

Article

Diabetes Distress and Advanced Diabetes Technology Use in Adults with Type 1 Diabetes

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Abstract

Background: Although technology has improved the quality of diabetes management, it may also introduce subjective burdens and reveal barriers to its use. The primary aim of this research was to investigate the association between the use of advanced diabetes technology, such as continuous glucose monitoring, insulin pumps, mobile applications, and diabetes distress in adults with type 1 diabetes mellitus (T1DM). **Methods:** This multicenter, cross-sectional study conducted across Southeastern European countries included 499 adults with T1DM. All participants signed informed consent and completed the 20-item Problem Areas in Diabetes (PAID) Questionnaire. A total score of 40 or above was classified as high diabetes distress. Statistical analyses were performed using ANOVA, χ^2 test, and logistic regression. **Results:** The mean age of participants was 49.11 ± 13.99 years, with a mean HbA1c value of $7.9 \pm 1.46\%$. The mean PAID total score was 29.19 ± 19.51 . High levels of diabetes distress were found in 28.86% of the participants. About 20% of participants used advanced diabetes technologies. Significant predictors of diabetes distress were gender, BMI, and HbA1c. After accounting for these predictors, advanced technology use was associated with a 42% lower likelihood of experiencing high levels of diabetes distress compared to those who used blood glucose meters. **Conclusions:** Diabetes distress remains a frequent issue among individuals with T1DM. However, patients using advanced diabetes technologies exhibited less distress. Our findings highlight the importance of a comprehensive approach to T1DM management that integrates technological advancements and psychosocial support.

Keywords: diabetes distress; advanced technology; type 1 diabetes



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1. Introduction

Patients with type 1 diabetes (T1DM) typically need lifelong insulin therapy for metabolic control, prevention of chronic complications, and sustain survival. Although insulin treatment is life-saving, the quality of glucose control largely depends on patients' motivation, education, and empowerment for glucose monitoring and therapy adjustments [1]. In addition, patients with T1DM need to adopt a complex lifestyle to maintain good metabolic control. Failure to meet treatment targets can lead to constant worrying about weight gain, hypoglycemic and hyperglycemic events, and feelings of guilt, contributing to noticeable emotional discomfort and leaving patients feeling overwhelmed and burned out. If this distress reaches a clinically significant level, it may be diagnosed

as diabetes distress [2]. By definition, diabetes distress refers to the patients' negative emotional reactions related to the challenges of living with diabetes [3]. The concept of 'diabetes distress' was first introduced into psychosocial research in 1995 and has since been acknowledged as one of the most prevalent and significant psychosocial obstacles to optimal diabetes management. It affects approximately 20–40% of individuals living with T1DM [4,5]. Given its association with poorer glycemic control and an increased risk of long-term complications, diabetes distress is clinically significant and can be measured using validated assessment tools [6]. In more detail, individuals living with T1DM are primarily concerned about the future, the potential for developing complications, and the risk of hypoglycemia [7]. While current guidelines recommend routine screening for diabetes distress in persons with type 1 diabetes (T1DM), implementation in clinical practice remains limited [8]. Diabetes distress is highly relevant in the era of modern diabetes technologies, as their use requires the acquisition of new developed skills and behavior change.

Modern diabetes technologies, including insulin pumps (IPs) and insulin pens, continuous glucose monitors (CGM), and mobile applications (MAs), have been shown to improve diabetes outcomes in large randomized trials [9]. When paired with education, modern diabetes technologies (CGM, IPs, and MAs) offer numerous advantages and may improve health and increase the quality of life for diabetic individuals [10]. However, several barriers hinder both the adoption and effective use of advanced diabetes technology. These tools may unintentionally exacerbate diabetes distress due to behavioral changes related to their use. For instance, using CGM enables close monitoring of glucose levels, which can lead to increased anxiety simply because of the high volume of readings. Moreover, adjusting to new technologies can involve challenges related to constant connectivity and the pressure to stay updated with advancements and upgrades, potentially fostering a negative psychological relationship with these tools. An emotional state often referred to as technology-related stress may subsequently develop. This condition is characterized by anxiety, tension, or distress arising from feeling overwhelmed by the demands of advanced technology. Such feelings may occur when patients struggle to adapt to or effectively manage these tools, limiting their acceptance and sustained use. Therefore, although technological advancements have improved diabetes care, subjective psychological concerns may present obstacles to their effective implementation.

The primary goal of the present research was to explore the association between the use of advanced diabetes technologies and diabetes-related distress in adults living with T1DM. The secondary aims included identifying predictors and key factors contributing to diabetes-related distress.

2. Materials and Methods

This cross-sectional study encompassed participants from Southeastern European countries, including Bulgaria, Croatia, and Serbia. The study protocol defined several inclusion criteria: a confirmed diagnosis of T1DM for more than 1 year, age over 26 years, and a documented hemoglobin A1c (HbA1c) measurement obtained within one month before study enrollment. This age limit was implemented to ensure that all study participants, though already adults, were receiving care from an adult diabetologist instead of a pediatric endocrinologist.

Exclusion criteria included non-T1DM diagnoses, insulin regimen changes in the previous three months prior to study enrollment, and those who had received any non-insulin pharmacological treatment since their T1DM diagnosis were excluded from this

study. Consecutively included participants, signed the written informed consent form, and completed the validated Problem Area in Diabetes (PAID) questionnaire.

The study was conducted in accordance with applicable regulations and received approval from the appropriate ethics committee at each participating site. Approval was granted by Croatia's Central Ethics Committee at the Agency for Medicinal Products and Medical Devices.

Data were collected from patients' medical records and supplemented with information collected during a single study visit at hospital centers between January and December 2018. To ensure a representative patient sample, participating physicians were randomly selected from a preestablished list of all endocrinologists and diabetologists in the participating countries using computer-generated randomization. Physicians who agreed to participate following phone contact were recruited until the target number was reached.

Collected data included demographics, T1DM duration, microvascular complications, HbA1c, hypoglycemic events, and diabetes technology use. Symptomatic hypoglycemic events were documented in the preceding three months. (≤ 3.9 and ≤ 3.0 mmol/L) were quantified. After data collection, participants completed the PAID questionnaire.

The PAID questionnaire is a 20-item standardized questionnaire that assesses diabetes-related emotional distress [11]. Items are self-rated on a 5-point Likert scale, ranging from 0 (not a problem) to 4 (serious problem). Scores are summed and multiplied by 1.25 to yield a total score from 0 to 100. A total PAID score of 40 and over is considered high and indicates diabetes-related distress [12].

The PAID scale addresses multiple emotional concerns related to diabetes and has been validated in both clinical practice and research [13]. Specific PAID questionnaire versions, translated into the local language and locally validated, were utilized in the study. A sample of the English version of the PAID questionnaire employed in the research can be found in Appendix A.

Statistical Analysis

Comparisons between different patient subgroups were analyzed using ANOVA, while the correlation between diabetes distress and the use of diabetes technology (advanced technology users vs. blood glucose meter users, i.e., BGM) was examined using the χ^2 test. To assess the impacts of various types of technology on diabetes distress levels, analysis of covariance (ANCOVA) was performed, controlling for age, gender, diabetes duration, microvascular diabetic chronic complications, number of severe hypoglycemic episodes, and HbA1c levels. Advanced technology users were defined as participants using one or more of the following: CGM, IPs, and MAs.

A binary logistic regression was applied, with the binarized distress measure as the dependent variable and advanced technology use as the predictor, adjusting for gender and age. A multiple-regression model was explored using a stepwise selection procedure, applying an entry criterion of 0.10 and a removal criterion of 0.05. A p -value < 0.05 was considered statistically significant.

3. Results

A total of 499 participants from Southeast Europe were included in the study sample. The majority of participants had longstanding T1DM with present microvascular complications. The participants' characteristics are presented in Table 1.

Table 1. Participants' characteristics/ total sample.

		N = 499	(%)
Gender	Male	231	(46.3)
	Female	268	(53.7)
Total		499	(100.0)
Age (years)	≤40	163	(32.7)
	41–60	215	(43.1)
	≥61	121	(24.2)
Total		499	(100.0)
Duration T1DM	<10 years	98	(19.6)
	≥10 years	401	(80.4)
Total		499	(100.0)
Microvascular diabetes complications	No	145	(29.4)
	Yes	348	(70.6)
Total		493	(100.0)
Country	Bulgaria	200	(40.1)
	Croatia	100	(20.0)
	Serbia	199	(39.9)
Total		499	(100.0)
Technology used	MA users	31	(6.3)
	IP users	32	(6.4)
	CGM users	36	(7.2)
	BGM users	400	(80.1)
Total		499	(100.0)

MA = mobile applications, IP = insulin pumps, CGM = continuous glucose monitors, BGM = blood glucose meter.

The participants' mean age was 49.11 ± 13.99 years, the mean HbA1c level was $7.9 \pm 1.46\%$, and the mean PAID total score was 29.19 ± 19.51 . Advanced technology users were significantly younger than BGM users ($p < 0.001$), while the difference in BMI between the two groups was marginal ($p = 0.076$), as presented in Table 2.

Table 2. Participants' characteristics.

	Total Sample		BGM Users		AT Users		<i>p</i>
	Mean	SD	Mean	SD	Mean	SD	
Age	49.11	13.99	50.23	14.11	44.59	12.49	<0.001
BMI	25.24	4.54	25.42	4.50	24.51	4.67	0.076
HbA1c (%)	7.90	1.46	7.88	1.45	7.96	1.6	0.633
PAID Total Score	29.19	19.51	29.50	20.25	27.92	16.27	0.469

t-test. Descriptive parameters are presented as mean values \pm standard deviation, SD. Abbreviations: BMI = Body mass index, HbA1c = Glycated Hemoglobin, PAID = Problem areas in diabetes, BGM = blood glucose meter AT = advanced technology.

In the study sample, 144 out of 499 participants (28.86%) experienced diabetes distress, as indicated by a PAID score of ≥ 40 , based on the predefined cut-off.

Regarding the technology used by study participants, most of them (99.0%) used blood glucose meters. Advanced technologies, with or without the concomitant usage of blood glucose meters, were used by 99 participants (19.8%). With reference to the type of advanced diabetes technology, CGMs were used by 7.2% of the study population, IPs by

6.4%, and MAs by 6.3% of participants. The CGM subgroup included participants using CGMs, with or without MAs. The IP subgroup included participants using IPs, with or without CGMs or MAs. The MA subgroup included participants who used apps only.

The use of advanced technologies was associated with a lower percentage of patients having a high PAID score ($p < 0.001$), although there was no association with the mean PAID score, as presented in Table 3.

Table 3. Diabetes distress among technology subgroups.

	AT (99)	BGM (400)	<i>p</i>
PAID score Mean (SD)	27.91 (16.27)	29.57 (20.22)	0.469
PAID \geq 40 (%)	20 (20.20%)	124 (31.00%)	<0.001

χ^2 test. PAID = Problem Areas in Diabetes, BGM = Blood glucose meter, AT = advanced technology.

Our study found significant differences between users of various diabetes technology types. Male participants with T1DM used advanced technologies less frequently than female participants ($p = 0.027$). Additionally, advanced technology users were significantly younger than non-users, whereas older participants primarily relied on blood glucose meters ($p < 0.001$). Microvascular complications were most common in the group of BGM users ($p = 0.003$). Finally, there was no significant difference in the number of hypoglycemic episodes between patient groups. These correlations are shown in Table 4.

Table 4. Characteristics of technology users.

		AT Users		BGM Users		<i>p</i>
		N	(%)	N	(%)	
Sex	Male	36	(36.4)	195	(48.8)	0.027
	Female	63	(63.6)	205	(51.2)	
Total		99	(100)	400	(100.0)	
Age (years)	\leq 40	43	(43.4)	120	(30.0)	<0.001
	41–60	44	(44.5)	172	(43.0)	
	\geq 61	12	(12.1)	108	(27.0)	
Total		99	(100)	400	(100.0)	
Duration of T1DM (years)	<10	21	(21.2)	77	(19.3)	0.66
	\geq 10	78	(78.8)	323	(80.7)	
Total		99	(100)	400	(100.0)	
Microvascular complications	No	41	(41.4)	104	(26.0)	0.003
	Yes	58	(58.6)	296	(74.0)	
Total		99	(100)	400	(100.0)	
Symptomatic hypoglycemia (mmol/L)	None	29	(29.3)	96	(24.0)	0.277
	\leq 3.9	70	(70.1)	304	(76.0)	
Total		99	(100)	400	(100.0)	
Symptomatic hypoglycemia mmol/L	None	47	(47.5)	217	(54.3)	0.227
	<3.0	52	(52.5)	183	(45.7)	
Total		99	(100)	400	(100.0)	

χ^2 test. Documented symptomatic hypoglycemic in the last 3 months. Abbreviations: BGM = Blood glucose meter, AT = advanced technology.

Independent contributions to diabetes distress were further investigated using logistic regression. Factors predicting high diabetes distress included female sex, increased body mass index (BMI), higher HbA1c, and older diabetes technology use (BGMs). Male patients were found to have a 46% lower likelihood of high diabetes distress. Furthermore, each increase of 1 kg/m² in BMI was linked to a 5% rise in the level of diabetes distress, while a 1% rise in HbA1c was linked to a 16% increase in the odds of high diabetes distress. Even after adjusting for these factors, advanced technology usage remained a significant determinant. T1DM patients who adopted new technologies had a 42% reduced likelihood of experiencing high diabetes distress levels compared to using BGMs (Table 5).

Table 5. Determinants predicting high levels of diabetes distress.

	<i>p</i>	OR	95% CI	
Sex (male)	0.004	0.543	0.359	−0.821
Age	0.374			
Age (41–60 years)	0.889	0.967	0.600	−1.557
Age (61+ years)	0.205	0.686	0.384	−1.228
Microvascular complications	0.303	1.294	0.793	−2.112
Duration T1DM (≥10 years)	0.678	1.123	0.650	−1.942
HbA1c (%)	0.034	1.162	1.012	−1.334
Hypoglycemia < 3.9	0.326	1.331	0.752	−2.358
Hypoglycemia < 3.0	0.281	1.296	0.809	−2.077
AT use	0.049	0.576	0.333	−0.996
BMI	0.033	1.052	1.004	−1.102

logistic regression. Abbreviations: HbA1c = Glycated hemoglobin, BMI = body mass index. T1DM = type 1 diabetes mellitus, AT = advanced technology.

4. Discussion

In this cross-sectional study conducted in Southeastern European countries, evaluating diabetes-related distress and the use of technology in individuals with T1DM, we found that 28.86% of participants experienced significant diabetes-related distress. This finding aligns with previous research, which has shown that 20–40% of people with T1DM report elevated diabetes distress [4] and with recent results from a Norwegian nationwide registry study indicating a prevalence of 21.7% [14].

Technology is a double-edged sword: on one hand, it reduces stress by making glucose monitoring and insulin delivery easier; on the other, it creates exposure to stress induced by technology, often referred to as technology—related stress, for patients who struggle to keep up with rapid advancements or find the devices burdensome. While innovations in diabetes technology may offer greater convenience and precision, they may also cause frustration and confusion, especially for patients who experience difficulties with technology [15].

In the present study, the use of advanced technologies independently predicts lower levels of diabetes-related distress at a statistically significant level. The proportion of T1DM patients using CGMs, IPs, and MAs was smaller compared to the global data documented in the SAGE study for the same period (7.2%, 6.4%, and 6.2% vs. 23%, 20% and 11.3%, respectively). However, the SAGE study showed substantial disparities between various geographic regions, with Western Europe exhibiting the highest technology penetration [16]. These differences largely reflect variations in device availability and healthcare policies among the countries involved. Notably, although diabetes technologies are now recommended as a standard of care in patients with T1DM, their adoption among the

T1DM population remains incomplete. Patient age has been identified as a significant limiting factor. According to recent real-world reports, the adoption of CGMs and IPs among the older population with T1DM remained significantly below 50% in 2021, even in Western European registries, albeit with an upward trend. In the United States, uptake of modern technology is even lower, with the use of CGM estimated at approximately 27% in the older population. Data on the prevalence of insulin pumps in this age group are limited, but suggest similarly low adoption rates, with limited evidence [17,18].

The relationship between technology and diabetes-related stress is complex, partially unknown, and unexplored. If patients experience technology—related stress due to device complexity, frequent updates, or data overload, their diabetes-related stress may increase. Conversely, if technology effectively reduces the burden of diabetes management (e.g., by automating glucose monitoring or insulin delivery), it may help alleviate diabetes-related stress. The impact likely varies depending on the patient's comfort with technology and the usability of the devices, the type of technology available (easy to use, demanding, using alarms, etc.) [19,20].

Technology-related stress may exacerbate certain negative physiological and psychological outcomes. Some previous results suggest that this type of stress could differentially affect the activity of the hypothalamic-pituitary-adrenocortical axis, potentially influencing the body's stress response [21]. Such a response could worsen glucose control. Therefore, it is essential to select the right type of diabetes technologies for each patient [22]. Furthermore, offering a greater variety of diabetes devices can meet the diverse needs of users. Even simple, user-friendly devices, alongside high-tech solutions, may better suit the lifestyle of different patient groups [23,24].

Addressing concerns about potential technology-related stress and demonstrating the benefits can enhance both health outcomes and quality of life. It is likely that the proportion of advanced technology users has increased today compared to the numbers obtained from our study cohort, due to increased availability, affordability, and endorsement by local clinical practices and policies. Otherwise, it would be more difficult to make meaningful comparisons with non-users and gain real insights.

The results of the present research showed that users of advanced technology had a smaller proportion of patients with a high PAID score compared to non-users. These results suggest that advanced technology use may help alleviate diabetes distress.

Such data have been observed in previous studies, which show that CGM not only helps lower stress for patients with T1DM, but also significantly reduces stress for the families who take care of them [25,26].

Higher HbA1c levels, frequent episodes of severe hypoglycemia, missed insulin boluses, and worse quality of life were significantly associated with higher diabetes distress scores ($p > 0.001$) [27].

Furthermore, the results of our study indicate that significant determinants of high diabetes distress were female gender, higher HbA1c, and higher BMI. These findings correspond with the findings from the T1 Exchange Clinic Registry study, which reported that diabetes distress in T1DM patients is more prevalent among females who have higher HbA1c [28]. Previous research has reported on gender specific differences in emotional responsiveness and expressivity [29]. In patients with T1DM, weight gain is related to intensified insulin therapy. Being overweight or obese is more prevalent in individuals with T1DM compared to the general population. Several factors, including demographic, clinical, environmental, and psychosocial (female sex, higher insulin needs, unhealthy eating patterns, depression, stress), contribute to the increased risk of overweight and obesity in T1DM [30,31]. Other research has found that higher stress levels, reduced quality of life, lack of social support, and a negative perception of physical self-image

are related to a higher BMI [32,33]. Moreover, in patients with T1DM, a higher BMI is also associated with lower levels of physical activity, creating a vicious cycle [33]. While previous studies demonstrated associations between diabetes-related distress and younger age as well as the duration of T1DM [28], our findings did not show differences in diabetes-related distress levels among different age groups. A potential interpretation for this discrepancy is the difference in the mean age of our cohort, 49.11 ± 13.99 years, compared to 37.64 ± 16.3 years in the T1 Exchange Clinic Registry [28].

Analyzing individuals with T1DM from the age of 26 and above, rather than starting at 18, is often done to ensure a more stable and representative adult population. Many people with type 1 diabetes between 18 and 25 years old are still transitioning from pediatric to adult care, both medically and psychosocially. They may face challenges related to hormonal changes, lifestyle instability, and shifting responsibility for disease management. They are so-called emerging adults [34]. By focusing on those 26 and older, we aimed to minimize variability associated with late adolescence and early adulthood and better capture long-term patterns of self-management and health outcomes. A study found that 64% of young adult T1DM patients who were still in pediatric care reported avoiding transitioning to adult care due to an emotional attachment to their pediatric provider [35].

The main methodological strength of this study is its relatively large cohort of the T1DM population from a real-world setting. The collected large dataset enhances the generalizability of the presented results. All potentially eligible individuals with T1DM at the study sites were consecutively invited to participate in this research, decreasing the risk of selection bias. In addition, participating investigators were chosen at random. Finally, diabetes-related distress was assessed utilizing a well-validated and comprehensive instrument.

On the other hand, this study has several limitations that need to be acknowledged. The study's cross-sectional design prevents the assessment of causal relationships. Furthermore, reliance on self-reporting and retrospective collection of data on hypoglycemic episodes may have led to underreporting and underestimating the true frequencies of these events. It is not excluded that participants using advanced technologies were early adopters or belonged to higher socioeconomic strata, which may have led to better diabetes control. However, in the landscape of a fast diabetes technology evolution and faster adoption in some geographies, the prevalence of new technology users may have significantly increased since the time of data collection, potentially including patients who are less comfortable with these new tools. Our study data were collected in 2018, in low-income and middle-income Southeastern European countries or underfunded healthcare systems lacking access to advanced diabetes technologies, which may limit the generalizability of the findings to other regions. However, even in wealthy societies, advanced diabetes technology is not accessible to everyone due to factors like insurance limitations, high costs, or systemic inequalities in healthcare access, and this study could be an input to make it more widely available. Differences in ethnic and cultural backgrounds, as well as health-related beliefs and attitudes, should be considered when comparing these results with those from other populations. Nonetheless, we believe that these results remain useful for addressing needs in developing countries or underserved populations in developed countries.

5. Conclusions

Our findings suggest that using advanced diabetes technologies does not impose an increased emotional burden on T1DM patients. On the contrary, technology use emerged as an independent predictor of significantly lower diabetes distress.

These findings underscore the importance of personalized care approaches that combine technology-enabled care with psychosocial support to improve quality of life in people living with type 1 diabetes.

Author Contributions: Concept and design: N.G. and M.B.; analysis of data and drafting of the manuscript: N.G.; interpretation of the data, reviewing drafts of the manuscript: N.G., M.B. and V.A. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the guidelines for Good Epidemiology Practice and principles laid down in the 1964 Declaration of Helsinki by the 18th World Medical Assembly and its later amendments. The study was reviewed and approved by Central Ethics Committee of the Agency for Medicinal Products and Medical Devices in Croatia (Approval Code: 530-07/18-01/24, ref. number: 381-15/60-18-02, Approval Date: 27 April 2018) and by the Independent Interdisciplinary Ethics Committee on Ethical Review for Clinical Studies in accordance with the local regulations in each participating country/study center.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: Author Natasa Grulovic is employed by the company Sanofi. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

Appendix A

Problem Areas in Diabetes (PAID) questionnaire, English Version

Problem Areas In Diabetes (PAID) Questionnaire					
INSTRUCTIONS: Which of the following diabetes issues are currently a problem for you? Circle the number that gives the best answer for you. Please provide an answer for each question.					
	Not a problem	Minor problem	Moderate problem	Somewhat serious problem	Serious problem
	0	1	2	3	4
1. Not having clear and concrete goals for your diabetes care?	0	1	2	3	4
2. Feeling discouraged with your diabetes treatment plan?	0	1	2	3	4
3. Feeling scared when you think about living with diabetes?	0	1	2	3	4
4. Uncomfortable social situations related to your diabetes care (e.g., people telling you what to eat)?	0	1	2	3	4
5. Feelings of deprivation regarding food and meals?	0	1	2	3	4
6. Feeling depressed when you think about living with diabetes?	0	1	2	3	4
7. Not knowing if your mood or feelings are related to your diabetes? ..	0	1	2	3	4
8. Feeling overwhelmed by your diabetes?	0	1	2	3	4
9. Worrying about low blood sugar reactions?	0	1	2	3	4
10. Feeling angry when you think about living with diabetes?	0	1	2	3	4
11. Feeling constantly concerned about food and eating?	0	1	2	3	4
12. Worrying about the future and the possibility of serious complications?	0	1	2	3	4
13. Feelings of guilt or anxiety when you get off track with your diabetes management?	0	1	2	3	4
14. Not "accepting" your diabetes?	0	1	2	3	4
15. Feeling unsatisfied with your diabetes physician?	0	1	2	3	4
16. Feeling that diabetes is taking up too much of your mental and physical energy every day?	0	1	2	3	4
17. Feeling alone with your diabetes?	0	1	2	3	4
18. Feeling that your friends and family are not supportive of your diabetes management efforts?	0	1	2	3	4
19. Coping with complications of diabetes?	0	1	2	3	4
20. Feeling "burned out" by the constant effort needed to manage diabetes?	0	1	2	3	4

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