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ORIGINAL ARTICLE

Inflammatory potential of the diet is associated with psychological stress in adults with type 2 diabetes: a methodological approach of e-Health

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Abstract

Objective We studied the presence of psychological stress in patients with type 2 diabetes (T2D) and if could be attributed to the consumption of a pro-inflammatory diet. We evaluated the inflammatory potential of the habitual Mexican diet, addressed by tools with an approach to collecting information on e-Health.

Methods In this cross-sectional analytic study of 238 Mexican adults with T2D, the profile of the inflammatory diet was obtained by the Dietary Inflammatory Index (DII), and the presence of psychological stress by the Diabetes Distress Scale-17 (DSS) was assessed. Multivariable logistic regression analysis was performed to estimate the association between diabetes stress and DII score. Sensitivity analysis was performed by Energy–Density Dietary Inflammatory Index (E-DII).

Results We demonstrated that there is an association between a profile of stress and high-inflammatory values of the DII score after adjustment for potential confounders (OR 2.40, 95% CI 1.2, 4.6).

Conclusion Using e-Health through web-based tools to collect information showed benefits of the application as a method of dietary assessment. We provide evidence showing that better values of the DII score and physical activity may play a protective role against the presence of psychological stress; DII and E-DII scores qualify and label habitual diet into pro and anti-inflammatory and are associated with psychological stress in T2D.

Keywords Chronic inflammation · Chronic stress · Dietary assessment · Dietary surveys · Psychosocial factors

Introduction

Type 2 diabetes (T2D) is a global disease, and Mexico is one of the countries with the highest prevalence [1]. The treatment of chronic diseases involves adjustment and change of a series of behavioral patterns, generally affecting lifestyle and choices about food and meals associated with inflammation generating psychological stress [2]. In general, psychological stress could be developed in response to the environment, including foods and meals that people could access and the emotional stress they endure [3]. Evidence has demonstrated that in T2D, diet and inflammatory status could influence the presence of stress [4], which may extend beyond it. Recently, we have shown that the diet possesses pro or anti-inflammatory properties [5]. It has been shown that the immune system is resynchronized by feeding [6], and immune responses are also orchestrated by an inflammatory diet and exhibit effects on intermediaries that coordinate several innate immune cells such as macrophages, monocytes, and neutrophils that are capable of producing glucocorticoids [7]; Consumption of pro-inflammatory dietary compounds such as sweetened drinks, sweet cereals, and sweet snacks and desserts has shown a relationship with cortisol levels [8].

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The high-level scores are associated with higher inflammatory status in cohort studies. A pro-inflammatory diet has been associated with T2D among adult Mexicans [8]. Additionally, stressful environments and large variability in quick-service food solutions represent the Mexican common lifestyle and provide information to characterize profile inflammatory [9].

The e-Health is an emergent technology tool for application in methods of dietary assessment. Studies have confirmed its reliability [10, 11]. Nowadays, it is possible to build web-based tools to evaluate the profile of psychological stress from paper-based tools [12]. Hence, it is possible to use web-dietary surveys to obtain a Dietary Inflammatory Index (DII®) [13] and an Energy–Density Dietary Inflammatory Index (E-DII™) [14] by computing scores of the inflammatory potential of the diet and characterizing the habitual diet. These forms represent a versatile approach, saving time, and costs [15].

We hypothesized that T2D patients with a pro-inflammatory diet were more likely to suffer psychological stress. Indeed, lifestyle such as health behaviors and food choices could be related to this condition. Investigating some domains of lifestyle and the profile of stress is needed to further understand the complex links between psychological stress and T2D [16].

For this purpose, we decided to explore the inflammatory profile of the Mexican habitual diet and its association with a profile of stress. Thus, the main objective of our study was to evaluate the inflammatory potential of the diet in the habitual Mexican diet and if there is a relation between the presence of psychological stress addressed by tools with an approach to collecting information on e-Health in Mexican adults with T2D.

Materials and methods

Study design

Mexican adults participated in this cross-sectional analytical study in an outpatient clinic-based sample physician-diagnosed with T2D. This was a convenience sample of adult population. We divided them into two groups according to the type of recruitment: (a) We used a community-based approach which entailed several different strategies to recruit participants (e.g., use of social media) and (b) patients of Diabetes Clinic at the "Adolfo López Mateos" Medical Center were invited. Patients were recruited from February to July 2022. The study included 230 participants.

The inclusion criteria for this study were as follows: (1) males and females, aged + 18; (2) diagnosed with type 2 diabetes for at least 1 month or more; (3) Mexican nationality and living in Mexico; (4) under medical care for diabetes in Mexico; (5) able to read and write Spanish to complete the forms, questionnaires, and tests; (6) access to the internet website; and (7) acceptance to participate in this study. The exclusion criteria were based on self-reports from participants of the following: (1) physical and/or mental conditions that obstruct participation; (2) incapacity to obtain reliable information; and (3) complications of T2D that interfered with or modified medical treatment as renal disease or replacement therapy.

Data collection: e-Health

The tool e-Health was used for data collection through a website with web-based questionnaires/tests from paper-based tools. The patients were instructed on how to access online to fill out the questionnaires/tests. Each patient's data was collected with the help of a major questionnaire divided into 3 sections: identification data, reported dietary data, and tests. Participants who did not know how to fill in were interviewed through video call. They received regular communication from the team through newsletters, reminder emails, and reminder texts for completion. Survey data collector kept records in the cloud, computing them until their analyses. Acceptability of the website was measured by the total of invitations, time using the website, incomplete questionaries, and rejection to participate in the study [17].

Obtaining dietary information and creating the Dietary Inflammatory Index

We evaluated dietary intakes based on a validated paper-based Food Frequency Questionnaire (FFQ) migrated to web-based [18, 19]; validity of a web-based FFQ has previously been reported [20]. We constructed, with the use of images for portion size estimation and multiple options, a web-based questionnaire which contained 160 food items combining the characteristics of a typical Mexican diet with multiple possible answers, divided into 8 sections. Possible answers indicated the frequency of consumption of each food in relative frequency (never, almost, and always) and absolute frequency (times per month, week, day). Kind and type of meals and foods were evaluated by quantifiers (e.g., cups, glasses, plates, portions) to obtain the amount of the food consumed. We applied a 24-h recall from three different days to contrast information. Dietary intake and nutrient composition were analyzed by ESHA's Food Processor® Nutrition Analysis software version 11.2.23 (ESHA Research©, Oregon, USA). Additionally, we evaluated the composition of Mexican foods through the Database of Mexican Foods Composition ("BAM") version 18.1.1(INSP, Mexico) [21] and polyphenol intake using the USDA Database for the Flavonoid Content of Selected Foods Release 3.0 [22] in combination with the Phenol Explorer Database version 3.6 [23].

Calculation of the DII score was obtained by computing the amounts of nutrients collected using the FFQ and transformed into intakes of food parameters from the individual diet composition. The DII development has been described elsewhere [13]. As result of calculation of the DII, we obtained individual scores and the inflammatory potential of the diet. According to composite global database and global scores, the scale of the DII score of the maximal pro-inflammatory diet was interpreted at + 7.98, the maximal anti-inflammatory DII score was interpreted at − 8.87, and the neutral/transition effect was at + 0.23.

Tests applied on study population

Profile of psychological stress

We evaluated stress variables, with measurements made with two instruments, the first one assesses perceived stress (PSS-14) [24], interpreted as very low stress (0 to 15 points) and high stress (16 to 21 points); the second tool evaluates the stress caused by diabetes and types of distress, the Diabetes Distress Scale-17 (DSS), that pre-establishes items from four domains of diabetes-related distress: emotional burden distress subscale, physician-related distress subscale, regimen-related distress subscale, and diabetes-related interpersonal distress subscale [12]. We obtained interpretations from subscale scores. The total score of DSS was interpreted as psychological stress and categorized as low-moderate stress (≤ 2.9 mean item score) and high stress (≥ 3.0 mean item score) [25]. Spanish versions of the instruments were validated in Mexican people living with T2D previously [26, 27].

Assessing self-management and quality of life

The Diabetes Self-Management Questionnaire (DSMQ) was applied for glycemic control assessment, and the subscale glucose management from DSMQ was utilized. Glucose management and interpretation were categorized low effective management (scale ranging from 0 to 5) and more effective management (scale ranging from 6 to 10). The questionnaire was designed to assess self-care behaviors which can be related to the measure of HbA1c [28]. For the assessment of adherence to medical treatment, we tested with the 8-item Morisky Medication Adherence Scale (MMAS-8); adherence is determined according to the final score (total sum of 8 points) and categorized as adherence (total of 8 points) and no adherence (< 8 total points). We evaluated lifestyle domains utilizing the Instrument to measure lifestyle of type 2 diabetes mellitus patients (*IMEVID).* This tool explored barriers to diabetes self-management such as physical activity, smoking, type of diet, cooking capacity, and effort to eat well (also called the "healthy eater" effect due to the intention of careful, health-conscious people to choose meals). The total scores were obtained; the results were categorized into a rating system as favorable (≥ 80 total points) and unfavorable lifestyle (≤ 80 total points). These tools were validated in the Mexican population with T2D [29–31].

Statistical analyses

A descriptive analysis of the socio-demographic characteristics of the study population was performed, and we analyzed the differences by type of recruitment. Continuous variables are described in terms of averages and standard deviations (mean ± SD) or median (minimum–maximum); categorical variables were described by numbers and percentages. The χ^2 test was used for interpreting categorical variables and Student's *t* test was for continuous variables. Spearman's correlation coefficient calculated the relation between diet and inflammation and stress response.

We constructed a dichotomous variable for analysis of the DII score, we divided the data into low-inflammatory scores (≤ 1.0) and high-inflammatory scores (> 1.0), and the χ^2 test was used to examine associations between stress variables and the inflammatory diet. We used bivariate analysis to estimate the association between diabetes stress and DII score; we used a simple univariable (unadjusted) and multivariable logistic regression analysis adjusted for predictors of stress (age, sex, physical activity, smoking, and body mass index (BMI)). To assess possible effect modification, analyses stratified by sex and age were performed. Logistic regression analyses were used to calculate ORs and 95% CIs of DII concerning to diabetes stress. Two-tailed *p* values were utilized, where a *p* value less than 0.05 was deemed statistically significant. Analyses were performed using IBM® SPSS® Statistics software version 25.0 and Graphpad© Prism software version 9.4.1 for drawing plots and DAGitty software version 3.0 for drawing and analyzing the acyclic graph.

Sensitivity analysis: comparison with the Energy–Density Dietary Inflammatory Index

E-DII was created to improve the prediction of observed relations between overall consumption of dietary energy and nutrient intakes and densities that differ among the studied population to determine the diet's overall inflammatory potential [14]. The energy-adjusted from every food parameter was expressed per thousand kilocalories (1000 kcal). The following 22 food parameters available for E-DII were used: carbohydrate; fiber; protein; total fat; saturated fat; monounsaturated fat; polyunsaturated fat; n-3 fatty acids; n-6 fatty acids; cholesterol; vitamins A, B1, B2, B3, B6, B12, C, D, and E; beta-carotene; folate; magnesium; iron; selenium; zinc; alcohol; and caffeine.

To explore whether E-DII provided a better adjustment to our multivariable-adjusted mixed model, we performed

Spearman's correlations between DII and E-DII, and we constructed E-DII quintiles; the ANOVA test was used to evaluate differences across quintiles, and the χ^2 test was used to examine the distribution of qualitative variables over E-DII quintiles. Finally, we used EB subscale and E-DII potential confounding factors in the stratified analysis.

Results

Study population and outcomes of data collection: e-Health

A total of 238 participants with T2D constituted our study population: 100 (42%) males and 138 (58%) females. The average age was 55.5 ± 12.1, BMI was 29.5 ± 5.5 kg/m^2, and duration of diabetes was 10.5 ± 8.8 years. The number of participants who were treated with oral-antidiabetic medication and insulin was 130 (38.1%), and 61 (25.6%) subjects consumed metformin. The median of physical activity was 85.0 (0–180) minutes/week, and 95 patients (39.9%) reported being sedentary (not any kind of physical activity was performed).

The acceptance rate of the website was 76.06% and according to the type of recruitment, there were statistical differences in age groups, occupation, duration of diabetes, and physical activity. General and socio-demographic characteristics of the study population are reported in Table 1.

Dietary Inflammatory Index

The DII score ranged between − 2.96 (maximal anti-inflammatory diet) and + 7.21 (maximal pro-inflammatory diet) (Fig. 1). The DII score as a dichotomous variable; a higher inflammatory index score was associated significantly (p 0.002) with combined therapy (oral antidiabetic medications and insulin) and a lower education level with a significantly (p 0.047) higher DII score. Age and sex were not significantly different in DII scores. The proportion of participants with low physical activity was also observed progressively and increasingly in higher values of DII score, but the difference did not reach statistical significance. Values and socio-demographic characteristics of DII score are shown in Supplementary information (Appendix A. Supplementary data, Table 2).

Tests applied on study population

Profile of psychological stress

The assessment of stress variables, 79 participants (33.2%) obtained a score that indicated stress perceived; 137 patients (57.6%) presented psychological stress; and 146 patients (61.3%) presented EB from the subscale. There were no significant differences between groups (Appendix A. Supplementary data, Table 3).

Regarding dichotomous DII, psychological stress and EB, PD, and RD subscales showed significant differences across values of DII. Mainly, the participants with stress exhibited pro-inflammatory values (67.9%) and with EB subscale (68.5%), with significant differences across DII scores ($p < 0.05$) (Appendix A. Supplementary data, Table 4).

Assessing self-management and quality of life

We evaluated self-management, and we found effective glucose management by 158 (66.4%) participants; no significant differences were observed between groups. Medical treatment adherence was reported by 56 (23.5%) patients. Only 39 participants (16.5%) obtained a favorable lifestyle category. In the lifestyle domains, the proportion of persons with a favorable score of effort to eat well, and cooking capacity were significantly lower in the high values of DII score ($p < 0.05$) (Appendix A. Supplementary data, Table 4).

We analyzed the relationship between psychological stress and barriers to diabetes self-management, demonstrating a relation between domains of DSS and adherence (p 0.007) and cooking capacity (p 0.004). Based on correlation analysis, significant positive associations between DII and E-DII ($r = 0.68$), adherence and lifestyle ($r = 0.36$), effort to eat well and lifestyle ($r = 0.28$), and adherence and effort to eat well ($r = 0.49$) were found. Negative associations were identified in DII scores and adherence ($r = -0.20$), lifestyle ($r = -0.11$), cooking capacity ($r = -0.26$), and effort to eat well ($r = -0.23$), in which adherence and effort to eat well were the most highly correlated ($r = 0.49$, $p < 0.0001$) (Fig. 2).

Models of logistic regression

After adjusting for age and sex, DII as a continuous or categorical variable, correlation between psychological stress and DII was significant; results are presented in Table 2. DII as a continuous variable showed a per-point decrease as a role of a protective factor of psychological stress in T2D (OR 0.86, 95% CI 0.74, 0.98; p 0.033). Compared with the participants that obtained lower scores, those in the upper scores of DII had 2.40 times (95% CI 1.2, 4.6; p 0.010, $r^2 = 0.113$) higher odds of having psychological stress after adjustment for potential confounders (Table 2, Fig. 3). Similarly, participants with higher scores of DII had 2.49 times (95% CI: 1.2, 4.9; p 0.009, $r^2 = 0.110$) higher odds of having emotional distress in comparison to subjects with the lowest DII scores (Appendix A. Supplementary data, Table 7).

Table 1 Characteristics of the study population with type 2 diabetes

	Overall study ($n=238$)	Community-based approach ($n=37$)	Diabetes clinic ($n=201$)	p
Sex, *n* (%)				
Male	100 (42.0)	18 (18.0)	82 (82.0)	0.374
Female	138 (58.0)	19 (13.8)	119 (86.2)	
Age, *y* *	55.54 ± 12.10	47.68 ± 9.49	56.99 ± 11.99	0.0001
Age groups, *n* (%)				
< 45	47 (19.7)	15 (31.9)	32 (68.1)	0.0001
45–60	101 (42.4)	18 (17.8)	83 (82.2)	
> 60	90 (37.8)	4 (4.4)	86 (95.6)	
BMI, kg/m^2 *	28.59 ± 5.57	29.95 ± 6.05	28.34 ± 5.45	0.139
Weight status, *n* (%)				
BMI < 24 kg/m^2	49 (20.6)	2 (4.1)	47 (95.9)	0.041
BMI 24–28 kg/m^2	71 (29.8)	12 (16.9)	59 (83.1)	
BMI > 28 kg/m^2	118 (49.6)	23 (19.5)	95 (80.5)	
Occupation, *n* (%)				
Unemployed	21 (8.8)	0 (0.0)	21 (100)	0.0001
Housekeeper	116 (48.7)	11 (9.5)	105 (90.5)	
Pensioner	8 (3.4)	4 (50.0)	4 (50.0)	
Active worker	93 (39.1)	22 (23.7)	71 (76.3)	
Educational level, *n* (%)				
None	21 (8.8)	1 (4.8)	20 (95.2)	0.0001
Low	131 (55.0)	9 (6.9)	122 (93.1)	
Medium	42 (17.6)	9 (21.4)	33 (78.6)	
Medium–high	33 (13.9)	9 (27.3)	24 (72.7)	
High	11 (4.6)	9 (81.8)	2 (18.2)	
Medications, *n* (%)				0.351
Oral antidiabetic medications	81 (34.4)	16 (19.8)	65 (80.2)	
Insulin therapy	27 (27.5)	3 (11.1)	24 (88.8)	
Mix	130 (38.1)	18 (13.8)	112 (86.2)	
Duration of diabetes, *n* (%)				
< 10 y	119 (50.0)	27 (22.7)	92 (77.3)	0.002
≥ 10 y	119 (50.0)	10 (8.4)	109 (91.6)	
Smoking, *n* (%)				
Never-occasionally	205 (86.1)	27 (13.2)	178 (86.8)	0.012
Usually	33 (13.9)	10 (30.3)	23 (69.7)	
Alcohol status, *n* (%)				
Never-occasionally	209 (87.0)	31 (14.8)	178 (85.2)	0.415
Usually	29 (12.2)	6 (20.7)	23 (79.3)	
Physical activity duration, *n* (%)				
MET- m/w*	306.4 ± 23.8	378.0 ± 62.5	293.3 ± 25.6	0.522
< 150 m/w	163 (68.5)	20 (12.3)	143 (87.7)	0.040
≥ 150 m/w	75 (31.5)	17 (22.7)	58 (77.3)	
DII score (−9 to +8) *	2.38 ± 2.04	2.65 ± 1.83	2.33 ± 2.08	0.469
E-DII score (−5.81 to 4.82) *	2.82 ± 1.11	3.37 ± 0.79	2.72 ± 1.14	0.469
Effective glucose management, *n* (%)	158 (66.4)	24 (15.2)	134 (84.8)	0.769

Description of characteristics of the study population are presented by type of recruitment and general. Educational levels were considered without completion of any education system, elementary–middle school, high school, bachelor, and postgraduate degrees. A mix of antidiabetic medications was included: oral medication and insulin therapy. Consumption of alcohol and smoking were categorized by amounts and frequency. p Value < 0.05. *Values are presented as mean ± SD. Abbreviations: *DII* Dietary Inflammatory Index, *E-DII* Energy–Density Dietary Inflammatory Index, *n* number, *m/w* minutes per week, *y* year

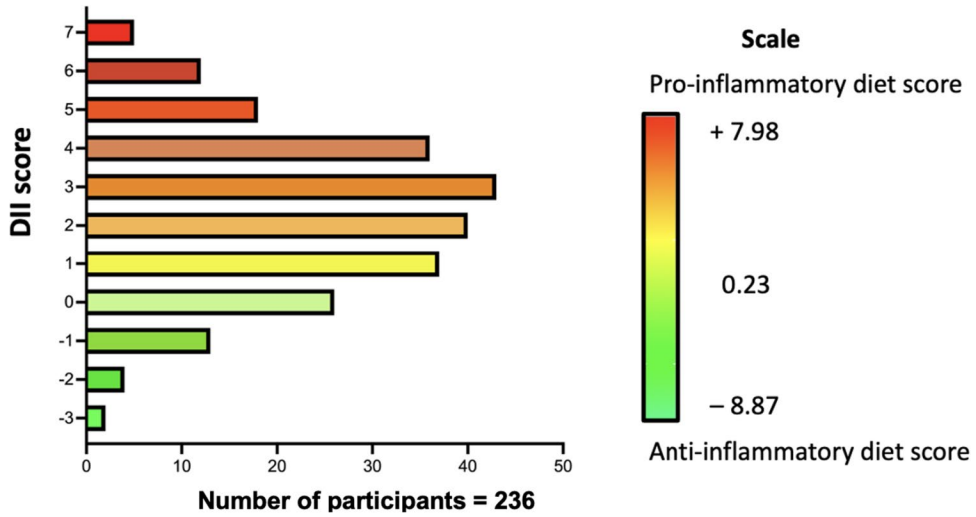

Fig. 1 DII scores obtained from the study population. Frequency distribution of DII is presented. A summary of the frequency distribution by DII individual score shows a concentration of participants in the zone of a pro-inflammatory score. The scale contained global scores as the reference of the global database. The red color is indicative of the highest profile of inflammation (maximal pro-inflammatory diet up to + 7.98), and the green color is indicative of the highest profile of anti-inflammation (maximal anti-inflammatory DII score up to − 8.87). Middle colors are orientated to a neutral transition (median is + 0.23). *Y*-axis: individual DII scores obtained in our population. *X*-axis: number of participants. Abbreviations: DII, Dietary Inflammatory Index

Sensitivity analysis: comparison with the Energy–Density Dietary Inflammatory Index

A sensitivity analysis was conducted. Thus, correlation analysis was performed, revealing a strong relationship between DII and E-DII ($r = 0.68$, $p < 0.0001$). The highest was the negative correlation between E-DII and effort to eat well ($r = -0.35$, $p < 0.0001$).

Results of the stratified analysis of the subscale of EB and E-DII are shown in Fig. 4. We found that physical activity level acts as a protective factor (OR 0.37, 95% CI 0.20, 0.64; *P 0.001*), and we observed that participants ($n = 46$) with a most pro-inflammatory diet (Q3) had higher odds of having emotional distress in comparison with a most anti-inflammatory diet (Q1) (OR 3.26, 95% CI 1.26, 8.38; *p* 0.014).

Discussion

Our study showed that psychological stress is associated with the consumption of a pro-inflammatory diet in patients with T2D (Table 2, Fig. 3). Most of the patients in our study presented values concentrated in worse scores of a dietary profile of inflammation (Fig. 1) and the presence of psychological stress (Table 3, S2).

We observed that participants with the most-proinflammatory scores had higher OR and showed about twofold higher likelihood of having psychological stress (OR 2.40, 95% CI 1.2, 4.6), compared to participants that consumed a habitual diet with low scores of DII after adjustment for potential confounders, and sensitivity analysis confirmed this association using adjustment by energy. The clinical relevance was 11% ($r^2 = 0.113$), and when DII scores decreased to better values (most anti-inflammatory diet), there is a 14% (2% to 26%) less possibility of having psychological stress (OR 0.86, 95% CI 0.74, 0.98).

Several studies have confirmed that the consumption of pro-inflammatory diets had a higher risk of developing T2D compared with the consumption of anti-inflammatory diets [32, 33]. In this study, the mean DII score in our population was 2.38 and was higher than in other studies, contrary to the mean value of DII in the Mexico City Diabetes Mellitus Survey, which included 27 food parameters with a mean of 0.68 [34], and the Xinjiang population with a mean of 0.81 [35]. However, the National Health and Nutrition Survey ("ENSANUT") reported that one of every two adults in Mexico does not consume fruits and vegetables daily; on the other hand, among the food groups not recommended for daily consumption, the most consumed in Mexican adults were sweetened drinks (69.3%), followed by sweet cereals (41.3%) and sweet snacks and desserts (26.6%) [36]. A more plausible explanation is that our results might suggest that the population consumed more amounts of pro-inflammatory items and nutrients, and less of anti-inflammatory compounds (i.e., polyphenols).

Some studies have proven that a high inflammatory score is also a potent marker of inadequate quality of the diet and may further contribute to chronic stress, which also creates a chain of behaviors that can negatively affect

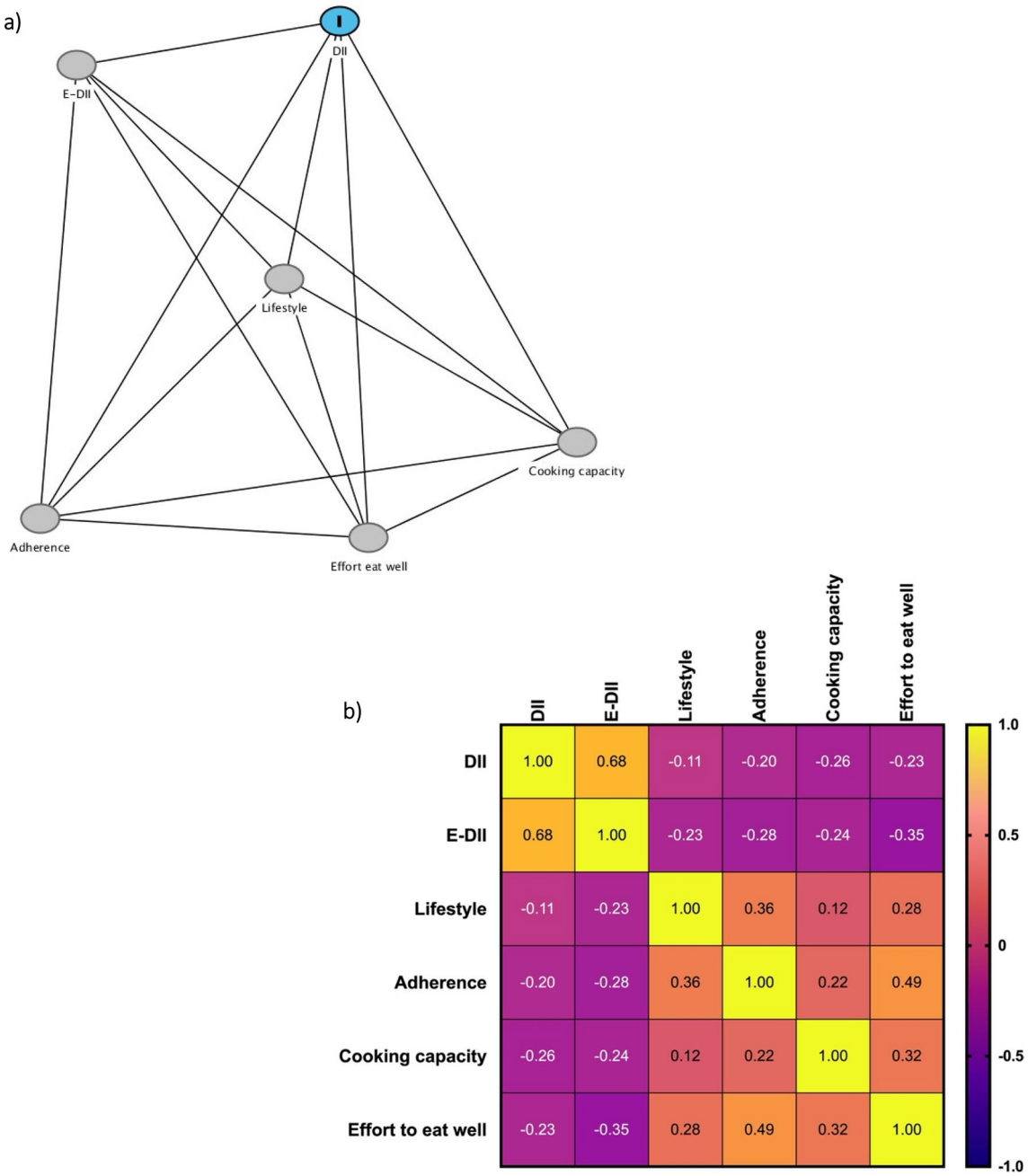

Fig. 2 Correlations between DII, E-II, and total scores from tests applied on study population; lifestyle domains are associated with the DII. **a** DAG scheme of correlations between DII and total scores of different domains of lifestyle assessed through scales obtained from tools applied on study population. **b** Heat map shows the factors associated positively and negatively correlated with DII. Abbreviations: *DAG* directed acyclic graph, *DII* Dietary Inflammatory Index, *E-DII* Energy–Density Dietary Inflammatory Index, *I* outcome

eating habits [32, 37]. In the present study, we evaluated lifestyle domains, showing a negative correlation between DII scores and effort to eat well, in the same way, DII scores and cooking capacity (Fig. 2). Furthermore, we evaluated the presence of EB, and we observed that 57.6% of participants had a have moderate-high emotional distress, of which 68.49% consumed a pro-inflammatory diet (Table 4). Evidence has shown that stress may affect eating behavior, such as emotional eating, lack of time, or motivation to prepare nutritious and balanced meals [38].

Additionally, according to the type of recruitment, statistical differences were observed in the duration of diabetes and physical activity; most of the participants from the diabetes clinic (78.3%) obtained high values of dietary inflammation and combined therapy of oral antidiabetic drugs and insulin. We hypothesize that these differences

Table 2 Results of multivariate logistic regression models examining the relation between the Dietary Inflammatory Index and psychological stress in type 2 diabetes

DII	T2D *n*	Unadjusted OR (95% CI)	*p*	Age and sex-adjusted OR (95% CI)	*p*	Fully adjusted OR (95% CI)	*p*
Continuous variable	236	0.90 (0.79–1.02)	0.123	0.86 (0.75–0.99)	0.038*	0.86 (0.74–0.98)	0.033*
Categorical variable							
D1	61	1 (reference)		1 (reference)		1 (reference)	
D2	175	2.28 (1.2–4.3)	0.011*	2.38 (1.2–4.5)	0.008*	2.40 (1.2–4.6)	0.010* $\mathbf{r^2 = 0.113}$

Simple and multiple logistic regression was performed on the study population with type 2 diabetes. Logistic model fully adjusted: age, sex, PA, BMI, and smoke. DII individual scores as continuous variable is presented. Categorical variable is expressed such as D1 (anti-inflammatory values) versus D2 (pro-inflammatory values). $*p < 0.05$. Abbreviations: *BMI* body mass index, *CI* interval confidence, *n* number, *PA* physical activity, *OR* odds ratio, *T2D* type 2 diabetes

are because people who navigate in the hospital environment have a poor quality of health.

The e-Health tools offer advantages in visual representation and equal instructions in obtained dietary information reducing observer bias in lieu of traditional-based methods [15]. In our study, the data collected on the website suggests that the e-Health approach offered our participants versatility and the possibility of collecting information during the pandemic and creating online innovation elements for a better understanding (e.g., use of images for

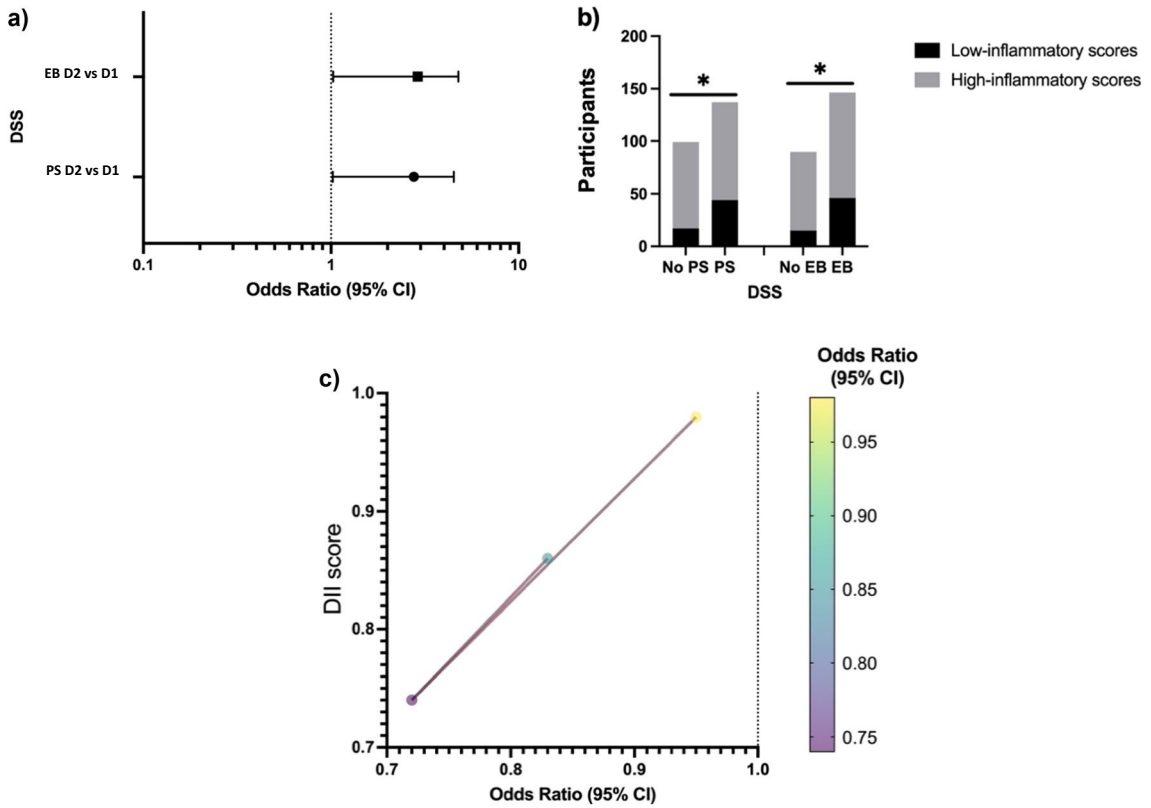

Fig. 3 Odds ratio (95% CI) of DII and DSS. **a** The plot of OR and psychological stress was generated, and an analysis of DII categories (*X-axis*) and values of OR (*Y*-axis) was presented. **b** The plot of OR and EB was generated, and an analysis of DII categories (X-axis) and values of OR (*Y*-axis) was presented. **c** Plotting of the OR of the DSS and EB in relation to DII individuals scores as continues variable is presented. *Y*-axis indicates individual scores of DII obtained of our population. *X*-axis indicates OR values obtained in multiple logistic regression. Blue color indicates final point value of EB and yellow color the final point value of stress. Abbreviations: *CI* confidence interval, *DII* Dietary Inflammation Index, *DSS* Diabetes distress scale, *EB* Emotional Burden distress, *OR* odds ratio, *PS* psychological stress, *vs* versus

portion size estimation); furthermore, we only had an 0.8% drop-out of participants that did not complete the tests and a moderate rate of acceptability to the website; we think that information obtained in web-based tools could reduce costs and time vs traditional methods and improve self-management, offering an alternative to assessment of dietary information.

Previous studies reported increased feasibility of dietary assessment [10, 11], however, in our study, due to the lack of assessment for accuracy on web-based tools, our results cannot confirm feasibility and adoption of e-Health; despite this, we are convinced that it is useful as an emergent technology implying development and progress.

Our methodological barriers were for adequately assessing dietary information which is an actual challenge in nutrition research, and the best methods for dietary collection are still unclear [39]. We noticed that obtaining dietary information on self-report carries the risk of misreporting, which could affect our results. Additionally, we know that seasonality or temporality can affect the collection of dietary information [17]; in our study, this could be modified by nutrient intake or the kind of foods and meals consumed; seasonal variation is beyond the scope of this study's assessment of consumption.

Finally, our population has mostly dietary pro-inflammation values and high BMI levels (overweight and obesity). Studies, in consequence, could be applied to multicenter locations and increased size population of T2D to explore an equilibrium of study population. Conducting studies on cohorts with lower BMI levels in comparison may lead to the discovery of more insightful correlations.

In summary, we demonstrated that there is a significant association between a profile of stress and high inflammatory values of the DII score and relationships with an unfavorable lifestyle and worse DII scores. The low values of the DII score and physical activity may play a protective role against the presence of a profile of stress. Domains of favorable lifestyle in patients with T2D were negatively correlated with individual DII scores. Stress was presented in most of the participants. The analysis presented supports our theory that a pro-inflammatory diet contributes to chronic stress; these results should be confirmed in patients with T2D in further prospective cohort studies, and future clinical trials should consider implementing and establishing strategies for nutritional therapy and anti-inflammatory patterns that might bring light to the dietary treatment of T2D.

People living with T2D in Mexico are characterized by lower consumption of anti-inflammatory and higher consumption of pro-inflammatory compounds; our study revealed that our Mexican population with T2D has scores of dietary inflammation indicative of a pro-inflammatory diet. T2D is a disease with inflammatory activity and per se causes psychological and emotional distress in persons who suffer it. The study's clinical implications highlight the possible potential for preventing diabetes distress by evaluating the inflammatory profile and making adjustments to the consumption of pro-inflammatory compounds while promoting the intake of anti-inflammatory compounds. Anticipating solutions is necessary to innovate new strategies for nutrition therapy focusing on potential inflammatory characteristics of the diet, continuing to assess the most adequate food consumption instrument applied in adults, and promoting healthy environments is required.

Conclusion

We conclude that the use of e-Health through web-based tools to collect information on a website showed a medium rate of acceptability and offered benefits in the application as a method of dietary assessment**,** which requires more studies evaluating accuracy and feasibility. DII and E-DII scores qualify and labeled habitual diet in pro and anti-inflammatory terms and are associated with psychological stress in T2D.

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Author contribution All authors read and approved the final manuscript. All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by AISR and RVR. The first draft of the manuscript was written by AISR, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data Availability Data are available upon request from the Corresponding Author.

Declarations

Ethical clearance All participants included in the study gave written informed consent for inclusion. The study was carried out following the Guidelines of the Declaration of Helsinki, and the study protocol was approved by the Ethics Committee of *Universidad Autónoma del Estado de México* (register number: 4851/2019E).

Conflict of interest The authors declare no competing interests.

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