) means of outcome variables by Medicaid expansion status

	Non-expansion (n=6,138)		Expansion (n=6,230)		p-value
	n	Mean (95% CI)	n	Mean (95% CI)	
Access	6,137	1.33 (1.30, 1.35)	6,230	1.42 (1.37, 1.48)	0.000
Diabetes management	5,746	11.62 (11.10, 12.13)	5,929	11.08 (10.54, 11.62)	0.150
Health status	6,088	1.11 (1.05 , 1.18)	6,199	1.13 (1.05, 1.20)	0.824

Table 4.3 Unadjusted changes in self-reported access, diabetes management, and health status

	Non-expansion (n=10,875)		Expansion (n=11,460)		Difference in Differences	
	Pre	Post	Pre	Post	Unadjusted Changes	
	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	P
Access	1.33 (1.30, 1.35)	1.35 (1.24, 1.45)	1.42 (1.37, 1.48)	1.66 (1.61, 1.70)	0.21 (0.10, 0.33)	0.004
Diabetes manageme nt	11.62 (11.10, 12.13)	10.62 (9.99, 11.24)	11.08 (10.54, 11.62)	12.53 (11.98, 13.08)	2.46 (1.38, 3.53)	<.000
Health status	1.11 (1.05 , 1.18)	1.13 (1.01, 1.25)	1.13 (1.05, 1.20)	1.19 (1.09, 1.29)	0.06 (-0.12, 0.23)	0.555

Notes: Pre indicates from 2011 through 2013. Post indicates from 2014 through 2016.

The unadjusted change was significantly different between the expansion and the non-expansion states in self-reported access to health care (0.21, 95% CI = 0.10, 0.33, p = 0.004) and diabetes management (2.46, 95% CI = 1.38, 3.53, p = <.000), while no significant change was evident in self-reported health status (0.06, 95% CI = -0.12, 0.23, p = 0.555), as shown in Table 4.3.

In the adjusted model in Table 4.4, the significant change was consistent in self-reported access to health care (0.09, 95% CI = 0.01, 0.13, p = 0.002) and self-reported diabetes management (1.91, 95% CI = 0.81, 2.30, p = 0.001). The change in self-reported health status was 0.10 (95% CI = 0.01, 0.20, p = 0.026), which was statistically significant. The results of the sensitivity analysis were similar to those of the main model, as shown in Appendix B, self-reported access to health care (0.10, 95% CI = 0.02, 0.18, p = 0.013), self-reported diabetes management (1.94, 95% CI = 0.81, 3.07, p = 0.001), and self-reported health status (0.10, 95% CI = 0.01, 0.20, p = 0.033).

Table 4.4 Adjusted changes in self-reported access, diabetes management, and health status

	Non-expansion (n=10,875)		Expansion (n=11,460)		Difference in Differences	
	Pre	Post	Pre	Post	Unadjusted Changes	
	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	P
Access	1.47 (1.40, 1.54)	1.57 (1.45, 1.68)	1.43 (1.39, 1.47)	1.62 (1.54, 1.69)	0.09 (0.01, 0.13)	0.023
Diabetes manageme nt	11.67 (10.60, 12.74)	11.38 (10.03, 12.72)	10.82 (9.93, 11.72)	12.44 (11.44, 13.43)	1.91 (0.81, 2.30)	0.001
Health status	1.22 (1.15, 1.29)	1.10 (0.92, 1.29)	1.23 (1.10, 1.37)	1.22 (1.01, 1.43)	0.10 (0.01, 0.20)	0.026

Notes: Pre indicates from 2011 through 2013 and Post indicates from 2014 through 2016. Multivariate regression adjusted for population characteristics, such as age, gender, race/ethnicity, education, marital status, employment, comorbidity, and state and quarter-year fixed effects.

In the subgroup comparison analysis (Table 4.5), though there are four groups, the key interest of the present study is comparisons between Medicaid expansion and Medicaid non-expansion groups among states with high diabetes rates because those states need substantial improvements in diabetes management to reduce the high burden of the disease. The unadjusted comparisons between the states that did expand and those that did not among states with high diabetes rates showed that the former reported significant improvements in comparison to the latter in self-reported access to health care (0.36, 95% CI 0.23, 0.48, p = <.000) and diabetes management (2.50, 95% CI 0.70, 4.30, p = 0.007) but not in self-reported health status (0.16, 95% CI -0.01, 0.33, p = 0.066).

In comparing the adjusted changes in outcomes between the Medicaid expansion and the Medicaid non-expansion status among states with high diabetes rates, the findings were statistically significant in outcomes (Table 4. 6) as self-reported access to health care (0.20, 95% CI 0.09, 0.31, p = 0.000) and health status (0.17, 95% CI 0.09, 0.26, p = <.000). Self-reported diabetes management (1.63, 95% CI -0.04, 3.29, p = 0.055) was close to being statistically significant.

Table 4.5 Unadjusted changes in self-reported access, diabetes management, and health status between subgroups

		Pre ①	Post ②	Δ (②-①)		Group comparisons	
		Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	p	Mean (95% CI)	p
Access							
	H - N	1.33 (1.31, 1.35)	1.32 (1.21, 1.43)	-0.01 (-0.12 0.09)	0.802	-	-
	H - E	1.37 (1.31, 1.43)	1.71 (1.66, 1.76)	0.34 (0.28, 0.41)	<.000	0.36 (0.23, 0.48)	<.000
	N - N	1.31 (1.26, 1.38)	1.43 (1.38, 1.48)	0.11 (0.06, 0.16)	0.001	0.12 (0.08, 0.24)	0.036
	N - E	1.44 (1.26, 1.51)	1.65 (1.60, 1.70)	0.21 (0.14, 0.28)	<.000	0.22 (0.10, 0.35)	0.001
Diabetes manage ment							
	H - N	11.77 (11.14, 12.41)	10.58 (9.81, 11.34)	-1.19 (-2.15, -0.24)	0.014	-	-
	H - E	10.99 (9.86, 12.13)	12.30 (11.45, 13.15)	1.31 (-0.22, 2.83)	0.093	2.50 (0.70, 4.30)	0.007
	N - N	11.28 (1.60, 11.95)	10.72 (9.82, 11.61)	-0.56 (-1.33, 0.21)	0.157	0.63 (-0.60, 1.86)	0.313
	N - E	11.10 (10.49, 11.72)	12.57 (11.96, 13.19)	1.47 (0.59, 2.35)	0.022	2.66 (1.36, 3.96)	<.001
Health status							
	H - N	1.14 (1.06, 1.122)	1.15 (1.02, 1.29)	0.01 (-0.14, 0.17)	0.887	-	-
	H - E	0.98 (0.91, 1.05)	1.15 (1.03, 1.27)	0.17 (0.10, 0.24)	<.000	0.16 (-0.01, 0.33)	0.066
	N - N	1.06 (0.99, 1.12)	1.06 (1.01, 1.11)	0.00 (-0.05, 0.05)	0.983	-0.01 (-0.18, 0.15)	0.898
	N - E	1.16 (1.09, 1.25)	1.20 (1.08, 1.32)	0.03 (-0.09, 0.14)	0.644	0.02 (-0.18, 0.21)	0.875

Notes: H-N indicates high diabetes states that did not expand Medicaid (AL, GA, MS, NC, OK, SC, TN, TX). H-E indicates high diabetes states that expanded Medicaid (AR, DE, KY, WV). N-N indicates low diabetes states that did not expand Medicaid (FL, ID, KS, ME, MO, NE, SD, VA, WI, WY). N-E indicates low diabetes states that expanded Medicaid (AZ, CO, CT, DC, HI, IL, IA, MD, MA, MN, NV, NJ, NM, ND, OH, OR, RI, VT, WA).

Table 4.6 Adjusted changes in self-reported access, diabetes management, and health status between subgroups

		Pre ①	Post ②	Δ (②-①)		Group comparisons	
		Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	p	Mean (95% CI)	p
Access							
	H - N	1.32 (1.24, 1.40)	1.38 (1.27, 1.49)	0.06 (-0.05, 0.17)	0.275	-	-
	H - E	1.41 (1.36, 1.45)	1.67 (1.58, 1.77)	0.26 (0.14, 0.38)	<.000	0.20 (0.09, 0.31)	0.000
	N - N	1.44 (1.36, 1.51)	1.57 (1.47, 1.68)	0.13 (0.06, 0.21)	0.001	0.07 (-0.01, 0.16)	0.083
	N - E	1.51 (1.45, 1.57)	1.67 (1.59, 1.74)	0.15 (0.05, 0.26)	0.003	0.09 (0.00, 0.18)	0.042
Diabetes manage ment							
	H - N	10.10 (9.10, 11.11)	9.68 (8.45, 10.91)	-0.43 (-1.23, 0.38)	0.298	-	-
	H - E	9.45 (8.45, 10.44)	10.65 (9.36, 11.95)	1.20 (-0.70, 3.10)	0.215	1.63 (-0.04, 3.29)	0.055
	N - N	10.04 (8.53, 11.55)	9.92 (8.36, 11.47)	-0.12 (-1.21, 0.97)	0.827	0.30 (-0.67, 1.28)	0.542
	N - E	12.59 (11.59, 13.58)	14.24 (13.41, 15.08)	1.66 (0.22, 3.10)	0.024	2.08 (0.86, 3.30)	0.001
Health status							
	H - N	1.39 (1.27, 1.50)	1.26 (1.04, 1.47)	-0.13 (-0.29, 0.04)	0.141	-	-
	H - E	1.32 (1.20, 1.44)	1.37 (1.19, 1.55)	0.05 (-0.12, 0.21)	0.592	0.17 (0.09, 0.26)	<.000
	N - N	1.32 (1.22, 1.42)	1.27 (1.04, 1.38)	-0.11 (-0.25, 0.04)	0.159	0.02 (-0.07, 0.10)	0.649
	N - E	1.10 (0.96, 1.23)	1.07 (0.86, 1.27)	-0.03 (-0.20, 0.11)	0.740	0.10 (-0.02, 0.22)	0.105

Notes: H-N indicates high diabetes states that did not expand Medicaid (AL, GA, MS, NC, OK, SC, TN, TX). H-E indicates high diabetes states that expanded Medicaid (AR, DE, KY, WV). N-N indicates low diabetes states that did not expand Medicaid (FL, ID, KS, ME, MO, NE, SD, VA, WI, WY). N-E indicates low diabetes states that expanded Medicaid (AZ, CO, CT, DC, HI, IL, IA, MD, MA, MN, NV, NJ, NM, ND, OH, OR, RI, VT, WA).

4.4. Discussion

The present study evaluated changes in self-reported access to care, self-reported diabetes management, and self-reported health status between Medicaid expansion and non-expansion states from 2011 through 2016. This study contributes to the growing body of literature about the impacts of the ACA's Medicaid expansion on diabetes management. First, covering both clinical and self-management adherence in diabetes management as a comprehensive diabetes management strategy, this study provides evidence of the impacts of Medicaid expansion on managing diabetes. Second, this study additionally evaluates changes in outcomes between states that expanded Medicaid and those that did not accounting for diabetes rates of the states. This analysis shows that the Medicaid expansion was associated with significant improvements in self-reported access to health care and self-reported diabetes management. In addition, the self-reported health status outcome variable revealed a difference between expansion and non-expansion states in that the former presented better health status. Among states with high diabetes rates, those that opted in Medicaid expansion experienced improvements in evaluated outcomes compared to those that opted out of Medicaid expansion: self-reported access to healthcare, self-reported health status, and self-reported diabetes management. These findings suggest that Medicaid expansion was associated with substantial improvements in the management of diabetes and health status, particularly among states with large diabetes populations that expanded the Medicaid. However, health disparities in non-Medicaid expansion states with high diabetes rates appear to be an emerging public health concern.

Previous studies on the general population have documented the positive impact of the ACA's Medicaid expansion on a variety of health indicators, such as access, health behaviors, and health outcomes.[31, 42, 43] Some studies focused specifically on individuals with diabetes and noted the potential positive effects of the new policy on diabetes management.[20] Researchers found that Medicaid-expanded states experienced improved accessibility, suggesting health benefits of the Medicaid expansion in the population with diabetes.[23] Another study reported an improvement in health care access but not receipt of diabetes care provided by clinicians,[25] while researchers found an increase in prescription.[26] However, their results were limited by either using one or two years of data after expansion or including only a few aspects of diabetes management. Furthermore, there have been only a few studies about the impact of Medicaid expansion focusing on the population with diabetes. The current study used data over an extended period and it examined diabetes management as a comprehensive diabetes strategy by including diabetes care provided by healthcare professionals, diabetes self-management, and health status. In addition, this study evaluated the impact of Medicaid expansion on diabetes management accounting for diabetes rates of the states. The improved access and diabetes management adherence found in this study are positive signals for the better health outcomes that follow as the literature established the link between the former and the latter.[44] The literature also suggests that people with diabetes who adhere well to diabetes management are more likely to prevent progression in diabetes-related complications.[45]

It is similarly important to acknowledge the evolving concerns of health disparities between expansion and non-expansion among states with high diabetes populations. While the focus of previous studies has been mainly on the health benefits of the new policy implementation, this study alarms public health communities about the emerging health inequalities in states with high diabetes populations that opted out of

Medicaid expansion. It suggests that those states would have encountered an exacerbated health of their population because of comparatively less access to healthcare and adherence to diabetes management.[46] Researchers found that the decisions of states to opt in or out of the Medicaid expansion were influenced by a variety of factors, such as professional and business lobbyists, and public interest groups, [47] which might not reflect well on the health needs of the population. Policy makers may consider public health benefits as high priority in the process of policy decision making in order to improve health of the population.

4.5. Limitation

We acknowledge important limitations in this study. First, it is difficult to infer a causal relationship with cross-sectional data by nature although the quasi-experimental model could alleviate the data's weakness. Future studies with prospective designs would strengthen the investigation of the impact of the Medicaid expansion. Another limitation is that this study did not account for the differences in implementing Medicaid expansion under the Section 1115 Medicaid Waivers, as states could have varying rules under the waivers. Third, with only a small body of available literature on this population, more studies are essential to improving our understanding of diabetes management and health status after the Medicaid expansion. Fourth, while a range of indicators for diabetes management is possible, our data include only a subset. Physiologic measures are important constituents in determining the impact of the Medicaid expansion on diabetes management. It is also important to acknowledge that self-reporting does not necessarily reflect the physiological health outcomes assessed by healthcare providers. Fifth, the BRFSS is a self-reported survey, which is subject to recall bias. Although researchers note that findings with self-reported data are consistent with those of nonsurvey-based data, [48] because of errors in memory and recall biases, there is speculation of the limitations of self-reported health. Furthermore, in comparison to physiological outcomes evaluated by healthcare professionals, personal perceptions could influence self-reported health. This may undermine the accuracy of the findings of this study. Objective measures in future studies are needed to improve the understanding of the impact of Medicaid expansion and confirm the findings in this study. [34]

Nevertheless, the findings of this study comparing important elements of diabetes management add to the literature, suggesting substantial positive impacts of Medicaid expansion on the health of the population with diabetes in expansion states, in comparison to that in non-expansion states and evolving health inequalities between states with high diabetes populations.

4.6. Conclusion

This study provides evidence that the Medicaid expansion under the ACA is associated with substantial improvements in access to healthcare and diabetes management in persons with diabetes. There is also an indication of improved health outcome in states that expanded Medicaid in comparison to those that did not. In addition, states with high diabetes rates that adopted the Medicaid expansion experienced significant health benefits. In contrast, states with a high diabetes burden that did not expand Medicaid under the ACA may be facing exacerbated public health practices and outcomes, suggesting emerging health inequalities between the states. The findings of the present study provide policy implications for local, state, and national health policy makers in America in their efforts of diabetes management and its control.

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5. CONCLUSIONS

5.1. Summary of the study

This dissertation aimed to investigate individual and social aspects of diabetes management focusing on depression, PA, and the impacts of Medicaid expansion. The findings of each section add to the literature for improving diabetes management.

First, the systematic review confirmed the association between depression and PA in type 2 diabetes as over 71% of the sample studies found a significant negative relationship between the two elements. When included only studies classified as high quality or reliability after quality assessment, the figure turned to be over 82%, which further strengthens the evidence of the link between depression and PA in type 2 diabetes.

This review had a particular interest in measures of PA and depression as different types of instruments have appeared in the literature. In measuring PA, individual study-specific methods were most frequently used and for measuring depression, PHQ-9 (or PHQ-8) was the most popular method. A wide range of measures suggests a lack of standard methods that can be extensively accepted in examining the association. Another finding showed that a majority of prior studies relied on a limited scope of PA rather than comprehensive measures covering leisure, non-leisure, and work-related activities. Furthermore, only a few studies conducted prospective studies, of which most had relatively short follow-up periods. Although the significant association between depression and PA was consistent, future studies may address these limitations to strengthen the knowledge base in the relationship between depression and PA in type 2 diabetes. Moreover, while studies have often been focused on a dose-response aspect, there is an increasing demand for evidence of differences in the association across diverse population subgroups.

Second, the empirical analysis of the association between depression and PA in diabetes confirms that there is a link between depression and PA, suggesting that a higher level of PA is associated with lower rates of depression. The key interest of the study though was the different risk of depression associated with PA across population groups: gender, age, and race/ethnicity.

The findings revealed no gender difference in the risk of depression at each level of PA. Given females are relatively sedentary and show higher rates of depression than males, this may suggest that females could promote their mental health by adopting active lifestyles to the similar extent males do. The findings also showed evidence of the different risk of depression between ethnic groups. A group of minorities may have greater health benefits than the white group in reducing depression by adhering to the recommended PA, while no significant difference was found in other ethnic groups. However, among only those with clinically significant depression, ethnic minorities showed no longer significant difference from the white group, while the Hispanic group turned to be statistically significant in the risk of depression. Given mixed findings among ethnic groups, more studies are needed to improve understanding of the ethnic differences in the effect of PA on depression. In addition, considering the diversity of the minority group, it is necessary to segment the population and understand the preferences and patterns of PA, which would enrich the knowledge for each population and the differences in the effect of PA on health outcomes between ethnic groups.

Age is another important consideration in depression and PA. Although depression is more prevalent in younger adults, its severity is more intense among older adults. The findings showed that older adults exhibited a relatively lower likelihood of depression than younger adults when engaging in regular PA. The findings would be a basis for people to seriously consider adopting active lifestyles to promote mental health as they are aging. The findings of this study would invigorate future studies to improve a body of knowledge about the age differences in depression associated with PA.

Third, the dissertation evaluated the impacts of Medicaid expansion on diabetes management. Given a substantial number of persons with diabetes were not insured before Medicaid expansion under the ACA, it is important to evaluate how the new policy affected management of diabetes. The findings revealed that Medicaid expansion was associated with significant improvements in self-reported - access to care, diabetes management, and health status. This provides evidence of the positive impacts of Medicaid expansion on health practices and outcomes in persons with diabetes. The study further evaluated differences in diabetes management by Medicaid expansion status accounting for diabetes rates of the states. The findings showed that states with high diabetes rates that expanded Medicaid experienced substantial improvements in self-reported - access to care, diabetes management, and health status compared to those that opted out of Medicaid. However, while health benefits in expanded states are remarkable, it is equally paramount to acknowledge health inequalities that Medicaid non-expansion states are facing in their health practices and outcomes, in particular, among those with high diabetes rates.

The findings of this dissertation suggest that individual and social efforts together contribute to diabetes management. They also provide critical implications to not only individuals with diabetes but also local and state as well as national health policy makers for effective management and control of diabetes.

5.2. Contribution to the literature

- A significant association between depression and PA in persons with diabetes
- Need for guidelines for objective measurements and well-designed prospective studies to strengthen the evidence base for this association and its directionality
- A growing demand for examining variations in this association between populations with different characteristics
- No difference between genders in the risk of depression associated with PA. E vidence of ethnic differences in the association between depression and PA. Greater health benefits among older adults compared to younger adults in reducing the risk of depression by adopting physically active lifestyles
- Medicaid expansion associated with substantial improvements in self-reported access to health care, diabetes management, and health status in persons with diabetes

- Substantial gains in self-reported access to health care, diabetes management, and health status in states with high diabetes populations that expanded Medicaid compared to in those that did not expand Medicaid

- States with high diabetes rates that opted out of Medicaid expansion may be facing exacerbated public health practices and outcomes, suggesting evolving health inequalities

5.3. Future research

- Develop objective measures for PA and depression
- Develop more evidence for different effects of PA on health outcomes for diverse population groups
- Evaluate expanded indicators of diabetes management including physiological and clinical aspects for the impact of Medicaid expansion
- Conduct prospective or experimental studies to confirm or compare the findings to those of survey-based cross-sectional studies

APPENDIX A

SENSITIVITY ANALYSIS FOR THE ASSOICATION BETWEEN DEPRESSION AND PHYISCAL ACTIVITY IN PERSONS WITH DIABETES

A.1 Association between depression and physical activity in persons with diabetes (PHQ-8 scores' cut points at >= 10), no interaction model

Effect	Model 1 OR (95% CI)
Age	
<45	-
45-64	0.72 (0.60, 0.88)‡
65>=	0.37 (0.26, 0.52)‡
Gender	
Male	-
Female	1.25 (0.99, 1.59)
Race/Ethnicity	
White	-
Hispanic	1.19 (0.92, 1.53)
Black	0.54 (0.46, 0.64)‡
Other	0.79 (0.55, 1.13)
Marital status	
Married	-
Divorced/Separated	1.09 (0.88, 1.36)
Never married	0.80 (0.53, 1.21)
Education	
<high school	-
High school	0.80 (0.64, 1.00)*
Some college	1.00 (0.82, 1.21)
College grad	0.71 (0.59, 0.86)‡
Employment	
Employed	-
Home/student	1.46 (0.89, 2.41)
Unemployed	2.94 (2.18, 3.96)‡
Retired	1.33 (1.08, 1.63)†
Insurance	
No	-
Insured	0.69 (0.40, 1.17)
Smoking	
Never	-
Former	0.79 (0.63, 1.00)
Current	1.53 (1.08, 2.18)‡

A.1 Association between depression and physical activity in persons with diabetes (PHQ-8 scores' cut points at >= 10), no interaction model - Continued

Effect	Model 1 OR (95% CI)
PA	
Inactive	-
Moderate	0.80 (0.64, 1.00)‡
Active	0.56 (0.50, 0.63)‡
Year	
2011	-
2015	1.04 (0.87, 1.24)
Comorbidity	1.53 (1.45, 1.62)‡

*Notes: P<.05, †P<.01, ‡P<.001.

A.2 Difference in the association between depression and physical activity (PHQ-8 scores' cut points at >= 10) across age, gender, and race/ethnicity

Effect	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
Age			
<45	-	-	-
45-64	0.71 (0.59, 0.86)‡	0.71 (0.58, 0.86)‡	1.10 (0.83, 1.92)
65>=	0.57 (0.42, 0.76)‡	0.37 (0.26, 0.52)‡	0.64 (0.38, 1.08)
Gender			
Male	-	-	-
Female	1.26 (0.87, 1.80)	1.24 (0.99, 1.57)	1.23 (0.98, 1.56)
Race/Ethnicity			
White	-	-	-
Hispanic	1.20 (0.93, 1.54)	0.85 (0.59, 1.23)	1.20 (0.92, 1.57)
Black	0.54 (0.46, 0.64)‡	0.58 (0.49, 0.68) ‡	0.52 (0.45, 0.61)‡
Other	0.78 (0.54, 1.13)	1.08 (0.76, 1.55)	0.79 (0.55, 1.14)
Marital status			
Married	-	-	-
Divorced/Separated	1.08 (0.88, 1.34)	1.09 (0.87, 1.36)	1.11 (0.89, 1.38)‡
Never married	0.80 (0.52, 1.21)	0.79 (0.53, 1.19)	0.81 (0.54, 1.23)
Education			
<high school	-	-	-
High school	0.80 (0.64, 1.00)*	0.80 (0.64, 1.01)	0.80 (0.65, 0.99)*
Some college	1.00 (0.82, 1.22)	1.02 (0.84, 1.24)	1.01 (0.84, 1.21)
College grad	0.71 (0.59, 0.85)‡	0.72 (0.60, 0.86)‡	0.70 (0.58, 0.85)‡
Employment			
Employed	-	-	-
Home/student	1.45 (0.88, 2.40)	1.47 (0.90, 2.43)	1.43 (0.87, 2.34)
Unemployed	2.98 (2.16, 4.10)‡	2.99 (2.18, 4.09)‡	2.94 (2.14, 4.04)‡
Retired	1.33 (1.08, 1.65)†	1.33 (1.08, 1.64)†	1.33 (1.07, 1.67)†
Insurance			
No	-	-	-
Insured	0.68 (0.39, 1.18)	0.69 (0.40, 1.20)	0.70 (0.41, 1.38)
Smoking			
Never	-	-	-
Former	0.79 (0.62, 1.00)	0.79 (0.62, 1.00)	0.79 (0.63, 0.98)*
Current	1.53 (1.07, 2.17)‡	1.54 (1.08, 2.22)*	1.54 (1.19, 2.00)†
PA			
Inactive	-	-	-
Moderate	1.04 (0.85, 1.29)	0.77 (0.63, 0.95)*	1.84 (0.68, 5.00)
Active	0.49 (0.37, 0.64)‡	0.57 (0.47, 0.69)‡	1.13 (0.49, 2.57)
Year			
2011	-	-	-
2015	1.04 (0.87, 1.25)	1.04 (0.87, 1.25)	1.08 (0.90, 1.31)

A.2 Difference in the association between depression and physical activity in persons with diabetes across age, gender, and race/ethnicity (PHQ-8 scores' cut points at >= 10) - Continued

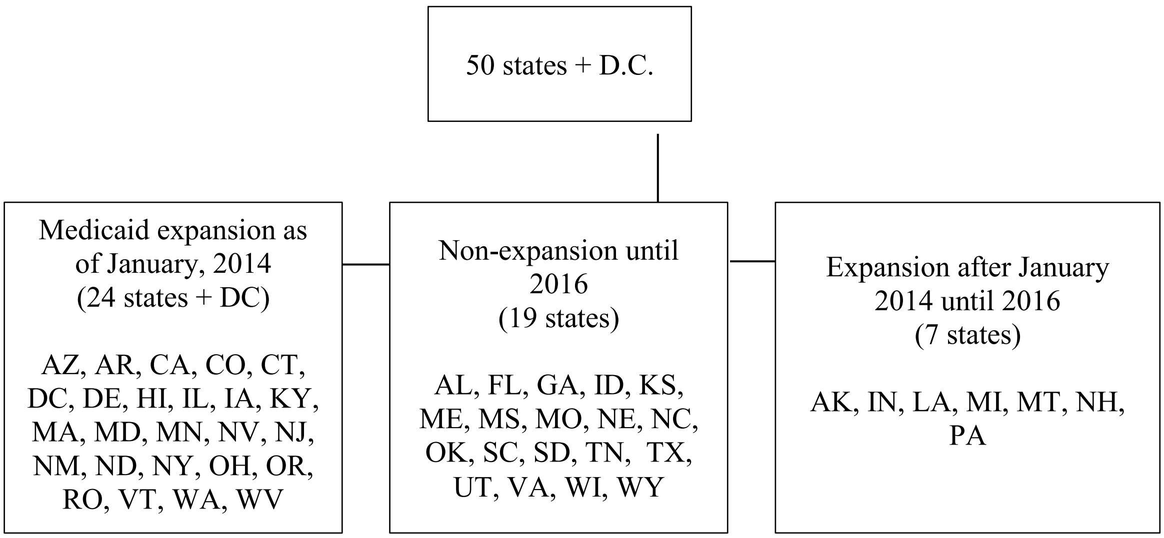
Effect	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
Comorbidity	1.53 (1.45, 1.62)‡	1.53 (1.45, 1.63)‡	1.53 (1.44, 1.63)‡
Gender*PA			
Moderately active	-		
Male	-		
Female	0.66 (0.42, 1.03)		
Active			
Male	-		
Female	1.28 (0.80, 2.05)		
Race/Ethnicity*PA			
Moderately active			
White		-	
Hispanic		2.13 (1.39, 3.28)‡	
Black		0.88 (0.55, 1.41)	
Other		0.63 (0.22,1.76)	
Active			
White		-	
Hispanic		1.62 (1.18, 2.21)†	
Black		0.89 (0.57, 1.37)	
Other		0.43 (0.18, 1.05)	
Age*PA			
Moderately active			
<45			-
45-64			0.51 (0.19, 1.34)
65>=			0.28 (0.09, 0.84)*
Active			
<45			-
45-64			0.51 (0.21, 1.23)
65>=			0.43 (0.17, 1.09)

*Notes: Model 1 adds an interaction between PA and gender. Model 2 adds an interaction between PA and race/ethnicity. Model 3 adds an interaction between PA and age. P<.05, †P<.01, ‡P<.001.

APPENDIX B

THE IMPACT OF MEDICAID EXPANSION ON DIABETES MANAGEMENT

B.1 Selection of states for the main model



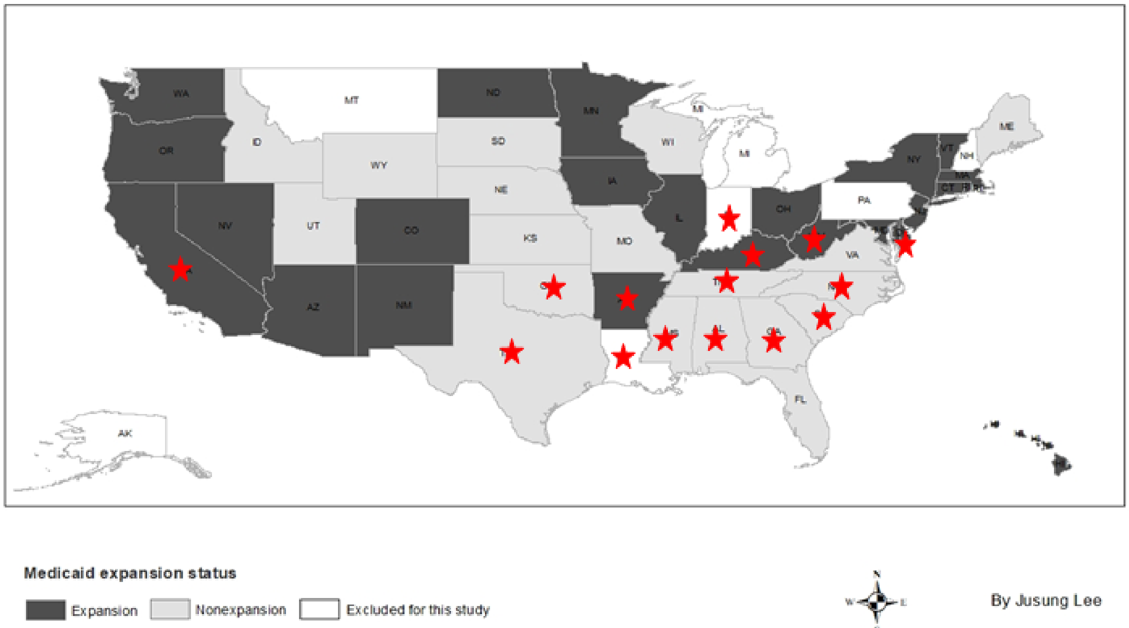
Notes: No data for CA and NY in Medicaid expansion states and for UT in Medicaid non-expansion states.

B.2 Medicaid expansion status at the end of 2016

B.3 Four groups by diabetes rates and Medicaid expansion status

	Diabetes rates	Medicaid expansion	States
Group 1 (H –N)	High	Non-expansion	AL, GA, MS, NC, OK, SC, TN, TX
Group 2 (H – E)	High	Expansion	AR, DE, KY, WV
Group 3 (N – N)	Non-high	Non-expansion	FL, ID, KS, ME, MO, NE, SD, VA, WI, WY
Group 4 (N – E)	Non-high	Expansion	AZ, CO, CT, DC, HI, IL, IA, MD, MA, MN, NV, NJ, NM, ND, OH, OR, RI, VT, WA).

B.4 States with high diabetes rates



B.5 Inclusion of states for sensitivity analysis

DID estimates (2) in table 5

Medicaid expansion in 24 states + D.C.: AZ, AR, CA, CO, CT, DE, D.C., HI, IL, IA, KY, MD, MA, MN, NV, NJ, NM, NY, ND, OH, OR, RI, VT, WA, WV. Among states that expanded Medicaid as of January 2014, five states (DE, DC, MA, VT, NY – already provided expanded coverage before 2014) were excluded resulting in 19 states (CA- no data) for the sensitivity analysis.

Medicaid non-expansion until 2016 in 19 states: AL, FL, GA, ID, KS, ME, MS, MO, NE, NC, OK, SC, SD, TN, TX, UT, VA, WI, WY *Among states that did not expand until 2016, one state (WI – provided expanded coverage under non-expansion status) was excluded resulting in 18 states (UT- no data) for the sensitivity analysis.

B.6 Sensitivity analysis

	Main model		New model	
	Mean (95% CI)	p	Mean (95% CI)	p
Access	0.09 (0.01, 0.13)	0.023	0.10 (0.02, 0.18)	0.013
Diabetes management	1.91 (0.81, 2.30)	0.001	1.94 (0.81, 3.07)	0.001
Health status	0.10 (0.01, 0.20)	0.026	0.10 (0.01, 0.20)	0.033

*Notes: The main model with 25 expansion states (CA, NY- no data) and 19 non-expansion states (UT- no data).

The new model 20 expansion states (CA- no data) excluding DE, MA, VT, NY, DC and 18 non-expansion states (UT- no data) excluding WI.