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## Original research

## Control of type 2 diabetes mellitus during the COVID-19 pandemic

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## ABSTRACT

**Aims:** Type 2 Diabetes Mellitus (T2DM) is a prevalent chronic condition that can lead to significant complications if not well controlled. The COVID-19 pandemic created disruptions in daily life; however, it is unknown whether the pandemic's disruptions affected the ability for adults with T2DM to control their condition. This study aims to fill the knowledge gap with the experiences of adults with T2DM in Arkansas, U.S. during the COVID-19 pandemic.

**Methods:** This study analyzed cross-sectional, observational survey data collected from adults ( $\geq 18$  years) who live, work, or receive healthcare in Arkansas; self-reported a diagnosis of T2DM; and completed the diabetes module of the *Impact of COVID-19* online survey ( $n = 131$ ) fielded in July–August 2020. Descriptive statistics were used to characterize the sample and survey responses, and multivariate regression was used to identify demographics, self-care behaviors, and access issues associated with uncontrolled T2DM ( $\text{HbA1c} \geq 9\%$  or  $74.9$  mmol/mol) or with an increase in HbA1c.

**Results:** 28.2% reported an increase in their HbA1c since the pandemic began, and 18.2% had uncontrolled T2DM. Educational level, eating healthily, and weight gain were negatively associated with uncontrolled T2DM. Eating less healthily and having difficulty accessing diabetes related medication were positively associated with an increase in HbA1c.

**Conclusions:** Adults with T2DM in Arkansas were reasonably able to maintain control of their T2DM during the five months post the first case of COVID-19 diagnosed in the state. However, T2DM self-management interventions targeting those with lower educational levels that are focused on eating habits and/or that improve access to diabetes medication should be considered for future public health emergencies.

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## 1. Introduction

Type 2 diabetes mellitus (T2DM) is a chronic condition requiring maintenance of glucose levels. The age-adjusted prevalence of adult Americans with diabetes mellitus (DM) is 9.2%, the majority of whom have T2DM [1]. The American Diabetes Association recommends adults with T2DM to engage in self-care behaviors to manage their T2DM and prevent complications, including regular glucose monitoring, healthy eating, controlling weight, being physically active, and regularly seeing a healthcare provider [2].

Adults with T2DM experience more severe COVID-19 symptoms, require more intensive medical treatment (e.g., use of mechanical ventilation), and die from COVID-19 more often than

those without T2DM, independent of glucose control prior to infection [3,4]. However, uncontrolled T2DM does seem to place people at higher risk of poor outcomes from COVID-19. Bhandari et al. (2020) found that COVID-19-related symptoms among adults with uncontrolled T2DM (defined in their article as  $\text{HbA1c} > 8\%$  or  $64$  mmol/mol) were significantly worse compared to those with controlled T2DM. Adults with uncontrolled T2DM hospitalized due to COVID-19 were significantly more likely to require ventilation, to have longer hospital stays, and had higher mortality than those with controlled T2DM [5]. These results underscore the need for adults with T2DM to be diligent in efforts to prevent COVID-19 exposure and to engage in T2DM self-care.

The COVID-19 pandemic has significantly disrupted daily life around the globe. To minimize the spread, countries have initiated a variety of measures, including mask mandates; school closures; restrictions on business operations, public events, and visitations to some facilities (e.g., hospitals and nursing homes); and lock-downs

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of whole communities [6]. These measures have had negative effects for some adults, such as loss of income, food insecurity, and intensified stress, and effects on society, including high unemployment levels, disruption of trade and distribution of goods, and exacerbation of health disparities [7]. For adults with T2DM, COVID-19 mitigation measures may have negatively affected their ability to manage their condition. Previous research conducted after major disasters, such as hurricanes and earthquakes, has shown that substantial numbers of those seeking healthcare after disasters presented with adverse health outcomes from exacerbations of chronic diseases rather than injuries from the disasters [8–10]. A 2008 comprehensive literature review on the effect of disasters on T2DM reported increased glucose levels post-disaster, even among patients without medication interruptions [8,11]. The vulnerability of certain groups (older adults, minority racial/ethnic populations, and those with low socio-economic status and/or without health insurance) is magnified by disasters, resulting in increased risk of morbidity and mortality [8].

Although this current literature provides some insights on the experiences of adults with T2DM during the early months of the COVID-19 pandemic, it lacks information on T2DM control and self-care behaviors during the pandemic compared to before the pandemic and whether challenges and/or changes in self-care were associated with uncontrolled T2DM or an increase in HbA1c levels. Most publications on T2DM and COVID-19 identified in the literature were focused on the elevated risks for contracting COVID-19 or were commentaries on *potential* challenges with T2DM self-care or the importance of self-monitoring HbA1c during the pandemic [3,12–15].

Only two studies were identified which specifically examined the effect of the COVID-19 pandemic on T2DM outcomes and T2DM-related self-care behaviors. Xue et al. (2020) examined fasting glucose from one group (n = 69) and glycated hemoglobin levels from another group (n = 50) of older Chinese adults with T2DM. Among the fasting group, post (January–March 2020) glucose levels were significantly higher compared to baseline (January–March 2019) levels; however, no significant baseline to post difference was observed. This study did not consider changes in the characteristics of patients (e.g., health status) or in their self-care behaviors [16]. A study by Quinn et al. (2020) assessed the value of MyDesmond, an online self-management application for adults with T2DM. This study sent an online survey to MyDesmond users (n = 10,000) which asked about changes in self-care behaviors due to COVID-19. Of the 803 respondents (8.03% response rate), 24% reported eating more than usual, 37% reported being less active than usual, and 20% reported reducing medication intake since the start of the pandemic [17]. These two studies are helpful for showing the negative effect of COVID-19 on T2DM outcomes and self-care behaviors. The findings, however, are limited by the low response rate and the limited scope [17]. The purpose of the present study is to fill the knowledge gap by describing the experiences of adults with T2DM in Arkansas, U.S. and determining if uncontrolled T2DM is associated with self-care behaviors during the COVID-19 pandemic.

## 2. Methods

This study used a cross-sectional observational design.

### 2.1. Study sample

This study was restricted to adults with a self-reported T2DM diagnosis (n = 131) who completed the *Impact of COVID-19* online survey. To be eligible to participate in the survey, individuals had

to be  $\geq 18$  years of age and report living, working, or receiving healthcare in Arkansas.

### 2.2. Recruitment

Emails, which included a description of the online survey, eligibility criteria, and a consent process, were sent to potential respondents (n = 4077) who had previously registered and had a valid email address on ARresearch.org, a volunteer research participant registry, developed by the Translational Research Institute at the University of Arkansas for Medical Sciences (UAMS). Prior to consenting, potential respondents verified that they met the eligibility criterion.

Of the 4077 recruitment emails sent out, 1288 surveys were completed (31.6% response rate). The final survey sample was reduced to 1205 after duplicate surveys were removed (n = 11, the first survey submitted was retained), eligibility criteria could not be determined (n = 37), respondents were ineligible (n = 19), or surveys were blank beyond the eligibility questions (n = 16). The prevalence rate of diabetes among the final survey sample was 10.9%, which is lower than the prevalence rate of diabetes among the general adult population in Arkansas (13.6%) [18]. For the present analysis, the analytic sample was limited to those who reported they had been diagnosed with T2DM (n = 131).

### 2.3. Instrument and data collection

The instrument was developed by researchers interested in assessing the effects of COVID-19 on Arkansans. The survey included 147 general questions and 19 questions specific to T2DM presented to respondents who self-reported a T2DM diagnosis. Survey questions were drawn from existing instruments and question databases, including the Behavioral Risk Factor Surveillance System (BRFSS) survey and the PhenX Toolkit [19,20]. The survey also requested respondents' name, birth date, and email address, which allowed for identification of duplicates; however, data were de-identified prior to the analysis. The survey was fielded in July and August 2020. Respondents who completed the survey received a \$20 gift card as remuneration.

### 2.4. Analysis

Mean and standard deviation were calculated for continuous variables, and frequency and percent were calculated for dichotomous and categorical variables. Multivariate complementary log–log regression was used to identify demographic characteristics (age, sex, race, and education), self-care behaviors (eating habits, weight change, and exercise), and access issues (issues accessing diabetes medication and diabetes-related medical supplies) that were associated with uncontrolled diabetes (defined as HbA1c  $\geq 9\%$  or 74.9 mmol/mol, the threshold commonly used to define uncontrolled T2DM) [21] and with an increase in HbA1c (defined as the response option of “higher” to the question, *How different was this [current] HbA1c reading from the reading before the start of the COVID-19 Pandemic?* In the initial models, the exercise measures dropped out or had extremely wide confidence intervals; therefore, these measures were excluded from the final models.

### 2.5. Human subjects protections

UAMS' Institutional Review Board approved the study protocol (IRB# 261226).

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**Table 1**  
Socio-demographic characteristics and health status of adults with T2DM.

	Mean (SD) or n (%)
<b>Socio-Demographic Characteristics</b>	
Age, in years (n = 131)	53.4 (14.7)
Female (n = 131)	92 (70.2)
Race/Ethnicity (n = 131)	
White	95 (72.5)
Black	18 (13.7)
Hispanic	14 (10.7)
Other racial or ethnic group	4 (3.1)
Marital status (n = 131)	
Married/Partnered	80 (61.1)
Unmarried/Not partnered	51 (38.9)
Highest school grade completed (n = 130)	
High school or less	25 (19.2)
College 1–3 years or tech school degree	44 (33.9)
College degree or more	61 (46.9)
Annual income (n = 117)	
Less than \$25,000	40 (34.2)
\$25,000–\$50,000	41 (35.0)
More than \$50,000	36 (30.8)
<b>Health Status</b>	
Self-rated physical health (n = 131)	
Fair/Poor	80 (61.1)
Good/Excellent	51 (38.9)
Comparison of physical health from before to during the pandemic (n = 130)	
Better	36 (27.7)
About the same	87 (66.9)
Worse	7 (5.4)
Years since diagnosed with T2DM (n = 119)	8.2 (8.1)

Abbreviations: SD, standard deviation; T2DM, type 2 diabetes mellitus.

the decision to submit the study for publication. All authors confirm that they had full access to all the data in the study and accept responsibility to submit for publication.

### 3. Results

Most survey respondents were female (70.2%), white (72.5%), and were on average 53.4 years of age (SD = 14.7 years). Just under two-thirds (61.1%) were married/partnered. The preponderance of respondents had a college degree or more (46.9%) and incomes between \$25,000 and \$50,000 (35.0%). The majority of respondents (61.1%) self-reported their physical health as fair/poor and 66.9% indicated their health was about the same as before the start of the COVID-19 pandemic. See Table 1.

Table 2 presents results related to glucose monitoring, use of diabetes medication, and access to diabetes-related medication and supplies. The average HbA1c reported by respondents was 7.5%; however, 18.2% of respondents indicated their HbA1c was greater than or equal to 9%. Just over half of the respondents (51.3%) indicated their HbA1c was about the same as before the pandemic, 20.5% indicated it was lower, and 28.2% indicated their HbA1c was higher than before the pandemic began.

Respondents reported testing their glucose on an average of 3.5 (SD = 2.9) days per week, which was about the same as before the pandemic for 73.6% of respondents; 12.0% of respondents reported testing their glucose on more days, while 14.4% of respondents reported testing their glucose on fewer days. Just under two-thirds of respondents (62.4%) reported always having access to a continuous glucose monitor (CGM), while 31.2% reported never having access to a CGM; 5.6% of respondents reported they gained access to a CGM during the pandemic, while 0.8% reported they lost access to a CGM during the pandemic. The majority of respondents (53.5%) indicated they used oral medication to control their T2DM, 14.2% indicating they used insulin, and 21.3% indicated they used both oral medication and insulin. Only 11.0% of respondents indicated they do not use insulin or oral medication to control their T2DM. Two-thirds of the respondents (67.2%) reported no issues

**Table 2**  
Glucose monitoring, medication use, and access to diabetes related medication and supplies among adults with T2DM during the first six months of the COVID-19 pandemic.

	Mean (SD) or n (%)
Self-reported HbA1c (n = 121)	7.5 (1.9)
HbA1c ≥ 9% or 74.9 mmol/mol (n = 121)	22 (18.2)
Difference in HbA1c from before to during the pandemic (n = 117)	
Higher	33 (28.2)
About the same	60 (51.3)
Lower	24 (20.5)
Average number of days over per week when glucose was tested (n = 126)	3.5 (2.9)
Comparison of frequency of testing from before to during the pandemic (n = 126)	
Testing more	15 (12.0)
Testing about the same	92 (73.6)
Testing less	18 (14.4)
Access to continuous glucose monitor (n = 125)	
Have never had access to CGM	39 (31.2)
Lost access to CGM during the pandemic	1 (0.8)
Gained access to CGM during the pandemic	7 (5.6)
Have always had access to a CGM	78 (62.4)
Medication use to control T2DM (n = 127)	
Insulin	18 (14.2)
Oral medication	68 (53.5)
Both insulin and oral medication	27 (21.3)
Neither insulin or oral medication	14 (11.0)
COVID-19 pandemic affected access to diabetes-related supplies (n = 131) <sup>a</sup>	
Yes, insulin	18 (13.7)
Yes, other diabetes medications	11 (8.4)
Yes, needles	10 (7.6)
Yes, glucometer	20 (15.3)
Yes, glucometer and/or test strips	20 (15.3)
No issues	88 (67.2)
Don't know/not sure	5 (3.8)

Abbreviations: CGM, continuous glucose monitor; HbA1c, hemoglobin A1c; SD, standard deviation; T2DM, type 2 diabetes mellitus.

<sup>a</sup> Percentages total more than 100% as respondents could check more than one.

with access to diabetes-related medication or supplies. COVID-19 affected access to insulin and other medications for 13.7% and 8.4% of respondents, respectively. Access to needles was an issue for 7.6% of respondents, and access to glucometers and/or tests strips was an issue for 15.3% of respondents.

Table 3 presents the results on changes in other self-care behaviors. The average number of days per week that respondents reported checking their feet was 3.9 (SD = 3.0) days. This was about the same number of days per week as before the pandemic for 81.0% of respondents; 8.3% of respondents reported checking their feet more, and 10.7% reported checking their feet less than before the pandemic. Respondents reported they inspected their shoes on an average of 2.2 (SD = 2.8) days per week, which was about the same as before the pandemic for 89.7% of respondents; 3.4% of respondents reported inspecting their shoes on more days, and 6.8% reported inspecting their shoes on fewer days compared to before the pandemic.

Respondents reported engaging in at least 30 min of non-exercise specific activity on an average of 2.1 (SD = 2.0) days per week and in at least 30 min of exercise specific activity on an average of 1.4 (SD = 2.0) days per week. Activity levels did not change for 36.7% and 46.7% of respondents, respectively, compared to before the pandemic. Only 5.8% of respondents reported more non-exercise specific activity, 8.2% reported more exercise specific activity than before the pandemic, and 57.5% and 45.1% of respondents reported less non-exercise and exercise specific activity, respectively, compared to before the pandemic.

Respondents reported eating five or more servings of fruits and vegetables on an average of 3.1 (SD = 2.2) days per week. About

**Table 3**

Self-care behaviors among adults with T2DM survey respondents during the first six months of the COVID-19 pandemic and reported changes from before the pandemic began.

	Mean (SD) or n (%)
Average number of days per week when feet were checked (n = 120)	3.9 (3.0)
Comparison of frequency of feet checking from before to during the pandemic (n = 121)	
Checking more	10 (8.3)
Checking about the same	98 (81.0)
Checking less	13 (10.7)
Number of days per week when shoes were inspected (n = 119)	2.2 (2.8)
Comparison of frequency of shoe inspections from before to during the pandemic (n = 117)	
Inspecting more	4 (3.4)
Inspecting about the same	105 (89.7)
Inspecting less	8 (6.8)
Number of days per week of at least 30 min of non-exercise specific activity (n = 119)	2.1 (2.0)
Comparison of frequency of non-exercise specific activity from before to during the pandemic (n = 120)	
More non-exercise specific activity	7 (5.8)
About the same level of non-exercise specific activity	44 (36.7)
Less non-exercise specific activity	69 (57.5)
Number of days per week of at least 30 min of exercise specific activity (n = 121)	1.4 (2.0)
Comparison of frequency of exercise specific activity from before to during the pandemic (n = 123)	
More vigorous exercise	10 (8.2)
About the same level of vigorous exercise	57 (46.7)
Less vigorous exercise	55 (45.1)
Number of days per week when 5 or more fruit and vegetable servings were eaten (n = 117)	3.1 (2.2)
Comparison of frequency of fruit and vegetable consumption from before to during the pandemic (n = 117)	
More days	78 (63.4)
About the same number of days	3 (2.4)
Less days	42 (34.2)
Number of sodas or pop with sugar consumed in the past month (n = 98)	19.2 (36.8)
Comparison of number of sodas or pop with sugar consumed from before to during the pandemic (n = 117)	
Number decreased	21 (18.0)
Number about the same	82 (70.1)
Number increased	14 (12.0)
Comparison of eating habits from before to during the pandemic (n = 120)	
Eating more healthy now	32 (26.7)
Eating about the same	42 (35.0)
Eating less healthy now	46 (38.3)
Comparison of weight from before to during the pandemic (n = 121)	
Lost weight	38 (31.4)
Weight stayed about the same	43 (35.5)
Gained weight	40 (33.1)

Abbreviations: CGM, continuous glucose monitor; SD, standard deviation; T2DM, type 2 diabetes mellitus.

two-thirds (63.4%) reported consuming five or more servings on more days, 34.2% reported consuming five or more servings on fewer days, and 2.4% reporting consuming five or more servings on the same number of days as before the pandemic. Respondents reported drinking an average of 19.2 (SD = 36.8) sodas or pop with sugar per month. There was no change in consumption for 70.1% of the respondents. The average sugary drinks consumed per month increased for 12.0% and decreased for 18.0% of respondents compared to before the pandemic. Thirty-five percent of respondents reported their eating habits were the same, 38.3% reported eating less healthy, and 26.7% reported eating healthier compared to before the pandemic began. Weight gain since the start of the pandemic was reported by 33.1% of respondents, weight loss was reported by 31.4% of respondents, and no weight change was reported by 35.5% of respondents.

The regression models identified several factors associated with uncontrolled T2DM (HbA1c  $\geq$  9%) and increases in HbA1c since the start of the pandemic (Table 4). Respondents with at least some college education had one-third the odds of having uncontrolled T2DM during the first six months of the COVID-19 pandemic compared to those with a high school education or less (OR = 0.34, SE = 0.17, p = 0.03). Respondents who reported healthier eating habits since the pandemic began had less than one-fifth the odds of having uncontrolled T2DM compared to those who reported no change in their eating habits (OR = 0.18, SE = 0.13, p = 0.02). Finally, respondents who reported a weight gain during the first six months of the COVID-19 pandemic had one-fourth the odds of having uncon-

trolled T2DM compared to those who reported their weight had remained the same (OR = 0.25, SE = 0.17, p = 0.04).

Regarding increases in HbA1c during the first six months of the COVID-19 pandemic, respondents who reported their eating was less healthy were nearly 4 times more likely to report their HbA1c had increased compared to those who reported no change in their eating habits (OR = 3.99, SE = 2.01, p = 0.006). Respondents who reported having at least some difficulty in accessing T2DM medication were more than 4 times more likely to report an increase in their HbA1c compared to those who had no difficulty accessing diabetes medication (OR = 4.21, SE = 1.28, p = 0.008).

#### 4. Discussion

The COVID-19 pandemic has affected nearly all Americans in some manner [22]; yet, information specific to how adults with T2DM were able or unable to control their condition during the early months of the pandemic has not been previously available. Our study found that on average, adults with T2DM in Arkansas were reasonably able to maintain control of their condition during the first six months of the pandemic; however, more than one-quarter (28.2%) of respondents saw an increase in their HbA1c since the pandemic began, and nearly one-fifth (18.2%) had uncontrolled T2DM (HbA1c  $\geq$  9). In comparison, a recent analysis of pre-pandemic (2013–2016) National Health and Nutrition Examination Survey (NHANES) data estimated the percentage of adults in the U.S. with uncontrolled DM was 14.5% [1]. The similarity of the percentages of uncontrolled T2DM from our results and the

**Table 4**  
 Characteristics associated with HbA1c ≥ 9 and with an increase in HbA1c among adults with T2DM survey respondents during the first six months of the COVID-19 pandemic.

	HbA1c ≥ 9 (n = 112)			HbA1c Increased (n = 106)		
	OR	SE	P <sup>a</sup>	OR	SE	P <sup>a</sup>
Age	1.02	0.02	0.32	0.99	0.02	0.76
Sex						
Female	1.36	0.71	0.56	0.44	0.21	0.08
Male	..	..	..	..	..	..
Race						
Minority Race	1.90	1.03	0.24	0.67	0.35	0.45
White	..	..	..	..	..	..
Education						
Some college or degree	0.34	0.17	0.03	1.03	0.55	0.95
HS education or less	..	..	..	..	..	..
Change in eating habits						
Less healthy	0.56	0.31	0.30	3.99	2.01	0.01
More healthy	0.18	0.13	0.02	0.48	0.36	0.33
No change	..	..	..	..	..	..
Weight change						
Lost weight	0.64	0.34	0.40	0.87	0.45	0.76
Gained weight	0.25	0.17	0.04	1.53	0.79	0.41
No change	..	..	..	..	..	..
Difficulty obtaining healthcare						
At least some difficulty	1.35	0.80	0.61	4.21	1.28	0.01
No difficulty	..	..	..	..	..	..
Difficulty obtaining needed medication and/or supplies						
At least some difficulty	2.87	1.71	0.08	1.01	0.53	0.98
No difficulty	..	..	..	..	..	..

Abbreviations: HbA1c, hemoglobin A1c; HS, high school; OR, odds ratio; SE, standard error; T2DM, type 2 diabetes mellitus.

<sup>a</sup> Significant (P < .05).

NHANES analysis is somewhat surprising given past reports of the effect of natural disasters on HbA1c [11]. Our results are from July and August 2020, five months after the first COVID-19 case was reported in Arkansas. By this time, significant action had been taken by the state and federal governments, including the distribution of relief funds. Such action may have dampened any initial disruption in diabetes control or the pandemic may not have been as influential as expected. Additional surveys over the course of and after the COVID-19 pandemic are warranted to understand the long-term consequences on T2DM management.

We sought to identify whether demographic characteristics, changes in self-care behaviors, or issues with accessing diabetes-related medication and supplies during the pandemic were associated with increases in HbA1c and uncontrolled T2DM. Age, race, and sex of the respondents were not associated with increases in HbA1c or uncontrolled T2DM; however, education attainment level was negatively associated with having uncontrolled T2DM. Education, through access to resources, improved disease knowledge, and health literacy has been shown to improve health outcomes, including for diabetes [23].

The lack of an association with uncontrolled T2DM with race/ethnicity is interesting as African Americans have been found to be significantly more likely to have uncontrolled T2DM than Whites, after adjusting for demographic characteristics, comorbid conditions, and geography [24]. The lack of an association between race and uncontrolled T2DM or increasing HbA1c found in the present study may be due to the small number of adults from racial/ethnic minority groups in our sample. Future research on this topic should try to increase participation from racial/ethnic minority groups, which can be achieved through targeted recruitment approaches. For example, prior research found African Americans were more responsive to participating in survey research through in-person recruitment compared to recruitment from research registries, which was used in this study [25].

Of the nine self-care behaviors asked about in the survey, the highest percentage of respondents reported the practice of six of the self-care behaviors stayed the same as compared to before the COVID-19 pandemic began (foot check, shoe check, soda consump-

tion, weight maintenance, and glucose monitoring). In our adjusted models, we did not find a change in any of these behaviors to have a significant association with having either uncontrolled T2DM or an increase in HbA1c. Many of these behaviors can be performed without requiring additional resources or settings outside one's home (e.g., foot and shoe check, drinking less soda) and so may have been less affected by COVID-19 mitigation efforts.

More than half of the respondents (57.5%) reported less non-exercise specific activity, and 45.1% reported less exercise specific activity compared to before the pandemic began. The decline in exercise-specific activity among the respondents to this survey was higher than among respondents to a survey on the effect of COVID-19 on exercise fielded by Gunton et al. The Gunton et al. survey showed that 35.7% of those survey respondents (n = 331) had decreased their frequency of moderate exercise; however, 45.7% of those respondents decreased their frequency of vigorous exercise, compared to before the pandemic [26]. The difference between the results of Gunton et al. and ours may be in part due to difference in the exercise questions used and/or the health status of respondents; the present analysis was restricted to adults with T2DM with a majority (61.1%) of whom reported their physical health as fair/poor, while the Gunton et al. analysis was not restricted by health conditions. Adults at greater risk of experiencing poorer COVID-19 outcomes (e.g., adults with T2DM) and those in generally fair/poorer health may have been more inclined to stay isolated inside and thus not engage in exercise than those of a more general population.

Respondents indicated their eating habits had become less healthy as compared to before the pandemic began, although 63.4% of respondents indicated they were eating fruits and vegetables on more days than before the pandemic. Interestingly, research conducted prior to the pandemic showed that cooking meals at home was significantly associated with healthy eating, as measured with a higher Healthy Eating Index 2015 score [27]. Presumably, with self-quarantine recommendations and reduced service capacity and/or closures of restaurants, more adults would be cooking at home more and likely eating healthier. However, survey respondents may have continued to eat restaurant food through carry-out

or delivery options and/or engaged in emotional eating, which has been shown to be associated with high levels of COVID-19-induced stress [28]. Consistent with prior research, poor eating habits were found in our adjusted models to be significantly associated with uncontrolled T2DM and an increase in HbA1c since the start of the pandemic. Surprisingly, weight gain was found in our adjusted models to be significantly associated with reporting controlled T2DM. Although counterintuitive, it may be that individuals who are using insulin and/or medications to treat their diabetes are increasing their dosage in response to changes in diet and activity levels in order to better manage their T2DM. Increases in insulin and some diabetes medications are linked to increases in weight, which may explain these findings [29]. To further explore the connection between increases in weight and diabetes management, researchers will need to include questions regarding changes in treatment protocols during COVID-19.

Access to diabetes-related medications and glucose monitoring supplies are important in the control of T2DM [30]. Two-thirds of respondents indicated they had no difficulties in accessing medications or supplies. Those who reported difficulties in accessing medication, however, were significantly more likely to have reported an increase in HbA1c. Future research should be undertaken to understand what specific access issues encountered during the pandemic (e.g., financial access issues, supply chain issues, self-pick-up versus delivery) created the medication access issues to target ways to improve diabetes-related medication access during future public health emergencies.

#### 4.1. Limitations

The results must be interpreted in light of several limitations. Respondents self-selected into the study and are predominately white, female, and highly educated. The resulting sample selection bias may make the results less generalizable to Arkansans or other populations; however, the results of the study remain important as they shed light on the effect of COVID-19 on the management of T2DM. Additionally, all responses were self-reported, presenting a risk of response bias. The risk was minimized by use of validated survey questions (e.g., BRFSS survey questions), results of which have been shown to be similar to in-person data collection for many measures [31]. Finally, the adjusted models did not include some factors (e.g., access to healthcare providers) which can affect T2DM control [30], resulting in potential omitted variable bias. Future research should incorporate data on other factors as well as work to increase the sample size to more tightly isolate the effects of the COVID-19 pandemic.

## 5. Conclusion

This study provides previously unavailable information on the effect of the first six months of the COVID-19 pandemic on HbA1c and self-care among adults with T2DM in Arkansas. In general, most did not experience adverse changes to their HbA1c levels, even if they changed their self-care behaviors or reported difficulties accessing diabetes medication or related supplies. However, eating habits, weight change, and difficulties in accessing diabetes medication and educational attainment were significantly related to having uncontrolled T2DM or increases in HbA1c levels compared to before the pandemic started. Given the increased risk of COVID-19 complications and death among those with uncontrolled T2DM, even small to moderate challenges to self-care behavior are important to understand and address. These findings can help guide future research on self-care behavior and the development of response plans for future public health emergencies to improve T2DM management during such periods.

## Author contributions

Holly C. Felix conceptualized the analysis presented in the paper, assisted with survey development, conducted the literature review, led data interpretation, led writing of the original draft and contributed to the review/editing of the subsequent versions of the paper, approved final version of the paper, and agreed to be accountable for all aspects of the work.

Jennifer A. Andersen assisted with survey development, verified the underlying data, led the data analysis and development of the tables, contributed to the literature review, contributed to data interpretation and review/editing of the paper, approved final version of the paper, and agreed to be accountable for all aspects of the work.

Don E. Willis assisted with survey development, and contributed to data interpretation, assisted with review/editing of the paper, approved final version of the paper, and agreed to be accountable for all aspects of the work.

Joseph R. Malhis contributed to data interpretation and review/editing of the paper, approved final version of the paper, and agreed to be accountable for all aspects of the work.

James P. Selig assisted with survey development, verified the underlying data, contributed to data interpretation, assisted with review/editing of the paper, approved final version of the paper, and agreed to be accountable for all aspects of the work.

Pearl A. McElfish conceptualized the survey, acquired funding to field the survey, led development of the survey, and contributed to data interpretation and review/editing of the paper.

## Data sharing

The deidentified data underlying the results presented in this study may be made available upon request from the corresponding author Dr. Pearl A. McElfish, at [pamelfish@uams.edu](mailto:pamelfish@uams.edu). The data are not publicly available in accordance with funding requirements and participant privacy.

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## Declaration of interest

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There are no additional conflicts of interest to report.

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