The relationship between the World Index for Sustainability and Health (WISH) score and mental health in women: A cross-sectional study

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ABSTRACT

Diet quality has been associated with mental health, and recently, there has been growing interest in the association between sustainability of diets and human health. The objective of this cross-sectional study was to explore the relationship between a newly developed dietary index for health and sustainability, and psychological disorders among Iranian women. Participants in this cross-sectional study included 479 women living in Tehran with no history of chronic disease. A validated 168-item food frequency questionnaire was used to assess dietary intake. The World Index for Sustainability and Health (WISH) was calculated, consisting of four sub-scores: less healthy, healthy, low environmental impact, and high environmental impact. Participants psychological status was assessed using the Depression Anxiety Stress Scale-21. Logistic regression models were used to examine the association between WISH and psychological disorders. Participant ages ranged from 20-50 years, with a mean age of 31.86 (SD:7.68) years. After adjusting for potential confounders (age, energy, BMI, marital status, education, family history of chronic disease, body satisfaction, socio-economic status, physical activity, smoking), women in the highest tertile of the healthy sub-score had significantly lower odds of experiencing depression (OR: 0.40; 95% CI: 0.24-0.67), anxiety (OR: 0.45; 95% CI: 0.23-0.87) and psychological distress (OR: 0.46; 95% CI: 0.28-0.77) compared to the reference group. Similarly, the less healthy sub-score was significantly associated with depression (OR: 0.51; 95% CI: 0.32-0.89), anxiety (OR: 0.44; 95% CI: 0.25-0.78), and psychological distress (OR: 0.57; 95% CI: 0.36-0.90). An inverse association was observed between the low environmental impact sub-score and depression (OR: 0.32; 95% CI: 0.19-0.54), anxiety (OR: 0.38; 95% CI: 0.18-0.76), and psychological distress (OR: 0.30; 95% CI: 0.17-0.51). However, no further significant associations were found with the high environmental impact sub-score, except with depression (OR: 0.57; 95% CI: 0.33-0.96). The healthy and low environmental impact sub-scores of the WISH were found to be inversely associated with depression, anxiety, and psychological distress. However, due to the cross-sectional study design, causality cannot be inferred. Further prospective studies are required to validate and expand upon these findings and explore potential mechanisms and alternative explanations, such as reverse causation. While this study suggests that choosing a diet that is both healthy for individuals and sustainable for the environment may be associated with lower risk of mental health issues among women, more research is needed.

INTRODUCTION

Anxiety, depression, and psychological distress are recognized as leading causes of disability; and according to the 2017 Global Burden of Disease report, depression has impacted 264 million people worldwide [1]. Notably, international and national statistics consistently report a higher prevalence of depression among women compared to men [2]. In Iran, approximately 20% of the adult population experience anxiety and depression, with higher prevalence among women compared to men [3]. Recent reviews have highlighted strong connections between mental and physical health, particularly with cardiovascular diseases [4], cancer [5], all-cause mortality, [6], and reduced life expectancy.

Research has consistently shown that women face unique challenges and vulnerabilities that can potentially impact their mental well-being. Recognizing this gender-specific burden, the World Health Organization (WHO) has identified women's health as a critical priority, highlighting the need for focused research in this area due to the historically limited and sometimes unreliable body of research dedicated to women's health [7]. Furthermore, women's mental health during the reproductive years holds particular significance, as it can have far-reaching implications, including for fertility outcomes.

Diet has gained attention as a modifiable risk factor for mental health problems. A recent review emphasized the importance of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), vitamin E, magnesium, and folic in psychiatric disorders [8]. Furthermore, previous studies have observed associations between higher consumption of fruits, vegetables, fish, legumes, and nuts with lower risk of psychological disorders [9; 10; 11; 12; 13; 14; 15; 16]. Conversely, a recent meta-analysis demonstrated a positive association between intake of red and processed meat and depression [17]. Considering the synergistic effects of nutrients and foods, investigating diet-disease associations from a holistic perspective (examining the entire diet) is a desirable approach.

Previous studies have explored the relationship between mental health and various diet quality scores, including the Mediterranean Diet Score (MDS) [18], the Healthy Eating Index (HEI) [19], the Dietary Phytochemical Index (DPI) [20], the Food Quality Score (FQS) [21], Dietary Total Antioxidant Capacity (DTAC) [22], and the Recommended Food Score (RFS) [23]. These indices primarily recommend increased consumption of plant-based foods while limiting intake of animal foods [18; 19; 20; 21; 22].

In recent years, due to the growing prevalence of diet-related diseases and the bidirectional impact of food systems on climate change, researchers have shown increased

interest in sustainable diets [24; 25; 26]. Sustainable diets are characterized by their affordability and cultural acceptability, health-promoting effects, and lower environmental impacts [27]. They primarily consist of plant-based foods that provide protection against both adverse health outcomes and environmental consequences [26]. Notably, Willett et al. recently developed specific guidelines known as the EAT-Lancet recommendations for a healthy diet from sustainable food systems [25]. These recommendations emphasize high consumption of whole grains, vegetables, fruits, legumes, nuts, and unsaturated oils, moderate intake of poultry and seafood, and limited or no consumption of refined grains, starchy vegetables, red and processed meat, and added sugar [25]. Several indices have been proposed to combine the environmental and health aspects of diet [28; 29]. The WISH was established based on the EAT-Lancet recommendations [25] and encompasses both diet quality and environmental sustainability in a single scoring system [29]. However, to date, the association between WISH and mental disorders has not been investigated. Therefore, the current observational study aims to evaluate the potential relationship between WISH and mental health outcomes, including depression, anxiety, and psychological distress in a population of Iranian women.

METHODS AND MATERIALS

Study population

This cross-sectional study was conducted with women who attended ten healthcare centers in the south of Tehran from September 2017 to September 2018. The prevalence of mental disorders was used to estimate the sample size, with P = 26% [30]; α = 0.05; d = 4.12, using the formula: $N = \frac{[(z_{1-\frac{\alpha}{2}})^2 P(1-P)]}{d^2}$. The following inclusion criteria were considered: 1) being an Iranian woman aged 20-50 years, 2) having no history of chronic disease (cardiovascular disease, cancer, diabetes, thyroid disease, liver disease, pulmonary disease, multiple sclerosis, epilepsy, or kidney dysfunction), or psychological disease requiring antipsychotic medications, and 3) not currently following a specific diet. Pregnant, lactating, and menopausal women were excluded. Participants with energy intake higher than 3,500 or lower than 500 kcal/d (n=31) and those with missing psychological profile data on the Depression and Anxiety Stress Scale-21 (n=3) were excluded from the analysis. Ultimately, 479 individuals were eligible for the current study.

Dietary intake assessment

Participants' dietary intakes were collected using a validated semi-quantitative 168-item Iranian food frequency questionnaire (FFQ), administered through face-to-face interviews [31]. A trained dietitian asked about the frequency of consumption on a daily, weekly, or monthly basis, as well as the usual serving size of food items. Then, a guideline for household measures [32] was used to convert serving sizes to grams per day. Finally, energy and main nutrients were computed using a modified version of NUTRITIONIST IV software for Iranian foods (version 7.0; N-Squared Computing, Salem, OR, USA).

World Index for Sustainability and Health (WISH) calculation

The WISH was determined based on a method developed by Trijsburg et al. [29], which scores both diet healthiness and environmental impact. Detailed information about the construction and validation of WISH has been provided elsewhere [29]. WISH scores have been applied and calculated to other lower- and middle-income countries (e.g. for women in rural East Africa), supporting the index's broader applicability [33]. The WISH index considered thirteen food groups, including vegetables, fruits, whole grains, fish, red meat, dairy, chicken, eggs, nuts, legumes, saturated oils, unsaturated oils, and added sugars. Food groups were categorized based on their health-related (protective, neutral, or limited) and environmental (low, medium, or high) impacts. This score includes four sub-scores: healthy (vegetables, fruits, whole grains, fish, dairy, egg, chicken, nuts, legumes, unsaturated oils), less healthy (red meat, saturated oils, added sugar), low environmental impact (whole grains, vegetables, fruits, legumes, unsaturated oils, added sugars), and high environmental impact (red meat, dairy, egg, chicken, nuts, fish, saturated oils). For the healthy and low environmental sub-scores, a value of 0-10 indicates the lowest to the highest consumption of the components. In the case of the less healthy and high environmental sub-score, higher values correspond to less consumption of the components. Finally, a higher total score indicates a healthier or more environmentally friendly diet.

Psychological profile assessment

The Depression Anxiety Stress Scale-21 (DASS-21), a validated self-reported questionnaire, consists of seven items in three subscales, to assess psychological distress, depression, and anxiety. Answers are given on a four-point Likert scale ranging from 0 (never) to 3 (always). Scores on each subscale range from 0 to 21. The Iranian version of the DASS-21, which has been validated and deemed reliable, was used in this study [34]. Since the original scale of DASS is based on 42 questions, DASS-21 final scores in each subscale were

doubled. Finally, depression, anxiety, and psychological distress were defined as scores of ≥ 10, ≥ 8, and ≥ 15, respectively. The Cronbach alpha indices for the subscales were as follows: depression = 0.81, anxiety = 0.74, distress = 0.78.

Anthropometric and socio-demographic assessment

Body weight was measured using a digital scale (SECA, Hamburg, Germany) while participants wore minimal clothing and no shoes. Height was measured using an inflexible measuring rod with a precision of 0.1 cm. Body Mass Index (BMI) was calculated as BMI = weight (kg)/ height^2 (m). Demographic information including age, marital status (married/single), smoking (yes/no), socioeconomic status (SES) [35] (education, family size, employment status and occupation, homeownership, home equipment diversity, number of rooms, and domestic/international travel), education, body satisfaction (yes/no), medication or vitamin supplement usage (yes/no), history of chronic disease (cancer, diabetes, cardiovascular, liver, pulmonary, kidney, thyroid diseases, hypertension, multiple sclerosis (MS), epilepsy), and family history of these diseases (yes/no), were collected using an interview-based questionnaire. Physical activity level was determined by having participants directly log the average time and total duration that they devoted to various physical activities over a 24-hour period. Then, physical activity level was computed as metabolic equivalent minutes per week (MET/min/wk) [36]. Finally, four categories were used to indicate the level of physical activity (light, moderate, strong, and intense).

Statistical analysis

The distribution of variables was analyzed using the Kolmogorov–Smirnov test. Continuous variables were presented as mean ± standard deviation, while categorical variables were presented as frequencies (N) and percentages (%). Chi-square and one-way ANOVA tests were used to compare the general characteristics of participants across the tertiles of WISH sub-scores. Study participants' dietary intakes across tertiles of WISH scores were compared using ANCOVA adjusted for energy intake. Binary logistic regression analysis was also applied to assess the relationship between less healthy, healthy, low environmental impact, and high environmental impact scores and odds of having each of the three psychological profiles (anxiety, depression, and psychological distress) by including age, energy, BMI, marital status, education, family history of chronic disease, sleep duration, duration of time spent outside, prescription medications, vitamin supplementation, body satisfaction, SES, and physical activity in the multivariable-adjusted model. Covariates were selected based on clinical knowledge and a comprehensive literature review [20; 21; 37] and

baseline variables associated with having each of the three psychological profiles, as illustrated in Supplementary Figure 1 using a Directed Acyclic Graph (DAG). Variables that met both the statistical criteria (favorable AIC/BIC values, low multicollinearity) and the practical significance criterion (10-15% effect size change) were selected as confounders for inclusion in our multivariable logistic regression models. Statistical analyses were performed with SPSS statistical package software (SPSS Inc., Chicago IL. USA Version 27), and $p<0.05$ was considered significant.

RESULTS

Table 1 presents the characteristics of women categorized according to WISH sub-scores. The mean age, weight, BMI, and physical activity of the participants was 31.9 (7.7) years, 64.5 (12.0) kg, 24.5 (4.5) kg/m^2, and 39.9 (6.8) MET/min/wk, respectively. We observed that higher healthy, less healthy, low environmental, and high environmental scores were associated with lower odds of depression and psychological distress. Additionally, women with higher healthy and low environmental, and lower less healthy sub-scores reported lower levels of anxiety. No significant differences in socioeconomic status, education status, supplement usage, medication use, family history of chronic disease, and body satisfaction were observed.

The energy-adjusted dietary intakes of participants across tertiles of healthy, less healthy, low environmental, and high environmental impacts sub-scores are presented in **Table 2**. Higher intakes of carbohydrate, fiber, polyunsaturated fatty acid (PUFA), vitamin A, vitamin B1, vitamin B6, vitamin C, magnesium, vegetables, fruit, fish, legumes, nuts, and unsaturated oil, and lower intakes of cholesterol, vitamin B2, vitamin D, calcium, eggs, meat, and dairy were associated with third tertiles of the healthy sub-score. Women scoring in the highest less healthy tertile had lower consumption of energy, protein, carbohydrates, fat, fiber, monounsaturated fatty acid (MUFA), vitamin B1, vitamin B2, vitamin B6, vitamin B9, calcium, magnesium, zinc, meat, fruit, dairy, saturated oil, and sugar but higher intakes of vitamin A, vegetables, chicken, unsaturated oil, compared to those in the lowest tertile. Women in the third tertile of low environmental impact reported significantly greater intake of energy, protein, fiber, vitamin A, vitamin B2, vitamin B6, vitamin B9, vitamin C, calcium, magnesium, vegetables, fruit, dairy, meat, legumes, and unsaturated oil compared to participants in the first tertile. However, they showed lower intakes of sugar. Participants in the top environmental tertile had lower intakes of energy, protein, carbohydrate, fat, fiber, MUFA, cholesterol, vitamin D, vitamin B1, vitamin B2, vitamin B6, calcium, whole grains,

fruits, egg, dairy, meat, chicken, and saturated oil compared to those in the bottom environmental tertile. Women in the lowest tertile consumed less fish and nuts.

Table 3 shows adjusted ORs for depression, anxiety, and stress comparing tertiles of healthy, less healthy, low, and high environmental scores. The healthy score was inversely associated with the odds of depression (OR: 0.40; 95% CI: 0.24-0.67; p=0.001), anxiety (OR: 0.45; 95% CI: 0.23-0.87; p=0.023) and distress (OR: 0.46; 95% CI: 0.28-0.77; p=0.003). The less healthy score was positively associated with distress (OR: 0.57; 95% CI: 0.36-0.90; p=0.016), depression (OR: 0.51; 95% CI: 0.32-0.89; p=0.004), and anxiety (OR: 0.44; 95% CI: 0.25-0.78; p=0.004). In addition, scores for low environmental impact were inversely associated with depression (OR: 0.32; 95% CI: 0.19-0.54; p <0.001), distress (OR: 0.30; 95% CI: 0.17-0.51; p<0.001), and anxiety (OR: 0.38; 95% CI: 0.18-0.76; p=0.012). An inverse association was found between scores indicating high environmental impact and depression (OR: 0.57; 95% CI: 0.33-0.96; p=0.031). However, we failed to detect a significant association between high environmental score with anxiety (OR: 0.56; 95% CI: 0.29-1.08; p=0.090) or distress (OR: 0.62; 95% CI: 0.37-1.06; p=0.080).

DISCUSSION

In this cross-sectional study, we investigated the mental health of Iranian women in relation to WISH sub-scores. Our results revealed that healthier scores were correlated with lower odds of depression, anxiety, and psychological distress. In addition, we found an inverse correlation between less healthy scores and psychological disorders. Considering environmental dietary indicators, a negative association was seen between the low environmental impact sub-score and depression, anxiety, and psychological distress. However, the high environmental impact sub-score was not related to odds of mental disorders, except for depression. To the best of our knowledge, this is the first study to assess WISH score in relation to depression, anxiety, and psychological distress.

The current study was conducted among a sample of Iranian adult women. Findings indicated that Iranian women consume vegetables, fruits, dairy products, fish, chickens, eggs, nuts, legumes, and unsaturated oils within the EAT-Lancet guidelines suggested range. Nevertheless, due to the moderate environmental impact of dairy products, their consumption could be slightly decreased. In low to middle-income countries, the majority of energy intake comes from carbohydrates [38]. Based on the results of the present study, the average amount of whole grains consumed by this population is considerably lower than the recommended range. On the other hand, the consumption of less healthy food groups, including red meats,

saturated oils, and added sugar was relatively higher than the recommended values and should be decreased. In summary, our study population could improve their current WISH score by consuming higher amounts of whole grains and fish while limiting less healthy food intake. Notwithstanding the average amounts of food consumed by our population, we should be cautious in generalizing these intake values to the whole Iranian female population, as adherence to the EAT-Lancet recommendations can be relatively expensive and may differ across individuals with various socioeconomic statuses [39].

Vegetables, legumes, whole grains, fruits, and unsaturated oils are the components of both the healthy and low environmental impact sub-scores [29]. In addition, fish, chicken, eggs, dairy, and nuts are known to be healthy foods [29]. We found an inverse association between the healthy sub-score of WISH and mental disorders. Consistent with our findings, a previous meta-analysis of observational studies found fruits, vegetables, and fish, intake to be inversely linked with psychological disorders within the general population [11; 12]. Furthermore, another cross-sectional study among 24,776 Chinese participants revealed that consumption of whole grains ≥2 times/week was associated with a 32% and 24% lower odds of depression in males and females, respectively [40]. Similarly, another cross-sectional study of 3,172 Iranian adults also reported a negative association between whole grain consumption and odds of anxiety in women, while a positive association was observed for refined grains and anxiety and depression [41]. A review of 13 studies investigating dairy products in relation to mental disorders found inconsistent results [42]. However, because of methodological differences and considering various sub-types of dairy products in the studies included, conclusions could not be made, and further studies were recommended [42].

We found an inverse association between the low environmental impact sub-score and odds of depression, anxiety, and psychological distress. Plant-based food groups as well as added sugars, are considered to have less impact on the environment. We previously mentioned results from earlier studies that had investigated the relation between specific plant-based food groups and mental health [11; 12]. Added sugars were also included in the less environmental impact sub-score [29]. Despite categorization as a low environmental impact food, added sugars were found to be an unhealthy risk factor for mental health conditions. A meta-analysis by *Hu et al.* [43] revealed that intake of sugar-sweetened beverages could be modestly related to depression (OR=1.31). Also, a cohort study of 935 Japanese adults reported that higher soft drink consumption was positively associated with risk of depression [44]. Additionally, a study among 4,741 adults in South Australia concluded there was a direct

link between consuming soft drinks and psychological disorders [45]. Similarly, sugar and sweeteners were positively associated with anxiety [46]. Wattick et al. demonstrated a similar relation between added sugar intake and anxiety in 1,959 college students [47]. Nevertheless, it is worth mentioning that added sugar is one of the components of the low environmental impact sub-score, and other healthy components such as vegetables, fruits, and whole grains might counteract the deleterious effects of added sugars on mental health. Furthermore, EAT-Lancet guidelines recommended caution associated with added sugar intake, because of the possible health concerns, suggesting a cut-off value of 31 g/day [25; 29].

We found that having a less healthy WISH score on any of the sub-scales was related to lower odds of psychological disorders. Higher scores indicate healthier diets with lower consumption of red meats, saturated fats, and added sugars. In our earlier report, *Darooghegi et al.* found that women with the highest levels of red meat intake had substantially increased odds of anxiety, depression, and psychological distress [48]. A study by *Kouvari et al.* on 1,514 men and 1,528 women revealed that moderate (second tertile) consumption of total meat and red meat was negatively associated with odds of depression indicating a U-shaped association [49]. Also, *Kazemi et al.* found an increased chance of depression among adults who have higher intakes of red meat, especially among people of normal weight and males [50]. *Olivan-Blazquez et al.* concluded that adults who consume more than 1 serving/day of red meat had higher likelihood of depressive symptoms [51]. Also, a meta-analysis found that red and processed meat intake could be positively linked to high levels of depression or depression [17]. Furthermore, several animal studies revealed that saturated fatty acids might be a responsible nutrient associated with anxiety [52; 53; 54]. Despite the deleterious effect of animal products on health as well as the environment, some important nutrients including iron, calcium, zinc, and vitamin B12 are mainly provided by animal-based foods [55]. Strategies including supplementation, considering meat alternatives and promotion of nutrient absorption from plant-based foods should be considered to overcome the possible deficiencies [56].

Dietary intake of individual nutrients and food groups is an important approach for exploring diet-disease associations. However, our dietary intakes are a combination of various foods with different nutritional values, and specific nutrients might interact in the human body. Therefore, considering dietary intake wholistically could be a better option for investigating diet in relation to disease. In agreement with our findings, earlier meta-analyses reported an inverse association between the Mediterranean Diet and HEI, which highly

consists of plant-based foods as well as unsaturated fats, and depression [57; 58]. Furthermore, a cross-sectional study on Iranian adults found an inverse association between the Mediterranean Diet and anxiety and psychological distress [18]. Also, a cross-sectional study among Australian vegans and vegetarians found a protective relation between a plant-based diet and depression [59]. Similarly, our previous report using the same data revealed an inverse relation between overall and healthful plant-based dietary patterns and anxiety, depression, and psychological distress [60]. However, higher scores for the unhealthful plant-based dietary pattern have been shown to be related to increased odds of depression by 91% [60]. Another cross-sectional study among diabetic women in Iran found that the unhealthful plant-based diet was a predictor of increased depression, anxiety, and stress, but no significant relation was found between the healthful plant-based diet and mental disorders [61]. On the other hand, a recent meta-analysis did not find a significant relation between vegetarian diets and risk of anxiety and depression [62]. It is important to note that discrepancies among studies may be due to different study designs and populations. Most prior studies on the relation between plant-based dietary patterns and mental disorders have been cross-sectional, thus, more prospective studies are required to rule out the possibility of reverse causation.

There are several proposed mechanisms by which healthy and low environmental impact sub-scores may be related to mental health. These sub-scores mainly reflect plant-based foods (providing considerable amounts of fiber, magnesium, and B vitamins), which have been found to be protective for mental disorders [63; 64; 65]. Furthermore, these sub-scores recommend unsaturated fat consumption, which has been inversely associated with depression [66]. The low glycemic index of plant-based diets could be another possible mechanism. Adhering to a low glycemic index diet could reduce insulin resistance, which has been found to be negatively associated with mental health [67; 68]. Also, inflammation is a key factor in the pathophysiology of psychological disorders [69], and adherence to plant-based diets could be an important approach for controlling inflammation [70; 71].

In the current study, we considered possible confounding of several factors in the association between WISH score and mental disorders. These confounders included age, energy, BMI, marital status, educational level, family history of chronic disease, body satisfaction, SES, physical activity, and smoking. The associations we observed were mostly unchanged after adjusting for these confounders. It should be acknowledged that residual confounding may still exist due to errors in classifying participants based on the confounding variables or due to errors in measuring confounders. Also, there may be additional

confounders that we did not collect data on. For instance, sleep and psychological disorders share common causes and also have bidirectional associations (e.g. sleep disturbances have been found to be a strong causal factor for mental disorders [72]). Also, abundant evidence indicates a potential role of diet in sleep health [73]. Given the points mentioned above, the relation between diet and mental disorders in our study might still be confounded by some mismeasured or unmeasured factors, which should be considered in the interpretation of the results. In addition, reverse causality is an important phenomenon, and the actual associations might be in the reverse direction of which we hypothesized. In this scenario, individuals with depression, anxiety, or stress might alter their dietary intakes in response to their specific mental health conditions. These dietary behaviors (e.g. eating sweet foods) may result from an effort to enhance their mood, poor appetite, or lack of motivation to buy or prepare healthy foods [74; 75]. For instance, a longitudinal study observed that depressive symptoms were related to changes in vegetables, meats, and dairy products intake,[76] suggesting that a bidirectional relationship could exist between diet and depression. Such studies in which the relation between diet and mental disorders is explored in both directions are scarce and need to be prioritized in future research. To control for bias from reverse causation, we did not include participants who had used antidepressant drugs as they tend to have more severe mental disorders and are more likely to alter their dietary intakes due to their condition. Notwithstanding, a bidirectional relation may exist between dietary intakes and mental disorders [76], and reverse causality cannot be ruled out in our study. It is important to consider this point in interpreting our findings. Further prospective cohort studies are required to understand reverse causation.

There are some strengths of our study. It is the first study to examine the association between WISH scores and mental health conditions. Furthermore, we used validated questionnaires for dietary intake, mental health, and assessment of physical activity. Also, although residual confounding might still remain, several potential confounders were taken into account in our analyses. For the interpretation of the results, several limitations were also important. First, the cross-sectional nature of our study limited our ability to infer causal relationships. Therefore, prospective studies are needed to further explore the relationships between diet and mental disorders. Second, despite using validated DASS-21 and FFQ questionnaires, they are subjected to under- or over-reporting, leading to potential participant misclassification. Third, despite being a universal score, the WISH has not been specifically validated among females, or among Iranians in particular. Therefore, we recommend that

future studies examine the reliability and validity of this index among different populations to assess its robustness. Finally, caution should be taken in generalizing our findings to other populations including males, older adults, and those with other health conditions.

In conclusion, adherence to a healthier diet with less environmental impact was associated with better psychological health among women. Due to the worsening trends in our environment and the increasing prevalence of psychological disorders, more prospective studies that include both genders are warranted to understand the causality of the observed associations and explore potential mechanisms.

ABBREVIATIONS ANOVA: Analysis of Variance; BMI: Body Mass Index; CI: confidence interval; DASS: Depression Anxiety Stress Score; DHA: docosahexaenoic-acid; DPI: Dietary Phytochemical Index; DTAC: Dietary Total Antioxidant Capacity; EPA: eicosapentaenoic-acid; FFQ: Food Frequency Questionnaire; FQS: food quality score; HEI: Healthy Eating Index; MDS: Mediterranean diet score; MET: metabolic equivalent; MS: multiple sclerosis; MUFA: monounsaturated fatty acid; OR: odds ratio; PUFA: polyunsaturated fatty acid; RFS: recommended food score; SES: socioeconomic status; TUMS: Tehran University of Medical Sciences; USA: United States of America; WISH: World Index for Sustainability and Health.

Ethics approval and consent to participate All participants were provided written consent based on the guidelines of Declaration of Helsinki. The study protocol (98-01-161-42024) was approved by the Medical Research Ethics Committee of Tehran University of Medical Sciences (TUMS).

Consent for publication Not applicable

Availability of data and materials The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Competing interests The authors declare that they have no competing interests

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Authors' contributions AJ contributed to conception, design, search, statistical analyses. AJ and KL drafted the manuscript. LA, HM, BZ, MDM, and ASH contributed to design and data interpretation. PJS edited and commented on the manuscript. LA supervised the study critically. All authors have read and approved the final manuscript.

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Table 1. General characteristic of participants across the tertiles of WISH sub-scores

Variable		**Healthy**			**P-value**	**Less healthy**			**P-value**	**Low environmental impact**			**P-value**	**High environmental impact**			**P-value**
	Total (n=478)	T1 (n=154)	T2 (n=161)	T3 (n=158)		T1 (n=194)	T2 (n=38)	T3 (n=247)		T1 (n=151)	T2 (n=176)	T3 (n=152)		T1 (n=146)	T2 (n=167)	T3 (n=166)	
Age (year)	31.86 (7.68)	31.78 (7.83)	31.89 (7.78)	31.89 (7.49)	0.899	32.15 (7.65)	31.03 (7.42)	31.76 (7.76)	0.611	30.97 (7.52)	31.04 (7.65)	33.68 (7.60)	0.002	32.88 (7.48)	32.15 (8.12)	30.66 (7.29)	0.010
Weight (kg)	64.45 (11.99)	63.16 (11.12)	64.40 (12.59)	65.79 (12.11)	0.051	64.56 (11.42)	64.76 (11.59)	64.32 (12.52)	0.829	63.35 (11.30)	63.75 (11.68)	66.37 (12.82)	0.028	64.86 (11.79)	63.87 (12.26)	64.69 (11.93)	0.926
BMI (kg/m^2)	24.48 (4.52)	23.94 (4.07)	24.57 (4.97)	24.90 (4.45)	0.059	24.59 (4.48)	24.13 (4.24)	24.44 (4.62)	0.741	23.92 (4.28)	24.16 (4.06)	25.40 (5.13)	0.004	24.77 (4.77)	23.31 (4.40)	24.39 (4.44)	0.477
Physical activity (MET min/wk.)	39.90 (6.79)	39.23 (7.07)	40.06 (7.31)	40.37 (5.91)	0.143	40.08 (7.55)	38.95 (5.92)	39.90 (6.27)	0.797	38.47 (6.80)	40.44 (7.20)	40.66 (6.09)	0.006	40.32 (7.36)	40.06 (7.25)	39.36 (5.70)	0.215
Socioeconomic status, n (%)					0.442				0.518				0.711				0.665
Low	2	1 (50)	1 (50)	0 (0)		1 (50)	0 (0)	1 (50)		1 (50)	1 (50)	0 (0)		1 (50)	1 (50)	0 (0)	
Medium	177	64 (36.2)	53 (29.9)	60 (33.9)		71 (40.1)	18 (10.2)	88 (49.7)		59 (33.3)	64 (36.2)	54 (30.5)		50 (28.2)	62 (35)	65 (36.7)	
High	262	78 (29.8)	96 (36.6)	88 (33.6)		108 (41.2)	15 (5.7)	139 (53.1)		75 (28.6)	99 (37.8)	88 (33.6)		87 (33.2)	89 (34)	86 (32.8)	
Married, n (%)	290	98 (33.8)	98 (33.8)	94 (32.4)	0.723	128 (44.1)	23 (7.9)	139 (47.9)	0.227	83 (28.6)	108 (37.2)	99 (34.1)	0.107	103 (35.5)	97 (33.4)	90 (31)	0.052
Education status, n (%)					0.809				0.446				0.832				0.211

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≤Diploma	164	52 (31.7)	50 (30.4)	54 (32.9)		70 (42.6)	15 (9.1)	71 (43.2)		45 (27.4)	58 (35.3)	53 (32.3)		50 (30.4)	63 (38.4)	43 (26.2)	
>Diploma	379	107 (28.2)	126 (33.2)	109 (28.7)		105 (27.7)	115 (30.3)	122 (32.1)		113 (29.8)	110 (29)	119 (31.3)		112 (29.5)	113 (29.8)	117 (30.8)	
Smoking, n (%)	4	0	3	1	0.180	4	0	0	0.052	2	2	0	0.385	0	3	1	0.202
Family history of chronic disease, n (%)	264	91 (34.5)	89 (33.7)	84 (31.8)	0.718	108 (40.5)	20 (7.6)	137 (51.9)	0.988	81 (30.7)	100 (37.9)	83 (31.4)	0.721	81 (30.7)	93 (35.2)	90 (34.1)	0.886
Body size satisfaction, n (%)	320	102 (31.9)	107 (33.4)	111 (34.7)	0.736	121 (37.8)	28 (8.8)	171 (53.4)	0.146	96 (30)	123 (38.4)	101 (31.6)	0.569	90 (28.1)	116 (36.3)	114 (35.6)	0.241
Depression, n (%)	240	100 (41.8)	73 (30.5)	66 (27.6)	<0.001	115 (48.1)	16 (6.7)	108 (45.2)	0.003	99 (41.4)	81 (33.9)	59 (24.7)	<0.001	78 (32.6)	92 (38.5)	69 (28.9)	0.028
Anxiety, n (%)	382	136 (35.6)	124 (32.5)	122 (31.9)	0.033	167 (43.7)	33 (8.6)	182 (47.6)	0.003	134 (35.1)	132 (34.6)	116 (30.4)	0.004	123 (32.2)	134 (35.1)	125 (32.7)	0.143
Psychological distress, n (%)	203	81 (39.9)	68 (33.5)	54 (26.6)	0.006	98 (48.3)	16 (7.9)	89 (43.8)	0.009	85 (41.9)	68 (33.5)	50 (24.6)	<0.001	67 (33)	79 (38.9)	57 (28.1)	0.033

WISH; World Index for Sustainability and Health.

Values are means ± SDs; one-way ANOVA for continuous variables and chi-square test for categorical variables were used to generate p-values; BMI, body mass index, MET-h, metabolic equivalent task hours.

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Table 2. Energy-adjusted dietary intakes of study participants across the tertiles of WISH sub-scores

Variable	Healthy			P-value	Less Healthy			P-value	Low Environmental			P-value	High Environmental			P-value
	T1 (n=157)	T2 (n=162)	T3 (n=160)		T1 (n=194)	T2 (n=38)	T3 (n=247)		T1 (n=151)	T2 (n=176)	T3 (n=152)		T1 (n=146)	T2 (n=167)	T3 (n=166)	
Energy (kcal/d)	1999.43 (43.59)	2102.10 (37.57)	2096.21 (22.14)	0.075	2259.02 (34.42)	2056.91 (79.72)	1916.73 (27.58)	<0.001	1960.07 (44.82)	2113.35 (35.37)	2117.92 (33.46)	0.004	2257.45 (38.43)	2079.89 (36.32)	1885.04 (35.02)	<0.001
Protein (g/d)	74.52 (2.29)	76.48 (1.49)	74.41 (1.25)	0.087	80.76 (1.72)	66.89 (3.08)	72.01 (1.22)	<0.001	69.36 (1.84)	75.96 (1.34)	79.95 (1.92)	0.003	83.96 (2.02)	75.67 (1.53)	66.86 (1.38)	0.017
Carbohydrate (g/d)	273.19 (6.19)	293.90 (6.06)	296 (5.17)	0.020	307.38 (5.59)	291.07 (11.57)	271.94 (4.32)	<0.001	270.65 (6.48)	293.28 (5.55)	298.53 (5.35)	0.204	303.71 (6.21)	291.20 (5.88)	270.41 (5.28)	<0.001
Fat (g/d)	73.65 (2.08)	76.43 (1.67)	76.13 (1.69)	0.616	86.53 (1.63)	76.35 (3.74)	66.56 (1.22)	<0.001	72.42 (2.11)	77.84 (1.66)	75.60 (1.68)	0.105	85.98 (1.86)	75.65 (1.60)	65.90 (1.69)	<0.001
Fiber (g/d)	13.68 (0.38)	17.25 (0.51)	19.12 (0.46)	<0.001	16.88 (0.43)	17.01 (0.84)	16.52 (0.41)	<0.001	13.36 (0.44)	16.62 (0.41)	20.12 (0.46)	<0.001	17.00 (0.43)	17.15 (0.53)	15.99 (0.47)	0.002
PUFA (g/d)	15.30 (0.47)	16.49 (0.43)	17.43 (0.53)	0.032	18.14 (0.45)	16.10 (0.84)	15.11 (0.36)	0.462	15.51 (0.50)	16.73 (0.45)	16.96 (0.49)	0.845	17.48 (0.51)	16.58 (0.45)	15.32 (0.48)	0.633
MUFA (g/d)	21.27 (0.67)	22.75 (0.64)	22.46 (0.63)	0.925	26.15 (0.55)	23.67 (1.50)	18.81 (0.43)	<0.001	21.43 (0.70)	22.80 (0.62)	22.17 (0.62)	0.168	25.85 (0.64)	21.99 (0.57)	19.10 (0.62)	0.001
Cholesterol (mg/d)	240.69 (8.08)	220.83 (7.22)	194.41 (6.24)	<0.001	243.38 (7.31)	210.40 (14.14)	200.23 (5.18)	0.508	209.97 (8.20)	227.11 (7.13)	217.04 (6.61)	0.412	272.90 (7.43)	218.56 (6.69)	170.63 (5.71)	<0.001
Vitamin A (RAE/d)	1112.13 (49.33)	1432.49 (76.44)	1546.47 (67.18)	<0.001	1362.23 (45.29)	1307.83 (116.1)	1377.05 (63.75)	0.016	1027.48 (43.46)	1326.49 (52.36)	1746.65 (87.58)	<0.001	1463.07 (57.94)	1412.37 (77.01)	1232.70 (61.24)	0.713

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Vitamin D (mg/d)	2.39 (0.15)	2.19 (0.13)	1.71 (0.09)	<0.001	2.16 (0.11)	1.95 (0.26)	2.06 (0.11)	0.113	1.78 (0.11)	2.24 (0.14)	2.23 (0.12)	0.142	2.65 (0.13)	2.22 (0.15)	1.47 (0.08)	<0.001
Vitamin B1 (mg/d)	1.44 (0.04)	1.54 (0.03)	1.61 (0.03)	0.001	1.61 (0.03)	1.51 (0.08)	1.47 (0.02)	0.001	1.41 (0.03)	1.54 (0.03)	1.64 (0.03)	0.432	1.60 (0.03)	1.53 (0.03)	1.46 (0.03)	<0.001
Vitamin B2 (mg/d)	1.84 (0.05)	1.87 (0.05)	1.74 (0.04)	<0.001	1.89 (0.04)	1.73 (0.11)	1.73 (0.04)	<0.001	1.62 (0.05)	1.88 (0.04)	1.93 (0.04)	<0.001	2.06 (0.05)	1.86 (0.05)	1.56 (0.04)	<0.001
Vitamin B6 (mg/d)	1.18 (0.04)	1.36 (0.04)	1.44 (0.03)	<0.001	1.37 (0.03)	1.36 (0.08)	1.29 (0.03)	<0.001	1.15 (0.04)	1.34 (0.03)	1.49 (0.04)	<0.001	1.36 (0.04)	1.38 (0.04)	1.24 (0.04)	<0.001
Vitamin B9 (µg/d)	267.23 (7.00)	319.11 (7.56)	364.08 (8.27)	<0.001	327.33 (7.29)	316.35 (16.98)	309.23 (6.72)	0.004	260.65 (7.26)	313.49 (7.17)	377.44 (7.70)	<0.001	333.08 (7.40)	316.92 (8.42)	303.30 (8.50)	0.160
Vitamin B12 (µg/d)	4.50 (0.20)	4.69 (0.25)	4.46 (0.22)	0.508	4.86 (0.20)	4.93 (0.81)	4.25 (0.15)	0.157	4.13 (0.23)	4.89 (0.22)	4.57 (0.23)	0.389	5.03 (0.21)	4.61 (0.23)	4.07 (0.22)	0.935
Vitamin C (mg/d)	110.03 (5.19)	150.24 (6.86)	159.13 (4.65)	<0.001	144.94 (5.59)	140.84 (10.56)	136.05 (4.66)	0.059	114.12 (6.22)	140.42 (5.72)	165.32 (4.99)	<0.001	141.61 (5.95)	143.79 (6.26)	134.87 (5.43)	0.030
Calcium (mg/d)	1061.63 (33.47)	1072.00 (25.51)	1005.50 (21.64)	0.006	1068.58 (24.60)	973.01 (56.11)	1040.25 (22.48)	<0.001	928.57 (28.34)	1078.02 (26.90)	1126.80 (25.03)	<0.001	1168.57 (28.83)	1076.43 (30.06)	908.69 (19.09)	0.002
Magnesium (mg/d)	242.21 (6.02)	272.96 (6.09)	281.31 (4.98)	<0.001	273.56 (4.98)	264.98 (13.54)	259.58 (4.82)	<0.001	232.15 (5.71)	267.73 (5.54)	296.59 (5.19)	<0.001	281.11 (5.58)	272.07 (6.36)	245.66 (5.17)	0.122
Zinc (mg/d)	8.96 (0.42)	9.08 (0.20)	8.91 (0.18)	0.292	9.74 (0.31)	7.79 (0.38)	8.57 (0.19)	0.011	8.33 (0.28)	8.98 (0.19)	9.63 (0.37)	0.094	10.03 (0.39)	9.11 (0.22)	7.93 (0.22)	0.395
Whole grain (g/d)	10.95 (0.93)	12.19 (1.09)	11.68 (1.01)	0.917	11.52 (0.93)	10.88 (2.21)	11.80 (0.81)	0.058	10.16 (0.91)	11.62 (1.01)	13.05 (1.10)	0.406	10.81 (0.97)	13.41 (1.09)	10.52 (0.95)	0.021
Vegetable (g/d)	243.57	337.93	423.11	<0.001	325.52	343.10	342.08	0.024	231.10	312.32	465.90	<0.001	347.84	331.61	328.42	0.753

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	(10.65)	(15.42)	(15.42)		(10.95)	(30.98)	(13.89)		(9.51)	(12.30)	(16.92)		(14.37)	(16.43)	(14.45)	
Egg (g/d)	24.72 (1.22)	21.62 (1.31)	16.39 (1.02)	<0.001	22.09 (1.26)	21.63 (2.31)	19.83 (0.86)	0.415	19.39 (1.20)	21.43 (1.30)	21.74 (1.10)	0.639	28.61 (1.31)	21.09 (1.28)	13.89 (0.70)	<0.001
Fish (g/d)	6.46 (0.52)	10.58 (2.07)	11.84 (0.78)	0.030	10.21 (1.74)	9.55 (1.69)	9.23 (0.56)	0.714	9.74 (2.21)	9.04 (0.61)	10.28 (0.78)	0.635	7.24 (0.55)	10.55 (2.01)	10.87 (0.78)	0.002
Fruit (g/d)	251.72 (17.00)	336.79 (18.80)	326.36 (12.03)	0.003	311.09 (17.59)	304.33 (30.23)	301.14 (11.32)	0.011	249.81 (18.75)	314.27 (15.11)	350.43 (14.60)	0.003	301.98 (17.73)	319.61 (17.87)	294.18 (13.65)	0.009
Dairy (g/d)	495.25 (21.08)	471.16 (17.93)	388.54 (13.42)	<0.001	465.26 (16.49)	369.02 (30.81)	453.29 (14.65)	0.001	387.18 (18.05)	479.66 (16.96)	482.65 (18.31)	0.006	546.37 (19.80)	467.65 (19.40)	351.69 (10.65)	<0.001
Meat (g/d)	48.04 (3.44)	45.23 (2.43)	38.58 (2.12)	0.009	57.22 (2.42)	21.03 (0.64)	37.01 (2.15)	<0.001	49.05 (3.49)	43.46 (2.27)	39.39 (2.33)	0.003	56.74 (2.83)	41.63 (2.07)	34.98 (2.95)	<0.001
Chicken (g/d)	19.82 (1.24)	18.80 (1.07)	16.91 (0.85)	0.092	17.92 (0.90)	15.12 (1.76)	19.48 (0.91)	0.019	18.06 (0.98)	17.89 (0.92)	19.66 (1.29)	0.496	21.51 (1.46)	18.33 (0.89)	16.04 (0.79)	0.015
Legume (g/d)	37.18 (2.32)	45.05 (2.60)	63.86 (3.75)	<0.001	49.23 (2.89)	40.98 (4.12)	49.58 (2.52)	0.098	31.89 (2.47)	47.59 (2.82)	66.85 (3.30)	<0.001	53.08 (2.96)	45.17 (2.77)	48.55 (3.43)	0.259
Nut (g/d)	8.32 (0.54)	12.13 (0.77)	13.83 (0.82)	<0.001	12.50 (0.75)	14.24 (2.27)	10.19 (0.46)	0.089	9.98 (0.83)	11.79 (0.72)	12.51 (0.66)	0.422	10.44 (0.61)	12.42 (0.80)	11.36 (0.78)	<0.001
Unsaturated oil (g/d)	11.46 (0.49)	12.56 (0.53)	14.45 (0.66)	0.002	12.06 (0.49)	10.73 (1.15)	13.76 (0.47)	<0.001	11.14 (0.51)	13.25 (0.48)	14.02 (0.70)	0.008	12.38 (0.68)	12.86 (0.52)	13.19 (0.52)	0.063
Saturated oil (g/d)	11.89 (1.27)	12.12 (1.10)	11.67 (1.05)	0.732	19.90 (1.17)	17.55 (2.63)	4.74 (0.44)	0.001	12.46 (1.31)	12.09 (1.06)	11.11 (1.05)	0.157	19.27 (1.46)	11.06 (0.98)	6.25 (0.71)	<0.001
Sugar (g/d)	33.26 (3.17)	35.49 (4.77)	31.24 (3.44)	0.659	55.48 (4.83)	34.82 (6.62)	15.72 (0.79)	<0.001	58.29 (6.05)	28.60 (2.15)	14.03 (2.23)	<0.001	37.72 (3.52)	35.80 (5.07)	27.00 (2.40)	0.719

SFA: saturated fatty acid; PUFA: polyunsaturated fatty acid; MUFA; monounsaturated fatty acid; WISH: World Index for Sustainability and Health.

Values are mean ± SE. All values are adjusted for energy intake using ANCOVA

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Table 3. Multiple-adjusted odds ratio (OR) and 95% confidence intervals (CI) across the tertiles of WISH sub-scores

Variable	**Healthy**			**P trend**	**Less healthy**			**P trend**	**Low impact environmental**			**P trend**	**High impact environmental**			**P trend**
	T1 (n=157)	T2 (n=162)	T3 (n=160)		T1 (n=194)	T2 (n=38)	T3 (n=247)		T1 (n=151)	T2 (n=176)	T3 (n=152)		T1 (n=133)	T2 (n=143)	T3 (n=145)	
Depression																
Crude	1	0.47 (0.29-0.75)	0.38 (0.23-0.61)	<0.001	1	0.46 (0.21-1.01)	0.59 (0.40-0.88)	0.012	1	0.50 (0.31-0.81)	0.34 (0.21-0.56)	<0.001	1	1.02 (0.64-1.64)	0.63 (0.40-1.02)	0.056
Model[1]	1	0.48 (0.29-0.80)	0.40 (0.24-0.67)	0.001	1	0.41 (0.18-0.93)	0.51 (0.32-0.89)	0.004	1	0.51 (0.31-0.84)	0.32 (0.19-0.54)	<0.001	1	0.96 (0.58-1.60)	0.57 (0.33-0.96)	0.031
Anxiety																
Crude	1	0.47 (0.25-0.88)	0.44 (0.23-0.82)	0.013	1	0.83 (0.29-2.36)	0.43 (0.25-0.73)	0.001	1	0.37 (0.19-0.72)	0.38 (0.19-0.75)	0.009	1	0.67 (0.36-1.24)	0.52 (0.28-0.95)	0.032

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Model[1]	1	0.43 (0.22-0.83)	0.45 (0.23-0.87)	0.023	1	0.90 (0.31-2.61)	0.44 (0.25-0.78)	0.004	1	0.33 (0.17-0.66)	0.38 (0.18-0.76)	0.012	1	0.64 (0.34-1.22)	0.56 (0.29-1.08)	0.090
Stress																
Crude	1	0.68 (0.42-1.09)	0.44 (0.27-0.72)	0.001	1	0.64 (0.29-1.40)	0.55 (0.37-0.83)	0.004	1	0.43 (0.27-0.69)	0.32 (0.19-0.53)	<0.001	1	0.90 (0.56-1.45)	0.60 (0.37-0.98)	0.039
Model[1]	1	0.68 (0.41-1.12)	0.46 (0.28-0.77)	0.003	1	0.66 (0.29-1.49)	0.57 (0.36-0.90)	0.016	1	0.40 (0.24-0.67)	0.30 (0.17-0.51)	<0.001	1	0.88 (0.53-1.47)	0.62 (0.37-1.06)	0.080

WISH: World Index for Sustainability and Health.

These values are odds ratios (95% CIs)

[1]Logistic regression model included age, energy, BMI, marriage, education, family history of chronic disease, body satisfaction, SES, physical activity, smoking

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