scientific reports

Check for updates

OPEN

Conquering diabetes by overcoming psychological barriers and embracing health

Fanni Őry[1]✉, Botond László Kiss[1,2], András Norbert Zsidó[1,2,3] & Szidalisz Ágnes Teleki[1]

Living with chronic conditions like diabetes mellitus (DM) or insulin resistance (IR) requires significant self-management, adding to daily life stressors. This stress, known as diabetes distress, along with health empowerment from proper diet and lifestyle, and motivation to eat healthily, greatly impacts quality of life and disease outcomes. Different patient subgroups (type 1 diabetic (T1DM), type 2 diabetic (T2DM), and insulin resistant (IR) individuals) face these challenges differently. This research aims to compare people with IR and DM to those without, and to compare IR, T1DM and T2DM subgroups on psychological factors. Data was collected via an online questionnaire from 746 participants (average age 37.5 years). Among them, 405 had IR ($N=177$) or DM (Type 1: $N=116$; Type 2: $N=112$), and 341 were controls. Results showed that T2DM individuals scored lower than controls on Identified Regulation, Interoceptive Awareness, and Search for Meaning in Life, while the IR group had higher body-mind disconnection. T1DM individuals experienced the highest emotional distress due to the disease but the lowest distress from regular check-ups compared to T2DM and IR groups. The gradient boosting classification model indicated that IR and T1DM groups are homogeneous, whereas T2DM is heterogeneous, with significant within-group variation in disease experience and management. Despite similarities in daily life challenges, significant differences exist in disease experience among the groups. Individual characteristics of T2DM individuals further diversify their attitudes towards disease management.

Keywords Diabetes mellitus, Insulin resistance, Diabetes distress, Health empowerment, Motivation for healthy eating, Body responsiveness, Meaning in life

Theoretical background

Diabetes mellitus and insulin resistance

Diabetes mellitus (DM) is one of the major chronic diseases today[1,2]. Data for 2021 show that 537 million people are currently living with DM around the world, with a 46% increase predicted by 2045 [1]. DM is an endocrine disease, a carbohydrate metabolism disorder, more specifically a glucose processing disorder[1,3–5]. It is diagnosed by a significantly elevated blood glucose level[6,7]. It is caused by the inadequate pancreatic β-cell function, which leads to a lack of or insufficient production of the insulin hormone[4,5]. Without the necessary amount of insulin, cells are unable to absorb glucose from the blood[7]. This means that glucose is not converted into energy that the body can use but accumulates in the blood[3]. As a result, blood glucose levels rise and do not fall without external intervention[5,7]. Depending on the reason for the inability of the pancreas to produce the hormone insulin and the extent to which its function is impaired, there are two main types of DM[4,5,7]. Depending on the type, treatment may vary: insulin therapy, medication and lifestyle changes may be recommended[1,2,8].

Type 1 diabetes mellitus (T1DM) develops from autoimmune causes at an early age, before the age of 30 [4,9]. In this case, the pancreas's insulin-producing cells are damaged, i.e., destroyed or inactive, due to immune causes. Consequently, to survive insulin must be injected into the body from an external source[5]. Today exogenous insulin is delivered by PEN injection or insulin pump device[7].

The development of type 2 diabetes mellitus (T2DM) is mainly due to lifestyle factors such as obesity, a sedentary lifestyle, and an inadequate diet[5,7], although genetic predisposition is also thought to play a role[10]. It is

[1]Faculty of Humanities and Social Sciences,Institute of Psychology, University of Pécs, 6 Ifjúság Street, Pécs 7624, Hungary. [2]Szentágothai Research Centre, University of Pécs, Pécs, Hungary. [3]Research Centre for Contemporary Challenges, University of Pécs, Pécs, Hungary. ✉email: ory.fanni@pte.hu

often diagnosed after the age of 40 years in people with a genetic predisposition and an inappropriate lifestyle[5]. A comprehensive lifestyle change is essential for its management[10]. However, in most of the cases lifestyle changes must be complemented by medication or, in more severe cases, insulin therapy[4]. It may be possible to identify a pre-existing reversible condition of T2DM[1].

This pre-existing prior condition of T2DM is called insulin resistance (IR). In many cases IR can be reversed with a healthy diet and regular exercise[11,12]. It can be grouped with DM because it is also a metabolic disorder that is caused by abnormalities in insulin receptors. In fact, IR develops when cells become insensitive to the action of insulin hormone for some reason[13]. It can exist on its own, or it can develop into diabetes or co-exist with other chronic conditions (e.g. PCOS; Ighbariya & Weiss, 2017). IR, like T2DM, is closely associated with certain lifestyle characteristics (e.g. obesity) as well as genetic factors[11,12,14]. Obese people, and even children, are at particular risk of metabolic disorders[14,15]. The symptoms and possible consequences and complications of IR are like those of diabetes. Although it is a less severe and often reversible condition, it is mostly a chronic, lifelong metabolic problem requiring constant attention and illness management, that can have a significant impact on the quality of life[16].

Living with a chronic illness

IR and DM both worsen the quality of life and have many negative consequences, making them a major public health problem around the world[2,6].The treatment of people with diabetes and DM's complications (e.g. slow-healing wounds, skin infections, cardiovascular problems, kidney failure, sexual dysfunction, vision problems, neuropathy, limb amputation), functional decline, and high premature mortality rates place a significant disease burden on both the health care system and society[1,4,6,8,17].

The diagnosis of IR or DM is often experienced as a crisis, a grief reaction, and a traumatic event[18]. The burden of living with these states is significant, with psychosocial effects impacting self-care, long-term glycemic control, risk of complications, and quality of life[17,19]. Diabetic people frequently perceive the daily management of their disease as a significant challenge as it demands a considerable investment of energy and commitment from the person with diabetes[18,20]. This is particularly the case when they are striving to achieve a state of optimal metabolic health, a goal that is often unattainable (Silva et al., 2018). Furthermore, the self-care guidelines are often intricate and opaque, which can result in diabetic people experiencing feelings of frustration, anger, being overwhelmed or defeated and lacking motivation to adhere to disease management[21]. Often, illness-related conflicts with loved ones arise and the patient's relationship with health professionals may become tense as well[22].

Diabetes distress

The additional workload associated with the management of DM can contribute to an overall increase in stress levels. This negative emotional or affective experience, arising from the challenge of living with the specific demands of DM, is known as diabetes distress[23]. Diabetes distress refers to the worries, doubts, fears, and threats associated with coping with DM, including its management, the risk of complications, possible loss of functions and concerns about access to care[22–24]. Diabetes distress is an expected response to DM: it doesn't necessarily represent psychopathology and shouldn't be considered a co-morbidity, it is simply an emotional aspect of DM[23]. It is a multifaceted construct that has implications for various aspects of DM management and self-care, and is common in both T1DM and T2DM diabetic individuals and can also be extended to IR persons. It is associated with lower levels of self-care, general emotional well-being, and with worse metabolic outcomes of illness management[20,22–25].

Health empowerment

Health empowerment is an important indicator of health behavior[26–28]. It can be interpreted in two different contexts[26,29]. In an intrapersonal sense, it expresses the extent to which an individual can make autonomous decisions about maintaining their health. It therefore includes both knowledge and skills related to health maintenance[27,30]. In an interpersonal sense, health empowerment expresses the extent to which an individual can cooperate with professionals to maintain their health[29]. In conclusion, patient empowerment can be defined as the process by which a patient strives to gain comprehensive and effective control over the management of their illness, while developing a close relationship with specialists who can provide professional guidance and information to support the patient's goals[28]. In essence, it is the patient's own control and responsibility over the quality of their own life[28,30].

Enhanced health empowerment is associated with improved health outcomes across a diverse range of individuals with chronic diseases[26–28,30] and in individuals who are generally healthy[31,32]. However, in patient populations, it is crucial to monitor specific health behaviors to prevent adverse outcomes[26,27,30]. In contrast, individuals who are in good health do not feel direct pressure to engage in specific behaviors. Instead, they act in a considered manner, weighing the potential benefits and risks involved[32]. The provision of appropriate, reliable, and easily accessible sources of information is a crucial element in the enhancement of health empowerment in both groups[31,33].

As early as the 1990s, Anderson and his colleagues highlighted the significance of developing programs centered on patient empowerment within the context of diabetes care. The intervention, which had been tested, led to an increase in patients' self-efficacy regarding diabetes management and enabled them to control their blood glucose levels more effectively[33]. In individuals with type 2 diabetes, diabetes empowerment is associated with enhanced effective self-care behaviors (e.g., dietary habits, physical activity, or foot care), improved medication adherence, and greater knowledge[30].

Motivation for healthy eating

Regardless of the reason why someone is trying to regulate their diet (e.g. health, weight loss), as with health empowerment, maintaining a healthy diet requires motivation[34,35]. Motivation is essential for an individual to be able to change their behavior[34]. According to Deci and Ryan (2000) there are 3 different types of motivation in the regulation of behavior: intrinsic motivation, extrinsic motivation and amotivation. In intrinsic motivation, there is a strong internal drive for the individual to feel competent and effective in achieving the goal, without the need for external, material motivators. In the case of extrinsic motivation, the individual acts under the influence of various external motivators (e.g. rewards, expectations of others). An amotivated state is when the individual is unable to control their behavior to achieve the desired goal[36]. Deci and Ryan have provided a more detailed examination of the various levels of behavioral regulation in their theory of self-determination. 6 levels were defined along a dimension, with intrinsic motivation at one end and amotivation at the other: intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation[37]. For illustrative examples of the functioning of these motivational levels in relation to healthy eating, see Table 1 on page 369 of the 2021 article by Román and her colleagues[35].

In general, previous research has demonstrated that maintaining a healthy diet is more likely to succeed when the motivation to do so is intrinsic[38–41]. External motivators are less effective in maintaining a balanced diet in the long term[38]. Intrinsic motivation is shaped by external influences as parental example or social expectations[40,42]. An excellent example of how intrinsic motivation to eat healthily can be effectively shaped by appropriate information from adolescence is provided in Bryan and his colleagues' 2016 article. By defining healthy eating as an autonomous action that defies parental control and the manipulative tactics of the food industry, adolescents were able to make healthier food choices[39]. The individual's subjective experience of the effectiveness of their own actions in this regard is of critical importance in the consolidation of intrinsic motivation to eat healthily[39,42,43]. Individuals who perceive themselves to be efficacious agents in the process are more likely to exhibit stable intrinsic motivation[43]. According to people living with DM, higher levels of perceived self-efficacy in diabetes management increase the motivation to maintain an appropriate diet and reduce the risk of developing eating disorders[42,44,45]. Furthermore, consciousness may serve as a reinforcing factor, with access to appropriate information being a crucial element[38,41,42].

The process of internalizing healthy eating motivation does not differentiate between people with IR and DM and people without these diseases. However, a distinction can be made in that people with IR and DM receive prompt feedback on their dietary choices, as they are required to monitor their body's condition with greater precision and regularity. Consequently, upon observing incremental outcomes, they may cultivate a robust intrinsic motivation to maintain healthy eating habits in a more expeditious manner than their counterparts in the general population. It should be noted, however, that the development of healthy eating motivation has not yet been the subject of a specific study among people with IR and DM and healthy controls.

Body responsiveness

The incorporation of physical activities, such as yoga and mindfulness meditation, that are specifically designed to enhance body awareness and responsiveness has been demonstrated to have a beneficial influence on the formation of healthy eating habits[46–48]. Body responsiveness can be defined as 'the tendency to integrate body sensations into conscious awareness to guide decision making and behavior and not suppress or react impulsively to them' (Daubenmier et al., 2013, p. 781). Furthermore, body responsiveness mediates the relationship between body objectification and increased risk of developing eating disorders[46]. It has a positive effect in improving eating habits by promoting intuitive eating and preventing emotional eating[48,49]. Body responsiveness is positively related to positive indicators of psychological well-being (e.g., satisfaction, positive affect, resilience)

Demographic variable			Village	Town	City	County	Capitol
Place of residence		Count	66	115	218	192	155
		%	8.8	15.4	29.2	25.7	20.8
			Primary	Secondary level	Higher education		
Highest level of education		Count	9	401	336		
		%	1.2	53.8	45		
			Single	In a relationship	Married	Widow(er)	
Marital status		Count	200	236	307	3	
		%	26.8	31.6	41.2	0.4	
			0–5 year	5–20 years	20- years		
Time since diagnosis		Count	206	152	47		
		%	50.9	37.5	11.6		
			Exogenous insulin	Medication	Dietary change		
Type of diabetes	Type I.	Count	111	10	47		
	Type II.	Count	20	89	72		
	Insulin resistant	Count	0	85	163		

Table 1. Detailed demographic data on samples, including place of residence, highest level of education, marital status, time since diagnosis and type of treatment.

and negatively related to maladaptive psychological functioning (e.g., impulsive acting out of negative emotions, mood disorders; Tihanyi et al., 2017).

Higher levels of body responsiveness have been demonstrated to have a positive impact on an individual's behavior, as evidenced by their efficacy in the management of both diabetes and insulin resistance. The inclusion of body responsiveness in our study was motivated by two factors. Firstly, there is a paucity of research examining its role in the context of living with a chronic metabolic disorder. Secondly, the aforementioned effects of body responsiveness on DM and IR provide a rationale for its inclusion in our study.

Meaning in life

The psychological variables mentioned before collectively encapsulate the degree of activity necessary to sustain a state of optimal well-being. However, beyond action, a sense of belief is also required, namely that the activities undertaken daily are worthwhile and make sense. This is why we believe it is essential to address the construct of meaning in life as well.

The concept of meaning in life can be defined as a mental state that is constituted through a multitude of diverse, subjective experiences[50]. What factors contribute to the meaningfulness of an experience? The process of assigning meaning to an experience involves establishing a network of associations and interpretations that facilitate the comprehension of that experience and inform future actions[51]. The concept of meaning provides individuals with the perception that their lives are significant and have a purpose, that they are more than the mere accumulation of seconds, days, and years[50,51]. The concept of meaning in life can be conceptualized in two dimensions: that of living and that of seeking. The act of living a meaningful life entail engaging in actions and experiencing situations that one deems to be genuinely worthwhile and fulfilling[51,52]. The seeking of meaning in life can function as a kind of motivational base[52]. It encourages the individual to address and rectify the dysfunctional aspects of their life. Nevertheless, excessive searching and an inability to cope with the resulting frustration can precipitate the onset of mental conditions and disorders that pose a threat to physical and psychological well-being[50–52]. Despite this latter exaggeration, the meaning in life is presented as a positive psychological variable in the studies[51,53].

A new study provides definitive evidence that a clear protective function of meaning in life emerges among people with type 2 diabetes mellitus (T2DM). It is an indisputable conclusion that death anxiety and experiential avoidance have a deleterious effect on quality of life. However, the negative effect of the two variables under investigation was no longer evident when a high level of meaningfulness of life was present[53]. The process of meaning-making has been shown to result in significant positive changes in the way young people with T1DM live with diabetes. Individuals who view diabetes as an opportunity for personal growth and empowerment, and who therefore invest time and energy in managing their condition, have been found to experience additional distress. However, this approach has also been shown to lead to positive outcomes in terms of disease indicators[54].

Individuals managing a chronic condition as complex as IR or DM have several options at their disposal. These options can assist individuals in mitigating the adverse consequences associated with the additional distress experienced in relation to the illness. It is evident that empowerment in disease management, intrinsic motivation to adhere to a healthy diet, enhanced bodily responsiveness, and the identification of meaning in life serve as protective factors in this process. Those with IR and DM are more likely to prioritize the aforementioned factors than individuals without IR or DM. This does not imply that individuals without IR or DM are not mindful of these aspects. However, on average, individuals with IR and DM tend to demonstrate a higher level of awareness regarding their bodies and diets compared to individuals without IR or DM.

The aim and hypotheses of the present study

The aim of this research is twofold. First, we want to examine the differences between people with IR and DM along the measured health psychological variables compared to a control group of people without IR or DM. Further, we are interested in how the protective variables are affected by diabetes distress in IR, T1DM and T2DM groups.

In our first hypothesis (H1) we predict that there will be significant differences between people with IR or DM and people without IR or DM according to the followings:

- H1a: There will be no significant difference in the level of subjectively perceived health-empowerment between the individuals with IR and DM and the individuals without IR or DM, because the two groups have completely different dimensions of health. However, T2DM group will report significantly lower empowerment than T1DM and IR group.
- H1b: The T1DM group will differ positively from the other groups in the degree of integrated regulation. The T2DM group is expected to be significantly different from the other groups in that they will have the highest degree of external regulation.
- H1c: People with IR and DM will have higher body responsiveness than people without IR or DM. Among people with IR and DM, T1DM group will stand out in terms of body awareness, while the body-mind disconnection is highest among T2DM individuals.
- H1d: There will be no difference between groups in the presence of meaning in life, but there will be a difference in the level of searching it. The T2DM group will search the meaning in life the less.

Our second hypothesis (H2) is that the groups of IR, T1DM and T2DM individuals would differ significantly from each other in the level of diabetes distress, regardless of the time since diagnosis. According to our assumptions, the level of diabetes distress will be highest among T2DM individuals, and lowest among T1DM individuals, while IR individuals will be between the two diabetic groups.

In our third hypothesis (H3), we are interested in the homogeneity of IR, T1DM and T2DM groups along the measured variables. We hypothesized that the most homogeneous group is the T1DM group, while IR group can be considered a slightly more heterogeneous group, and the T2DM group will emerge as the most heterogeneous group.

Methods

Participants and procedure

We conducted an a priori power analysis using G*Power[55] to test for one-way analyses of variance with four groups, and also for covariance analysis with three groups and one covariate variable. The analyses indicated a required total minimum sample size of 280 and 251, respectively, with a conservative approach ($f = 0.25$, $1-\beta = 0.95$). However, we sought to collect more data than this with the purpose of conducting a classification model. A total of 746 (623 female and 123 male) individuals participated in the study voluntarily. The mean age of the sample was 37.5 (SD = 14.7) with an age range of 18–78. Our sample consisted of healthy controls, so of people without IR or DM ($N = 341$, mean age: 34.2, SD = 14.5) and people diagnosed with insulin resistance and diabetes ($N = 405$, mean age: 40.3, SD = 14.3). We differentiated between Type 1 ($N = 116$, mean age: 35.9, SD = 13.5) and Type 2 ($N = 112$, mean age: 53.0, SD = 10.3) diabetics and insulin-resistant individuals ($N = 177$, mean age: 35.1, SD = 11.8). More detailed demographic data are presented in Table 1.

The data was collected from October 2023 to March 2024. Data collection was made online with an open survey. Recruitment was conducted using convenient sampling. Participants were recruited from Facebook groups focused on living with and managing diabetes. Additionally, participants without IR or DM were recruited through the University of Pécs mailing list. Only individuals older than 18 years who had given informed consent were allowed to complete the questionnaire package. Participation was voluntary and anonymous, and respondents could stop at any point without any consequences. Respondents could review and change their answers before submission, but they could entry from an IP address once. The participants didn't get any incentives for participation. The questionnaire package for data collection was created on the Google Forms online platform. We tested the survey before the real data collection for usability and technical functionality with the help of five of our colleagues, one of whom is living with diabetes. The collected data is stored on a secure USB drive. In addition to demographic questions, the questionnaire package contained 7 questionnaires, which are presented below. The present study was approved by the Scientific and Research Ethics Committee of the Health Sciences Council (ETT TUKEB: BM/4911-2/2023) and by the Joint Committee on Research Ethics in Psychology (EPKEB: 2022 – 134) too. The research was designed and conducted following the ethical principles of the Declaration of Helsinki (WHO, 2001).

Measurements/questionnaires

To measure the degree of distress associated with diabetes we used the *Diabetes Distress Scale* (DDS; Polonsky et al., 2005; Hungarian adaptation: Heckenberger-Nagy et al., 2024). It measures the daily experiences of people with diabetes that arise specifically from the challenge of living with the demands of diabetes, regardless of the type of diabetes. The questionnaire consists of 17 items and is answered on a 6-point Likert scale (1 = No problem and 6 = Very serious problem), on which respondents can express the extent to which the challenges in each statement are a problem for them in their daily lives. The statements are grouped into the 4 following factors: *Emotional Burden* (EB) (e.g., "feeling that diabetes is taking up too much of my mental and physical energy every day."), *Regimen Distress* (RB) (e.g., "not feeling confident in my day-to-day ability to manage diabetes."), *Physician Distress* (PD) (e.g., "feeling that my doctor doesn't know enough about diabetes and diabetes care."), and *Interpersonal Distress* (ID) (e.g., "feeling that friends or family are not supportive enough of self-care efforts."). The reliability of the subscales on our sample were satisfactory (McDonald's omega = 0.868-0.914).

The *Health Empowerment Scale* (HES; Náfrádi et al., 2018; Hungarian adaptation: Papp-Zipernovszky et al., 2021) measures how much individuals care about their health, how much they have the resources to do so, and how much autonomy they must take the necessary actions. Respondents can express the nature of their health behavior on a 7-point scale (1 = Not at all and 7 = To a great extent). Items are categorized into 4 factors: *Competence* ('I am confident about my ability to deal with my health'), *Meaningfulness* ("Dealing with my health is very important for me"), *Impact* ("I have a great deal of control over managing my health") and *Self-determination* ("I can decide on my own how to handle my health"). Higher scores on both the subscales and the total score indicate that the individuals have greater autonomy. Our data showed good reliability of the questionnaire (McDonald $\omega = 0.949$).

To assess attitudes towards healthy eating and its underlying self-regulatory and motivational background we used the *Motivation for Healthy Eating Scale* (MHES; Kato et al., 2013; Hungarian adaptation: Román et al., 2021). The scale uses 18 statements and respondents are asked to rate them from 1 (strongly disagree) to 6 (strongly agree). Along with the different sources of motivation, the statements of the questionnaire can be categorized into 6 factors, such as *Amotivation* ("Regulating eating habits is not so important"), *External regulation* ("I am expected to eat healthily"), *Introjected regulation* ("'I would feel ashamed of myself if I didn't eat healthily."), *Identified regulation* ("I think that healthy eating has a positive effect on body and soul") *Integrated regulation* („Eating healthy is an integral part of my life"), and *Intrinsic motivation* ("I take pleasure in fixing healthy meals"). Based on our data, the reliability of the subscales was good (McDonald $\omega = 0.744–0.877$).

The *Body Responsiveness Questionnaire* (BRQ; Daubenmier, 2005; Hungarian adaptation: Tihanyi et al., 2017) was used to assess the ability to coordinate body-consciousness. The questionnaire consists of 7 items. The items are divided into 2 factors: *Importance of Interoceptive Awareness* (I-subscale, "It is important for me to know how my body is feeling throughout the day.") and *Perceived Disconnection* (PD-subscale, " My mind and my body often want to do different things."). In addition, a total score can be calculated for the scale. Respondents can use a 7-point Likert-type scale (1 = Not at all true for me and 7 = Totally true for me) to express their level

of agreement with the statement. Based on our data, the reliability of the two subscales was found to be good (McDonald ω = 0.744–0.815).

The *Meaning in Life Questionnaire* (MLQ; Steger et al., 2006)Hungarian adaptation: Martos & Konkolÿ Thege, 2012) captures the construct of meaning in life along the cognitive aspects of the individual completing it. The questionnaire consists of 10 items. The answers are given on a 7-point Likert scale (1 = Not at all true and 7 = Totally true), where the respondent can express how much they agree with the statement. Statements can be categorized into 2 factors: *Presence* ("I have found a purpose in life that I am satisfied with.") and *Search* ("I am seeking meaning in my life."). The reliability of the two subscales was good on our sample (McDonald ω = 0.827−0.933).

Statistical plan

First, we analyzed the differences between all four samples (Type 1 and Type 2 diabetes, insulin resistance and control) on the questionnaires (BRQ, MHES, HES, and MLQ) and in terms of age using ANOVAs. The relevant assumptions were met, Leven's test for equality of variances was nonsignificant in all cases and the dependent variables were all normally distributed (as evidenced by the kurtosis and skewness values <|2|). We teased apart significant main effects with Tukey corrected pairwise comparisons.

Next, we compared the IR, T1DM and T2DM groups with regards to their scores on the DDS subscales. We used ANCOVAs here with the time since receiving their diagnosis as the covariate variable. Again, all assumptions were met, and significant main effects were broken down with Tukey corrected pairwise comparisons.

Finally, we performed a gradient boosting classification to observe how the observed variables (BRQ, MHES, HES, MLQ, DDS) can predict IR, T1DM and T2DM group membership. We also entered age and time since diagnosis into the model to control for their effects. Boosting is a scalable and efficient tree boosting supervised machine learning algorithm; an ensemble learning method that works by constructing a strong classifier from several weak classifiers. Ensembles are constructed using Decision Tree models as the weak learning model, where Decision Trees are sequentially added to the ensemble and fitted to reduce the prediction errors of the preceding models. Models are fitted by gradient boosting using a gradient descent optimization algorithm. The data was split into training, validation and test subsets with the proportion of 65:15:20, respectively. Regarding the algorithm shrinkage was set to 0.1, interaction depth to 1, minimum observations in node were 10, training data used per tree 50%, the number of trees were optimized (with a maximum of 100). We assessed the performance of the classification model through the receiver operating characteristic curve (ROC) analysis and the Area Under Curve (AUC). Additionally, the relative feature importance is an index to evaluate the effect of the variable on the results in the model.

Results

We began by examining our first hypothesis (H1) concerning the differences between people with IR or DM and people without IR or DM in terms of our study variables. Our first hypothesis was only partially confirmed. We found significant main effects for the Identified regulation subscale of MHES (MHES_Identified), for both body responsiveness subscales (BRQ_I and BRQ_PD), and Search subscale of MLQ (MLQ_Search). For BRQ PD, people in the insulin resistant group scored higher than people in the other three groups. The difference between the other groups was nonsignificant. On the BRQ I, MHES Identified and MLQ Search subscales scores were lower for the Type 2 diabetes group compared to the control group. The other groups did not differ from each other. See Table 2 for all statistical results and Fig. 1 and Supplementary Table 1 for descriptive statistics.

Next, we compared the IR, T1DM and T2DM groups in terms of Diabetes Distress Scale (DDS) scores regardless of the time since diagnosis to address our second hypothesis (H2). We found significant differences between the groups on the Emotional Burden (EB) and Physician Distress (PD) subscales. On EB T1DM group scored higher than T2DM and IR groups, while the latter two did not differ from each other. In contrast on PD, T1DM group scored lower than T2DM and IR groups, while the latter two did not differ from each other. See Table 3 for all statistical results and Fig. 2 and Supplementary Table 1 for descriptive statistics.

We then addressed our last hypothesis (H3) concerning the classification of the IR, T1DM and T2DM groups. See Table 4 for model performance metrics. The ROC curves are shown in Fig. 3, the AUC was 0.769 for the T1DM group, 0.783 for the T2DM group, and 0.807 for the IR group. This means that the classification was successful, and the discriminative ability of the model was good for all three groups. Relative influence scores are shown on Fig. 4 and in Supplementary Table 2. The time since diagnosis was the feature that had the greatest impact on the outcome of the model. We included this in the model because groups differed in terms of this variable (see Table 2 and Supplementary Table 1) and wanted to control for its effect. After this, DDS PD had a relatively large impact closely followed by BRQ PD and MHES Intrinsic motivation subscale. MLQ Presence, DDS RB and DDS EB also had a meaningful influence on the model outcome. The other variables were not selected into the model.

Discussion

Diabetes and insulin resistance are both major chronic diseases. Both diseases have an impact on individuals' everyday lives, as they need to take medication, follow a special diet, see a doctor more regularly and maintain proper exercise. All of this can cause considerable distress to people with IR and DM. Several psychological and personality traits can play an important role in coping with elevated levels of distress. The identification of factors that contribute to effective coping with stress and disease management by IR, T1DM and T2DM groups can assist clinicians in developing a more nuanced understanding of them, thereby enabling them to provide more targeted support.

Variable		df	F/t	*p*	$\eta^2 p$
HES	Group	3, 742	1.445	0.228	0.006
MHES_Intrinsic	Group	3, 742	1.510	0.197	0.008
MHES_Integrated	Group	3, 742	1.140	0.332	0.005
MHES_Identified	Group	**3, 742**	**4.370**	**0.005**	**0.017**
	Type 1-Insulin resistant	742	− 1.199	0.628	
	Type 1-Type 2	742	1.219	0.615	
	Type 1-Control	742	− 1.935	0.214	
	Insulin resistant -Type 2	742	2.523	0.057	
	Insulin resistant-Control	742	− 0.700	0.897	
	Type 2-Control	**742**	**− 3.393**	**0.004**	
MHES_Introjected	Group	3, 742	1.212	0.304	0.005
MHES_External	Group	3, 742	2.078	0.102	0.008
MHES_Amotivation	Group	3, 742	1.607	0.186	0.006
BRQ_PD	Group	**3, 742**	**12.274**	**< 0.001**	**0.047**
	Type 1-Insulin resistant	**742**	**− 3.555**	**0.002**	
	Type 1-Type 2	742	− 0.547	0.947	
	Type 1-Control	742	1.252	0.594	
	Insulin resistant -Type 2	**742**	**2.918**	**0.019**	
	Insulin resistant-Control	**742**	**6.038**	**< 0.001**	
	Type 2-Control	742	1.901	0.229	
BRQ_I	Group	**3, 742**	**3.055**	**0.028**	**0.012**
	Type 1-Insulin resistant	742	0.893	0.809	
	Type 1-Type 2	742	1.523	0.424	
	Type 1-Control	742	− 0.836	0.837	
	Insulin resistant -Type 2	742	0.787	0.860	
	Insulin resistant-Control	742	− 2.121	0.147	
	Type 2-Control	**742**	**− 2.677**	**0.038**	
MLQ_Presence	Group	3, 742	1.735	0.158	0.007
MLQ_Search	Group	**3, 742**	**5.299**	**0.001**	**0.021**
	Type 1-Insulin resistant	742	− 0.426	0.974	
	Type 1-Type 2	742	1.159	0.653	
	Type 1-Control	742	− 2.274	0.105	
	Insulin resistant -Type 2	742	1.693	0.328	
	Insulin resistant-Control	742	− 2.089	0.158	
	Type 2-Control	**742**	**− 3.654**	**0.002**	

Table 2. Detailed statistical results for differences among the four groups on the BRQ, MHES and MLQ subscales, the HES scale and age with main effects and follow-up pairwise comparisons. P-values are Tukey corrected for post hoc comparisons. *HES* Health Empowerment Scale, *MHES* Motivation for Healthy Eating Scale, *BRQ_I* Body Responsiveness Scale Importance of Interoceptive Awareness factor, *BRQ_PD* Body Responsiveness Scale Perceived Disconnection factor, *MLQ* Meaning in Life Questionnaire.

According to our results, there was not any difference between the people living with IR or DM and the people living without IR or DM in the level of health empowerment. However, contrary to our assumptions (H1a), the T2DM group did not differ significantly from the IR and T1DM groups. The reason for the absence of a distinction between individuals with and without illness is that the two groups exhibit entirely disparate dimensions of health and, consequently, of their endeavors to achieve and maintain optimal well-being. Individuals with DM or IR primarily focus on maintaining their condition and, secondarily, on achieving what is essentially termed a healthy level, for example, during fluctuations in blood glucose levels[27,30]. In contrast, individuals without IR or DM may focus on enhancing their body's functional capacity[32]. Additionally, individuals with IR and DM are required to monitor specific health indicators, have access to precise data through electronic devices, and are subject to more frequent screenings and medical examinations than the individuals without IR or DM. This provides them with prompt, direct, and dependable feedback regarding the efficacy of their efforts, which is typically not the case for individuals without IR or DM. The observation that T2DM people not only exhibited no notable deviation from the other groups in their health empowerment scores, but also did not have the lowest average score (the IR group had), may be attributed to the fact that T2DM is a condition that most people are able to address with a sense of urgency and commitment[33,58]. Conversely, IR may be perceived by the individuals as a less severe condition, even if it is regarded as amenable to reversal[59]. Therefore, lifestyle modifications are less rigorous and less efficacious.

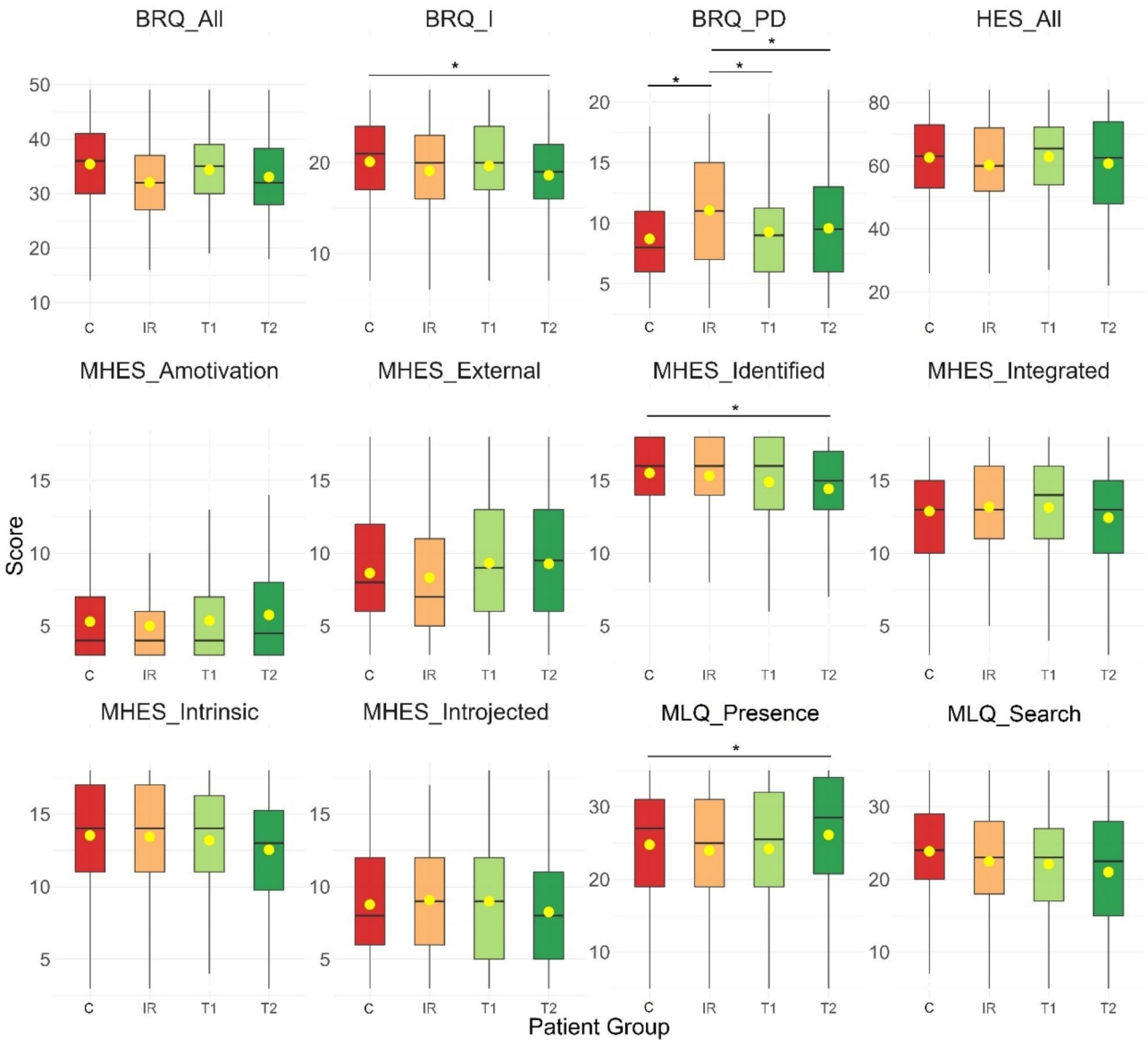

Fig. 1. Group scores visualized as boxplots presented on separate panels. The significant group differences can be seen on the BRQ I, BRQ PD, MHES Identified regulation and MLQ Search subscales. The groups: *C* Control; *IR* Insulin resistant; *T1* Type 1 diabetes; *T2* Type 2 diabetes. The variables: *HES* Health Empowerment Scale, *MHES* Motivation for Healthy Eating Scale, *BRQ_I* Body Responsiveness Scale Importance of Interoceptive Awareness factor, *BRQ_PD* Body Responsiveness Scale Perceived Disconnection factor, *MLQ* Meaning in Life Questionnaire.

The results for the type of motivation to eat healthily were not along the lines expected from previous studies (H1b). There was no significant difference in the level of integrated motivation between T1DM and the other groups, nor in the level of external regulation between T2DM and the other groups. The only difference was in the Identified Regulation subscale. Here the score of the T2DM group was significantly lower compared to the control group. Regarding the motivation for healthy eating, it can be observed that the proportion of individuals exhibiting amotivation, controlled (external and introjected regulation) and autonomous self-regulation (identified, integrated regulation and internal motivation) is identical across the examined groups. The significantly lower Identified regulation score observed in T2DM people indicates that they may experience greater difficulty in aligning their self-identity with the altered identity associated with the disease. Individuals with T1DM and IR appear to present fewer challenges than individuals with T2DM, at least when compared to the identification process of individuals without IR or DM. Receiving a diagnosis of a chronic condition such as DM can be a challenging experience[60]. The disease redefines the identity[61]. The process of identifying with a changed identity and adapting to the new situation represents a significant challenge, particularly for an adult who has lived most of their life being able to consume food without restrictions[60,61]. This way, the concept of Identified regulation in the context of healthy eating ('I think that healthy eating has a positive effect on body

DDS		df	F/t	*p*	$\eta^2 p$
EB	Diabetes Type	2, 401	6.001	0.003	0.029
	Type 1-Insulin resistance	401	3.071	0.006	
	Type 1-Type 2	401	3.162	0.005	
	Type 2-Insulin resistance	401	0.115	0.993	
	Time since diagnosis	1, 401	15.062	< 0.001	0.036
PD	Diabetes Type	2, 401	9.588	< 0.001	0.046
	Type 1-Insulin resistance	401	− 4.372	< 0.001	
	Type 1-Type 2	401	− 2.898	0.011	
	Type 2-Insulin resistance	401	1.679	0.215	
	Time since diagnosis	1, 401	0.028	0.867	< 0.001
RB	Diabetes Type	2, 401	2.217	0.110	0.011
	Time since diagnosis	1, 401	0.201	0.654	< 0.001
ID	Diabetes Type	2, 401	2.036	0.132	0.010
	Time since diagnosis	1, 401	3.135	0.077	0.008

Table 3. Detailed statistical results for differences among the IR, T1DM and T2DM groups on the diabetes distress scale (DDS) subscales and the time since receiving their diagnosis with main effects and follow-up pairwise comparisons. P-values are Tukey corrected for post hoc comparisons. Name of the subscales: *EB* Emotional Burden, *PD* Physician Distress, *RB* Regimen Burden, *ID* Interpersonal Distress.

and soul.' in Román et al., 2021, p. 369) may be perceived as a restriction rather than a positive experience for a T2DM individual.

Regarding the motivation for healthy eating, it is also pertinent to provide a more detailed picture based on the descriptive data. It can be considered a positive outcome that the scores on the motivation forms pertaining to autonomous self-regulation are markedly higher than those on the controlled self-regulation methods and in the amotivation category in each examined group. In each group, identified regulation achieved the highest value compared to the other forms of autonomous self-regulation (integrated and intrinsic). These results suggest that motivation to eat healthily in the study population is driven by subjective experiences of eating. If an individual can follow the right diet and experience its positive effects on their body and general well-being, they can integrate it into their life in the long term. For T2DM people, integration can be complicated by the perception of the disease as an external regulatory force that forces them to eat healthily. For this reason, it can be difficult to experience their actions to follow a healthy diet as self-motivated, despite positive experiences.

Although there were differences between the groups in both subscales of body responsiveness scores (BRQ), they were not in line with the predicted directions (H1c). In the case of Importance of Interoceptive Awareness subscale, the T1DM group did not stand out compared to the others. Although the highest score was achieved by the control group, a significant difference was only found between the control group and the T2DM group as T2DM individuals achieved the lowest score, and the control group got the highest. In the case of the Perceived Disconnection subscale, the T2DM group did not differ from the others, but the IR group did. The score of the IR group was significantly higher than the scores of all the other groups, i.e. body-mind disconnection was the highest in their case. The strikingly low interoceptive awareness score of the T2DM group may be due to a lack of confidence in their own body. Indeed, type 2 diabetes is usually latent for a long time, with symptoms that are not prominent[5]. That's why T2DM individuals seem to be unable to trust their own body's signals to regulate their behavior after diagnosis as well. Another explanation may come from the lifestyle of T2DM people. Lifestyle factors such as unhealthy diet and lack of exercise play a significant role in the development of type 2 diabetes[7,10]. Basically, these people are less aware of their own body's needs, and they can regulate their behavior less based on these signals, which is an attitude that cannot be suddenly changed by a diagnosis. The surprising finding that people with IR have the highest body-consciousness disconnection may be because they receive a diagnosis of a chronic condition, but it is not necessarily permanent. Indeed, IR is still a reversible condition[59]. It is therefore possible that these people may feel the greatest pressure to adhere to a prescribed diet to reverse the condition[11]. This may be why they are the most impulsive in responding to the demands of their body that do not fit in with the diet they are following and try suppressing them.

There was no difference between the groups in the presence of meaning in life (H1d). In the search for meaning, T2DM group achieved the lowest score, which was significantly different from the scores of the control group who got the highest score. This result may be due to the higher average age of T2DM group compared to the other groups. T2DM is mostly diagnosed at an age over 40 or even later[5]. At this stage of life, individuals have already found the things that give meaning to their everyday lives, so they are no longer actively looking for them[50–52]. A DM diagnosis can reduce the desire to search even further, as its management takes up the individuals' attention capacity and energy[58,62].

The T1DM group did not score the lowest on all subscales of the Diabetes Distress Scale so our second hypothesis (H2) was only partially fulfilled. There was no difference in the degree of interpersonal distress and diet-related burden between IR, T1DM and T2DM groups. The T1DM group scored lowest only for doctor-related distress, which was significantly different from the scores of the other groups. However, the T1DM group scored highest on the emotional distress subscale, significantly different from the other 2 groups. The results

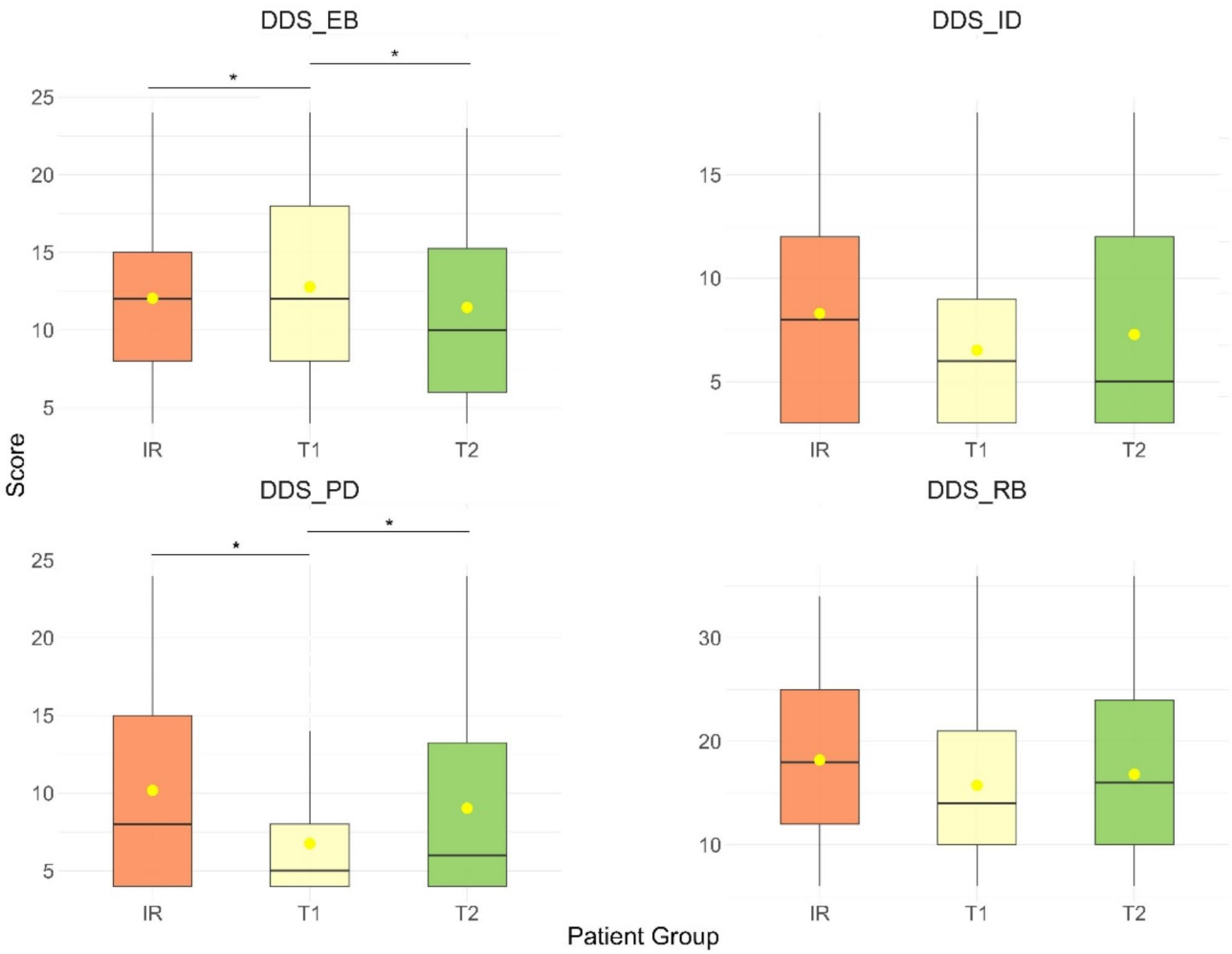

Fig. 2. Patient group scores (*IR* Insulin resistant; *T1* Type 1 diabetes; *T2* Type 2 diabetes) on the four subscales (*EB* Emotional Burden, *PD* Physician Distress, *RB* Regimen Burden, *ID* Interpersonal Distress) of the Diabetes Distress Scale (DDS) visualized as boxplots presented on separate panels. Significant group differences can be found on the Emotional Burden (EB) and Physician Distress (PD) subscales.

regarding the various aspects of diabetes distress led to the conclusion that for all these groups, their condition causes difficulties in the interpersonal arena to a similar degree and following a suitable diet and controlling their eating poses a similar challenge. T1DM group experiences much less difficulty (M = 6.75, SD = 3.79) with regular meetings with the treating physician, participation in check-ups and the hospital environment than their T2DM (M = 9.03, SD = 6.07) and IR (M = 10.18, SD = 6.35) counterparts. This may simply stem from the fact that, since they have mostly lived with the disease since childhood[5], they have become accustomed to frequent visits to health care facilities from an early age[63]. For people with T2DM and IR, however, the contrast in the number of medical consultations before and after diagnosis can be large. Although consulting a doctor is the least challenging for T1DM people, the treatment of DM imposes the greatest emotional burden on them. Based on the results of a qualitative research[64], the reason for this may be that people with T1DM interpret the diabetes self-management process as a matter of life and death. They see that failure to act appropriately would have life-threatening consequences. This may be because during their teenage years, they were not yet willing to accept their condition, leading to significantly more risky behaviors compared to now as adults. These behaviors often resulted in negative, frightening experiences, and sometimes even life-threatening situations[63]. People with T2DM do not see such a serious consequence if they just follow the rules more laxly. Furthermore, T1DM individuals interpret their disease more as a personal struggle to cope with and because of which they must deal with all kinds of factors (e.g. stigmatization, worries about the future and pregnancy) every day (Balfe et al., 2013; Orben et al., 2022). This may also stem from the onset during youth, as stigmatization can be much more pronounced in childhood or adolescence compared to adulthood, where the condition is better known and more understood[63].

The classification modeling results were in close alignment with those of previous studies (H3). The IR group is the most homogeneous group, closely followed by the T1DM group, while people with T2DM form the most heterogeneous group. This means that the T2DM group has the largest inter-individual variance in the

	Relative Influence	Mean dropout loss
Time since diagnosis	63.789	288.650
DDS_PD	9.377	230.236
BRQ_PD	7.472	229.491
MHES_Intrinsic	7.343	229.850
MLQ_Presence	5.042	228.671
DDS_RB	4.209	227.821
DDS_EB	2.767	227.490
DDS_ID	0.000	226.149
BRQ_I	0.000	226.149
MHES_Integrated	0.000	226.149
MHES_Identified	0.000	226.149
MHES_Introjected	0.000	226.149
MHES_External	0.000	226.149
MHES_Amotivation	0.000	226.149
HES	0.000	226.149
MLQ_Search	0.000	226.149

Table 4. Detailed results showing performance metrics of the boosting classification model for the IR, T1DM and T2DM groups. Mean dropout loss is based on 50 permutations. *HES* Health Empowerment Scale, *MHES* Motivation for Healthy Eating Scale, *BRQ_I* Body Responsiveness Scale Importance of Interoceptive Awareness factor, *BRQ_PD* Body Responsiveness Scale Perceived Disconnection factor, *MLQ* Meaning in Life Questionnaire, *DDS* Diabetes Distress Scale and its subscales: *EB* Emotional Burden, *PD* Physician Distress, *RB* Regimen Burden, *ID* Interpersonal Distress.

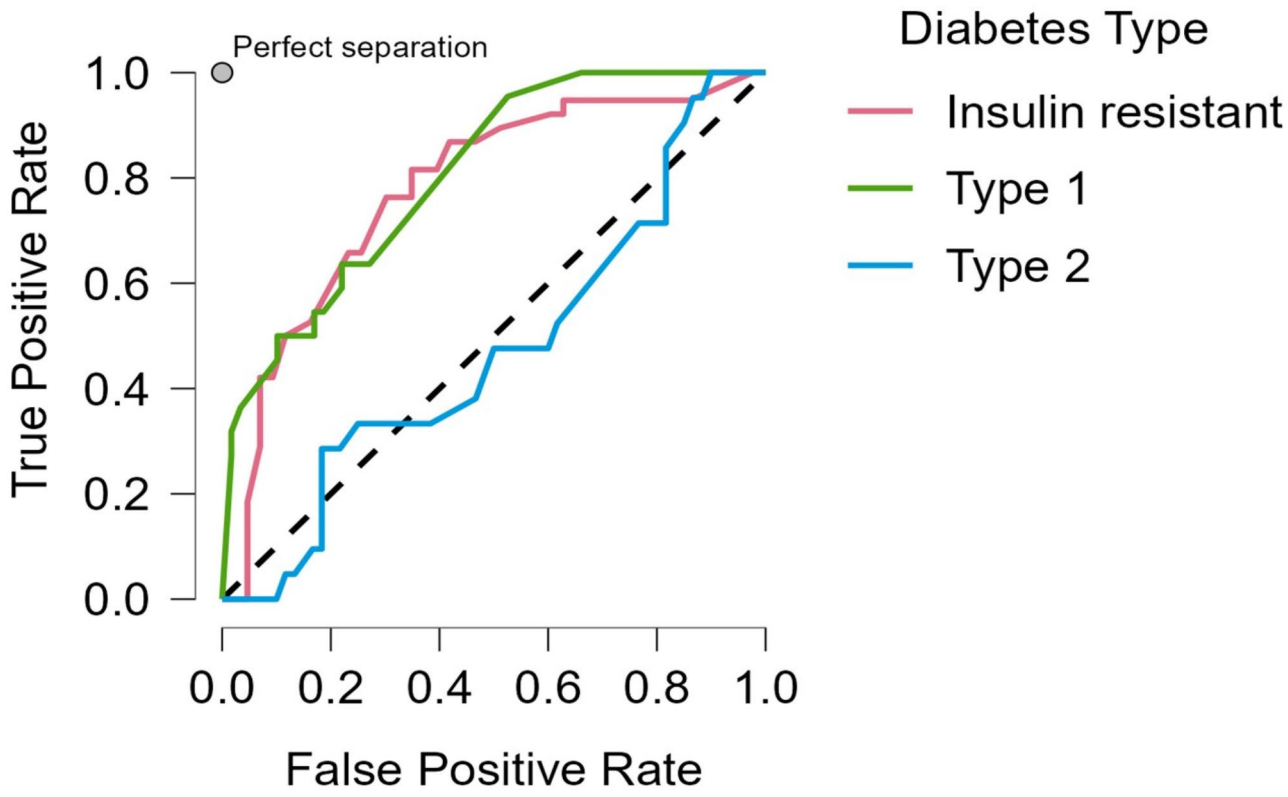

Fig. 3. ROC curves for the three patient groups based on the results of the boosting classification model.

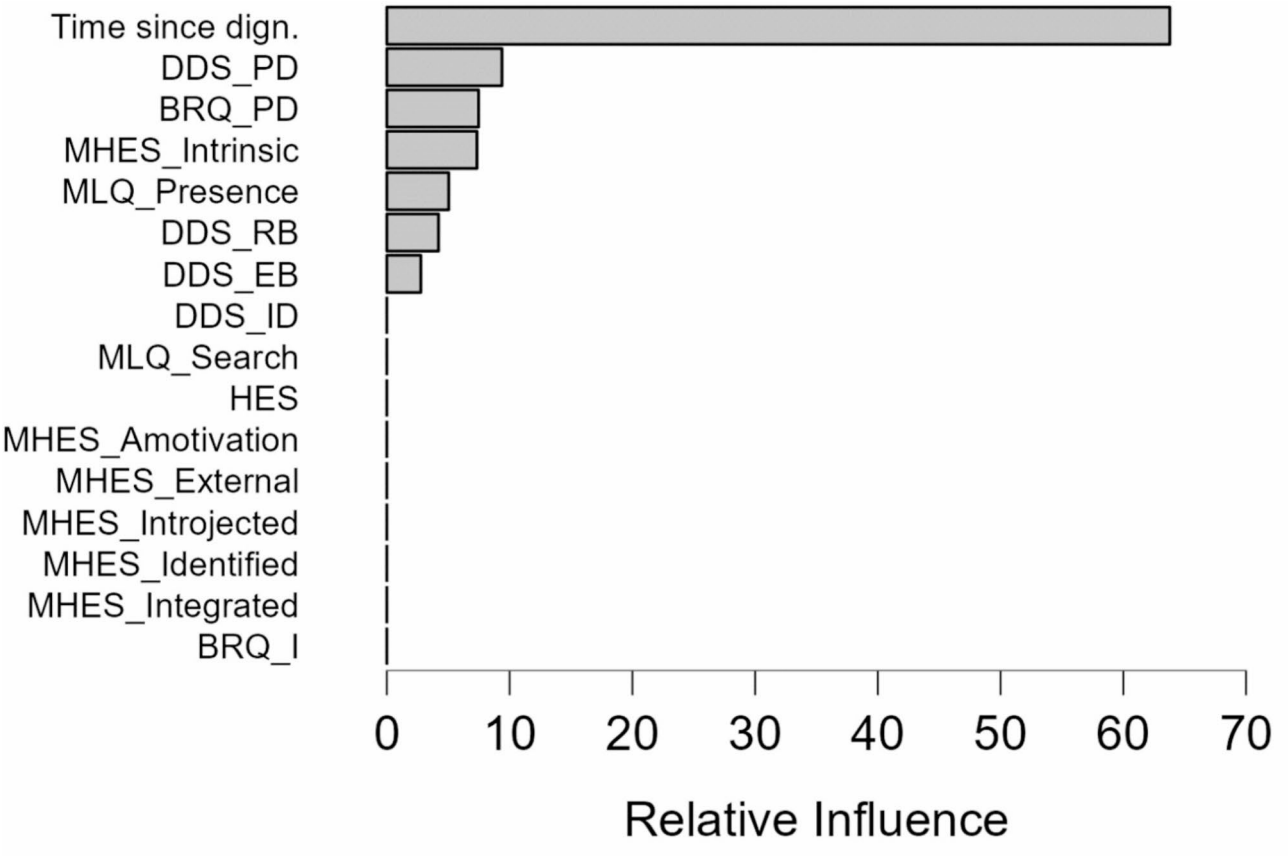

Fig. 4. The relative influence values of independent variables in the boosting classification model.

level of the examined variables. Unsurprisingly, the time since diagnosis was the feature that had the greatest impact on the outcome of the model. We included it in the model because we wanted to control for its effect as the differences according to this variable originate from the basic characteristics of each disease type[5,59]. The time since diagnosis was the feature that had the greatest impact on the outcome of the model. A universal characteristic of the T1DM group is familiarity and habituation with the treating physician and the hospital environment. In contrast, the T2DM and IR groups are more characterized by fear and frustration in this topic. Body-mind disconnection (BRQ_PD) and healthy eating intrinsic motivation (MHES_Intrinsic) appeared in the model with similar strengths. In the case of body-mind disconnection, the defining feature is the emotional reaction. While people with IR react intensely to the needs of their body that deviate from the prescribed dietary guidelines, while people with T1DM have fewer such physical needs or no longer pay attention to them. Those T1DM individuals who have lived with the disease since early childhood do not desire unhealthy foods at all (e.g. white bread, fast food, sugary foods), because their bodies are completely unaccustomed to them, or that they have never tasted these foods before[65]. Intrinsic motivation in relation to healthy eating can be decisive in the model because IR individuals are the ones who can best experience their creativity and freedom in relation to their eating, since their condition is less severe. Due to the perception of people with T1DM that if they do not strictly follow the regulations, it could have serious negative consequences[64], they are less able to experience freedom when it comes to eating. In the eyes of people with T2DM, the guidelines seem like serious restrictions and deprivations, which take away sources of pleasure from their lives[62]. The presence of the meaning in life may play a role in the isolation of the T2DM group in the model. Due to the higher average age of the T2DM group[5], they are in a stage of life where they have already found the activities in their lives that make their everyday life meaningful. The IR and T1DM groups are even more in the search phase due to their younger age. The regimen burdens of diabetes distress can put the greatest pressure on people with IR. Since in their case there is still hope that they can reverse their condition by making and maintaining appropriate diet and lifestyle changes[16]. For T1DM group, the way they should eat to maintain proper blood sugar levels is nearly natural. Through many difficulties and challenges, they had to face as a child and a teenager (e.g., natural physical changes and their consequences), individuals with T1DM have developed adaptive coping strategies by adulthood to live as easily as possible with diabetes[63]. In the case of people with T2DM, it is very variable how each individual approaches the dietary requirements[62]. In accordance with the above, the emotional burden related to the disease is the most fluctuating among T2DM individuals, while the level and quality is similar between people with T1DM and IR. Overall, we can conclude that the reversibility of the condition among people with IR is both a relief and a burden. In the case of people with T1DM, the habituation of the condition makes self-management easier

and adds stress at the same time. While the disease management of T2DM individuals is highly individual-dependent, this subgroup is less characterized by universal features compared to the IR and T1DM groups.

Limitations and future plans

Our study has its limitations. First, we used self-report surveys but did not collect (more objective) physiological (e.g. filling out the same questionnaires about the patients by their doctors) nor biological data (e.g. daily average blood sugar level). Second, this study was a cross-sectional study. Although we controlled for time since diagnosis, we would still get much more reliable results in a longitudinal study.

A subsequent study would be enhanced by the further subdivision of patient groups according to the type of treatment. The degree of distress associated with the disease may be significantly influenced by whether only one drug is taken with breakfast or whether blood glucose levels are monitored throughout the day and the appropriate amount of insulin is administered. In addition, an important third group of diabetics, gestational diabetics, should also be studied along the variables used in the present study. It would be interesting to compare gestational diabetics with non-diabetic pregnant women and with other groups of diabetic people. We could get an idea of what it means to encounter a chronic condition, but only temporarily, during an already special period like pregnancy.

Conclusion

Despite the limitations of the present study, two major insights emerged. Firstly, our research identified factors primarily related to insulin resistance (IR) and diabetes mellitus (DM) that significantly characterize individual subgroups, thereby supporting previously discovered correlations. Additionally, new perspectives and psychological variables, such as bodily responsiveness and the meaningfulness of life, which have not been previously addressed in this context, were identified.

Our findings revealed no difference in the level of health empowerment between individuals living with IR or DM and those without these conditions. Similarly, there was no significant difference in health empowerment levels among the IR, T1DM and T2DM groups. However, regarding motivation for healthy eating, the T2DM group scored significantly lower in Identified Regulation compared to the control group. The T2DM group also exhibited the lowest level of interoceptive bodily awareness, while the IR group showed the highest level of tension in response to discrepancies between bodily desires and conscious regulations. All groups experienced the meaning in life similarly, but the T2DM group was less likely to seek it. It emerged that the treatment of people with IR and T1DM can be simpler than that of people with T2DM, as the reactions and attitudes of the former groups towards their diagnosis and disease are more predictable and clearer. In contrast, physicians treating T2DM individuals must prepare for a wide spectrum of reactions and attitudes towards the disease and self-management and adapt their treatment and motivational strategies accordingly.

Ultimately, our research emphasizes that DM and IR are conditions that require examination from multiple perspectives to be fully understood. To properly support these individuals, it is essential to strive for as much diverse knowledge on the subject as possible. By broadening our understanding of the psychological challenges associated with these conditions, we can develop more holistic and effective approaches to patient care.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Received: 4 October 2024; Accepted: 17 December 2024
Published online: 30 December 2024

References

1. International Diabetes Federation. *IDF Diabetes Atlas 2021–10th Edition* (www.diabetesatlas.org, 2021).
2. Teleki, S. *Krónikus Megbetegedések Klinikai Egészségpszichológiai Vonatkozásai* (Akadémiai Kiadó, 2023).
3. Karádi, I. A neuroendokrin rendszer és az anyagcsere vizsgálata. In *a belgyógyászat alapjai 1*. (ed. Tulassy, Z) 101–115. (Medicina Könyvkiadó, 2010).
4. Wagner, J. & Tennen, H. Coping with diabetes: psychological determinants of diabetes outcomes. in *Coping with Chronic Illness and Disability. Theoretical, Empirical, and Clinical Aspects* (eds. Martz, E. & Livneh, H.) 215–240 (Springer US, 2007).
5. American Diabetes Association. 2. Diagnosis and classification of diabetes: standards of Care in Diabetes—2024. *Diabetes Care*. **47**, S20–S42 (2024).
6. Silva, J. A. et al. Diagnosis of diabetes mellitus and living with a chronic condition: participatory study. *BMC Public. Health* **18**, (2018).
7. Petersmann, A. et al. Definition, classification and diagnosis of diabetes mellitus. *Exp. Clin. Endocrinol. Diabetes*. **127**, S1–S7 (2019).
8. American Diabetes Association. Improving Care and promoting health in populations: standards of care in diabetes—2024. *Diabetes Care*. **47**, S11–S19 (2024).
9. Haller, M. J., Atkinson, M. A. & Schatz, D. Type 1 diabetes mellitus: Etiology, presentation, and management. *Pediatr. Clin. N. Am.* **52**, 1553–1578. https://doi.org/10.1016/j.pcl.2005.07.006 (2005).
10. Taylor, R. Type 2 diabetes: etiology and reversibility. *Diabetes Care*. **36**, 1047–1055 (2013).
11. Martins, F. O. & Conde, S. V. Impact of diet composition on insulin resistance. *Nutrients* **14**, (2022).
12. Roberts, C. K., Hevener, A. L. & Barnard, R. J. Metabolic syndrome and insulin resistance: underlying causes and modification by exercise training. *Compr. Physiol.* **3**, 1–58 (2013).
13. Kahn, C. R. et al. The syndromes of insulin resistance and acanthosis nigricans. *N. Engl. J. Med.* **294**, 739–745 (1976).
14. Ighbariya, A., Weiss, R. & Insulin Resistance Prediabetes, metabolic syndrome: what should every pediatrician know? *JCRPE J. Clin. Res. Pediatr. Endocrinol.* **9**, 49–57 (2017).
15. Barazzoni, R., Gortan Cappellari, G., Ragni, M. & Nisoli, E. Insulin resistance in obesity: an overview of fundamental alterations. *Eat. Weight Disord.*. **23**, 149–157 (2018).

16. Tanase, D. M. et al. The Intricate Relationship between Type 2 Diabetes Mellitus (T2DM), Insulin Resistance (IR), and Nonalcoholic Fatty Liver Disease (NAFLD). *J. Diabetes Res.* **2020** (2020).
17. Kolarić, V., Svirčević, V., Bijuk, R. & Zupančič, V. Chronic complications of diabetes and quality of life. *Acta Clin. Croat.* **61**, 520–527 (2022).
18. Pintér, J. N. *A Krónikus Betegségek Lélektana. Válság És Megújulás* (L'Harmattan Kiadó, 2018).
19. Rubin, R. R. & Peyrot, M. Quality of life and diabetes. *Diabetes Metab. Res. Rev.* **15**, 205–218 (1999).
20. Polonsky, W. Emotional and quality-of-life aspects of diabetes management. *Curr. Diab Rep.* **2**, 153–159 (2002).
21. Ngoatle, C. & Mothiba, T. M. How is it to live with diabetes Mellitus? The voices of the diabetes Mellitus clients. *Int. J. Environ. Res. Public. Health* **19**, (2022).
22. Polonsky, W. et al. Assessing psychosocial distress in diabetes: development of the diabetes distress scale. *Diabetes Care*. **28**, 626–631 (2005).
23. Polonsky, W. et al. Assessment of diabetes-related distress. *Diabetes Care*. **18**, 754–760 (1995).
24. Skinner, T. C., Joensen, L. & Parkin, T. Twenty-five years of diabetes distress research. *Diabet. Med.* **37**, 393–400 (2020).
25. Fisher, L., Polonsky, W. H. & Hessler, D. Addressing diabetes distress in clinical care: a practical guide. *Diabet. Med.* **36**, 803–812 (2019).
26. Náfrádi, L., Nakamoto, K., Csabai, M., Papp-Zipernovszky, O. & Schulz, P. J. An empirical test of the health empowerment model: does patient empowerment moderate the effect of health literacy on health status? *Patient Educ. Couns.* **101**, 511–517 (2018).
27. Funnell, M. & Anderson, R. Empowerment and self-management of diabetes. *Clin. Diabetes*. **22**, 123–128 (2004).
28. Tengland, P. A. Empowerment: A conceptual discussion. *Health Care Anal.* **16**, 77–96 (2008).
29. Schulz, P. J. & Nakamoto, K. Health literacy and patient empowerment in health communication: The importance of separating conjoined twins. *Patient Educ. Couns.* **90**, 4–11. https://doi.org/10.1016/j.pec.2012.09.006 (2013).
30. Hernandez-Tejada, M. A. et al. Diabetes empowerment, medication adherence and self-care behaviors in adults with type 2 diabetes. *Diabetes Technol. Ther.* **14**, 630–634 (2012).
31. Williams, J. et al. Impact of a health empowerment-focused program on adult employee's motivators of and barriers to engaging in healthy behaviors. *Am. J. Health Educ.* **51**, 169–178 (2020).
32. Spencer, G. Young people and health: towards a new conceptual framework for understanding empowerment. *Health (U.K.)*. **18**, 3–22 (2014).
33. Anderson, R. M. et al. Patient empowerment results of a randomized controlled trial. *Diabetes Care*. **18**, 943–949 (1995).
34. Kato, Y., Iwanaga, M., Roth, R., Hamasaki, T. & Greimel, E. Psychometric validation of the motivation for healthy eating scale (MHES). *Psychology* **04**, 136–141 (2013).
35. Román, N., Rigó, A., Kato, Y., Horváth, Z. & Urbán, R. Cross-cultural comparison of the motivations for healthy eating: investigating the validity and invariance of the motivation for healthy eating scale. *Psychol. Health*. **36**, 367–383 (2021).
36. Ryan, R. M. & Deci, E. L. Intrinsic and extrinsic motivations: classic definitions and new directions. *Contemp. Educ. Psychol.* **25**, 54–67 (2000).
37. Deci, E. & Ryan, R. The general causality orientations scale: self-determination in personality. *J. Res. Pers.* **19**, 109–134 (1985).
38. Guertin, C. & Pelletier, L. The relationship between autonomous and controlled motivation and eating behaviors: examining the roles of self-regulating eating quality and quantity. *Motiv. Emot.* **46**, 621–639 (2022).
39. Bryan, C. J. et al. Harnessing adolescent values to motivate healthier eating. *Proc. Natl. Acad. Sci. U. S. A.*. **113**, 10830–10835 (2016).
40. Oftedal, B., Bru, E. & Karlsen, B. Motivation for diet and exercise management among adults with type 2 diabetes. *Scand. J. Caring Sci.* **25**, 735–744 (2011).
41. Martinez, K. et al. Psychological factors associated with diabetes self-management among adolescents with type 1 diabetes: a systematic review. *J. Health Psychol.* **23**, 1749–1765 (2018).
42. Lakerveld, J. et al. Motivation: key to a healthy lifestyle in people with diabetes? Current and emerging knowledge and applications. *Diabet. Med.* **37**, 464–472 (2020).
43. Brouwer, A. M. & Mosack, K. E. Motivating healthy diet behaviors: the self-as-doer identity. *Self Identity*. **14**, 638–653 (2015).
44. Eisenberg, M. H., Lipsky, L. M., Dempster, K. W., Liu, A. & Nansel, T. R. I should but I can't: controlled motivation and self-efficacy are related to disordered eating behaviors in adolescents with type 1 diabetes. *J. Adolesc. Health*. **59**, 537–542 (2016).
45. Vallis, M. et al. Stages of change for healthy eating in diabetes relation to demographic, eating-related, health care utilization, and psychosocial factors. *Diabetes Care*. **26**, 1468–1474 (2003).
46. Daubenmier, J. The relationship of yoga, body awareness, and body responsiveness to self-objectification and disordered eating. *Psychol. Women Q.* **29**, 207–219 (2005).
47. Daubenmier, J., Sze, J., Kerr, C. E., Kemeny, M. E. & Mehling, W. Follow your breath: respiratory interoceptive accuracy in experienced meditators. *Psychophysiology* **50**, 777–789 (2013).
48. Daubenmier, J. et al. Mindfulness intervention for stress eating to reduce cortisol and abdominal fat among overweight and obese women: An exploratory randomized controlled study. *J. Obes.* **2011** (2011).
49. Tihanyi, B. T., Ferentzi, E., Daubenmier, J., Drew, R. & Köteles, F. Body responsiveness questionnaire: validation on a European sample, mediation between body awareness and affect, connection with mindfulness, body image, and physical activity. *Int. Body Psychother. J.* **16**, 56–73 (2017).
50. King, L. A. & Hicks, J. A. The science of meaning in life. *Annu. Rev. Psychol.* **72**, 561–584 (2021).
51. Steger, M. F., Frazier, P., Kaler, M. & Oishi, S. The meaning in life questionnaire: assessing the presence of and search for meaning in life. *J. Couns. Psychol.* **53**, 80–93 (2006).
52. Martos, T. & Konkolÿ Thege, B. Aki Keres, és aki talál-az élet értelmessége keresésének és megélésének mérése az Élet Értelme Kérdőív magyar változatával. *Magyar Pszichologiai Sz.* **67**, 125–149 (2012).
53. Aliche, C. J., Ifeagwazi, C. M. & Ezaka, E. S. Moderating role of meaning in life in the relationship of death anxiety, experiential avoidance and health-related quality of life among type 2 diabetes patients. *South. Afr. J. Psychol.* **53**, 533–547 (2023).
54. Kruger, S., Deacon, E., van Rensburg, E. & Segal, D. G. Young adult women's meaning-making of living with type 1 diabetes: towards growth and optimism. *Psychol. Health*. **38**, 573–590 (2023).
55. Faul, F., Erdfelder, E., Lang, A. G. & Buchner, A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods*. **39**, 175–191 (2007).
56. Heckenberger-Nagy, E. et al. Psychometric evaluation of the Hungarian adaptation of the diabetes distress scale in individuals with type 2 diabetes. *J. Nurs. Meas.* **JNM-2023** https://doi.org/10.1891/JNM-2023-0112 (2024).
57. Papp-Zipernovszky, O., Csabai, M., Schulz, P. J. & Varga, J. T. Does health literacy reinforce disease knowledge gain? A prospective observational study of Hungarian copd patients. *J. Clin. Med.* **10**, (2021).
58. DeFronzo, R. A. et al. Type 2 diabetes mellitus. *Nat. Rev. Dis. Primers* **1**, (2015).
59. Ogawa, W. et al. New classification and diagnostic criteria for insulin resistance syndrome. *Diabetol. Int.* **13**, 337–343 (2022).
60. Teleki, S. & A távolított betegség - A betegségfeldolgozás nehezítettsége és megjelenése a betegségtörténetekben. in Lélek és történelem 3.1: Távolság (ed Papp, B.) (ELTE Eötvös Kiadó, 2022).
61. Sakalys, J. A. Restoring the patient's voice:the therapeutics of illness narratives. *J. Holist. Nurs.* **21**, 228–241 (2003).
62. Abolghasemi, R. & Sedaghat, M. The patient's attitude toward type 2 diabetes mellitus, a qualitative study. *J. Relig. Health*. **54**, 1191–1205 (2014).
63. Bombaci, B. et al. Psychological and clinical challenges in the management of type 1 diabetes during adolescence: a narrative review. *Children* **9**, 1085 (2024).

64. Orben, K., Ritholz, M. D., McCalla, M. & Beverly, E. A. Differences and similarities in the experience of living with diabetes distress: a qualitative study of adults with type 1 and type 2 diabetes. *Diabet. Med.* **39**, (2022).
65. Balfe, M. et al. What's distressing about having type 1 diabetes? A qualitative study of young adults' perspectives. https://doi.org/10.1186/1472-6823-13-25 (2013).

Author contributions

F.Ő.: Conceptualization, methodology, data collection, data curation, writing-original draft, funding acquisition; B.L.K.: methodology, data curation, visualization, writing-original draft, funding acquisition; A.N.ZS.: Formal analysis, writing-review and editing reviewing, supervision, funding acquisition. SZ.Á.T.: Conceptualization, writing-review and editing reviewing, supervision. All authors reviewed the manuscript.

Funding

FŐ was supported by the ÚNKP-23-3 New National Excellence Programs of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund. ANZS was supported by the ÚNKP-23-5 New National Excellence Programs of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund. ANZS was also supported by OTKA PD 137588 and OTKA FK 146604 research grants. BLK received support from OTKA K 143254 research grant. ANZS was also supported by the János Bolyai Research Scholarship provided by the Hungarian Academy of Sciences.

Declarations

Competing interests

The authors declare no competing interests.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used DeepL Write in order to improve the quality of the English scientific wording. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Additional information

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-024-83837-y.

Correspondence and requests for materials should be addressed to F.Ő.