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The influence of daily stress on glycemic control and mortality in adults with diabetes

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Abstract There is mixed evidence regarding the relationship between different types of stress and outcomes in adults with diabetes. The aim of this study was to understand the relationship between daily stress and glycemic control (HbA1c), and to examine whether multiple daily stressors is associated with early mortality among individuals with diabetes. This was a cross-sectional analysis of national Midlife Development in the United States (MIDUS) study data. A total of 141 adults with diabetes completed the National Study of Daily Experiences (NSDE) project during the initial phase of the study, which was summarized through a series of measures about daily stress frequency, type and impact. General linear models investigated the relationship between daily stress and HbA1c. Kaplan–Meier curves based on national death index information linked to MIDUS were investigated for individuals reporting no/one stressor per week versus multiple stressors per week. On average, this population of adults with diabetes reported 3.1 days with a stressor and 2.45 stressor types per week. No significant relationships existed between glycemic control and frequency of daily stress. Higher stress from work was associated with higher HbA1c ($\beta = 0.65$, 95% CI 0.08, 1.22) and higher perceived risk of stress influencing physical health was associated with higher HbA1c ($\beta = 0.60$, 95% CI 0.01, 1.20). In conclusion, while many ways of measuring daily stress were shown not to have a significant influence on glycemic control, daily stress related to work and the perceived risk of stress influencing one's physical health may influence outcomes for adults with diabetes. Interventions incorporating stress management, and in particular coping with the risk that stress has on health may help adults with diabetes better manage glycemic control over time.

Keywords Diabetes · Stress · Glycemic control · Mortality · Work stress

Introduction

Diabetes is a growing epidemic in the United States, where the total prevalence in adults is now reported at 14%, with approximately 95% of all diabetes cases being type 2 (Mendola et al., 2018). The rates for individuals 20 years and older indicate 9.7% of adults have diagnosed diabetes, and 4.3% are undiagnosed (Mendola et al., 2018). As the 7th leading cause of death, individuals with diabetes are more likely to develop end-stage renal disease, and major cardiovascular diseases such as ischemic heart disease and stroke (CDC, 2017). In addition, the cost of diabetes increased by 26% since 2012 after adjusting for inflation, with those diagnosed spending on average 2.3 times more per year on healthcare expenditures than those not diagnosed (ADA, 2018).

Significant evidence exists regarding the influence psychosocial stress has on risk of disease, acceleration of disease, and overall health (Epel et al., 2018; Pearlin, 2010; Pearlin et al., 2005). A critical barrier to understanding the impact of stress on health is the complex nature of measuring multiple layers of stress (social, psychological and physiological), and the variety of possible modes of influence (Epel et al., 2018). For example, economic hardship across the life course, trauma, a cluster of stressful events, and daily

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stressors may influence health differently and challenge the coping and adaptive responses of individuals in different ways (Pearlin, 2010; Pearlin et al., 2005). A recent transdisciplinary model of stress suggests there are two major pathways through which stress influences health: the influence of chronic stress on the body and brain, and the neural and peripheral effect of stress responses on the body's physiological response, the perception of stress, and behavioral habits (Epel et al., 2018). In this model, daily stressors are separated from traumatic life events, and though considered minor they may exert influence on health if experienced in a chronic manner (Epel et al., 2018).

A number of studies show a relationship between stress and type 2 diabetes onset (Sui et al., 2016; Kramer et al., 2000; Garay-Sevilla et al., 2000), with traditional risk factors such as hypertension, physical activity, and BMI not explaining much of the stress-diabetes relationship (Harris et al., 2017). Diabetes specific stress, such as diabetes distress, has been consistently associated with glycemic control (Hilliard et al., 2016; Young-Hyman et al., 2016; Kuniss et al., 2018). However, evidence for the relationship between non-diabetes specific stress and glycemic control is mixed (Marcovecchio and Chiarelli, 2012). For example, in a study of patients with type 2 diabetes in India, higher levels of perceived stress were associated with increased HbA1c and decreased treatment adherence (Vasanth et al., 2017). Stress from work, particularly in women, was also associated with increased risk of diabetes onset (Sui et al., 2016; Pan et al., 2017). However, a study of middle-aged individuals with type 2 diabetes showed no relationship between stress from work and glycemic control, and in a study of individuals with type 1 diabetes, neither the type of stress (diabetes specific or general life stress) were found (Annor et al., 2015; Butler et al., 2017). Chronic stress is strongly associated with specific subgroups that face high levels of adversity, and studies suggest the type of stressor and other psychosocial resources may either increase or buffer the diabetes-stress relationship (Hilliard et al., 2016; Fisher et al., 2007; Kahn and Pearlin, 2006; Peyrot et al., 1999; Griffith et al., 1990). Additionally, though evidence indicates stress related hyperglycemia in trauma patients is associated with mortality, a gap in the current literature is understanding the overarching relationship between stress and mortality in individuals with diabetes (Kerby et al., 2012). Finally, little is known about the role of daily stressors and the impact on mortality in patients with diabetes. Recent evidence suggests the role of work-related stress on risk of early mortality among men and women with cardiometabolic disease, including diabetes, however caution has been raised concerning the interpretation and implications of the findings (Kivimäki et al., 2018; Yang and Hu, 2018).

Given the mixed evidence on the relationship between different types of stress and outcomes in adults with diabetes, the aim of this study was to understand the relationship between the frequency, type, and impact of daily stress and glycemic control (HbA1c). In addition, though preliminary in nature due to sample size, this study also aimed to investigate whether multiple daily stressors was associated with early mortality in order to better elucidate the influence of stress on outcomes in populations with diabetes. We hypothesized that a higher frequency of daily stress would have a relationship with glycemic control and mortality, particularly work-related stress.

Methods

Population sample

This study was a cross-sectional analysis of data collected through the Midlife Development in the United States (MIDUS) study. MIDUS is a national longitudinal study of health and well-being in middle age adults, which was first conducted in 1995–1996 (Wave 1) and based on a nationally representative random-digit-dial (RDD) sample of noninstitutionalized, English-speaking adults, aged 25–74 (Midlife in the United States, 2018; ICPSR, 2018). The purpose of the study was to investigate the role of behavioral, psychological, and social factors in understanding age-related differences in physical and mental health. MIDUS wave 1 comprised of 7108 adults who participated in a phone interview and then were invited to complete a self-administered questionnaire (SAQ). The second phase of MIDUS (Wave 2, conducted in 2004–2006) largely repeated baseline assessments (e.g., phone interview and extensive self-administered questionnaire). In addition, the protocol was expanded to include biomarkers and neuroscience. The purpose of the Biomarker Project was to add comprehensive biological assessments on a subsample of MIDUS respondents, thus facilitating analyses that integrate behavioral and psychosocial factors with biology.

Participants of the MIDUS study who completed the main project, Biomarker project, and Stress project from MIDUS Wave 2, and who had diagnosed or undiagnosed diabetes were eligible for our analysis. Of those who participated in Wave 1, 4041 also participated in Wave 2, completing both the phone interview and SAQ. Of those completing the main project, 1054 participants completed the Biomarker project, and 1842 participants completed the Daily Stress project. A total of 876 participants completed the main project, Biomarker collection and the Daily Stress projects. Of this number, 146 participants had diagnosed or undiagnosed diabetes and were eligible for inclusion in the analysis. We excluded 5 participants with no measured blood hemoglobin HbA1c, giving us a final sample size of 141. Participants were followed from the beginning of wave 2 (January 1st, 2004) to death or last date of death date available in the mortality data (May 2015). The average follow-up time was 11 years.

Diabetes and HbA1c assessment

Biomarker data was collected during a 24 h stay at one of 3 General Clinical Research Centers during Wave 2 of MIDUS (Midlife in the United States, 2018; ICPSR, 2018). Participants completed medication history, a physical exam, and a bone densitometry scan, in addition to self-administered questionnaires. Overnight urine samples and fasting blood samples were collected during the 24 h stay. Hemoglobin A1c (HbA1c) was collected as part of the blood sample measurements. Though individuals in the dataset were followed over time, glycemic control was not measured at multiple time-points and therefore longitudinal models could not be used.

This analysis focuses on 141 participants with diagnosed or undiagnosed diabetes based on blood hemoglobin HbA1c levels taken during the biomarker project and responses to questions asking if participants had been diagnosed with diabetes. Diagnosed diabetes was defined by an answer of yes to questions regarding diagnosis or a diabetes prescription recorded. Respondents were not asked if they were diagnosed with type 1 or type 2 diabetes so we refer to diabetes in general. Individuals who answered no but their HbA1c $\geq$ 6.5% or blood fasting Glucose levels $\geq$ 126 mg/dl, were defined as undiagnosed diabetes. 36.2% of the sample was undiagnosed.

Daily stress measurements

The Daily Stress project was incorporated into the phone-based questions and included short telephone interviews asking about participants daily experiences across eight consecutive days (Ryff and Almeida, 2017a, b). On the final interview day, the participants answered several questions about their previous week (Ryff and Almeida, 2017a, b). Data collection was spread throughout the year. Questions asked in the Daily Stress project were based on a previously validated scale, the daily inventory of stressful experiences (DISE) (Almeida et al., 2002). The DISE is a semi-structured instrument that assesses a wide array of daily stressful experiences and provides summary measures of daily stress (Almeida et al., 2002). The inventory consists of a series of stem questions asking whether certain types of events had occurred in the past 24 h along with a set of guidelines for probing affirmative responses (Almeida et al., 2002). DISE included 7 stem questions:

1. "Did you have an argument or disagreement with anyone since yesterday?";
2. "Since yesterday, did anything happen that you could have argued about but you decided to let pass in order to avoid a disagreement?";
3. "Since yesterday, did anything happen at work or school (other than what you already mentioned) that most people would consider stressful?";
4. "Since yesterday, did anything happen at home (other than what you already mentioned) that most people would consider stressful?";
5. "Many people experience discrimination on the basis of such things as race, sex, or age. Did anything like this happen to you since yesterday?";
6. "Since yesterday, did anything happen to a close friend or relative (other than what you've already mentioned) that turned out to be stressful for you?";
7. "Did anything else happen to you since yesterday that people would consider stressful?".

The dataset is organized by person-day responses. We summarized the stress-related measurement by person through a number of measures for daily stress frequency, type, and impact as specified by directions for analyzing the validated questionnaire data. (Ryff and Almeida, 2017a, b; Almeida et al., 2002). In addition, we created a series of dichotomized variables to better understand possible thresholds for association with diabetes outcomes.

A. Daily Stress Frequency

   (a) Number of days with stressor—count of reported days with stressor.
   (b) Average number of stressors per day—mean of reported number of stressors every day.
   (c) Any stressor reported—dichotomous variable with yes indicating 1 or more stressors over reported days.
   (d) Multiple stressors reported—dichotomous variable with yes indicating 2 or more stressors over reported days.

B. Daily Stress Type

   (a) Number of stressor types—count of reported stressor types over reported days.
   (b) Average stressor severity—mean of the stressor severity average per reported day.
   (c) Stress from an argument—dichotomous variable with yes indicating at least one day having a report of stress from an argument.
   (d) Stress from work during the week—dichotomous variable with yes indicating at least one day having a report of stress from work.

(e) Stress from home during the week—dichotomous variable with yes indicating at least one day having a report of stress from home.

C. Daily Stress Impact

(a) Average number of physical symptoms—mean of number of physical symptoms reported to result from stress per day averaged over the week.
(b) Average physical symptoms severity—mean of physical symptom severity score reported per day averaged over the week.
(c) Average negative affect—mean of negative affect reported per day averaged over the week.
(d) Stress disrupting daily routine—dichotomous variable with yes indicating respondent felt stress was disrupting their daily routine.
(e) Stress influencing financial situation—dichotomous variable with yes indicating respondent felt stress was influencing financial situation.
(f) Stress influencing physical health—dichotomous variable with yes indicating respondent felt stress was influencing physical health.
(g) Stress influencing future plans—dichotomous variable with yes indicating respondent felt stress was influencing future plans.

Mortality

Mortality information was collected during Wave 2 and Wave 3 (Midlife in the United States, 2018). We used the mortality statistics from Wave 3, which includes 3 general sources: (1) tracing conducted before, during, and after fielding; (2) formal National Death Index (NDI) searches; and (3) longitudinal sample maintenance. Mortality outcome of interest in this analysis only includes all-cause death. The follow up was censored at the last date of death date available in the mortality data (May 2015).

Covariates

Covariates included gender, age (treated as continuous), race/ethnicity (dichotomized as non-Hispanic White and other Minority), education (dichotomized as high school diploma or less and higher education), marital status (dichotomized as married and not married), household total income (dichotomized at the median which was less than $54,000 and $54,000 or more).

Statistical analysis

All analyses were performed using SAS version 9.4 (SAS institute, Cary NC), using a $p<0.05$ cut off to indicate significance. All analyses were identified a priori, with plans to conduct unadjusted and adjusted comparisons for each measure of daily stress on glycemic control, and one measure of daily stress on mortality. Since there were no repeated measures for our primary outcome (HbA1c) or the daily stress analyses were treated as cross-sectional. First, frequencies were run to summarize the sample demographics, mean and median was calculated for HbA1c, and summaries were run for each of the daily stress measures. Secondly, unadjusted linear regression models between each daily stress measure and HbA1c were calculated as a preliminary step to regression analysis. Thirdly, general linear regression models were used to assess the relationship between daily stress measurements and HbA1c. For each model HbA1c as a continuous measure served as the outcome. Each daily stress measurement was assessed in a separate model as the primary independent variable. After unadjusted models, each relationship was adjusted for age, gender, race/ethnicity, education, marital status, and income. Finally, a Kaplan–Meier curve was calculated for survival of individuals noting no/one stressor per week, and those indicating multiple stressors per week. Given the low event rate of mortality we did not run adjusted hazard models, and presented the unadjusted curves in results.

Results

The sample included 141 adults with diabetes. Table 1 provides sample demographics. Among adults with diabetes, 94.3% participants reported having any stress during the reported days, 72.3% reported having more than one stressor types. 51.1% were age 60 years old and above; 9.2% were minorities; 48.9% household total income were less than 54 thousand; 27.7% were not married, 24.8% had high school or below education. The mean HbA1c for the sample was 7.3 ± 1.57.

Table 2 provides information on the unadjusted relationship between daily stress measures and HbA1c, and the distribution of daily stress measurements provided in the dataset prior to summary dichotomous variables being created. Among adults with diabetes, the average number of days in a week with stressor was 3.04 ($\pm$1.86) days, and on average there were 2.45 ($\pm$1.42) stressor types over the week. The average stressor severity on a scale of 0-3 was 1.7 ($\pm$0.66), the average number of physical symptoms from stress were 2 ($\pm$1.85), the average physical symptom severity was 2.66 ($\pm$1.35) out of 10, and the average negative affect was 0.18 ($\pm$0.20) out of 3. Significant unadjusted relationships existed between HbA1c and stress from work ($p=0.02$), stress from home ($p=0.03$), and average physical symptom severity ($p=0.04$).

Table 1 Sample demographics of MIDUS participants with diabetes (n = 141)

	n (%)
Gender	
Male	70 (49.65%)
Female	71 (50.35%)
Age in years at interview	
Mean ± Dev (min–max)	60.2 ± 11.14 (37–81)
Race	
White	127 (90.07%)
Minority	13 (9.22%)
Education level	
High school diploma or less	35 (24.82%)
Higher education	105 (74.47%)
Marital status	
Married	102 (72.34%)
Not married	39 (27.66%)
Household total income category	
Less than $54,000	69 (48.94%)
$54,000 or more	68 (48.23%)
Individuals with any stressor	
No stressor	8 (5.67%)
With stressor	133 (94.33%)
Individuals with multiple stressor types	
No or single stressor	39 (27.66%)
With multiple stressors	102 (72.34%)
Blood hemoglobin (HbA1C) (%)	
Mean ± dev (min–max)	7.3 ± 1.57 (5.1–15.2)
Median (IQR)	6.80 (6.5–7.8)
Diagnosed diabetes	90 (63.83%)
Undiagnosed diabetes	54 (38.30%)
Follow-up time in years	
Mean ± Dev (min–max)	10.96 ± 1.43 (2.45–11.37)

Table 3 presents the adjusted linear analyses for the relationship between glycemic control (HbA1c) and daily stress measures. For adults with diabetes, higher stress from work was associated with higher HbA1c levels ($\beta = 0.64$, 95% CI 0.07, 1.20) and higher perceived risk of stress influencing physical health was associated with higher HbA1c levels ($\beta = 0.62$, 95% CI 0.04, 1.21). Other adjusted relationships were not statistically significant using a cut-off of $p < 0.05$.

Figure 1 shows the survival estimates for individuals with one or no stressors compared to those with multiple stressors. Though hazard estimates were not significant, the Kaplan–Meier curve indicates those reporting multiple stressors had an earlier drop in survival than those with one or no stressor.

Discussion

Using a cohort of individuals with diabetes, this study found that the majority of measures for stress frequency, type, and impact are not significantly associated with glycemic control. It did find, however, that adults who report more stress from work, and those who report feeling the risk of stress in their lives may impact their physical health had higher HbA1c (worse control). In addition, though daily stress did not have a significant influence on overall mortality in adults with diabetes, those with multiple stressors reported over an average week seemed to have an earlier decline in survival. While these results necessitate replication in larger samples, this study suggests that the relationship between stress and glycemic control in adults with diabetes may extend beyond diabetes distress and include daily stress, including work and the impact of stress on physical health.

This study adds important information to the literature on the relationship between stress and health outcomes in adults with diabetes. First, it highlights the importance of daily stress as a possible influence on glycemic control, and hence complications and outcomes over time. We did not find a significant relationship between the frequency of stress and glycemic control. However, the type of stress may be important to consider in understanding how stress influences diabetes outcomes. While stress at home and interpersonal conflict were not significantly associated with glycemic control, stress from work was significantly associated with glycemic control. In addition, our findings suggest the psychosocial impact of stress may be more detrimental than the stress itself on physical outcomes like glycemic control. For example, while the more quantitative measures of stress, such as number of stressors, number of days with a stressor, or average stressor severity, was not associated with glycemic control, the perceived risk of stress on physical health was significant. Rather than providing general coping strategies, it may be important to support adults with diabetes cope with concerns over the risk that stress may have on their health or address particular types of stress. Incorporating stress management into diabetes education, with specific efforts to highlight the utility of using stress management tactics to help keep HbA1c in control may be an effective way to address psychosocial concerns influencing diabetes outcomes.

These results expand on work conducted regarding the influence of stress from work, showing that it may not only influence diabetes onset as shown by prior studies (Sui et al., 2016; Pan et al., 2017; Annor et al., 2015), but also glycemic control. A population-based prospective study highlighted the residual effects of work stress over the lifetime, indicating that women over 60 who reported stress from work were more likely to be diagnosed with incident cases of diabetes over a 6-year follow-up period than those who did not

Table 2 Unadjusted relationship between daily stress measures and HbA1c

	Mean (SD)	Range	Unadjusted β (95% CI)	*p* value
Frequency of stress				
Number of days with stressor	3.04 (1.86)	0–7	−0.13 (−0.27, 0.01)	0.07
Average number of stressors per day	0.55 (0.46)	0–3	0.05 (−0.52, 0.63)	0.85
Any stressor compared to no stressor	Dichotomous variable		−0.03 (−1.17, 1.11)	0.96
Multiple stressors compared to no/single stressor	Dichotomous variable		0.06 (−0.53, 0.65)	0.84
Type of stress				
Number of stressor types reported	2.45 (1.42)	0–6	−0.02 (−0.21, 0.16)	0.81
Average stressor severity	1.70 (0.66)	0–3	0.01 (−0.41, 0.43)	0.97
Stress from argument	Dichotomous variable		−0.42 (−0.94, 0.11)	0.12
Stress from work	Dichotomous variable		0.68 (0.12, 1.24)	0.02
Stress from home	Dichotomous variable		−0.58 (−1.11, −0.06)	0.03
Impact of stress				
Average number of physical symptoms	2.03 (1.85)	0–11	−0.12 (−0.26, 0.02)	0.09
Average physical symptoms severity	2.66 (1.35)	0–7	−0.20 (−0.39, −0.01)	0.04
Average negative affect	0.18 (0.20)	0–2	−1.02 (−2.32, 0.29)	0.13
Risk of stress to disrupting daily routine	Dichotomous variable		−0.05 (−0.41, 0.31)	0.80
Risk of stress to financial situation	Dichotomous variable		0.40 (−0.26, 1.06)	0.24
Risk of stress to physical health	Dichotomous variable		0.34 (−0.23, 0.92)	0.24
Risk of stress to future plans	Dichotomous variable		−0.04 (−0.69, 0.60)	0.89

Table 3 Adjusted relationship between daily stress measures and glycemic control

Primary independent variable	Glycemic control[a]	
	β (95% CI)	*p* value
Frequency of stress		
Number of days with stressor	−0.15 (−0.29, −0.0002)	0.05
Average number of stressors per day	0.11 (−0.46, 0.69)	0.70
Any stressor compared to no stressor	−0.01 (−1.18, 1.16)	0.99
Multiple stressors compared to no/single stressor	0.03 (−0.57, 0.63)	0.92
Type of stress		
Number of stressor types reported	−0.01 (−0.20, 0.19)	0.95
Average stressor severity	0.22 (−0.23, 0.67)	0.34
Stress from argument	−0.49 (−1.02, 0.05)	0.07
Stress from work	**0.64 (0.07, 1.20)**	**0.03**
Stress from home	−0.43 (−0.96, 0.11)	0.11
Impact of stress		
Average number of physical symptoms	−0.05 (−0.20, 0.10)	0.50
Average physical symptoms severity	−0.11 (−0.31, 0.10)	0.30
Average negative affect	−0.91 (−2.33, 0.51)	0.21
Risk of stress to disrupting daily routine	0.04 (−0.34, 0.42)	0.84
Risk of stress to financial situation	0.30 (−0.44, 1.03)	0.43
Risk of stress to physical health	**0.62 (0.04, 1.21)**	**0.04**
Risk of stress to future plans	−0.12 (−0.79, 0.56)	0.73

Bold coefficients indicate significance at $p < 0.05$

[a]Sdjusted for age, gender, race, education, marital status, and income

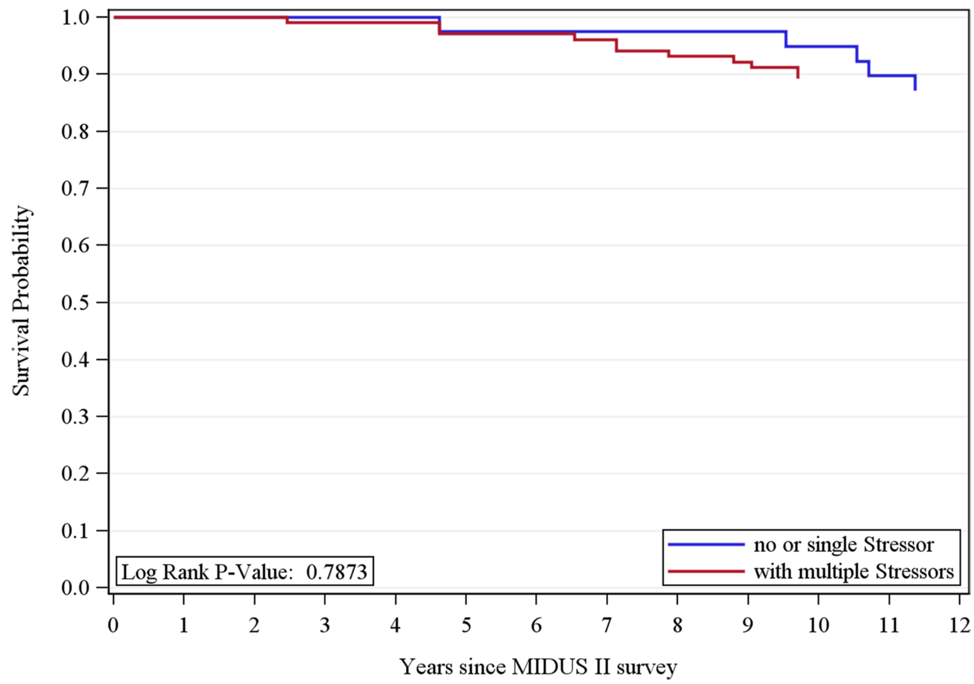

Fig. 1 Kaplan–Meier survival estimates for individuals with multiple stressors versus one/no stressors

report stress from work (Pan et al., 2017). The relationship was stronger when stress from work combined with household stress was tested, showing women who reported both were 2.4 times more likely to be diagnosed during follow-up (Pan et al., 2017). Studies have also noted that low levels of emotional support concurrent to stress from work in women increased risk for diabetes (Norberg et al., 2007). Contrary to our results, prior studies did not find a relationship between stress from work and glycemic control after controlling for sociodemographics and health behaviors (Annor et al., 2015). Therefore, these results suggest further efforts may be needed to identify effective ways to mitigate the influence of stress from work on individuals with diabetes.

In addition, these results highlight the importance of considering the psychosocial influence of stress on individuals. The relationship between glycemic control and worry over the risk of stress to physical health highlights the importance of not only teaching about the relationship between stress and diabetes, but working with individuals to develop healthy coping skills. Coping, problem-solving, and stress management have been areas of focus for diabetes research in the past. Coping that is task-oriented and problem focused, rather than wish-fulfillment coping style, and making use of past experience for focus of self-management goals was associated with better glycemic control (Fisher et al., 2007). There has also been some indication that cognitive-behavior therapy and behavioral activation focused on individuals with both depression and diabetes may decrease glycemic control, however, treatment was focused on depression rather than stress (Fisher et al., 2007; Egede et al., 2018). Small reductions in HbA1c have been seen in pilot stress management interventions, and mixed results on relaxation techniques (Fisher et al., 2007; Armani Kian et al., 2018; Rosenzweig et al., 2007; Wagner et al., 2016; Surwit et al., 2002; Stenstrom et al., 2003; Koloverou et al., 2014; Inouye et al., 2015). Though a number of studies have indicated improving coping skills is effective, little attention is given to developing healthy coping and directly addressing stress in clinical practice (Fisher et al., 2007). This may be a result of significant number of patients with diabetes reporting a lack of sufficient diabetes education and self-management training (Fisher et al., 2007; Peyrot et al., 2013). Therefore, support prior recommendations that stress may need to be considered a risk factor that should be discussed with individuals in the clinical encounter and incorporated into diabetes education and self-management training (Harris et al., 2017).

Though this study used a cohort of individuals followed over time and incorporated a series of possible aspects of daily stress, there are limitations to these results. First, the data cannot speak to causality as the glycemic control was measured at the same time as one of the repeated measures of daily stress. Secondly, the sample size was relatively small and a larger cohort would allow for incorporation of additional covariates to ensure stress continued to exert a significant independent influence. This is particularly relevant for the investigation with mortality, as the small number of events did not allow adjustment for confounders. Thirdly, the glycemic control in this cohort was particularly good, with a mean just above 7%. Therefore, populations with more uncontrolled diabetes may show a different relationship between stress and glycemic control, and should be targeted in future studies. Finally, there were a number of measures of stress incorporated into initial hypotheses. Given the multiple analyses, small effects, and number of null findings, results should be interpreted with caution and further studies should be conducted.

Conclusion

In conclusion, while many ways of measuring daily stress were shown not to have a significant influence on glycemic control, daily stress related to work and the perceived risk of stress influencing one's physical health may influence outcomes for adults with diabetes. Interventions incorporating stress management into diabetes education, and in particular providing training on coping with the concerns over the risk that stress has on health may help adults with diabetes better manage glycemic control and address diabetes outcomes over time.

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Compliance with ethical standards

Conflict of interest Rebekah J. Walker, Emma Garacci, Jennifer A. Campbell and Leonard E. Egede declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

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