frontiers | Research Topics

# Diet and training strategies to optimize health parameters


**Edited by**
Luis Suarez-Arrones, Gabriele Mascherini, Pascal Izzicupo,
Fábio Yuzo Nakamura, Javier Benítez-Porres,
Alejandro Galán-Mercant and Mora Murri

**Coordinated by**
Cristian Petri



**Published in**
Frontiers in Public Health
Frontiers in Nutrition


ISSN 1664-8714
ISBN 978-2-8325-6031-0
DOI 10.3389/978-2-8325-6031-0

## About Frontiers

Frontiers is more than just an open access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

## Frontiers journal series

The Frontiers journal series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the *Frontiers journal series* operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

## Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews. Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

## What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the *Frontiers journals series*: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area.

Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers editorial office: frontiersin.org/about/contact

# Diet and training strategies to optimize health parameters

**Topic editors**
Luis Suarez-Arrones — Universidad Pablo de Olavide, Spain
Gabriele Mascherini — University of Florence, Italy
Pascal Izzicupo — University of Studies G. d'Annunzio Chieti and Pescara, Italy
Fábio Yuzo Nakamura — University Institute of Maia (ISMAI), Portugal
Javier Benítez-Porres — University of Malaga, Spain
Alejandro Galán-Mercant — University of Cádiz, Spain
Mora Murri — University of Malaga, Spain

**Topic coordinator**
Cristian Petri — Universidad Pablo de Olavide, Spain

**Citation**
Suarez-Arrones, L., Mascherini, G., Izzicupo, P., Nakamura, F. Y., Benítez-Porres, J., Galán-Mercant, A., Murri, M., Petri, C., eds. (2025). *Diet and training strategies to optimize health parameters*. Lausanne: Frontiers Media SA.
doi: 10.3389/978-2-8325-6031-0

# Table of contents

Frontiers in Public Health

TYPE Editorial
PUBLISHED 10 February 2025
DOI 10.3389/fpubh.2025.1556859



OPEN ACCESS

EDITED AND REVIEWED BY
Terry Huang,
City University of New York, United States

*CORRESPONDENCE
Javier Benítez-Porres
benitez@uma.es
Mora Murri
moramurri@gmail.com

RECEIVED 07 January 2025
ACCEPTED 23 January 2025
PUBLISHED 10 February 2025

CITATION
Benítez-Porres J and Murri M (2025) Editorial: Diet and training strategies to optimize health parameters. *Front. Public Health* 13:1556859. doi: 10.3389/fpubh.2025.1556859



# Editorial: Diet and training strategies to optimize health parameters

Javier Benítez-Porres[1,2,3]* and Mora Murri[3,4,5]*

[1]Physical Education and Sport, Faculty of Medicine, University of Málaga, Málaga, Spain, [2]Internal Medicine Clinical Management, Málaga, Spain, [3]CIBER Fisiopatología de la Salud Carlos III, Málaga, Spain, [4]Endocrinology and Nutrition Clinical Management Málaga y Plataforma en Nanomedicina-IBIMA Plataforma BIONAND, Málaga, Spain, [5]Cardiology and Cardiovascular Surgery Department, Heart Area, Hospital Universitario Virgen de la Victoria, Málaga, Spain

KEYWORDS

**nutrition, sport, exercise, lifestyle, body composition, diet, microbiome**

Editorial on the Research Topic
Diet and training strategies to optimize health parameters

Non-communicable diseases (NCDs) represent the leading cause of mortality worldwide, accounting for 43 million deaths annually and 75% of global mortality (1). Over 32 million deaths occur in low- and middle-income countries, with cardiovascular diseases, cancers, chronic respiratory conditions, and diabetes contributing to more than 80% of premature deaths. Physical inactivity and unhealthy diets are significant contributors to the global burden of NCDs.

Nutrition is fundamental for human health, influencing growth, immunity, and disease prevention (2). Adequate nutrition supports maternal and child health, reduces the risk of chronic conditions like diabetes and cardiovascular diseases, and enhances longevity. However, malnutrition, encompassing both undernutrition and overnutrition, remains a global challenge, leading to stunting, nutrient deficiencies, and diet-related chronic diseases (3).

The present Research Topic highlights the interplay between diet, exercise strategies, and lifestyle behaviors in improving health and performance outcomes. By examining physiological and biological mechanisms, the studies explore how combined approaches can optimize health parameters and performance.

## Individual-level factors

Recent changes in dietary patterns have contributed to rising rates of malnutrition and diet-related chronic diseases. Zheng et al. found that healthy low-carbohydrate and low-fat diets reduced the risk of adiposity. Similarly, Zu et al. showed that higher dietary intake of flavonoids significantly reduced weight-adjusted waist index (WWI). Encouraging the consumption of flavonoid-rich foods to reduce obesity and related chronic diseases. These findings underscore the need for population-based interventions to promote healthier diets and reduce disease risk.

## Mental health and nutrition

Mental health also intersects with dietary behaviors in meaningful ways. Jin et al. linked depressive symptoms during pregnancy to impaired intuitive eating behaviors and poorer diet quality, emphasizing the need to integrate mental health support with nutrition education. Tokarek et al. further explored the role of personality traits, finding that neuroticism may led to poorer dietary choices, while conscientiousness was associated with healthier behaviors. Personality-driven interventions, such as stress management workshops and mindfulness-based interventions, can promote resilience and healthier habits in high-stress environments.

# Promising interventions

## Physical activity

Physical activity plays a pivotal role in preventing psychiatric, neurological, metabolic, cardiovascular, pulmonary, and musculoskeletal diseases, as well as cancer (4). Evidence consistently shows that higher levels of physical activity and reduced sedentary behavior lower all-cause mortality, particularly in middle-aged and older adults. Moderate-to-vigorous physical activity also reduces hospitalization risk from conditions like cardiovascular diseases.

Targeted interventions for specific demographics have shown promise. Park and Park found that resistance training significantly reduced hypertension risk, particularly among women, highlighting the need for gender-specific physical activity programs. Similarly, Khatib et al. identified energy availability issues among female athletes in Saudi Arabia, underscoring the necessity of educational programs promoting balanced nutrition and safe training practices.

## Workplace wellness programs

Onofrei et al. found that nurses with chronic conditions experienced higher stress levels, poorer health perception, and higher BMI, along with greater carbohydrate consumption. These findings underline the need for workplace wellness programs addressing mental health, nutrition, and physical activity. Healthcare professionals, often caught in high-stress environments, require targeted interventions to mitigate these risks.

# Environmental and policy considerations

## Urban and socioeconomic factors

Urban environments significantly influence chronic diseases prevalence. Irankhah et al. revealed that improving urban infrastructure and reducing socioeconomic disparities could lower NCD risks. Access to parks, pedestrian-friendly spaces, and affordable nutritious foods fosters healthier communities. Policy makers should prioritize creating environments conducive to healthy living.

Socioeconomic factors also play a pivotal role. Areba et al. identified education and employment as key determinants of food security among pregnant women. The researchers, emphasizing systemic interventions to address structural issues. Policies empowering women through education and economic opportunities can improve household food security and maternal and child health.

## Adherence to health guidelines

Wang et al. demonstrated that adherence to the American Heart Association's Life's Simple 7 (LS7) health guidelines reduced rheumatoid arthritis (RA) risk, particularly among men under 50 and women across all age groups. This highlights the importance of early and consistent lifestyle changes, including maintaining a healthy weight, regular physical activity, and balanced diets. Gender-specific messaging can further enhance public health initiatives.

# Integrated approaches for sustainable outcomes

Integrating dietary and physical activity interventions within broader policy frameworks is essential for sustainable health outcomes. Enhancing food literacy (Zhixue et al.) helps bridge the gap between awareness and action, while global efforts to regulate food marketing and reduce sugar consumption complement local community-specific programs addressing unique cultural and socioeconomic determinants of health.

The interplay between diet, physical activity, mental health, and social determinants forms the foundation of effective interventions. By addressing these interconnected factors, we can create holistic strategies that not only reduce NCD prevalence but also enhance overall quality of life.

Addressing NCDs requires a dual approach: tackling global challenges while tailoring interventions to local contexts. Globally, collaborative efforts are needed to regulate food marketing, reduce sugar consumption, and promote physical activity through international campaigns. Locally, community-specific programs can address unique cultural, economic, and social determinants of health.

# Future directions

Future research should focus on evaluating the long-term impact of combined dietary and physical activity interventions. Policymakers, healthcare professionals, and community leaders must collaborate to implement evidence-based solutions, ensuring accessibility and sustainability. Together, these efforts can pave the way for healthier individuals, communities, and nations.

# Author contributions

JB-P: Conceptualization, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MM: Conceptualization, Supervision, Validation, Writing – original draft, Writing – review & editing.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. MM was supported by Miguel Servet II program (CPII22-00013).


## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

## Publisher's note



## References


1. World Health Organization. *Non communicable diseases.* World Health Organization. (2024). Available at: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases (accessed January 13, 2025).

2. World Health Organization. *Nutrition*. World Health Organization. (2023). Available at: https://www.who.int/health-topics/nutrition#tab=tab_1 (accessed January 13, 2025).

3. Wawrzyniak A, Pietruszka B. Dietary habits and nutritional status of different population groups in relation to lifestyle factors and nutritional knowledge. *Nutrients*. (2023) 15:4609. doi: 10.3390/nu15214609

4. Lindblom H, Lowén M, Faresjö T, Hedman K, Sandström P. Disease prevalence and number of health care visits among members of a nationwide sports organization compared to matched controls. *BMC Public Health*. (2021) 21:455. doi: 10.1186/s12889-021-10466-9

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 10 October 2023
DOI 10.3389/fpubh.2023.1256883



OPEN ACCESS

EDITED BY
Javier Benítez-Porres,
University of Malaga, Spain

REVIEWED BY
Antonio Hernández-Mendo,
University of Malaga, Spain
Angelina Sutin,
Florida State University, United States

*CORRESPONDENCE
Michał Seweryn Karbownik
✉ michal.karbownik@umed.lodz.pl

RECEIVED 11 July 2023
ACCEPTED 21 September 2023
PUBLISHED 10 October 2023

CITATION
Tokarek J, Kapuścik A, Kućmierz J, Kowalczyk E and Karbownik MS (2023) Personality traits and health-related behaviors in medical students facing a stressful event. *Front. Public Health* 11:1256883. doi: 10.3389/fpubh.2023.1256883



# Personality traits and health-related behaviors in medical students facing a stressful event

Julita Tokarek[1], Angelika Kapuścik[2], Joanna Kućmierz[1], Edward Kowalczyk[3] and Michał Seweryn Karbownik[3]*

[1]Department of Pharmacology and Toxicology, Students Research Club, Medical University of Lodz, Lodz, Poland, [2]Students Research Club "Metoda", Institute of Sociology, Faculty of Economics and Sociology, University of Lodz, Lodz, Poland, [3]Department of Pharmacology and Toxicology, Medical University of Lodz, Lodz, Poland

**Background:** It is believed that personality traits have an impact on the propensity to change and maintain favorable lifestyle habits. This issue has been raised by multiple studies, however, none of them appeared to focus on population under severe psychological stress. The aim of the present study was to investigate the link between personality traits and health-related behaviors and measures such as dietary intake of specific food products, physical activity, body-mass index and the use of cigarettes in medical students facing a stressful event.

**Methods:** The study included a cohort of third-year medical students from the Medical University of Lodz, Poland, facing a stressful subject exam during the first COVID-19-related lockdown. At baseline, personality traits were evaluated with the use of the Polish version of the Big Five Inventory-Short questionnaire. Then, consumption of selected food products was monitored with the use of seven-day electronic dietary record. Also, some other health-related data was collected (body-mass index, physical activity and the use of cigarettes). General Linear Modeling techniques, logistic regression and exploratory factor analysis were applied to analyze the data.

**Results:** Four hundred and forty-four students completed the study. A two-factor pattern of food consumption was discovered by the exploratory factor analysis in the study group (34% of the variance explained). Higher conscientiousness, but not the other personality traits, was found to be significantly associated with generally healthier lifestyle manifested by higher consumption of vegetables, wholegrain products, fruits and nuts (adjusted beta 0.16, 95%CI 0.06 to 0.26, $p\eta^2 = 2.3\%$, $p = 0.0015$) and lower cigarette smoking (adjusted odds ratio 0.84, 95%CI 0.75 to 0.94, $p = 0.0020$), but insignificantly with physical activity and body-mass index.

**Conclusion:** Severely stressed medical students expressing high conscientiousness tend to present healthier behaviors. Therefore, interventions aimed at improving lifestyle habits in students with low conscientiousness might be useful.

KEYWORDS

**personality traits, conscientiousness, diet, health, behaviors, psychological stress**

# 1. Introduction

The average lifespan has increased in the past few decades due to socioeconomic and health-related development. As a result, it has led to a higher prevalence of chronic old-age diseases such as diabetes, obesity, cardiovascular diseases and cancer. Many of these diseases are conditioned by the modifiable risk factors including smoking, physical activity, alcohol intake, body weight and diet (1). Thereupon, changing and maintaining favorable lifestyle behaviors as early as possible in people's lives are a key strategy for good health and longevity.

Leading a healthy lifestyle may be challenging under psychological stress, which is very prevalent contemporarily. Under psychological stress, attention is redirected to stressor-related issues and dietary behaviors may be neglected (2). In particular, undergraduate students face multiple psychological stressors that may negatively affect their health behaviors (3). Recently, the general stress associated with academic workload has been further exacerbated by the COVID-19 pandemic and global lockdown (4); distancing from family members and friends, thereby diminished social interaction and emotional support together with new online teaching and assessment methods, which required appropriate digital infrastructure and skillset, have led to unprecedented psychosocial burden (5, 6). The emergent problems appeared to heterogeneously affect health-related behaviors (7), which, in turn, could depend on some personal factors (8).

Personality refers to individual differences in characteristic patterns of thinking and is one of the most significant aspects of human life. It has an influence on all human behaviors in both personal and social life (9). Personality development is a complex process influenced by factors such as genetics, environmental factors and temperament which is a precursor of the structure of personality (10). Personality traits may have an impact on propensity to change and maintain favorable lifestyle habits. This issue has been raised by multiple studies to highlight the link between personality traits and the tendency to consume specific food groups (11). In particular, neuroticism was associated with unhealthy diet habits such as low consumption of fruits and vegetables, and higher consumption of sugar and saturated fats (11). On the other hand, conscientiousness was found to be linked with higher scores on the health aware diet factor and higher intake of fruits and vegetables (11–13). Even though similar studies have already been conducted, none of them focused specifically on a population under severe psychological stress. In fact, the recent meta-analysis on this topic showed that further research is required to explore this relationship in more vulnerable groups (11).

The primary aim of the present study was to investigate the link between personality traits and dietary intake of specific food products in medical students facing a stressful subject examination in the first COVID-19-related lockdown. In addition, the other health-related measures (general quality of diet, physical activity, body-mass index and cigarette use) were also assessed as secondary outcomes in terms of their relationship to personality traits.

# 2. Methods

## 2.1. Ethical considerations

The study obtained the approval of the Bioethics Committee of the Medical University of Lodz, Poland (RNN/111/20/KE, received on April 2, 2020). All the participants gave their informed consent in an electronic manner. The study partially represents a secondary analysis of already published results (14, 15), however, it also includes new data.

## 2.2. Research design

In this study medical students were exposed to the growing stress related to an impending final subject examination. The study was performed during the first COVID-19 pandemic wave in Poland. At that time, several unprecedented social restriction measures had lasted continuously for 2–3 months in the country: suspension of stationary educational activities, travel restrictions and gathering ban, closure of non-essential retail outlets and services, ban on traveling alone for juveniles and obligation to wear masks (16). Although the number of COVID-19 cases did not exceed 500 a day at that time in Poland, the imposed lockdown measures and the surrounding atmosphere of insecurity could have deteriorated mental functioning of the study's participants even more.

This was a survey-based study. Personality traits were evaluated as predictors in the entrance survey, whereas consumption of selected foods was recorded as the primary outcome measure during 7 days preceding the final exam. Physical activity and general quality of diet were assessed as secondary outcomes a day before the final exam. Some secondary outcome measures (cigarettes, body-mass index) were evaluated in a cross-sectional manner at the entrance to the study (Figure 1).

The timeline of the study was as follows (Figure 1). After (A) collecting baseline sociodemographic and anthropometric characteristics, some health-related habits and personality traits as predictors (4–7 June 2020), the students were (B) followed up for 7 days in terms of their dietary behaviors (9–15 June 2020). Also, (C) pre-exam physical activity and general quality of diet were assessed in the last day of dietary recording (14–15 June 2020) – this period preceded (D) a stressful final subject exam (15 June 2020). Participants were recruited to the study for 2 weeks prior to its initiation.

The STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guidelines for reporting cohort studies (17) were applied to outline the study description.

## 2.3. Participants

The study included a cohort of third-year medical students of the Medical University of Lodz, Poland, taking the 60-min pharmacology exam in June 2020. No exclusion criteria were applied in the study. Students were approached during their pharmacology lecture and were invited to join the pre-study online meeting (Microsoft Teams; Microsoft, Redmont, WA, USA), when the general concept of the study was explained. MS Teams platform was also used to facilitate communication throughout the study and to distribute the surveys.

## 2.4. Instruments

The listed Instruments were used in the course of the study:

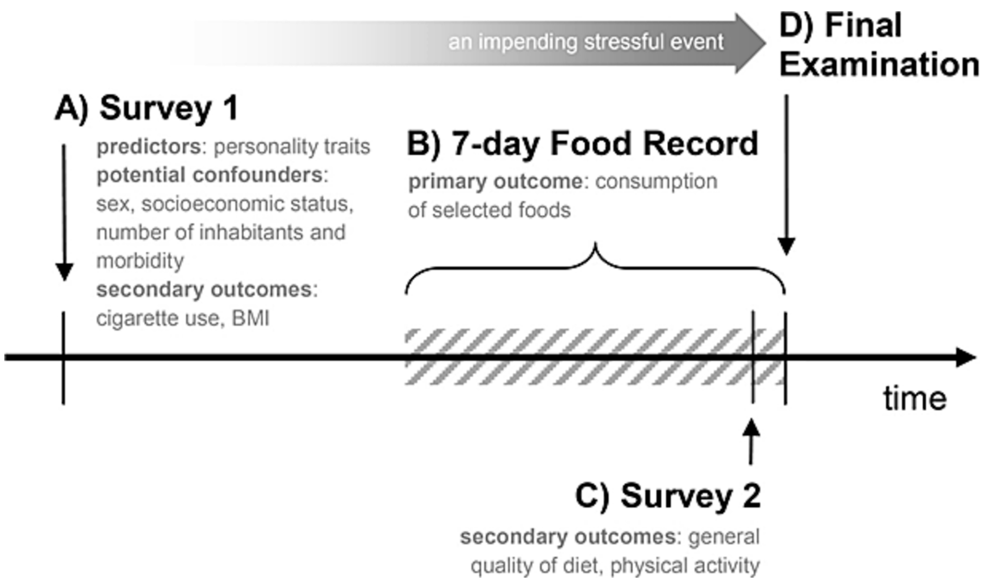



FIGURE 1
Timeline of the study procedures. Four steps of the study are indicated with letters A–D. All the participants were exposed to the growing stress accompanying the im-pending final exam (D). At the entrance, personality traits of the participants were assessed as predictors (A). The primary outcome measure of consumption of selected foods had been recorded for 7 days (B) and, in the last day, physical activity and general quality of diet were assessed as secondary outcomes (C). Some secondary outcome measures were evaluated also in a cross-sectional manner, at the entrance (A): cigarette smoking/use and the body-mass index (BMI). Some potential confounders (A) were also assessed.

- to assess predictors – personality traits:
  - o Polish version of the Big Five Inventory-Short (BFI-S) questionnaire (18, 19);

BFI-S assesses five dimensions of personality with the use of three items to each; participants are asked to express the extent to which they agree with each of the items in a seven-point Likert scale. Cronbach's alpha assessed in the study sample for the subscales was 0.65 for Neuroticism, 0.75 for Extraversion, 0.70 for Openness, 0.54 for Agreeableness and 0.68 for Conscientiousness.

- to assess primary outcome – food consumption:
  - o Food Record questionnaire

This was a seven-day selective dietary record questionnaire using the open-ended electronic Food Record (FR) form. Although the tool was previously used (14, 15), in the current study we performed its further validation, which confirmed its satisfactory accuracy, but somehow variable precision. Details of the methods used in the validation process and its results are reported in Supplementary material S1.

The FR was designed to collect the information regarding the mass of 34 food categories:

1. Meat, sausages, fish, seafood

a. red meat
b. white meat
c. fatty fish
d. other fish
e. fish oil
f. seafood

2. Dairy and eggs

a. milk
b. cottage cheese
c. cheese
d. yogurt, kefir, soured milk
e. eggs

3. Grain products

a. light bread
b. wholemeal bread, graham
c. cereal, groats, whole grain noodle
d. muesli
e. white rice
f. unpasteurized kvass and beer
g. wholemeal flour

4. Vegetables

a. potatoes
b. carrot, parsley, celery
c. beetroots
d. raw cucumber
e. pickled cucumber and pickling juice
f. cabbage
g. sauerkraut and pickling juice
h. other fermented vegetables and their pickling juice
i. onion, leek, garlic

j. leguminous vegetables
k. all other vegetables

5. Fruits and nuts

a. apples
b. citrus
c. bananas
d. all other fruits
e. nuts

Each of the food categories in the FR was described in detail and illustrated with several photos of food portion examples to enable mass estimation. The participants were asked to self-report the food quantity by filling the online FR form each time they consumed a meal/beverage within 7 days. In this study, consumption of the following foods was assessed as a sum of the abovementioned categories (indicated below in the brackets) and was used as the outcome measure:

- red meat (1a),
- white meat (1b),
- fish, fish oil and seafood (marine products) (1c – 1f),
- dairy (2a – 2d),
- eggs (2e),
- wholegrain products (3b, 3c, 3 g),
- light bread (3a),
- potatoes (4a),
- vegetables (4b – 4 k),
- fruits (5a – 5d),
- nuts (5e);

- to assess secondary outcomes:

o anthropometric questionnaire (body mass and height to calculate body-mass index);
o self-reported cigarette smoking or use of e-cigarettes;
o Polish version of the Starting the Conversation (STC) scale to assess general quality of diet (20), STC is composed of eight questions relating to consumption of selected foods and beverages; participants indicate frequency of consumption over several previous months using a three-point Likert scale; this was used for the purpose of comparison with the pre-exam quality of diet;
o single-item five-point semantic differential scale from 1 ("I have no physical activity at all") to 5 ("I play sports intensively five times a week") to assess physical activity, partially validated (16) against the Polish version of the International Physical Activity Questionnaire Short form (21, 22);

- to assess potential confounders:

o sociodemographic data questionnaire (year of birth, sex, socioeconomic status – measured subjectively using a single-item three-point Likert scale: low, middle, high – number of inhabitants in the place of family residence);
o self-reported morbidity (suffering from chronic diseases);

- to assess symptoms of depression:

o Polish version of the Patient Health Questionnaire-9 (PHQ-9) scale (23, 24);

- to assess symptoms of anxiety:

o Polish version of the Generalized Anxiety Disorder-7 (GAD-7) scale (25, 26);

PHQ-9 and GAD-7 assess the symptoms based on nine- and seven-symptom lists, respectively; participants indicate frequency of experiencing each of the symptoms with a four-point Likert scale; original tools apply a two-week time frame, however, for the purpose of this study, a one-week time frame of experiencing the symptoms was used (27, 28) to capture the critical time of examined health-related behavior (seven-day food record).

## 2.5. Procedure

### 2.5.1. Step A

Firstly, basal data on the participants were collected using the Internet survey (Step A in Figure 1 – Survey 1; Google Form; Google, Mountain View, CA, USA). The survey included among others:

- general information: sociodemographic, anthropometric and morbidity (suffering from chronic diseases); the data was used for descriptive purpose as well as to get potential confounders (sex, socioeconomic status, number of inhabitants and morbidity), effect modifiers (morbidity) and cross-sectional outcome measure (BMI);
- health-related habits:

o baseline physical activity, used for the purpose of comparison with the pre-exam physical activity;
o baseline general quality of diet;
o cigarette smoking or use of e-cigarettes, a cross-sectional outcome measure;

- personality traits, used as the predictor variable in the analysis.

### 2.5.2. Step B

Secondly, a few days after the baseline survey was conducted, the seven-day selective dietary record questionnaire using the open-ended electronic Food Record form (FR; Step B in Figure 1; Google Form) was applied.

### 2.5.3. Step C and D

Thirdly, mental health symptoms (depression and anxiety) were evaluated in the last day of food recording (a day before the final subject exam) to confirm the severity of mental burden related to the impending stressful event (Step C in Figure 1). The stressor (final exam in pharmacology – step D in Figure 1) was previously demonstrated to elicit physiological (heart rate) and psychological (state anxiety) stress response and its hormonal effect (rise in salivary cortisol) was notable as early as a day before (29). Mental health was also found to slightly deteriorate a few days before the exam (14). In addition, in the survey performed a day before the exam (Step C), pre-exam physical activity and pre-exam general quality of diet (STC) were evaluated as outcome measures using the same tool as in the first study step (adjusted to one-week time).

## 2.6. Data analysis

Baseline characteristics of the study participants were described by mean with standard deviation, median with 1st-3rd quartiles or absolute number with frequency for continuous, ordinal and categorical variables, respectively. General Linear Modeling (GLM) techniques were applied to assess the association between personality traits and health-related behavior (consumption of specific foods and physical activity). Cigarette use was assessed with logistic regression. Apart from the raw multivariate regression results, the multivariate regression analyses adjusted for potential confounders (sex, socio-economic status, number of inhabitants in the place of family residence and any chronic disease) were reported – these covariates were selected as potentially affecting both the predictors and outcomes; potential confounders were included as independent variables linearly linked to the outcome in the statistical models. A separate multivariate linear regression model was used for every food product. The Benjamini and Hochberg (B-H) correction for multiple comparisons was applied with the False Discovery Rate of 0.05. To identify potential links between health-related behaviors, exploratory factor analysis (EFA) with raw varimax factor rotations as well as hierarchical agglomerative clustering with Euclidean distance and complete-linkage were used. *p*-values below the B-H corrected significance levels were considered statistically significant. The analyses were performed using STATISTICA Software version 13.3 (Statsoft; Tulsa, OK, USA).

Due to the fact that no forced answering option was used in all the survey items, some missing data occurred in the database. The missingness pattern was assumed to be random. Missing data comprised 67/34,596 (0.19%) of the values in the database. All the missing values were imputed before any analysis with the use of Multiple Imputation by Chained Equations (MICE) method.

# 3. Results

## 3.1. Characteristics of the study sample

Four hundred and ninety students volunteered for the study. Forty-six participants (9.4%) dropped out during the course of the study (not providing food records for at least 3 days or not filling Survey 2). The number of the participants who completed the study was 444 and only data on these subjects was evaluated. The mean age of the participants was 22.7 and one third of them was male. Detailed characteristics of the study sample are presented in Table 1.

TABLE 1 Basal characteristics of the study participants ($n = 444$).

| Characteristics | Mean (standard deviation), median (1st–3rd quartiles) or absolute number (frequency) |
|---|---|
| **Sociodemographic and physical data** | |
| Age | |
| [years] | 22.7 (1.1), median (Q1–Q3): 22.0 (22.0–23.0) |
| Sex | |
| Female | 297 (66.9%) |
| Male | 147 (33.1%) |
| Socioeconomic status | |
| Low | 3 (0.7%) |
| Middle | 313 (70.5%) |
| High | 128 (28.8%) |
| Number of inhabitants in a place of family residence | |
| Below 5,000 | 103 (23.2%) |
| 5,000–50,000 | 139 (31.3%) |
| 50,000–500,000 | 113 (25.5%) |
| Over 500,000 | 89 (20.0%) |
| Anthropometry | |
| Body mass index [$kg \times m^{-2}$] | 22.0 (3.1), median (Q1-Q3): 21.5 (19.6–23.6) |
| Health-related behavior | |
| Current cigarette smoking/use[a] | 29 (6.5%) |
| **Morbidity** | |
| Any chronic disease | 172 (38.7%) |
| Allergic diseases | 106 (23.9%) |
| Neurological diseases | 6 (1.4%) |
| Psychiatric diseases | 26 (5.9%) |
| Cardiological diseases | 5 (1.1%) |
| Gastroenterological diseases | 28 (6.3%) |
| Immunological diseases | 8 (1.8%) |
| Cancerous diseases | 1 (0.2%) |
| Endocrine diseases | 42 (9.5%) |
| **Personality traits**[b] | |
| Neuroticism | 13 (9 – 16) |
| Extraversion | 12 (9 – 15) |
| Openness | 15 (12 – 17) |
| Agreeableness | 15 (12 – 17) |
| Conscientiousness | 16 (13 – 18) |

Q1, 1st quartile. Q3, 3rd quartile. [a]Fraction of the participants reporting either traditional cigarette smoking or e-cigarette use. [b]Expression of five personality traits was presented numerically in the range of 3–21, with the midpoint of 12.

## 3.2. Pre-exam mental health symptoms

As assumed, in the assessed pre-exam time period worrisome mental symptoms were observed: 35% of the students were characterized by mild depressive symptoms (PHQ-9 of 5–9) and additional 40% by moderate or more severe depressive symptoms (PHQ-9 ≥ 10). Furthermore, 35% of the students presented mild and another 34% moderate or more severe anxiety symptoms (GAD-7 of 5–9 and ≥10, respectively). Median (1st–3rd quartile) for depressive symptoms was 8 (4.5–12) and for anxiety symptoms 7 (4–12.5).

## 3.3. Pre-exam health-related behavior

Physical activity and general quality of diet were assessed twice in the study: at the entrance in relation to several months and a day before the stressful exam in relation to a previous week. The participants reported being significantly less physically active in the seven-day pre-exam period than at baseline (Wilcoxon signed-rank test, $p < 0.0001$), however, they presented relatively similar dietary practices to those at baseline as assessed by the STC score comparisons (Wilcoxon signed-rank test, $p = 0.13$).

As compared to other food groups, vegetables were the category of food products consumed in the highest amount; however, it could be even higher to comply with the common dietary guidelines (30). The students consumed a sufficient amount of fruits and dairy, as recommended (30). The fact that the study was conducted in June might have had an impact on these results because of many seasonal fruits and vegetables available. Furthermore, the consumption of marine products and nuts was insufficient to cover the demand for omega-3 fatty acids (30). Detailed data are presented in Table 2, whereas data on consumption of all food products included in the Food Record questionnaire in the seven-day pre-exam period are presented in Supplementary material – point 2.

## 3.4. Association between personality traits and health-related behavior under stress

In both the raw analysis and the analysis adjusted for covariates (sex, socioeconomic status, number of inhabitants in the place of family residence and any chronic disease), consumption of wholegrain products as well as the general quality of diet in the stressful period was found to be significantly positively associated with higher conscientiousness. Also, cigarette smoking appeared to be significantly negatively associated with this personality trait. Consumption of other food groups as well as physical activity were found insignificantly linked to personality traits. Detailed results of the covariate-adjusted associations are presented in Table 3, whereas the raw results in Supplementary material – point 3. Moreover, several sociodemographic covariates (used in the adjusted models) were linked to eating behaviors as detailed in Supplementary material – point 4.

Furthermore, with the use of the EFA, two unrelated patterns of food consumption were found as characterized by two orthogonal factors in the EFA. One of them could represent the food of overall high nutritional value and included wholegrain products, nuts, vegetables, fruits, as well as – to a lesser degree – marine products, white meat, dairy and eggs, while the other one could represent food of lower nutritional value and comprised potatoes, red meat and white bread. In the other words, people eating more vegetables, eat more wholegrain products, fruits and nuts; on the other hand people eating more red meat, eat more white bread and potatoes. The EFA results are presented in Figure 2 and are partially confirmed by hierarchical agglomerative clustering as reported in Figure 3.

Further analysis of the weighted sum of the products included in two abovementioned EFA-derived factors (factor loadings as weights in the equations) showed that products with higher nutritional value (Factor 1) were found to be significantly positively associated with higher conscientiousness, however, not with the other personality traits, in both raw and multivariate analysis. The results are presented in Table 4.

## 3.5. Sensitivity analysis in subgroups

In order to assess whether the reported effects are stable across different subgroups, we performed three sensitivity analyses. First one was done in a subgroup of people experiencing at least mild depressive or anxiety symptoms (PHQ-9 score $\geq 5$ or GAD-7 score $\geq 5$; $n = 368$, 82.9% of the whole sample) in the time preceding the stressful event, and the results showed that conscientiousness was still the only personality trait associated with healthier food consumption (Factor 1 in EFA) (adjusted beta 0.14, 95%CI 0.03 to 0.25, $p = 0.012$); also, there was no significant interaction between experiencing mental health symptoms (PHQ-9 score or GAD-7 score) and conscientiousness in predicting eating healthier foods (Factor 1 in EFA) ($p = 0.78$ and $p = 0.70$, respectively; covariate-adjusted analyses with all personality traits and the two-way interaction linearly included). The second sensitivity analysis included people having no

TABLE 2 Consumption of the analyzed food products in the seven-day pre-exam period.

| FR item number | Food product | Seven-day consumption [gram] | |
|---|---|---|---|
| | | Median (1st–3rd quartiles) | Mean (standard deviation) |
| 1a | Red meat | 380.8 (134.4–686.2) | 474.2 (445.1) |
| 1b | White meat | 336.0 (75.6–697.2) | 460.5 (464.4) |
| 1c – 1f | Marine products | 65.1 (0.0–224.0) | 145.5 (197.7) |
| 2a – 2d | Dairy | 1327.2 (784.0–2005.4) | 1545.6 (1110.2) |
| 2e | Eggs | 246.4 (123.2–409.4) | 288.3 (238.0) |
| 3b, 3c, 3 g | Wholegrain products | 641.2 (314.3–972.7) | 730.1 (585.7) |
| 3a | Light bread | 514.3 (230.7–842.9) | 569.2 (425.4) |
| 4a | Potatoes | 426.9 (201.6–672.0) | 469.7 (369.0) |
| 4b – 4 k | Vegetables | 1637.1 (1044.4–2438.8) | 1847.2 (1110.6) |
| 5a – 5d | Fruits | 1270.0 (634.4–1975.6) | 1468.0 (1062.8) |
| 5e | Nuts | 15.7 (0.0–67.2) | 50.9 (81.6) |

TABLE 3 Covariate-adjusted association between personality traits and health-related behavior under stress.

| Health-related behavior | Effect size measures and $p$-value | | | | |
|---|---|---|---|---|---|
| | Neuroticism | Extraversion | Openness | Agreeableness | Conscientiousness |
| **Consumption of selected food products – primary outcome** | | | | | |
| Red meat | 0.00 (−0.09 to 0.09) | 0.01 (−0.08 to 0.09) | −0.02 (−0.10 to 0.07) | 0.01 (−0.08 to 0.09) | 0.02 (−0.07 to 0.10) |
| | $p\eta^2 = 0.0\%$ $p = 0.96$ | $p\eta^2 = 0.0\%$ $p = 0.84$ | $p\eta^2 = 0.0\%$ $p = 0.68$ | $p\eta^2 = 0.0\%$ $p = 0.89$ | $p\eta^2 = 0.0\%$ $p = 0.71$ |
| White meat | 0.12 (0.02 to 0.22) | −0.00 (−0.09 to 0.09) | −0.10 (−0.19 to −0.00) | 0.00 (−0.09 to 0.10) | 0.08 (−0.01 to 0.18) |
| | $p\eta^2 = 1.3\%$ $p = 0.016$ | $p\eta^2 = 0.0\%$ $p = 0.99$ | $p\eta^2 = 0.9\%$ $p = 0.048$ | $p\eta^2 = 0.0\%$ $p = 0.95$ | $p\eta^2 = 0.6\%$ $p = 0.10$ |
| Marine products | −0.07 (−0.17 to 0.03) | 0.13 (0.03 to 0.22) | 0.05 (−0.04 to 0.15) | −0.07 (−0.17 to 0.03) | 0.11 (0.01 to 0.21) |
| | $p\eta^2 = 0.4\%$ $p = 0.19$ | $p\eta^2 = 1.5\%$ $p = 0.010$ | $p\eta^2 = 0.3\%$ $p = 0.27$ | $p\eta^2 = 0.5\%$ $p = 0.15$ | $p\eta^2 = 1.1\%$ $p = 0.029$ |
| Dairy | −0.01 (−0.11 to 0.10) | 0.02 (−0.08 to 0.12) | 0.02 (−0.08 to 0.12) | −0.03 (−0.13 to 0.07) | 0.12 (0.02 to 0.22) |
| | $p\eta^2 = 0.0\%$ $p = 0.93$ | $p\eta^2 = 0.0\%$ $p = 0.67$ | $p\eta^2 = 0.0\%$ $p = 0.67$ | $p\eta^2 = 0.1\%$ $p = 0.53$ | $p\eta^2 = 1.2\%$ $p = 0.020$ |
| Eggs | 0.06 (−0.04 to 0.16) | −0.04 (−0.14 to 0.05) | −0.02 (−0.12 to 0.07) | 0.05 (−0.05 to 0.15) | 0.11 (0.01 to 0.20) |
| | $p\eta^2 = 0.4\%$ $p = 0.88$ | $p\eta^2 = 0.2\%$ $p = 0.21$ | $p\eta^2 = 0.1\%$ $p = 0.37$ | $p\eta^2 = 0.2\%$ $p = 0.30$ | $p\eta^2 = 1.0\%$ $p = 0.036$ |
| Wholegrain products | −0.02 (−0.12 to 0.08) | 0.02 (−0.08 to 0.12) | 0.03 (−0.06 to 0.13) | −0.02 (−0.12 to 0.08) | **0.15 (0.05 to 0.25)** |
| | $p\eta^2 = 0.0\%$ $p = 0.72$ | $p\eta^2 = 0.0\%$ $p = 0.69$ | $p\eta^2 = 0.1\%$ $p = 0.50$ | $p\eta^2 = 0.0\%$ $p = 0.65$ | **$p\eta^2 = 2.0\%$ $p = 0.0029$** |
| Light bread | −0.00 (−0.10 to 0.09) | −0.06 (−0.15 to 0.03) | −0.04 (−0.14 to 0.05) | −0.02 (−0.11 to 0.08) | −0.07 (−0.16 to 0.02) |
| | $p\eta^2 = 0.0\%$ $p = 0.94$ | $p\eta^2 = 0.4\%$ $p = 0.20$ | $p\eta^2 = 0.2\%$ $p = 0.38$ | $p\eta^2 = 0.0\%$ $p = 0.70$ | $p\eta^2 = 0.5\%$ $p = 0.14$ |
| Potatoes | 0.07 (−0.03 to 0.17) | −0.01 (−0.11 to 0.08) | 0.03 (−0.07 to 0.13) | −0.04 (−0.14 to 0.05) | 0.03 (−0.06 to 0.13) |
| | $p\eta^2 = 0.5\%$ $p = 0.15$ | $p\eta^2 = 0.0\%$ $p = 0.80$ | $p\eta^2 = 0.1\%$ $p = 0.53$ | $p\eta^2 = 0.2\%$ $p = 0.39$ | $p\eta^2 = 0.1\%$ $p = 0.51$ |
| Vegetables | −0.09 (−0.19 to 0.01) | 0.03 (−0.06 to 0.13) | 0.07 (−0.03 to 0.17) | 0.06 (−0.04 to 0.15) | 0.06 (−0.04 to 0.16) |
| | $p\eta^2 = 0.7\%$ $p = 0.080$ | $p\eta^2 = 0.1\%$ $p = 0.49$ | $p\eta^2 = 0.5\%$ $p = 0.15$ | $p\eta^2 = 0.3\%$ $p = 0.25$ | $p\eta^2 = 0.3\%$ $p = 0.24$ |
| Fruits | −0.10 (−0.20 to 0.00) | 0.02 (−0.08 to 0.12) | −0.06 (−0.15 to 0.04) | −0.02 (−0.11 to 0.08) | 0.08 (−0.01 to 0.18) |
| | $p\eta^2 = 0.8\%$ $p = 0.056$ | $p\eta^2 = 0.0\%$ $p = 0.70$ | $p\eta^2 = 0.3\%$ $p = 0.27$ | $p\eta^2 = 0.0\%$ $p = 0.75$ | $p\eta^2 = 0.6\%$ $p = 0.095$ |
| Nuts | −0.07 (−0.17 to 0.03) | −0.03 (−0.13 to 0.07) | 0.01 (−0.08 to 0.11) | −0.00 (−0.10 to 0.09) | 0.01 (−0.09 to 0.11) |
| | $p\eta^2 = 0.4\%$ $p = 0.18$ | $p\eta^2 = 0.1\%$ $p = 0.53$ | $p\eta^2 = 0.0\%$ $p = 0.77$ | $p\eta^2 = 0.0\%$ $p = 0.93$ | $p\eta^2 = 0.0\%$ $p = 0.79$ |
| **Other health-related measures – secondary outcomes** | | | | | |
| Physical activity[a] | −0.10 (−0.20 to 0.00) | −0.01 (−0.10 to 0.09) | 0.09 (−0.01 to 0.19) | −0.01 (−0.11 to 0.08) | 0.10 (−0.04 to 0.15) |
| | $p\eta^2 = 0.8\%$ $p = 0.056$ | $p\eta^2 = 0.0\%$ $p = 0.91$ | $p\eta^2 = 0.7\%$ $p = 0.071$ | $p\eta^2 = 0.0\%$ $p = 0.78$ | $p\eta^2 = 0.3\%$ $p = 0.027$ |
| General quality of diet[b] | 0.01 (−0.11 to 0.09) | 0.07 (−0.16 to 0.03) | 0.01 (−0.11 to 0.09) | −0.03 (−0.07 to 0.13) | **0.19 (−0.29 to −0.09)** |
| | $p\eta^2 = 0.0\%$ $p = 0.82$ | $p\eta^2 = 0.4\%$ $p = 0.18$ | $p\eta^2 = 0.0\%$ $p = 0.88$ | $p\eta^2 = 0.1\%$ $p = 0.52$ | **$p\eta^2 = 3.3\%$ $p = 0.0001$** |
| Cigarettes[c] | 0.99 (0.89 to 1.1) | 1.05 (0.96 to 1.17) | 0.94 (0.84 to 1.04) | 0.89 (0.79 to 1.01) | **0.84 (0.75 to 0.94)** |
| | $p = 0.91$ | $p = 0.26$ | $p = 0.22$ | $p = 0.064$ | **$p = 0.0020$** |
| BMI | −0.11 (−0.21 to −0.02) | −0.04 (−0.13 to 0.05) | −0.04 (−0.13 to 0.05) | 0.00 (−0.09 to 0.09) | −0.08 (−0.17 to 0.01) |
| | $p\eta^2 = 1.3\%$ $p = 0.017$ | $p\eta^2 = 0.2\%$ $p = 0.38$ | $p\eta^2 = 0.2\%$ $p = 0.40$ | $p\eta^2 = 0.0\%$ $p = 0.99$ | $p\eta^2 = 0.7\%$ $p = 0.09$ |

Consumption of selected food products, physical activity, general quality of diet and BMI were assessed with the use of multivariate linear regression and standardized ß with 95% confidence intervals (CI) and partial eta-square were presented as effect size measures. Cigarettes use was assessed with the use of multivariate logistic regression and odds ratio with 95% CI were presented as effect size measures. Each raw in the table depicts the results of a single multivariate model adjusted for sex, socioeconomic status, number of inhabitants in the place of family residence and the fact of any chronic disease. BMI – body-mass index. The values in bold are considered statistically significant at the Benjamini and Hochberg corrected significance level of 0.0037 (false discovery rate 0.05).

[a]Physical activity was assessed in the pre-exam stage of the study and is expressed in the five-point semantic differential scale from 1 ("I have no physical activity at all") to 5 ("I play sport intensively 5 times a week"), with the midpoint of 3.

[b]General quality of diet was assessed in the pre-exam stage of the study and is expressed as the number of points in the reverse-coded Starting the Conversation scale in the range from 0 (maximally unhealthy diet) to 16 (maximally healthy diet), with the midpoint of 8; Cronbach's alpha assessed in the study sample was 0.55.

[c]Odds ratio with 95% confidence intervals for reporting either traditional cigarette smoking or e-cigarette use.

endocrine or gastroenterological diseases ($n = 375$, 84.5%), which could have changed dietary patterns themselves; the effect in this regard was also similar to that of the main analysis (adjusted beta for conscientiousness 0.14, 95%CI 0.03 to 0.25, $p = 0.010$). The third sensitivity analysis was performed in the total sample, but with exclusion of chronic diseases as a covariate, due to the possibility that personality traits contribute to chronic diseases (e.g., development of psychiatric disorders), which could be better described as a mediator than a confounder. In this analysis the result turned out to be identical to the dependency found originally (adjusted beta for

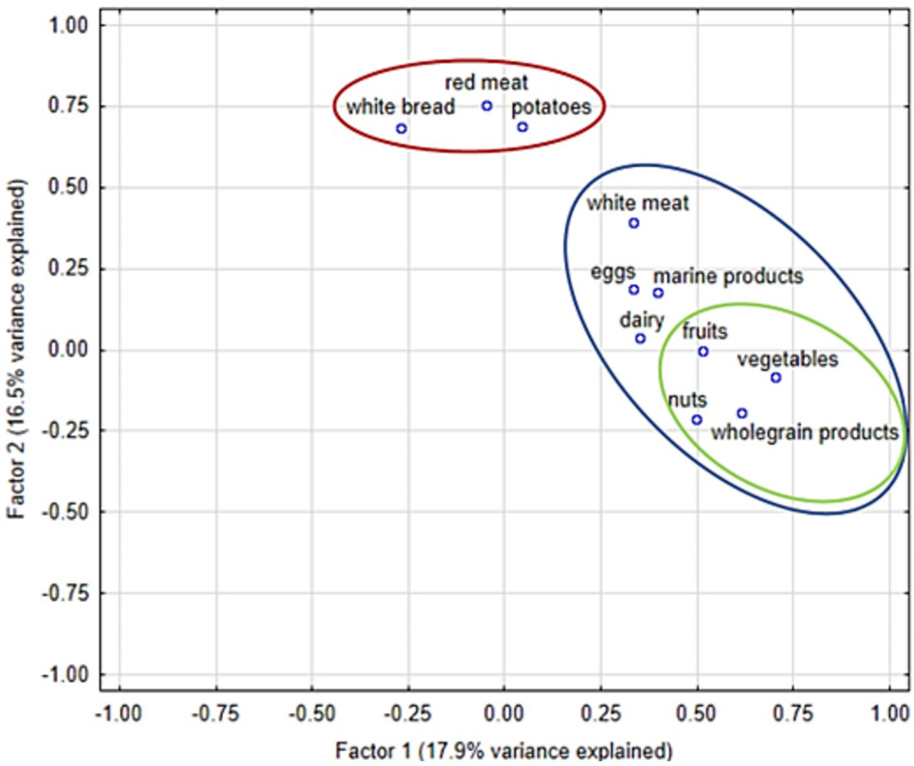



FIGURE 2
The results of the exploratory factor analysis (EFA) between 11 consumed food categories. Factor 1 – EFA-derived representation of products with higher nutritional value (blue ellipse – products included in Factor 1; green ellipse – products with highest loadings within Factor 1). Factor 2 – EFA-derived representation of products with lower nutritional value (red ellipse – products included in Factor 2).

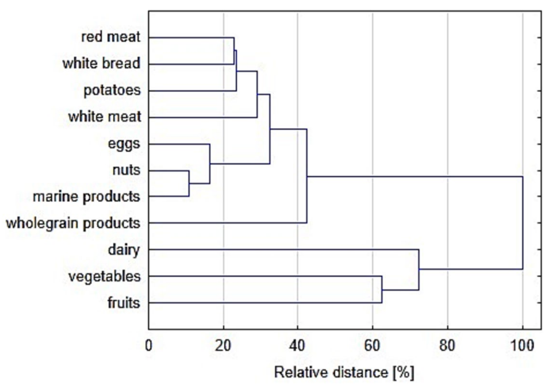



FIGURE 3
The results of the hierarchical agglomerative clustering between 11 consumed food categories. Euclidean distance and complete-linkage clustering methods were used.

conscientiousness 0.16, 95%CI 0.06 to 0.26, $p = 0.0015$). Finally – as the validation of the FR tool suggested some inter-individual differences in its precision – the other sensitivity analysis was performed in a subgroup of students reporting high adherence to the FR (declaring no more than 10% of consumed food products to be omitted, $n = 341$, 76.8%). In this subgroup the association between consumption of healthy foods (Factor 1 in EFA) and conscientiousness was significantly positive (adjusted beta 0.16, 95%CI 0.05 to 0.27, $p = 0.0062$). All these results support versatility of the positive association between conscientiousness and healthy food consumption.

# 4. Discussion

The association between personality traits and health-related behavior has been a subject of many studies (12, 13, 31–35). Nevertheless, the recent systematic review on this topic indicated the need for further investigation involving particular populations (11). Due to overwhelming psychological stress experienced in everyday live (the COVID-19 pandemic, the war waged nearby), it was particularly interesting to assess this relationship in a severely stressed population. Our data indicated that higher conscientiousness may help in leading a generally healthier lifestyle in this population. Such association – although in line with many previous studies (34, 36–38) – is particularly interesting, as the studied population of medical students presented relatively high background level of conscientiousness; we found no ceiling effect in this regard. Even though conscientiousness was found to be positively associated with eating healthy food, there was no reverse dependency between conscientiousness and consumption of less healthy products.

Our findings are in line with the existing body of literature, despite the specific type of the population examined. The study performed among South Korean college students described a positive correlation between conscientiousness and extensive self-reported physical activity and lower BMI, which may be indicative of a healthier lifestyle

TABLE 4 Association between personality traits and health-related measures under stress.

| | Neuroticism | Extraversion | Openness | Agreeableness | Conscientiousness |
|---|---|---|---|---|---|
| **Raw analysis** | | | | | |
| Factor 1[a] | −0.06 (−0.16 to 0.03) | 0.05 (−0.04 to 0.14) | 0.02 (−0.07 to 0.12) | 0.02 (−0.08 to 0.12) | **0.16 (0.07 to 0.26)** |
| | $p\eta^2=0.4\%$ $p=0.18$ | $p\eta^2=0.2\%$ $p=0.30$ | $p\eta^2=0.0\%$ $p=0.65$ | $p\eta^2=0.0\%$ $p=0.68$ | **$p\eta^2=2.5\%$ p = 0.0009** |
| Factor 2[b] | −0.08 (−0.18 to 0.02) | −0.05 (−0.15 to 0.04) | −0.01 (−0.11 to 0.08) | −0.06 (−0.16 to 0.03) | −0.10 (−0.20 to −0.00) |
| | $p\eta^2=0.6\%$ $p=0.10$ | $p\eta^2=0.3\%$ $p=0.26$ | $p\eta^2=0.0\%$ $p=0.79$ | $p\eta^2=0.4\%$ $p=0.20$ | $p\eta^2=1.0\%$ $p=0.040$ |
| **Adjusted analysis** | | | | | |
| Factor 1[a,c] | −0.08 (−0.18 to 0.02) | 0.04 (−0.05 to 0.14) | 0.03 (−0.07 to 0.12) | 0.01 (−0.09 to 0.11) | **0.16 (0.06 to 0.26)** |
| | $p\eta^2=0.5\%$ $p=0.12$ | $p\eta^2=0.2\%$ $p=0.37$ | $p\eta^2=0.1\%$ $p=0.58$ | $p\eta^2=0.0\%$ $p=0.84$ | **$p\eta^2=2.3\%$ p = 0.0015** |
| Factor 2[b,d] | 0.07 (−0.02 to 0.16) | −0.03 (−0.11 to 0.06) | −0.05 (−0.13 to 0.04) | −0.02 (−0.11 to 0.06) | −0.00 (−0.09 to 0.08) |
| | $p\eta^2=0.5\%$ $p=0.12$ | $p\eta^2=0.1\%$ $p=0.55$ | $p\eta^2=0.3\%$ $p=0.27$ | $p\eta^2=0.1\%$ $p=0.60$ | $p\eta^2=0.0\%$ $p=0.96$ |

Health- related behavior was expressed as factors obtained from the exploratory factor analysis (details in the text). The values in bold are considered statistically significant at the Benjamini and Hochberg corrected significance level of 0.0050 (false discovery rate 0.05).
[a]EFA-derived representation of products with higher nutritional value.
[b]EFA-derived representation of products with lower nutritional value.
[c]beta coefficients (value of *p*s) for covariates: sex −0.05 ($p=0.28$), socioeconomic status 0.00 ($p=0.92$), number of inhabitants in the place of family residence 0.11 ($p=0.02$) and any chronic disease −0.01 ($p=0.85$).
[d]beta coefficients (*value of p*s) for covariates: sex 0.52 ($p<0.0001$), socioeconomic status −0.01 ($p=0.86$), number of inhabitants in the place of family residence −0.07 ($p=0.10$) and any chronic disease 0.03 ($p=0.49$).

(31). Another study carried out among patients with metabolic syndrome in Poland suggested an association between low conscientiousness and the tendency to develop metabolic syndrome which may be diet-induced (32). The role of conscientiousness in terms of health-related measures was also taken into consideration in a study on child obesity, where a positive correlation between higher conscientiousness and lower BMI was demonstrated. Additionally, the participants with a stronger expression of this personality trait had a tendency to engage more in physical activity and paid attention to their diet in terms of ingredients and regular meal rhythms (33). Furthermore, the study performed in a large sample of adult Estonians also found the link between higher conscientiousness and health-aware diet (13). A specific population of 70-year-olds also demonstrated higher conscientiousness correlated with a more favorable diet and lower BMI (35). From a different perspective, another study conducted among young adults showed an association between higher conscientiousness and greater plant-food consumption (12). It all means that the phenomenon of conscientiousness predisposing to healthier habits is very versatile and works under various circumstances.

Conscientiousness is defined as a personality trait that reflects tendencies to be hardworking, rule-following, determined and task-oriented, set on planning and achieving goals (39). It is also described as a foundation of self-discipline and the basis for regulation of internal urges, which may function as a source of control over health-related behaviors (32). This personality construct may even be a vital determinant of positive aging and general human capital (40). In this light, it becomes clear why conscientiousness, not other personality indices, predicts more favorable health behaviors. In general, medical students who were examined in this study are knowledgeable about healthy diet. However, their behavior does not necessarily reflect the knowledge. This phenomenon, referred to as the knowledge–behavior gap, may be less pronounced in highly conscientious people, particularly in an unusual context, such as examination session (41).

As high conscientiousness can lead to development of more favorable health behaviors, people with low conscientiousness may require special attention. First of all, it is important to note that people with lower conscientiousness are not devoid of this quality, it is simply weaker. Therefore, they are less likely to follow through with plans and are less motivated to achieve their goals (42). That is why it could be intriguing to explore whether personality may be modified. Although classically regarded as stable, personality traits can evolve and may be modified with specific interventions, as suggested by evidence presented in the literature (43). The possibility of personality modification is particularly the case in young adults, whose development is still in progress (44). Individuals with low conscientiousness should attempt to modify their lifestyle by introducing mechanisms that may not only improve conscientiousness attributes but also contribute to more effective stress management and a greater awareness when planning a diet. The most well-known and effective method that develops conscientiousness is the behavioral activation method (43). Applying this approach, an individual monitors his/her habits and behaviors on a daily basis and defines them in terms of importance – duty or pleasure. A person learns the structure of their day and is able to define the activities that they consider pleasurable or obligatory. Someone who is not good at planning or organization, through systematic work on learning the schedule of the day, observing at what times of the day and night they function better or perform activities more efficiently, will eventually be able to effectively manage not only their functioning, but also their diet.

When an individual does not plan to modify his or her own personality traits, e.g., conscientiousness, but wishes to improve diet, attention should be paid to issues such as self-regulation and adherence to nutritional standards (45). The ability to self-regulate is recognized by researchers as an element specific to the human race, one that distinguishes us from other species. Self-regulation is nothing other than the ability to change one's own feelings, thoughts and actions. Thanks to it, individuals are capable of inhibiting, e.g., the process of gratification which can negatively affect our diet. By learning about the three stages of self-regulation, namely a sense of duty toward nutritional standards, observation of one's own habits, and the ability to change one's behavior when it is not in accordance with the standards, one can improve daily diet (45). Food standards are the norms, patterns, values or expectations that guide an individual in the process of self-regulation. The greater the commitment and loyalty to one's own set objectives, the better an individual can expect to do when starting a healthy diet. An equally important aspect is self-efficacy (46) – the greater the belief in one's own abilities, the easier it is to achieve a goal. It is important to note, however, that the nutritional patterns we follow are also socially and culturally conditioned (45). It is worth paying attention to the characteristics of stimuli associated with general diet that reach us. We should analyze how we re-late to them, and how strongly they construct our lifestyle.

Apart from conscientiousness, the literature reports the connection between neuroticism and the tendency to consume unhealthy diet (47–50). It is manifested by a preference for sugar-containing products (sweets, chocolate, and soft drinks) (47–49). A few of the studies also found the association between higher neuroticism and increased salty food intake, along with reduced fish and vegetables consumption (47, 50). Our results did not confirm the link between neuroticism and unhealthy habits, however, this might have been a false-negative effect as some *p*-values for this link were relatively low. Especially the association between neuroticism and BMI presents some but inconclusive trend. This uncertain outcome might be a result of the fact that BMI of great majority of the participants falls within the normal range, hence the low variance and lack of discrimination of this feature by personality traits was observed. It is also worth noting that considering all the stressors reflected in high degree of anxiety and depression symptoms, the studied population appeared to collectively present "neurotic behavior," which might stifle potential dependencies involving this personality trait.

As for sociodemographic factors, among the surveyed students, there was an association found between sex and the products consumed. Men more often included such products as red and white meat, eggs, light bread and potatoes in their diet. Women, on the other hand, consumed more vegetables, fruits and nuts. These results are consistent with those obtained in other studies (51, 52) suggesting that men consume more animal-derived and fatty meals and are less likely to become vegetarians, whereas women present a greater engagement in healthy nutrition. This difference may also simply result from higher energy demand in males (30). Additionally, our results showed a positive correlation between the size of the place of residence of the family of origin and the products consumed or the lifestyle. Students coming from larger cities consumed more vegetables, fish and seafood, and paid more attention to physical activity. This may be intriguing and counterintuitive, however, it finds some confirmation in the other study linking the residence in rural areas with greater consumption of fats and oils than that observed in bigger cities (53).

The present study has several limitations. Firstly, to a large degree it is a secondary analysis of an existing database – a participant subsample has been already described with regard to consumption of fermented food and mental health in previous papers (14, 15). As such, the certainty of the reported findings may be diminished and the choice of specific food groups included in the questionnaire was dictated by the requirements of that primary study. Moreover, the sample size is relatively small for detecting weaker associations between personality traits and behavior. Secondly, personality traits were assessed based on a shortened version of a questionnaire (Big Five Inventory-Short), which relies on three items for each personality trait only. Nevertheless, the questionnaire assures its validity (18, 19). The internal consistency measures were deemed acceptable for most personality traits (54) with the exemption of Agreeableness for which Cronbach's alpha was impaired; in consequence the results for Agreeableness should be regarded with caution. Thirdly, our Food Record questionnaire neither includes all the food groups (e.g., data on consumption of sweets, coffee, alcohol and drugs was not collected, which might affect the consumption of products with low nutritional value), nor evaluates the ways in which the meals were prepared; however, the Food Record measure was additionally validated to assure its high accuracy. Moreover, we did not examine students' inhabiting conditions – whether they live with their parents, with roommates or on their own, which might have an impact on their daily dietary choices. Finally, the study is based on self-reported data (in particular physical activity might have been collected through accelerometers), and therefore may be more declarative and socially desirable.

## 5. Conclusion

Severely stressed medical students showing high conscientiousness tend to present healthier behaviors expressed as dietary patterns (more consumption of vegetables, wholegrain products, fruits and nuts) and avoiding cigarette smoking. The results are consistent with literature reports on other populations, which may suggest high versatility of the phenomenon, even in the population of high background conscientiousness. Interventions aimed at improving lifestyle habits in students with lower conscientiousness might be useful.

## Data availability statement

The dataset for this article is not publicly available due to concerns regarding participant anonymity. Requests to access the dataset should be directed to the corresponding author.

## Ethics statement

The studies involving humans were approved by Bioethics Committee of the Medical University of Lodz, Poland. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

JT: Conceptualization, Data curation, Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing.

AK: Writing – original draft. JK: Writing – original draft. EK: Funding acquisition, Validation, Writing – review & editing. MK: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This paper has been supported by the Medical University of Lodz with the grant no. 503/1-108-01/503-11-001 (received by EK).

## Acknowledgments

We thank all the medical students for their participation in the study. We also thank Agnieszka Heftowicz, a medical doctor and a dietician, for her help with the interpretation of the results.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1256883/full#supplementary-material

## References

1. Li Y, Schoufour J, Wang DD, Dhana K, Pan A, Liu X, et al. Healthy lifestyle and life expectancy free of cancer, cardiovascular disease, and type 2 diabetes: prospective cohort study. *BMJ*. (2020) 368:l6669. doi: 10.1136/bmj.l6669

2. Schultchen D, Reichenberger J, Mittl T, Weh TRM, Smyth JM, Blechert J, et al. Bidirectional relationship of stress and affect with physical activity and healthy eating. *Br J Health Psychol*. (2019) 24:315–33. doi: 10.1111/bjhp.12355

3. Acharya L, Jin L, Collins W. College life is stressful today – emerging stressors and depressive symptoms in college students. *J Am Coll Heal*. (2018) 66:655–64. doi: 10.1080/07448481.2018.1451869

4. Li X, Fu P, Fan C, Zhu M, Li M. COVID-19 stress and mental health of students in locked-down colleges. *IJERPH*. (2021) 18:771. doi: 10.3390/ijerph18020771

5. Chaturvedi K, Vishwakarma DK, Singh N. COVID-19 and its impact on education, social life and mental health of students: a survey. *Child Youth Serv Rev*. (2021) 121:105866. doi: 10.1016/j.childyouth.2020.105866

6. Elmer T, Mepham K, Stadtfeld C. Students under lockdown: comparisons of students' social networks and mental health before and during the COVID-19 crisis in Switzerland. *PLoS One*. (2020) 15:e0236337. doi: 10.1371/journal.pone.0236337

7. Bennett G, Young E, Butler I, Coe S. The impact of lockdown during the COVID-19 outbreak on dietary habits in various population groups: a scoping review. *Front Nutr*. (2021) 8:626432. doi: 10.3389/fnut.2021.626432

8. Robert M, Deschasaux-Tanguy M, Shankland R, Druesne-Pecollo N, Esseddik Y, Szabo de Edelenyi F, et al. Association between positive psychological traits and changes in dietary behaviour related to first COVID-19 lockdown: a general population-based study. *Appetite*. (2022) 171:105885. doi: 10.1016/j.appet.2021.105885

9. Suciu N, Meliț LE, Mărginean CO. A holistic approach of personality traits in medical students: an integrative review. *IJERPH*. (2021) 18:12822. doi: 10.3390/ijerph182312822

10. Lenkiewicz K, Srebnicki T, Bryńska A. Mechanisms shaping the development of personality and personality disorders in children and adolescents. *Psychiatr Pol*. (2016) 50:621–9. doi: 10.12740/PP/36180

11. Esposito CM, Ceresa A, Buoli M. The association between personality traits and dietary choices: a systematic review. *Adv Nutr*. (2021) 12:1149–59. doi: 10.1093/advances/nmaa166

12. Conner TS, Thompson LM, Knight RL, Flett JAM, Richardson AC, Brookie KL. The role of personality traits in Young adult fruit and vegetable consumption. *Front Psychol*. (2017) 8:119. doi: 10.3389/fpsyg.2017.00119

13. Mõttus R, Realo A, Allik J, Deary IJ, Esko T, Metspalu A. Personality traits and eating habits in a large sample of Estonians. *Health Psychol*. (2012) 31:806–14. doi: 10.1037/a0027041

14. Karbownik MS, Mokros Ł, Dobielska M, Kowalczyk M, Kowalczyk E. Association between consumption of fermented food and food-derived prebiotics with cognitive performance, depressive, and anxiety symptoms in psychiatrically healthy medical students under psychological stress: a prospective cohort study. *Front Nutr*. (2022) 9:850249. doi: 10.3389/fnut.2022.850249

15. Karbownik MS, Mokros Ł, Kowalczyk E. Who benefits from fermented food consumption? A comparative analysis between psychiatrically ill and psychiatrically healthy medical students. *IJERPH*. (2022) 19:3861. doi: 10.3390/ijerph19073861

16. Karbownik MS, Horne R, Paul E, Kowalczyk E, Szemraj J. Determinants of knowledge about dietary supplements among polish internet users: Nationwide cross-sectional study. *J Med Internet Res*. (2021) 23:e25228. doi: 10.2196/25228

17. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. (2008) 61:344–9. doi: 10.1016/j.jclinepi.2007.11.008

18. Strus W, Cieciuch J. Higher-order factors of the big six – similarities between big twos identified above the big five and the big six. *Personal Individ Differ*. (2021) 171:110544. doi: 10.1016/j.paid.2020.110544

19. Gerlitz JY, Schupp J. *Zur Erhebung der Big-Five-basierten Persönlichkeitsmerkmale im SOEP*. Berlin: DIW (2005).

20. Paxton AE, Strycker LA, Toobert DJ, Ammerman AS, Glasgow RE. Starting the conversation. *Am J Prev Med*. (2011) 40:67–71. doi: 10.1016/j.amepre.2010.10.009

21. Biernat E, Stupnicki R, Gajewski AK. International physical activity questionnaire (IPAQ) – polish version. *Physical Educ Sport*. (2007) 51:36–9. doi: 10.2478/v10030-007-0004-0

22. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc*. (2003) 35:1381–95. doi: 10.1249/01.MSS.0000078924.61453.FB

23. Kroenke K, Spitzer RL, Williams JBW. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med*. (2001) 16:606–13. doi: 10.1046/j.1525-1497.2001.016009606.x

24. Ślusarska B, Nowicki G, Piasecka H, Zarzycka D, Mazur A, Saran T, et al. Validation of the polish language version of the patient health Questionnaire-9 in a population of adults aged 35–64. *Ann Agric Environ Med*. (2019) 26:420–4. doi: 10.26444/aaem/99246

25. Babicki M, Mastalerz-Migas A. The occurrence of anxiety disorders among polish people during the COVID-19 pandemic. *Psychiatr Pol*. (2021) 55:497–509. doi: 10.12740/PP/OnlineFirst/126230

26. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med*. (2006) 166:1092. doi: 10.1001/archinte.166.10.1092

27. Feng Y, Huang W, Tian TF, Wang G, Hu C, Chiu HFK, et al. The psychometric properties of the quick inventory of depressive symptomatology-self-report (QIDS-SR) and the patient health Questionnaire-9 (PHQ-9) in depressed inpatients in China. *Psychiatry Res*. (2016) 243:92–6. doi: 10.1016/j.psychres.2016.06.021

28. Nowlin R.B., Brown S.K. Monitoring patient treatment outcomes in inpatient psychiatric care with the PHQ-9. Available at:: https://www.psychiatrictimes.com/view/monitoring-patient-treatment-outcomes-in-inpatient-psychiatric-care-with-the-phq-9 (Accessed May 24, 2022).

29. Karbownik MS, Kręczyńska J, Kwarta P, Cybula M, Wiktorowska-Owczarek A, Kowalczyk E, et al. Effect of supplementation with Saccharomyces Boulardii on academic examination performance and related stress in healthy medical students: a randomized, double-blind, placebo-controlled trial. *Nutrients*. (2020) 12:1469. doi: 10.3390/nu12051469

30. US Department of Agriculture and US Department of Health and Human Services. *Dietary guidelines for Americans, 2020–2025* US Government Publishing Office (2020).

31. Bessey D. Determinants of lifestyle choices among south Korean college students: an experimental analysis. *RMHP*. (2022) 15:93–105. doi: 10.2147/RMHP.S333968

32. Burnos A, Skrobowski A. Temperamental and personality traits as factors related to changes in health Behaviors and quality of life in patients with metabolic syndrome in Poland. *Front Psychol*. (2021) 12:709935. doi: 10.3389/fpsyg.2021.709935

33. Sutin AR, Terracciano A. Mother and child personality traits associated with common feeding strategies and child body mass index. *Appetite*. (2018) 125:295–301. doi: 10.1016/j.appet.2018.02.009

34. Gartland N, Wilson A, Lawton R, O'Connor DB. Conscientiousness and engagement with national health behaviour guidelines. *Psychol Health Med*. (2021) 26:421–32. doi: 10.1080/13548506.2020.1814961

35. Mõttus R, McNeill G, Jia X, Craig LCA, Starr JM, Deary IJ. The associations between personality, diet and body mass index in older people. *Health Psychol*. (2013) 32:353–60. doi: 10.1037/a0025537

36. Wilson AE, O'Connor DB, Lawton R, Hill PL, Roberts BW. Conscientiousness and fruit and vegetable consumption: exploring behavioural intention as a mediator. *Psychol Health Med*. (2016) 21:469–75. doi: 10.1080/13548506.2015.1093644

37. Steptoe A, Easterlin E, Kirschbaum C. Conscientiousness, hair cortisol concentration, and health behaviour in older men and women. *Psychoneuroendocrinology*. (2017) 86:122–7. doi: 10.1016/j.psyneuen.2017.09.016

38. Singh P. Conscientiousness moderates the relationship between neuroticism and health-risk behaviors among adolescents. *Scandinavian J Psychology*. (2022) 63:256–64. doi: 10.1111/sjop.12799

39. Javaras KN, Williams M, Baskin-Sommers AR. Psychological interventions potentially useful for increasing conscientiousness. *Personal Disord Theory Res Treat*. (2019) 10:13–24. doi: 10.1037/per0000267

40. Roberts BW, Lejuez C, Krueger RF, Richards JM, Hill PL. What is conscientiousness and how can it be assessed? *Dev Psychol*. (2014) 50:1315–30. doi: 10.1037/a0031109

41. Conner M, Rodgers W, Murray T. Conscientiousness and the intention–behavior relationship: predicting exercise behavior. *J Sport Exerc Psychol*. (2007) 29:518–33. doi: 10.1123/jsep.29.4.518

42. Mroczkowska D. Wpływ sumienności i sposobów radzenia sobie w sytuacjach stresowych na jakość życia. *Hygeia Public Health*. (2013) 48:205–10.

43. Magidson JF, Roberts BW, Collado-Rodriguez A, Lejuez CW. Theory-driven intervention for changing personality: expectancy value theory, behavioral activation, and conscientiousness. *Dev Psychol*. (2014) 50:1442–50. doi: 10.1037/a0030583

44. Roberts BW, Mroczek D. Personality trait change in adulthood. *Curr Dir Psychol Sci*. (2008) 17:31–5. doi: 10.1111/j.1467-8721.2008.00543.x

45. Kadzikowska-Wrzosek R, Szczygieł D. Samoregulacja zachowań żywieniowych: wpływ standardów oraz mechanizmów kontroli działania. *Zeszyty Naukowe Akademii Morskiej Gdyni*. (2014) 86:43–56.

46. Sekuła M, Bonieka I, Paśnik K. Assessment of health behaviors, nutritional behaviors, and self-efficacy in patients with morbid obesity. *Psychiatr Pol*. (2019) 53:1125–37. doi: 10.12740/PP/OnlineFirst/81182

47. Keller C, Siegrist M. Does personality influence eating styles and food choices? *Appetite*. (2015) 84:128–38. doi: 10.1016/j.appet.2014.10.003

48. Parker G, Crawford J. Chocolate craving when depressed: a personality marker. *Br J Psychiatry*. (2007) 191:351–2. doi: 10.1192/bjp.bp.106.033746

49. Tiainen AMK, Männistö S, Lahti M, Blomstedt PA, Lahti J, Perälä MM, et al. Personality and dietary intake–findings in the Helsinki birth cohort study. *PLoS One*. (2013) 8:e68284. doi: 10.1371/journal.pone.0068284

50. Kikuchi Y, Watanabe S. Personality and dietary habits. *J Epidemiol*. (2000) 10:191–8. doi: 10.2188/jea.10.191

51. Rosenfeld DL, Tomiyama AJ. Gender differences in meat consumption and openness to vegetarianism. *Appetite*. (2021) 166:105475. doi: 10.1016/j.appet.2021.105475

52. Grzymisławska M, Puch E, Zawada A, Grzymisławski M. Do nutritional behaviors depend on biological sex and cultural gender? *Adv Clin Exp Med*. (2020) 29:165–72. doi: 10.17219/acem/111817

53. Samaniego-Vaesken M, Partearroyo T, Ruiz E, Aranceta-Bartrina J, Gil Á, González-Gross M, et al. The influence of place of residence, gender and age influence on food group choices in the Spanish population: findings from the ANIBES study. *Nutrients*. (2018) 10:392. doi: 10.3390/nu10040392

54. Ursachi G, Horodnic IA, Zait A. How reliable are measurement scales? External factors with indirect influence on reliability estimators. *Procedia Econ Finance*. (2015) 20:679–86. doi: 10.1016/S2212-5671(15)00123-9

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 29 November 2023
DOI 10.3389/fpubh.2023.1251002

Check for updates

OPEN ACCESS

EDITED BY
Javier Benítez-Porres,
University of Malaga, Spain

REVIEWED BY
Julio Martinez-Gonzalez,
Carlos Haya Hospital (Hospital Regional Universitario de Málaga), Spain
Faxue Zhang,
Wuhan University, China

*CORRESPONDENCE
Zhou Xiang
✉ xiangzhoul5@hotmail.com

†These authors have contributed equally to this work and share first authorship

RECEIVED 30 June 2023
ACCEPTED 06 November 2023
PUBLISHED 29 November 2023

CITATION
Wang J, Xing F, Sheng N and Xiang Z (2023) Association between Life's simple 7 and rheumatoid arthritis in adult Americans: data from the National Health and nutrition examination survey.
*Front. Public Health* 11:1251002.
doi: 10.3389/fpubh.2023.1251002



# Association between Life's simple 7 and rheumatoid arthritis in adult Americans: data from the National Health and nutrition examination survey

Jie Wang†, Fei Xing†, Ning Sheng and Zhou Xiang*

Department of Orthopaedics, Orthopaedic Research Institute, West China Hospital, Sichuan University, Chengdu, Sichuan, China

**Objective:** The study aimed to investigate the relationship between Life's Simple 7 (LS7) and the risk of rheumatoid arthritis (RA) in adult Americans.

**Methods:** A total of 17,532 participants were included in this study. The association between LS7 and the risk of RA was assessed using a weighted logistic regression model, with odds ratios (ORs) and 95% confidence intervals (CIs) calculated. Moreover, the nonlinear relationship was further characterized through smooth curve fitting (SCF) and weighted generalized additive model (GAM) analysis.

**Results:** After adjusting for all covariates, the weighted logistic regression model demonstrated that the LS7 was negatively correlated with the risk of RA. Compared to quintile 1 of LS7, the OR between the risk of RA and quartile 4 of LS7 (LS7.Q4) was 0.261 (95% CI, 0.203, 0.337) in males under 50 years old, while in females of the same age group, the OR was 0.183 (95% CI, 0.142, 0.234). For females aged between 50 and 70 years old, the OR between the risk of RA and LS7.Q4 was 0.313 (95% CI, 0.264, 0.371). In females aged 70 years or older, the OR between the risk of RA and LS7.Q4 was 0.632 (95% CI, 0.486, 0.822).

**Conclusion:** This finding suggested the healthy lifestyle behaviors represented by LS7 have a negative association with RA. However, further prospective studies are needed to verify the causal relationship in the results.

KEYWORDS

**Life's simple 7, rheumatoid arthritis, cardiovascular disease, healthy lifestyle behaviors, the American Heart Association (AHA)**

## 1 Introduction

Rheumatoid arthritis (RA) is a systemic autoimmune disease characterized by symmetric polyarthritis, affecting approximately 1% of the global population (1). It can present as fever, swollen and painful joints, joint disc formation, cartilage degeneration, bone erosion, joint deformity, functional disability, and progressive disability (1). Furthermore, RA is often accompanied by other comorbidities such as cardiovascular disease (CVD), severe infections, respiratory diseases, osteoporosis, cancer and so on (2–4). Compared to the general population, RA patients have a lower quality of life, higher economic burden, and greater risk of mortality (2–4). Although studies have reported that the progression of RA is related to various genetic factors, environmental factors, and lifestyle habits, the exact cause of the disease is not yet fully understood (5, 6).

It is worth noting that the relationship between RA and CVD is particularly strong (7–10). Previous studies have shown that RA patients have a CVD risk that is approximately 48% higher than the general population (9). In addition, CVD has been identified as the primary cause of premature death and sudden deaths in RA patients, and approximately 50% of RA patients' deaths can be attributed to CVD-related causes (7, 8). Therefore, thoroughly understanding the role of CVD-related risk factors in RA patients is crucial in the early identification, prevention, and treatment of RA (7). However, while studies have indicated that various CVD-related risk factors, such as hypertension, dyslipidemia, diabetes, or dietary quality are associated with RA, the results are still controversial. Some studies have found no significant differences in these factors between RA and non-RA subjects (7, 10–12). This phenomenon may be partially explained by the fact that the occurrence and progression of RA may be the result of multiple interacting factors, with inherent interactions among various factors themselves. Although a single factor may impact RA, its impact is limited and easily influenced. Therefore, when assessing the impact of CVD-related risk factors on RA, it may be more appropriate to integrate multiple relevant factors into a comprehensive evaluation index (7, 10).

In 2010, the American Heart Association (AHA) established an ideal cardiovascular health monitoring indicator called the Life's Simple 7 (LS7) that focuses on seven health factors to prevent CVD. The seven factors are divided into three medical examination indicators, which include total serum cholesterol, blood pressure, and fasting blood glucose, and four behavioral factors, which include smoking, body mass index (BMI), physical activity, and diet (13). The LS7 has been utilized by the AHA to achieve the strategic goal of monitoring and improving the cardiovascular health of Americans until 2020 and beyond (13). Numerous studies have shown that individuals with higher LS7 scores tend to have a better quality of life, lower risk of CVD, and all-cause mortality (14, 15). Furthermore, the LS7 can also be used to assess the risk of non-CVD such as cancer (16), diabetes (17), depression (18), ocular diseases (19), and kidney disease (20).

However, to our knowledge, there are currently no studies that have assessed the relationship between the combination of health factors defined by LS7 and the incidence of RA. Therefore, this study aims to explore the association between LS7 and RA in adult Americans.

# 2 Materials and methods

## 2.1 Study population

This study utilized data from the National Health and Nutrition Examination Survey (NHANES) spanning from 2005 to 2018. NHANES gathered information from a diverse and nationally representative sample of the civilian population in the United States, using a multistage probability design. In addition, NHANES was overseen and approved by the ethical review board of the National Center for Health Statistics, and all participants provided written informed consent. The detailed inclusion and exclusion criteria for this study were presented in Figure 1.

## 2.2 Assessment of RA

RA was diagnosed by health professionals and relevant information was collected through a questionnaire. Specifically, participants were asked two questions related to arthritis. Firstly, they were asked, "Has a doctor or other health professional ever told you that you have arthritis?" Those who answered "yes" were then asked the second question: "What type of arthritis is it?" Participants who answered "RA" were included in the study. Interview data that was incomplete, as well as people who had other types of arthritis such as osteoarthritis and psoriatic arthritis, were excluded from the study to ensure the accuracy of the findings.

## 2.3 LS7 calculation

The calculation method of LS7 is based on the AHA guidelines, with seven indicators including blood pressure, total cholesterol, glycated hemoglobin (HbA1c), smoking, BMI, physical activity, and diet (21). Table 1 displayed the definition of poor (score 0), moderate (score 1), and ideal (score 2) levels of each indicator. Blood pressure was calculated as the average of three continuous measurements obtained at a mobile examination center (MEC). Total serum cholesterol in the NHANES database was measured via enzymatic methods, while HbA1c was measured using a Tosoh G7 analyzer (Tosoh, Tokyo, Japan) (18). Smoking status was identified through self-report, and BMI was calculated by trained health technicians using height and weight data. Physical activity was assessed through a questionnaire survey of the frequency and duration of moderate and high-intensity sports activities in the past 30 days. In addition, this study used the Healthy Eating Index-2015 (HEI-2015) to evaluate diet, and dietary data were obtained from two 24-h recall interviews conducted by NHANES. The first interview was conducted at a MEC, and the second interview was conducted via telephone 3 to 10 days after the first interview. The average of the two 24-h recall data was calculated and used as the dietary data for this study. The sum of the scores for all seven indicators is the final LS7 score.

## 2.4 Covariates

Based on existing literature and clinical experience, this study selected covariates including age (<50 years, 50–70 years, ≥70 years), Sex (male, female), race (Mexican Americans, other Hispanic, non-Hispanic White, non-Hispanic Black, other race), educational level (less than 9th grade, 9–11th grade, high school, some college, college graduate), marital status (married, widowed, divorced, separated, never married, living with partner), and poverty income ratio (PIR) (<1, 1–3, ≥3), alcohol consumption (drink/d), and the estimated glomerular filtration rate (eGFR), which was calculated based on the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation (22).

## 2.5 Statistical analysis

All analyses were conducted using the sampling weights according to the NHANES sampling criteria. Means and proportions were used

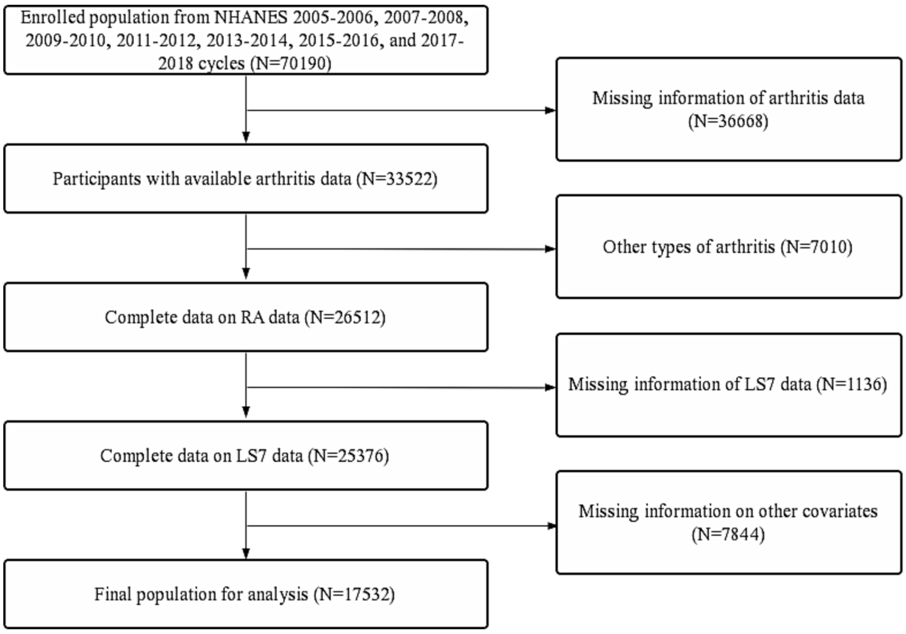



FIGURE 1
Flow diagram of inclusion criteria and exclusion criteria. NHANES, National Health and Nutrition Examination Survey; LS7, Life's Simple 7; RA, rheumatoid arthritis.

TABLE 1 The Life's Simple 7 scheme.

| | Score | | |
|---|---|---|---|
| | Poor (0) | Intermediate (1) | Ideal (2) |
| Blood pressure | Treated BP ≥140/90 mm Hg, and BP ≥140/90 mm Hg | SBP 120 to 139 mm Hg or DBP 80 to 89 mm Hg or treated to <120/80 mm Hg | <120/80 mm Hg, without BP-lowering meds |
| Total cholesterol | ≥240 mg/dL | 200 to 239 mg/dL or treated to <200 mg/dL | <200 mg/dL, without lipid-lowering medication |
| Glucose/diabetes | HbA1c >6.4% | HbA1c 5.7 to 6.4% or treated with insulin or oral meds to HbA1c <5.7% | HbA1c <5.7%, without meds |
| Smoking | Current smoker | Former smoker | Never smoker |
| Body weight | BMI ≥30 kg/m$^2$ | 25 to 29.9 kg/m$^2$ | <25 kg/m$^2$ |
| Physical activity | No activity | 1 to 149 min moderate/vigorous per week | ≥150 min moderate/vigorous per week |
| Diet | HEI <50 | HEI 50 to 80 | HEI >80 |

BMI, body mass index; BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HbA1c, hemoglobin A1c; HEI, healthy eating index.

to describe continuous and categorical variables, respectively. Student's t-test was used to compare continuous variables between the RA group and the non-RA group, while chi-square test was used for categorical variables. We evaluated the association between LS7 and RA risk using a weighted logistic regression model, which calculated odds ratios (ORs) and 95% confidence intervals (CIs). Nonlinear relationships were characterized using smooth curve fitting (SCF) and weighted generalized additive models (GAMs). Additionally, we conducted subgroup analyses using a weighted logistic regression model based on age and sex. To ensure robustness of data analysis, LS7 values were classified into quartiles, and linear trend tests were conducted. The same steps were followed to evaluate the relationship between LS7 quartiles [(LS7.Q)] and RA risk. Model 1 was not adjusted for covariates. Model 2 was adjusted for age (if applicable), sex (if applicable), and race. In Model 3, covariate adjustment included age (if applicable), sex (if applicable), race, educational level, marital status, PIR, eGFR, and alcohol consumption. We also incorporated missing variables in the covariates as dummy variables and included other types of arthritis in Non-RA group to performed the sensitivity analysis. The ability of LS7 to identify RA was analyzed using the receiver operating characteristic (ROC) curve. The cut-off value for LS7 to identify RA was determined based on the maximum Youden index (sensitivity + specificity - 1). Additionally, the usefulness of the LS7 cut-off value in assessing RA was evaluated using sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).

All analyses were performed using R software (version 4.0.3) and EmpowerStats (version 2.0). A two-sided value of p less than 0.05 was set to determine statistical significance.

# 3 Results

## 3.1 Baseline characteristics of participants

Initially, data from 70,190 participants were collected by merging the continuous NHANES cycles from 2005–2006, 2007–2008, 2009–2010, 2011–2012, 2013–2014, 2015–2016, and 2017–2018. Participants with missing data on arthritis ($n = 36{,}668$) and arthritis other than RA ($n = 7{,}010$) were excluded, along with those with missing data on LS7 ($n = 1{,}136$) and other covariates ($n = 7{,}844$). The final analysis included 17,532 participants (Figure 1). Compared to the non-RA group, the RA group had a significantly higher prevalence of diabetes (10.5% vs. 20.0%, $p < 0.001$), hypertension (25.7% vs. 54.2%, $p < 0.001$), and CVD (5.1% vs. 18.9%, $p < 0.001$). Furthermore, the RA group had significantly lower LS7 values than the non-RA group (8.7 ± 2.3 vs. 7.3 ± 2.2, $p < 0.001$). The analysis of other variables revealed that RA patients were generally older, female, non-Hispanic white, overweight, impoverished, widowed, had lower levels of education, smoked more, drunk less, exercised less, had higher serum total cholesterol levels, and poorer kidney function ($p < 0.05$, Table 2).

## 3.2 Association between LS7 and RA

### 3.2.1 Total analyses

In the weighted logistic regression model, LS7 showed a negative correlation with RA risk in Model 1. This trend remained stable even after adjusting for confounding factors in Model 2 (age, sex, and race) and Model 3 (all covariates), as demonstrated in Table 3. When LS7 was divided into quartiles, ORs between the risk of RA and LS7 across quintiles 2 (LS7.Q2), 3 (LS7.Q3), and 4 (LS7.Q4) compared with quintile 1 (LS7.Q1) in Model 1 were 0.681 (95% CI, 0.624, 0.744), 0.664 (95% CI, 0.619, 0.712) and 0.364 (95% CI, 0.335, 0.397), respectively. After adjusting for covariates in Model 2, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 were found to be 0.678 (95% CI, 0.621, 0.741), 0.653 (95% CI, 0.609, 0.701) and 0.354 (95% CI, 0.325, 0.386), respectively. Further adjusting for covariates in Model 3, the results showed that ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 were found to be 0.685 (95% CI, 0.627, 0.749), 0.692 (95% CI, 0.644, 0.744) and 0.398 (95% CI, 0.364, 0.435), respectively (Table 4). Notably, trend tests indicated a linear association between LS7 quartiles and RA diagnosis ($p$ for trend <0.05, Table 4). The SCF and GAM models also exhibited similar trends, as depicted in Figure 2A.

### 3.2.2 Subgroup analyses

After stratifying the participants by sex or age, the negative correlation trend between LS7 and RA risk remained robust, as shown in Table 3. The negative correlation was further confirmed by the SCF and GAM models (Figures 2B,C). In the male population, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 compared with LS7.Q1 in Model 1 were 0.701 (95% CI, 0.608, 0.809), 0.726 (95% CI, 0.649, 0.812) and 0.623 (95% CI, 0.549, 0.707), respectively. After adjusting for covariates, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 in Model 2 were 0.698 (95% CI, 0.605, 0.805), 0.716 (95% CI, 0.640, 0.802) and 0.604 (95% CI, 0.532, 0.685), respectively. Further adjusting for covariates in Model 3, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 were 0.680 (95% CI, 0.589, 0.786), 0.738 (95% CI, 0.658, 0.827) and 0.647 (95% CI, 0.568, 0.737), respectively (Table 4). In the female population, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 in Model 1 were 0.664 (95% CI, 0.594, 0.743), 0.624 (95% CI, 0.570, 0.683) and 0.249 (95% CI, 0.222, 0.280), respectively. After adjusting for covariates, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 in Model 2 were 0.663 (95% CI, 0.592, 0.742), 0.611 (95% CI, 0.558, 0.670) and 0.242 (95% CI, 0.215, 0.272), respectively. Further adjusting for covariates in Model 3, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 were 0.685 (95% CI, 0.611, 0.767), 0.658 (95% CI, 0.599, 0.722) and 0.281 (95% CI, 0.248, 0.318), respectively (Table 4).

In the participants aged below 50 years, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 in Model 1 were 0.771 (95% CI, 0.643, 0.924), 0.616 (95% CI, 0.533, 0.710) and 0.195 (95% CI, 0.165, 0.231), respectively. After adjusting for covariates, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 in Model 2 were 0.758 (95% CI, 0.632, 0.910), 0.606 (95% CI, 0.525, 0.700) and 0.187 (95% CI, 0.157, 0.221), respectively. Further adjusting for covariates in Model 3, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 were 0.735 (95% CI, 0.611, 0.884)), 0.640 (95% CI, 0.553, 0.741) and 0.220 (95% CI, 0.184, 0.262), respectively (Table 4). In the participants aged between 50 and 70 years, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 in Model 1 were 0.584 (95% CI, 0.515, 0.661), 0.674 (95% CI, 0.612, 0.742) and 0.492 (95% CI, 0.440, 0.550), respectively. After adjusting for covariates, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 in Model 2 were 0.582 (95% CI, 0.514, 0.659), 0.669 (95% CI, 0.607, 0.736) and 0.484 (95% CI, 0.433, 0.542), respectively. Further adjusting for covariates in Model 3, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 were 0.596 (95% CI, 0.525, 0.677), 0.708 (95% CI, 0.642, 0.782) and 0.540 (95% CI, 0.480, 0.607), respectively (Table 4). In the participants aged 70 years or older, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 in Model 1 were 0.785 (95% CI, 0.663, 0.930), 0.625 (95% CI, 0.538, 0.725) and 0.528 (95% CI, 0.429, 0.649), respectively. After adjusting for covariates, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 in Model 2 were 0.792 (95% CI, 0.668, 0.940), 0.625 (95% CI, 0.538, 0.726) and 0.533 (95% CI, 0.433, 0.655), respectively. Further adjusting for covariates in Model 3, ORs between the risk of RA and LS7 across LS7.Q2, LS7.Q3, and LS7.Q4 were 0.803 (95% CI, 0.676, 0.955), 0.652 (95% CI, 0.559, 0.760) and 0.587 (95% CI, 0.473, 0.728), respectively (Table 4).

When the participants were further cross-stratified by age and sex, the negative association between LS7 and RA risk was mainly presented in males under 50 years old, while it was gratifying that this negative correlation is significant in female populations of all age groups (Table 3). The results of the SCF and GAM models in Figure 3 further characterize this relationship. After adjusting for all covariates, ORs between the risk of RA and LS7.Q4 in Model 3 were also compared for different populations. In males under 50 years old, the OR between the risk of RA and LS7.Q4 was 0.261 (95% CI, 0.203,

TABLE 2 Weighted characteristics of the study population.

| | Non-RA (N = 16,124) | RA (N = 1,408) | *p* value |
|---|---|---|---|
| Age (%) | | | <0.001 |
| <50 | 65.9 | 22.9 | |
| ≥50, <70 | 27 | 52.8 | |
| ≥70 | 7.1 | 24.3 | |
| Sex (%) | | | <0.001 |
| male | 50.6 | 38.4 | |
| female | 49.4 | 61.6 | |
| Race (%) | | | <0.001 |
| Mexican Americans | 9.2 | 4.0 | |
| other Hispanic | 5.7 | 3.3 | |
| non-Hispanic White | 67.1 | 76.6 | |
| non-Hispanic Black | 10.6 | 10.3 | |
| other race | 7.5 | 5.9 | |
| BMI (%) | | | <0.001 |
| <25 | 31.9 | 23.1 | |
| ≥25, <30 | 33.8 | 32.9 | |
| ≥30 | 34.2 | 44.0 | |
| PIR (%) | | | 0.001 |
| <1 | 12.9 | 15.2 | |
| ≥1, <3 | 34.8 | 37.9 | |
| ≥3 | 52.3 | 46.9 | |
| Educational level (%) | | | <0.001 |
| less than 9th grade | 3.9 | 5.7 | |
| 9–11th grade | 9.2 | 11.6 | |
| high school | 22.3 | 25.6 | |
| some college | 31.3 | 32.7 | |
| college graduate | 33.2 | 24.4 | |
| Marital status (%) | | | <0.001 |
| married | 56.5 | 59.9 | |
| widowed | 3.1 | 12.2 | |
| divorced | 9.4 | 13.5 | |
| separated | 2.1 | 2.6 | |
| never married | 19.9 | 7.6 | |
| living with partner | 9.0 | 4.2 | |
| CVD (%) | | | <0.001 |
| No | 94.9 | 81.1 | |
| Yes | 5.1 | 18.9 | |
| Diabetes status (%) | | | <0.001 |
| No | 81.8 | 70.1 | |
| Yes | 10.5 | 20.0 | |
| borderline | 7.7 | 9.9 | |
| Hypertension status (%) | | | <0.001 |
| No | 74.3 | 45.8 | |
| Yes | 25.7 | 54.2 | |
| eGFR (mL/(min · 1.73 $m^2$), %) | | | <0.001 |

*(Continued)*

TABLE 2 (Continued)

| | Non-RA (N = 16,124) | RA (N = 1,408) | *p* value |
|---|---|---|---|
| <60 | 4.6 | 14 | |
| ≥60, <90 | 28.4 | 48.9 | |
| ≥90 | 67 | 37.1 | |
| Smoking (%) | | | <0.001 |
| Never | 58.7 | 45.8 | |
| Former | 22.5 | 36 | |
| Current | 18.8 | 18.2 | |
| Moderate or vigorous activity (%) | | | <0.001 |
| No | 38.5 | 49.2 | |
| Yes | 61.5 | 50.8 | |
| Alcohol consumption (drink/d, mean ± SD) | 1.5 ± 3.3 | 1.0 ± 2.5 | <0.001 |
| Total cholesterol (mg/dL) | 193.5 ± 40.8 | 199.8 ± 42.6 | <0.001 |
| LS7 | 8.7 ± 2.3 | 7.3 ± 2.2 | <0.001 |
| HEI-2015 | | | |
| Total Scores | 50.5 ± 13.8 | 51.1 ± 13.9 | 0.221 |
| Total Vegetables | 3.0 ± 1.7 | 3.1 ± 1.7 | 0.623 |
| Greens and Beans | 1.6 ± 2.2 | 1.3 ± 2.0 | <0.001 |
| Total Fruits | 1.9 ± 2.0 | 2.3 ± 2.1 | <0.001 |
| Whole Fruits | 2.0 ± 2.2 | 2.3 ± 2.2 | <0.001 |
| Whole Grains | 2.4 ± 3.2 | 2.7 ± 3.4 | 0.005 |
| Dairy | 5.1 ± 3.4 | 5.1 ± 3.4 | 0.893 |
| Total Protein Foods | 4.2 ± 1.3 | 4.1 ± 1.3 | 0.063 |
| Seafood and Plant | 2.3 ± 2.3 | 2.2 ± 2.2 | 0.055 |
| Fatty Acids | 5.0 ± 3.6 | 4.7 ± 3.6 | 0.017 |
| Sodium | 4.4 ± 3.5 | 4.7 ± 3.5 | 0.003 |
| Refined Grains | 6.1 ± 3.7 | 6.5 ± 3.6 | 0.002 |
| Saturated Fats | 5.9 ± 3.5 | 5.6 ± 3.6 | 0.010 |
| Added Sugars | 6.6 ± 3.4 | 6.5 ± 3.5 | 0.262 |

RA, rheumatoid arthritis; CVD, cardiovascular disease; HEI, healthy eating index; PIR, poverty income ratio; BMI, body mass index; eGFR, estimated glomerular filtration rate; SD, standard deviation; %, weighted percentage.

0.337), while in females of the same age group, the OR was 0.183 (95% CI, 0.142, 0.234). For females aged between 50 and 70 years old, the OR between the risk of RA and LS7.Q4 was 0.313 (95% CI, 0.264, 0.371). In females aged 70 years or older, the OR between the risk of RA and LS7.Q4 was 0.632 (95% CI, 0.486, 0.822). The robustness of the negative correlation between LS7 and RA was validated by the results of the sensitivity analysis (Appendix 1 and 2). All *p*-values for trend were < 0.05 according to Table 4.

### 3.2.3 ROC curve

The ability of LS7 to detect RA was assessed using ROC curve analysis. As shown in the Figure 4, the area under the curve (AUC) of the ROC curve was 0.672 (95% CI, 0.659, 0.686). The LS7 score identified a cutoff value of 7.5 based on the highest Youden index, with a sensitivity of 59.1% and specificity of 65.6%. The PPV and NPV were 13.0 and 94.8%, respectively.

## 4 Discussion

Based on a representative sample of adult Americans in the NHANES database, we found a negative correlation between LS7 scores and the risk of RA. Interestingly, the negative correlation was more pronounced in males of lower (under 50 years) age groups, while in females, this correlation held true across all age groups. Our results imply that a lifestyle reflective of LS7 may confer protective effects against RA, thus highlighting the importance of lifestyle choices in the prevention of this disease. In addition, when the LS7 score was determined to have a cutoff value of 7.5 based on the highest Youden index, the NPV in this study reached as high as 94.8%. This demonstrates its excellent screening value for identifying RA-negative patients. To our knowledge, this study is the first to explore the potential connection between LS7-based lifestyle and RA risk and provides novel insights into the role of lifestyle in disease prevention.

TABLE 3 Association of the LS7 and the risk of RA.

| | Male | Female | Total |
|---|---|---|---|
| Age < 50 | | | |
| Model 1 β (95% CI) *p* value | 0.826 (0.796, 0.856) <0.001 | 0.738 (0.715, 0.762) <0.001 | 0.775 (0.757, 0.794) <0.001 |
| Model 2 β (95% CI) *p* value | 0.812 (0.783, 0.843) <0.001 | 0.739 (0.716, 0.763) <0.001 | 0.770 (0.752, 0.789) <0.001 |
| Model 3 β (95% CI) *p* value | 0.813 (0.782, 0.845) <0.001 | 0.761 (0.735, 0.788) <0.001 | 0.790 (0.771, 0.811) <0.001 |
| Age ≥ 50, <70 | | | |
| Model 1 β (95% CI) *p* value | 0.985 (0.958, 1.012) 0.267 | 0.839 (0.821, 0.858) <0.001 | 0.893 (0.878, 0.908) <0.001 |
| Model 2 β (95% CI) *p* value | 0.987 (0.960, 1.015) 0.350 | 0.832 (0.813, 0.851) <0.001 | 0.891 (0.876, 0.906) <0.001 |
| Model 3 β (95% CI) *p* value | 0.990 (0.961, 1.019) 0.480 | 0.856 (0.836, 0.877) <0.001 | 0.907 (0.891, 0.924) <0.001 |
| Age ≥ 70 | | | |
| Model 1 β (95% CI) *p* value | 0.910 (0.864, 0.958) <0.001 | 0.889 (0.856, 0.923) <0.001 | 0.896 (0.869, 0.924) <0.001 |
| Model 2 β (95% CI) *p* value | 0.909 (0.863, 0.958) <0.001 | 0.894 (0.860, 0.929) <0.001 | 0.898 (0.871, 0.927) <0.001 |
| Model 3 β (95% CI) *p* value | 0.931 (0.881, 0.984) 0.011 | 0.908 (0.871, 0.946) <0.001 | 0.914 (0.885, 0.945) <0.001 |
| Total | | | |
| Model 1 β (95% CI) *p* value | 0.923 (0.904, 0.941) <0.001 | 0.819 (0.806, 0.833) <0.001 | 0.858 (0.847, 0.869) <0.001 |
| Model 2 β (95% CI) *p* value | 0.918 (0.900, 0.937) <0.001 | 0.815 (0.802, 0.829) <0.001 | 0.854 (0.843, 0.865) <0.001 |
| Model 3 β (95% CI) *p* value | 0.928 (0.909, 0.948) <0.001 | 0.834 (0.820, 0.849) <0.001 | 0.870 (0.858, 0.881) <0.001 |

Model 1: no covariates were adjusted.
Model 2: age (if applicable), sex (if applicable), and race were adjusted.
Model 3: age (if applicable), sex (if applicable), race, educational level, marital status, PIR, eGFR, and alcohol consumption were adjusted.
RA, rheumatoid arthritis; LS7, Life's Simple 7; PIR, poverty income ratio; eGFR, estimated glomerular filtration rate; SD, standard deviation; %, weighted percentage.

TABLE 4 Association of the LS7.Q and the risk of RA.

| | Male | Female | Total |
|---|---|---|---|
| Age < 50 | | | |
| Model 1 β (95% CI) *p* value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.737 (0.562, 0.966) 0.027 | 0.796 (0.622, 1.017) 0.068 | 0.771 (0.643, 0.924) 0.005 |
| Q3 | 0.656 (0.532, 0.809) <0.001 | 0.577 (0.475, 0.703) <0.001 | 0.616 (0.533, 0.710) <0.001 |
| Q4 | 0.294 (0.231, 0.374) <0.001 | 0.140 (0.110, 0.177) <0.001 | 0.195 (0.165, 0.231) <0.001 |
| Model 2 β (95% CI) *p* value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.689 (0.525, 0.904) 0.007 | 0.814 (0.636, 1.041) 0.101 | 0.758 (0.632, 0.910) 0.003 |
| Q3 | 0.612 (0.496, 0.755) <0.001 | 0.592 (0.486, 0.721) <0.001 | 0.606 (0.525, 0.700) <0.001 |
| Q4 | 0.266 (0.209, 0.339) <0.001 | 0.140 (0.111, 0.178) <0.001 | 0.187 (0.157, 0.221) <0.001 |
| Model 3 β (95% CI) *p* value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.635 (0.481, 0.838) 0.001 | 0.808 (0.630, 1.036) 0.093 | 0.735 (0.611, 0.884) 0.001 |
| Q3 | 0.596 (0.480, 0.741) <0.001 | 0.628 (0.514, 0.768) <0.001 | 0.640 (0.553, 0.741) <0.001 |
| Q4 | 0.261 (0.203, 0.337) <0.001 | 0.183 (0.142, 0.234) <0.001 | 0.220 (0.184, 0.262) <0.001 |
| P trend | <0.001 | <0.001 | <0.001 |
| Age ≥ 50, <70 | | | |
| Model 1 β (95% CI) *p* value | | | |
| LS7.Q | | | |

*(Continued)*

TABLE 4 (Continued)

| | Male | Female | Total |
|---|---|---|---|
| Q1 | 1 | 1 | 1 |
| Q2 | 0.540 (0.434, 0.671) <0.001 | 0.597 (0.512, 0.696) <0.001 | 0.584 (0.515, 0.661) <0.001 |
| Q3 | 0.705 (0.601, 0.827) <0.001 | 0.648 (0.574, 0.731) <0.001 | 0.674 (0.612, 0.742) <0.001 |
| Q4 | 1.005 (0.856, 1.180) 0.948 | 0.276 (0.236, 0.324) <0.001 | 0.492 (0.440, 0.550) <0.001 |
| Model 2 β (95% CI) *p* value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.540 (0.434, 0.671) <0.001 | 0.591 (0.507, 0.690) <0.001 | 0.582 (0.514, 0.659) <0.001 |
| Q3 | 0.702 (0.598, 0.824) <0.001 | 0.625 (0.553, 0.707) <0.001 | 0.669 (0.607, 0.736) <0.001 |
| Q4 | 1.031 (0.876, 1.212) 0.716 | 0.262 (0.223, 0.307) <0.001 | 0.484 (0.433, 0.542) <0.001 |
| Model 3 β (95% CI) *p* value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.524 (0.420, 0.654) <0.001 | 0.620 (0.530, 0.727) <0.001 | 0.596 (0.525, 0.677) <0.001 |
| Q3 | 0.691 (0.587, 0.813) <0.001 | 0.694 (0.611, 0.789) <0.001 | 0.708 (0.642, 0.782) <0.001 |
| Q4 | 1.061 (0.897, 1.256) 0.490 | 0.313 (0.264, 0.371) <0.001 | 0.540 (0.480, 0.607) <0.001 |
| P trend | 0.995 | <0.001 | <0.001 |
| Age ≥ 70 | | | |
| Model 1 β (95% CI) *p* value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.966 (0.736, 1.268) 0.804 | 0.692 (0.557, 0.859) <0.001 | 0.785 (0.663, 0.930) 0.005 |
| Q3 | 0.751 (0.591, 0.955) 0.019 | 0.558 (0.461, 0.675) <0.001 | 0.625 (0.538, 0.725) <0.001 |
| Q4 | 0.463 (0.316, 0.680) <0.001 | 0.553 (0.432, 0.709) <0.001 | 0.528 (0.429, 0.649) <0.001 |
| Model 2 β (95% CI) *p* value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.967 (0.736, 1.270) 0.808 | 0.704 (0.566, 0.875) 0.002 | 0.792 (0.668, 0.940) 0.007 |
| Q3 | 0.735 (0.578, 0.936) 0.012 | 0.567 (0.467, 0.687) <0.001 | 0.625 (0.538, 0.726) <0.001 |
| Q4 | 0.467 (0.318, 0.686) <0.001 | 0.563 (0.438, 0.723) <0.001 | 0.533 (0.433, 0.655) <0.001 |
| Model 3 β (95% CI) P value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.955 (0.721, 1.265) 0.748 | 0.723 (0.579, 0.904) 0.004 | 0.803 (0.676, 0.955) 0.013 |
| Q3 | 0.782 (0.610, 1.004) 0.054 | 0.581 (0.475, 0.709) <0.001 | 0.652 (0.559, 0.760) <0.001 |
| Q4 | 0.538 (0.361, 0.802) 0.002 | 0.632 (0.486, 0.822) <0.001 | 0.587 (0.473, 0.728) <0.001 |
| P trend | 0.002 | <0.001 | <0.001 |
| Total | | | |
| Model 1 β (95% CI) P value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.701 (0.608, 0.809) <0.001 | 0.664 (0.594, 0.743) <0.001 | 0.681 (0.624, 0.744) <0.001 |
| Q3 | 0.726 (0.649, 0.812) <0.001 | 0.624 (0.570, 0.683) <0.001 | 0.664 (0.619, 0.712) <0.001 |
| Q4 | 0.623 (0.549, 0.707) <0.001 | 0.249 (0.222, 0.280) <0.001 | 0.364 (0.335, 0.397) <0.001 |

*(Continued)*

10.3389/fpubh.2023.1251002

TABLE 4 (Continued)

| | Male | Female | Total |
|---|---|---|---|
| Model 2 β (95% CI) P value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.698 (0.605, 0.805) <0.001 | 0.663 (0.592, 0.742) <0.001 | 0.678 (0.621, 0.741) <0.001 |
| Q3 | 0.716 (0.640, 0.802) <0.001 | 0.611 (0.558, 0.670) <0.001 | 0.653 (0.609, 0.701) <0.001 |
| Q4 | 0.604 (0.532, 0.685) <0.001 | 0.242 (0.215, 0.272) <0.001 | 0.354 (0.325, 0.386) <0.001 |
| Model 3 β (95% CI) *p* value | | | |
| LS7.Q | | | |
| Q1 | 1 | 1 | 1 |
| Q2 | 0.680 (0.589, 0.786) <0.001 | 0.685 (0.611, 0.767) <0.001 | 0.685 (0.627, 0.749) <0.001 |
| Q3 | 0.738 (0.658, 0.827) <0.001 | 0.658 (0.599, 0.722) <0.001 | 0.692 (0.644, 0.744) <0.001 |
| Q4 | 0.647 (0.568, 0.737) <0.001 | 0.281 (0.248, 0.318) <0.001 | 0.398 (0.364, 0.435) <0.001 |
| P trend | <0.001 | <0.001 | <0.001 |

Model 1: no covariates were adjusted.
Model 2: age (if applicable), sex (if applicable), and race were adjusted.
Model 3: age (if applicable), sex (if applicable), race, educational level, marital status, PIR, eGFR, and alcohol consumption were adjusted.
RA, rheumatoid arthritis; LS7.Q, quartile of Life's Simple 7; PIR, poverty income ratio; eGFR, estimated glomerular filtration rate; SD, standard deviation; %, weighted percentage.

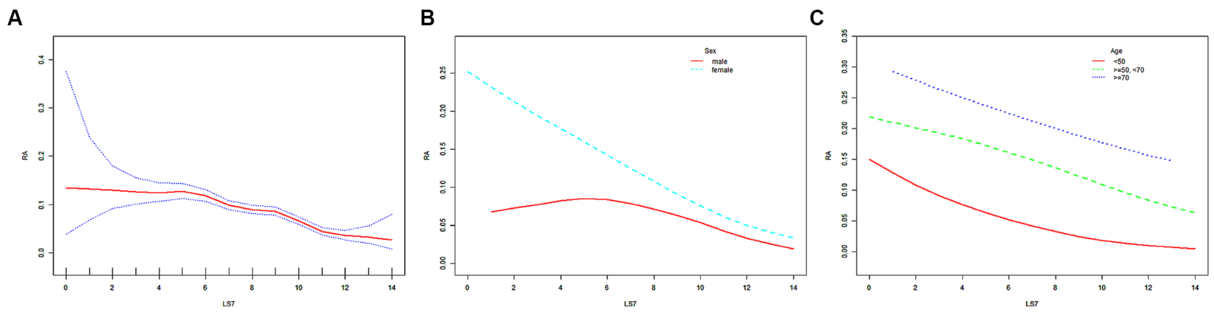



FIGURE 2
The SCF for the associations of LS7 with the risk of RA. Age (in **A,B**), sex (in **A,C**), race, educational level, marital status, PIR, eGFR, and alcohol consumption were adjusted. RA, rheumatoid arthritis; LS7, Life's Simple 7; PIR, poverty income ratio; eGFR, estimated glomerular filtration rate; SD, standard deviation; %, weighted percentage. The vertical axis represented the probability of RA.

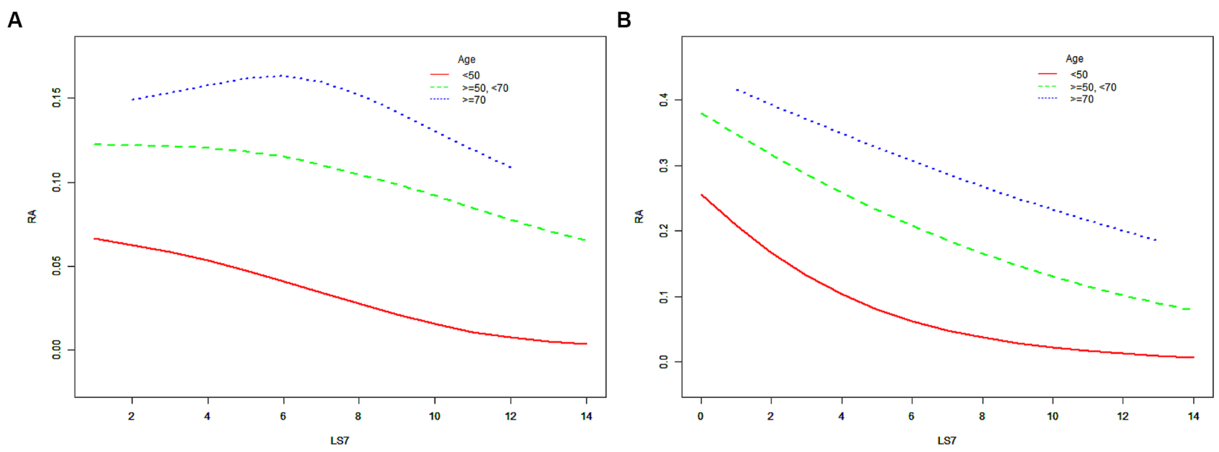



FIGURE 3
The SCF for the associations of LS7 with the risk of RA when the participants were further cross-stratified by age and sex. **(A)** male; **(B)** female. Race, educational level, marital status, PIR, eGFR, and alcohol consumption were adjusted. RA, rheumatoid arthritis; LS7, Life's Simple 7; PIR, poverty income ratio; eGFR, estimated glomerular filtration rate; SD, standard deviation; %, weighted percentage. The vertical axis represented the probability of RA.

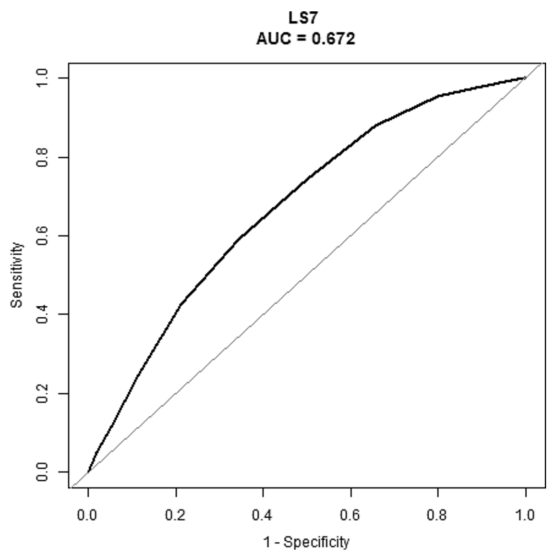



FIGURE 4
ROC of the LS7 to detect the risk of RA. RA, rheumatoid arthritis; LS7, Life's Simple 7; ROC, receiver operating characteristic; AUC, area under the curve.

Previous researches have linked individual components of LS7, such as smoking, obesity, diabetes, hypertension, high cholesterol, and less physical activity with an increased risk of RA (5, 23–27). Similarly, our study found that RA patients had a higher prevalence of diabetes, hypertension, overweight, elevated serum cholesterol, more smoking history, and lower physical activity levels compared to those without RA. Additionally, multiple studies have established shared mechanisms between RA and CVD, including inflammation mediators, changes in lipoprotein function and composition, peptide/protein modifications, increased oxidative stress, subsequent immune response, and endothelial dysfunction (7, 8, 28). CVD-related risk factors can impact RA through these shared mechanisms. For example, environmental factors like smoking, obesity, diabetes, and physical inactivity can induce immune dysfunction in susceptible individuals, resulting in increased production of pro-inflammatory cytokines such as interleukin-8 (IL-8), IL-17A, and tumor necrosis factor-alpha by inflammatory cells, and subsequent excessive production of neutrophil extracellular traps (NETs) (29, 30). Although NETs are antimicrobial structures made up of lysates and granule proteins from activated neutrophils, excessive formation of NETs can result in damage to vital organs, including the cardiovascular system, and increase the risk of immune-related diseases such as RA (29, 30). Therefore, the association between comprehensive LS7 scores and RA may be not surprising.

In fact, the high score of LS7 represents a healthy and upward lifestyle (31). Its significance for RA is not limited to its role in the origin of RA, but also in improving the quality of life of RA patients (23–26, 32–34). Numerous observational studies have highlighted the benefits of quitting smoking in mitigating RA-related outcomes, which has been supported by animal studies (32, 33). For instance, Donate et al. demonstrated that smoking can activate the aryl hydrocarbon receptor on Th17 cells in RA patients, thereby upregulating miR-132 and inhibiting the induction of cyclooxygenase-2, resulting in worsened arthritis inflammation and bone destruction (32). Recent toxic mechanism study conducted by Heluany et al. has also demonstrated that smoking can exacerbate joint symptoms, lung inflammation and lung metallothionein expression, and cause toxic damage to splenocytes by activating the nicotine/α7 nicotinic acetylcholine receptor pathway (33). Regarding physical exercise, many randomized trials have emphasized its benefits for RA patients' pain and disability (34). Meanwhile, literature reviews conducted by Metsios et al. and Verhoeven et al. have further highlighted the benefits of physical exercise, including improvement in self-esteem, reduction in depressive symptoms, better sleep quality, and reduced pain, and recommended that RA patients regularly engage in moderate aerobic exercise (25, 26). In addition, factors such as BMI, blood glucose, blood pressure, and total cholesterol are highly correlated with metabolic syndrome. As the crossroads of RA and related CVD, it is well known that improving metabolic syndrome benefits the progression of RA and related CVD diseases (23, 24). Moreover, extensive prior research has emphasized the importance of maintaining a healthy and balanced diet for individuals with RA (35–38). Several systematic reviews have indicated that supplementing with foods containing polyunsaturated fatty acids, vitamin D, quercetin, and probiotics containing lactobacillus can reduce RA disease activity and decrease the failure rate of drug therapy, providing a protective effect against the development of RA. Conversely, studies have suggested that RA patients should limit their consumption of red meat and sodium (35–38). Evidence indicated that the underlying mechanism by which dietary factors impact RA may be associated with alterations in gut microbiota (39, 40).

This study has several strengths. Firstly, it is the first study to investigate the relationship between the cumulative effects of CVD-related risk factors, as represented by LS7, and RA risk. Secondly, the study leveraged a large, nationally representative database with standardized data collection protocols, which reduces potential biases. Thirdly, the study conducted subgroup analyses based on sex and age groups and classified LS7 into quartiles, adding to the robustness of the data analysis. However, this study also has limitations. Firstly, the cross-sectional nature of the data means that there may be insufficient evidence to infer causality. Secondly, data collection methods, such as questionnaires and interviews, may introduce recall bias. Thirdly, although the study adjusted for covariates, unmeasured confounding factors may still exist. Finally, this study did not investigate the correlation between LS7 and biomarkers for RA, such as rheumatoid factor, as there was insufficient data available. Furthermore, it is worth noting that this study did not evaluate important indicators of RA severity and physical function, such as the clinical disease activity index, disease activity score with 28-joint count, or simplified disease activity index (4). This emphasizes the importance of conducting future prospective studies to address this gap in knowledge.

## 5 Conclusion

In conclusion, the results of this study indicated that adult Americans with a higher LS7 have a lower risk of RA. This finding suggested a negative association between the healthy lifestyle behaviors represented by LS7 with RA. However, further prospective studies are needed to verify the causal relationship in the results.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

NHANES was approved by the National Center for Health Statistics Research Ethics Review Board.

## Author contributions

JW, FX, and NS: conceptualization and investigation. JW: methodology, analysis, and writing original draft. JW, FX, NS, and ZX: writing—review and editing. All authors contributed to the article and approved the submitted version.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work was supported by the National Natural Science Foundation of China (82202705), and the Project of the Science and Technology Department of Sichuan Province (grant no. 2023NSFSC1738), and Clinical Research Incubation project of West China Hospital of Sichuan University (2019HXFH041), and the Sino-German Center for Research Promotion (GZ1219).

## Acknowledgments

The authors would like to express their gratitude to the NHANES database, for the data sources in this study.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1251002/full#supplementary-material

## References

1. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. *Bull World Health Organ*. (2003) 81:646–56.

2. Smolen JS, Aletaha D, McInnes IB. Rheumatoid arthritis. *Lancet*. (2016) 388:2023–38. doi: 10.1016/S0140-6736(16)30173-8

3. Smith MH, Berman JR. What is rheumatoid arthritis? *JAMA*. (2022) 327:1194. doi: 10.1001/jama.2022.0786

4. Aletaha D, Smolen JS. Diagnosis and Management of Rheumatoid Arthritis: a review. *JAMA*. (2018) 320:1360–72. doi: 10.1001/jama.2018.13103

5. Finckh A, Gilbert B, Hodkinson B, Bae SC, Thomas R, Deane KD, et al. Global epidemiology of rheumatoid arthritis. *Nat Rev Rheumatol*. (2022) 18:591–602. doi: 10.1038/s41584-022-00827-y

6. Scherer HU, Häupl T, Burmester GR. The etiology of rheumatoid arthritis. *J Autoimmun*. (2020) 110:102400. doi: 10.1016/j.jaut.2019.102400

7. England BR, Thiele GM, Anderson DR, Mikuls TR. Increased cardiovascular risk in rheumatoid arthritis: mechanisms and implications. *BMJ*. (2018) 361:k1036. doi: 10.1136/bmj.k1036

8. Semb AG, Ikdahl E, Wibetoe G, Crowson C, Rollefstad S. Atherosclerotic cardiovascular disease prevention in rheumatoid arthritis. *Nat Rev Rheumatol*. (2020) 16:361–79. doi: 10.1038/s41584-020-0428-y

9. Hadwen B, Stranges S, Barra L. Risk factors for hypertension in rheumatoid arthritis patients-a systematic review. *Autoimmun Rev*. (2021) 20:102786. doi: 10.1016/j.autrev.2021.102786

10. Gonzalez A, Maradit Kremers H, Crowson CS, Ballman KV, Roger VL, Jacobsen SJ, et al. Do cardiovascular risk factors confer the same risk for cardiovascular outcomes in rheumatoid arthritis patients as in non-rheumatoid arthritis patients? *Ann Rheum Dis*. (2008) 67:64–9. doi: 10.1136/ard.2006.059980

11. Hu Y, Sparks JA, Malspeis S, Costenbader KH, Hu FB, Karlson EW, et al. Long-term dietary quality and risk of developing rheumatoid arthritis in women. *Ann Rheum Dis*. (2017) 76:1357–64. doi: 10.1136/annrheumdis-2016-210431

12. Hu Y, Costenbader KH, Gao X, Hu FB, Karlson EW, Lu B. Mediterranean diet and incidence of rheumatoid arthritis in women. *Arthritis Care Res (Hoboken)*. (2015) 67:597–606. doi: 10.1002/acr.22481

13. Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic impact goal through 2020 and beyond. *Circulation*. (2010) 121:586–613. doi: 10.1161/CIRCULATIONAHA.109.192703

14. Hasbani NR, Ligthart S, Brown MR, Heath AS, Bebo A, Ashley KE, et al. American Heart Association's Life's simple 7: lifestyle recommendations, polygenic risk, and lifetime risk of coronary heart disease. *Circulation*. (2022) 145:808–18. doi: 10.1161/CIRCULATIONAHA.121.053730

15. Han L, You D, Ma W, Astell-Burt T, Feng X, Duan S, et al. National Trends in American Heart Association revised Life's simple 7 metrics associated with risk of mortality among US adults. *JAMA Netw Open*. (2019) 2:e1913131. doi: 10.1001/jamanetworkopen.2019.13131

16. Lau ES, Paniagua SM, Liu E, Jovani M, Li SX, Takvorian K, et al. Cardiovascular risk factors are associated with future Cancer. *JACC CardioOncol*. (2021) 3:48–58. doi: 10.1016/j.jaccao.2020.12.003

17. Fretts AM, Howard BV, McKnight B, Duncan GE, Beresford SA, Mete M, et al. Life's simple 7 and incidence of diabetes among American Indians: the strong heart family study. *Diabetes Care*. (2014) 37:2240–5. doi: 10.2337/dc13-2267

18. Gao B, Song S, Guo J. Associations between life's simple 7 and incident depression among adults aged 50 years and older: a 15-year cohort study. *Psychiatry Res*. (2023) 320:115046. doi: 10.1016/j.psychres.2022.115046

19. De La Cruz N, Shabaneh O, Appiah D. The Association of Ideal Cardiovascular Health and Ocular Diseases among US adults. *Am J Med*. (2021) 134:252–9.e1. doi: 10.1016/j.amjmed.2020.06.004

20. Rebholz CM, Anderson CA, Grams ME, Bazzano LA, Crews DC, Chang AR, et al. Relationship of the American Heart Association's impact goals (Life's simple 7) with risk of chronic kidney disease: results from the atherosclerosis risk in communities (ARIC) cohort study. *J Am Heart Assoc*. (2016) 5:e003192. doi: 10.1161/JAHA.116.003192

21. Lin MP, Ovbiagele B, Markovic D, Towfighi A. "Life's simple 7" and long-term mortality after stroke. *J Am Heart Assoc*. (2015) 4:e001470. doi: 10.1161/JAHA.114.001470

22. Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF, Feldman HI, et al. A new equation to estimate glomerular filtration rate. *Ann Intern Med*. (2009) 150:604–12. doi: 10.7326/0003-4819-150-9-200905050-00006

23. Kerekes G, Nurmohamed MT, González-Gay MA, Seres I, Paragh G, Kardos Z, et al. Rheumatoid arthritis and metabolic syndrome. *Nat Rev Rheumatol*. (2014) 10:691–6. doi: 10.1038/nrrheum.2014.121

24. Gremese E, Ferraccioli G. The metabolic syndrome: the crossroads between rheumatoid arthritis and cardiovascular risk. *Autoimmun Rev*. (2011) 10:582–9. doi: 10.1016/j.autrev.2011.04.018

25. Metsios GS, Kitas GD. Physical activity, exercise and rheumatoid arthritis: effectiveness, mechanisms and implementation. *Best Pract Res Clin Rheumatol*. (2018) 32:669–82. doi: 10.1016/j.berh.2019.03.013

26. Verhoeven F, Tordi N, Prati C, Demougeot C, Mougin F, Wendling D. Physical activity in patients with rheumatoid arthritis. *Joint Bone Spine*. (2016) 83:265–70. doi: 10.1016/j.jbspin.2015.10.002

27. Dessein PH, Stanwix AE, Solomon A. How could physical activity reduce inflammation and inflammatory gene expression in rheumatoid arthritis? *J Rheumatol*. (2022) 49:1299–302. doi: 10.3899/jrheum.220788

28. Santos-Moreno P, Burgos-Angulo G, Martinez-Ceballos MA, Pizano A, Echeverri D, Bautista-Niño PK, et al. Inflammaging as a link between autoimmunity and cardiovascular disease: the case of rheumatoid arthritis. *RMD Open*. (2021) 7:e001470. doi: 10.1136/rmdopen-2020-001470

29. Papayannopoulos V. Neutrophil extracellular traps in immunity and disease. *Nat Rev Immunol*. (2018) 18:134–47. doi: 10.1038/nri.2017.105

30. Lee KH, Kronbichler A, Park DD, Park Y, Moon H, Kim H, et al. Neutrophil extracellular traps (NETs) in autoimmune diseases: A comprehensive review. *Autoimmun Rev*. (2017) 16:1160–73. doi: 10.1016/j.autrev.2017.09.012

31. Lloyd-Jones DM, Allen NB, Anderson CAM, Black T, Brewer LC, Foraker RE, et al. Life's essential 8: updating and enhancing the American Heart Association's construct of cardiovascular health: a presidential advisory from the American Heart Association. *Circulation*. (2022) 146:e18–43. doi: 10.1161/CIR.0000000000001078

32. Donate PB, Alves de Lima K, Peres RS, Almeida F, Fukada SY, Silva TA, et al. Cigarette smoke induces miR-132 in Th17 cells that enhance osteoclastogenesis in inflammatory arthritis. *Proc Natl Acad Sci U S A*. (2021) 118:e2017120118. doi: 10.1073/pnas.2017120118

33. Heluany CS, Scharf P, Schneider AH, Donate PB, dos Reis Pedreira Filho W, de Oliveira TF, et al. Toxic mechanisms of cigarette smoke and heat-not-burn tobacco vapor inhalation on rheumatoid arthritis. *Sci Total Environ*. (2022) 809:151097. doi: 10.1016/j.scitotenv.2021.151097

34. Gwinnutt JM, Verstappen SM, Humphreys JH. The impact of lifestyle behaviours, physical activity and smoking on morbidity and mortality in patients with rheumatoid arthritis. *Best Pract Res Clin Rheumatol*. (2020) 34:101562. doi: 10.1016/j.berh.2020.101562

35. Gioia C, Lucchino B, Tarsitano MG, Iannuccelli C, Di Franco M. Dietary habits and nutrition in rheumatoid arthritis: can diet influence disease development and clinical manifestations? *Nutrients*. (2020) 12:1456. doi: 10.3390/nu12051456

36. Philippou E, Petersson SD, Rodomar C, Nikiphorou E. Rheumatoid arthritis and dietary interventions: systematic review of clinical trials. *Nutr Rev*. (2021) 79:410–28. doi: 10.1093/nutrit/nuaa033

37. Nelson J, Sjöblom H, Gjertsson I, Ulven SM, Lindqvist HM, Bärebring L. Do interventions with diet or dietary supplements reduce the disease activity score in rheumatoid arthritis? A systematic review of randomized controlled trials. *Nutrients*. (2020) 12:2991. doi: 10.3390/nu12102991

38. Vadell AKE, Bärebring L, Hulander E, Gjertsson I, Lindqvist HM, Winkvist A. Anti-inflammatory diet in rheumatoid arthritis (ADIRA)-a randomized, controlled crossover trial indicating effects on disease activity. *Am J Clin Nutr*. (2020) 111:1203–13. doi: 10.1093/ajcn/nqaa019

39. Gacesa R, Kurilshikov A, Vich Vila A, Sinha T, Klaassen MAY, Bolte LA, et al. Environmental factors shaping the gut microbiome in a Dutch population. *Nature*. (2022) 604:732–9. doi: 10.1038/s41586-022-04567-7

40. Nguyen Y, Mariette X, Salliot C, Gusto G, Boutron-Ruault MC, Seror R. Chronic diarrhoea and risk of rheumatoid arthritis: findings from the French E3N-EPIC cohort study. *Rheumatology (Oxford)*. (2020) 59:3767–75. doi: 10.1093/rheumatology/keaa133

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 01 December 2023
DOI 10.3389/fpubh.2023.1227994

Check for updates

OPEN ACCESS

EDITED BY
Javier Benítez-Porres,
University of Malaga, Spain

REVIEWED BY
Elnaz Daneshzad,
Tehran University of Medical Sciences, Iran
Rita de Cássia Akutsu,
University of Brasilia, Brazil

*CORRESPONDENCE
Siying Wu
fmuwsy@163.com
Huangyuan Li
fmulhy@163.com
Xiaoxu Xie
xiexiaoxu@aliyun.com

†These authors have contributed equally to this work and share first authorship

RECEIVED 24 May 2023
ACCEPTED 30 October 2023
PUBLISHED 01 December 2023

CITATION
Zheng L, Lu X, Guo J, Xu X, Yang L, Xie X, Li H and Wu S (2023) Association between longitudinal dietary patterns and changes in obesity: a population-based cohort study. *Front. Public Health* 11:1227994.
doi: 10.3389/fpubh.2023.1227994



# Association between longitudinal dietary patterns and changes in obesity: a population-based cohort study

Liuyan Zheng[1†], Xinyue Lu[1†], Jianhui Guo[2†], Xingyan Xu[1], Le Yang[1], Xiaoxu Xie[1*], Huangyuan Li[3*] and Siying Wu[1*]

[1]Department of Epidemiology and Health Statistics, School of Public Health, Fujian Medical University, Fuzhou, Fujian, China, [2]Institute of Child and Adolescent Health, School of Public Health, Peking University, Beijing, China, [3]Department of Preventive Medicine, School of Public Health, Fujian Medical University, Fuzhou, Fujian, China

**Introduction:** Research on the trajectory of dietary patterns and changes in obesity has been inconclusive.

**Methods:** This study described the dietary intake and adiposity trajectories of Chinese adults and assessed the association between dietary trajectories and changes in body mass index (BMI) and waist-to-hip ratio (WHR). We used data from 3, 643 adults who participated in the China Health and Nutrition Survey from 1997 to 2015. Detailed dietary data were collected by conducting three consecutive 24-h recalls. Multitrajectories of diet scores were identified by a group-based multitrajectory method. We described the change in BMI and WHR using group-based trajectory modeling. We assessed the associations between dietary trajectories and changes in people with obesity using a logistic regression model.

**Results:** Our study revealed four trajectories of low-carbohydrate (LCD) and low-fat diet (LFD) scores. Three adiposity trajectories were identified according to the baseline level and developmental trend of BMI and WHR. Compared with the reference group, which was characterized by sustained healthy dietary habits with healthy diet scores at baseline and sustained maintenance of healthy diet scores, the other three diet trajectories had a higher risk of falling into the adverse adiposity trajectory.

**Discussion:** Maintaining a healthy LCD and LFD can markedly decrease the risk of adiposity.

KEYWORDS

**low-carbohydrate diet, low-fat diet, multitrajectories, obesity change, body mass index, China**

## 1 Introduction

Obesity is a growing public health problem in which excess body fat has accumulated, and it poses a potential risk to an individual's health (1). Abdominal obesity, a distinctive form of obesity, constitutes a key element of metabolic syndrome (2). Numerous non-communicable diseases have been linked to obesity and abdominal obesity, such as cancer (3, 4), cardiovascular disease (5, 6), type 2 diabetes (6), and chronic kidney disease (7). Epidemiological data published by the World Health Organization show that the global prevalence of adiposity almost tripled between 1975 and 2016, and more than 650 million adults were estimated to be classified as obese in 2016 (1). The global spread of adiposity has been labeled a pandemic (8). This phenomenon was once seen as a problem only in upper-income countries but has been on the rise in low- and middle-income countries for many years (9). By 2018, ∼85 million Chinese individuals aged 18–69 were obese, three times the number in 2004 (10). The latest national prevalence figures for 2015–2019, using Chinese criteria, show that 34.3% of adults (aged 18 and over) in China are classified as overweight, while 16.4% are classified as obese (11). Moreover, 4.7 million people died prematurely with adiposity based on the Global Burden of Disease 2017 (12).

Obesity is the result of a mismatch between energy intake and energy expenditure. Diet, as the primary source of energy intake, plays a crucial role in the onset and progression of obesity. A large body of evidence suggests that it is the quality, not the quantity, of carbohydrates and fats that define disease and health outcomes (13–15). The Mediterranean diet is presently recommended as a management strategy for weight loss (16), and existing research shows that adherence to the Dietary Approaches to Stop Hypertension (DASH) diet is associated with a reduced risk of overweight and obesity in Iranian women (17). The common feature of both of these dietary patterns is that they are both varieties of "plant-based diets" that contain natural foods and less ultra-processed foods (18). But whether other prevailing dietary patterns that focus on fat and carbohydrates, including low-carbohydrate diets (LCDs) or low-fat diets (LFDs) can promote weight loss remains controversial. Individuals who follow LCDs restrict carbohydrates to increase their intake of fats and/or proteins, while those who follow LFDs restrict fats to increase carbohydrates. There are controversial viewpoints between LCDs and LFDs regarding weight loss (19–24).

This is probably due to inconsistencies in the definitions of LCD and LFD. Some studies (25, 26) have defined LCD or LFD, depending on the proportion of carbohydrate or fat intake to daily calorie intake, low-carbohydrate and low-fat diets can further reduce body weight by reducing liver volume. Other researchers have examined the different sources of carbohydrates, fats and proteins in diets over the past decades (20, 27). One of these studies (20), conducted in Iran, found no significant association between low-carbohydrate and low-fat diets and overweight or obesity. In China, dietary macronutrient intake has not remained static, but rather has changed over time. For example, fat consumption spiked from 1982 to 2012, while the estimated proportion of energy intake from carbohydrates declined (28). Moreover, little research has been conducted to explore the association between dietary trajectories and changes in adiposity based on follow-up over time. It remains unclear how the dynamics of dietary trajectories play a role in adiposity progression.

Unlike previous studies that analyzed dietary intake status based on single-point assessment, we describe distinct trajectories of LCDs and LFDs using data published from 1997 to 2015 in the China Health and Nutrition Survey (CHNS). We also analyzed the transition between normal weight and overweight during 15 years of follow-up in the current study. In addition, we examined the associations between these dietary trajectories and changes in BMI and WHR. We intended to investigate (1) the trajectories of dietary intake and adiposity in Chinese adults from 1997 to 2015; (2) the associations between dietary trajectories and the variations in BMI and WHR.

# 2 Materials and methods

## 2.1 Study participants

In this study, we utilized data collected by the CHNS from 1997 to 2015. The CHNS aims to gather representative information on important risk factors for public health, health outcomes, and the state of nutrition in Chinese communities (28). Since its establishment in 1989, the CHNS has been followed up every 2–4 years. A total of ten waves of data have been published, covering the years 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015. The surveys were authorized by the Institutional Review Boards of the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health, Chinese Centre for Disease Control and Prevention, and all participants gave valid informed consent. Details of the design and procedures of the CHNS have been reported (29).

Our analysis utilized data from nine waves of the CHNS spanning from 1997 to 2015. The 1989 wave was excluded as it did not include dietary assessment data for all participants. The 1991 and 1993 waves were excluded from the analysis due to inconsistencies in dietary coding compared to other years. It should be noted that the dietary data from the 2015 wave has not yet been fully published, so only the available data, such as the 2015 physical examination data, were used in our study. Participants with less than two waves of dietary data, body mass index (BMI) value and waist–hip ratio data, with extreme total dietary energy intakes (<800 or >6,000 kcal/d for males; <600 or >4,000 kcal/d for females) (30), with general and abdominal adiposity at baseline, and with missing covariates in all follow-up surveys in which they participated were excluded from the analysis. Participants who were pregnant, lactating, or younger than 18-year-old were also excluded. The final analysis included 3,643 study participants. Supplementary Figure S1 illustrates the process of selecting study participants.

## 2.2 Evaluation of LCD and LFD scores

The dietary scores used in this study were calculated from dietary information collected from the CHNS dataset. A 24-h dietary recall was used for each wave of the CHNS to gather dietary intake data from Chinese adults over three consecutive days, namely, two workdays and one weekend day. Household food consumption data were also collected over the same 3-day period. How detailed dietary data are collected and allocated in the CHNS has been described elsewhere (9, 31).

To reduce bias arising from underreporting of food consumption and to represent dietary ingredients, we calculated the LCD and LFD scores based on the percentage of energy intake rather than absolute intake (13, 32, 33). First, we categorized participants by gender. Second, we further divided the participants into 11 groups based on their energy percentage derived from fat, protein, and carbohydrates. To evaluate LCD, a scoring system was developed wherein individuals with the highest fat and protein intake in each stratum were awarded 10 points, while those with the lowest intake were given 0 points. The order of the layers was reversed for carbohydrates. The scores for the three macronutrients were then aggregated to produce the overall LCD score, which ranged from 0 to 30. To establish unhealthy and healthy LFD scores, similar approaches were used. Unhealthy LCD was determined based on the percentage of energy accounted for by high-quality carbohydrates, saturated fats, and animal protein, while the healthy LCD was calculated using low-quality carbohydrates, unsaturated fats, and plant protein as determining factors (Supplementary Table S1). Similar methods were used to compute both unhealthy and healthy LFD scores in our study (Supplementary Table S2). The distribution of energy percentage criteria for determining scores for low-carbohydrate and low-fat diets in men was presented in Supplementary Table S3. The distribution of energy percentage criteria for determining scores for low-carbohydrate and low-fat diets in women was presented in Supplementary Table S4.

## 2.3 Anthropometric variables

Adiposity was our outcome variable of interest. Standardized procedures were used by well-trained health workers to measure participants' height (Model 206, SECA), weight (Model 880, SECA), and waist circumference (WC) in CHNS. Weight (in kilograms) divided by height (in meter) squared equals BMI. Based on the cut-off values recommended by the Working Group on Obesity in China, BMI was classified into four categories in our study (underweight: BMI $< 18.5$; normal: $18.5 \leq$ BMI $< 24.0$; overweight: $24.0 \leq$ BMI $< 28.0$; and obesity: BMI $\geq 28.0$) (34) and assigned ascending values (1, 2, 3, 4). The second major outcome variable was abdominal obesity, which was defined as a waist-to-hip ratio (WHR) of $\geq$0.9 in males or $\geq$0.85 in females (35). For the non-abdominal obesity group, a score of 1 was assigned, and abdominal obesity was scored as 2. WHR was determined by dividing waist circumference by hip circumference. WC was measured at the end of exhalation at a midpoint between the top of the iliac crest and the bottom of the rib cage in CHNS. HC was taken at the level of maximum gluteal protrusion. The WC and HC were both measured with a SECA tape, accurate to the nearest 0.1 cm (36). Furthermore, we described the change in BMI and WHR using group-based trajectory modeling.

## 2.4 Covariates

In our study analysis, we incorporated two categories of diet-related and adiposity-related confounders, sociodemographic factors including sex, age, marital status, nationality, education, family economic level, geographic location, lifestyle factors including smoking, drinking, and physical activity (PA), and dietary energy. Marital status was classified into three groups: married, unmarried, and divorced/separated/widowed. Nationality was divided into Han and non-Han. Education level was categorized into three types: junior high school or below, senior high school, and college or above. Participants' yearly household income per capita at baseline was divided into three categories (low: <1,369.68$, middle: 1,369.68–2,739.35$, and high: >2,739.35$) based on the per capita annual family income tertiles. The geographic location was divided into four clusters: Liaoning, Heilongjiang, Jiangsu, and Shandong provinces (37). Provincial boundaries in China are based on a combination of cultural practices, topographical features and latitude and longitude. As a result, there are differences in food consumption patterns between geographical locations. Participants were classified as current smokers, ex-smokers and never drinkers, and current drinkers and never drinkers based on their recent smoking and drinking status, respectively. Participants' physical activity level was classified into three types (light, medium, and heavy) according to their self-reported activities, including occupational, domestic, transportation, and recreational sports activities. Total physical activity intensity is determined by a calculation based on metabolic equivalents, which takes into account the cumulative time spent each week in different physical activities, including those related to work, household chores, transport and leisure. The weekly scores for different types of physical activity are derived by multiplying the weekly frequency by the time spent per day. The resulting product, obtained by multiplying metabolic equivalents and duration and summing, represents the total amount of physical activity (38). In accordance with guidelines from the World Health Organization (39), participants were categorized into three groups based on their total weekly physical activity levels: (1) Light physical activity (<600 METs-min/week), (2) Moderate physical activity (600–1,199 METs-min/week), and (3) Heavy physical activity ($\geq$1,200 METs-min/week).

## 2.5 Statistical analysis

Continuous variables were expressed as medians (25th percentile, 75th percentile) due to non-normal distribution. Classification variables are presented as the number of people (%). The Mann-Whitney *U*-test and chi-square tests were used for comparison of continuous and categorical variables, respectively.

To analyze the trajectories of the LCD and LFD scores, including HLCD, ULCD, HLFD, and ULFD, and to classify them into four categories, we used group-based multitrajectory modeling (40). To illustrate the likelihood of subjects maintaining HLCD, ULCD, HLFD, and ULFD simultaneously over time, we created an annual model using a STATA multitrajectory modeling plugin (41), with trajectories defined based on the year as the time scale. Rigorous criteria were applied to determine the best-fitting model in the statistical analysis. (1) We utilized the Bayesian information criterion (BIC), with the lowest value indicating the best fit, and evaluated the percentage change in BIC to choose between more complex (adding a specific set of trajectories) and simpler models. (2) We enrolled at least 5% of the study participants in each trajectory category to guarantee an adequate sample size. (3) We determined the average posterior probability of membership within each group, with values >0.7 indicating satisfactory internal reliability (42). A group-based trajectory model was used to classify adiposity and abdominal obesity. The basic requirements for modeling using this approach are the same as those outlined above. After identifying the trajectories of the scores, we generated categorical variables to designate the trajectory categories of

TABLE 1 Characteristics of study participants by adiposity trajectory group.

| Characteristics | Overall | Normal weight | Overweight trajectory | | Overweight upwards trajectory | |
|---|---|---|---|---|---|---|
| | ($n = 3,643$) | ($n = 2,115$) | ($n = 1,243$) | $P^a$ | ($n = 285$) | $P^b$ |
| Trajectories | | | | 0.001 | | 0.008 |
| Group2, sustained healthy dietary habits | 909 (25.0) | 554 (27.5) | 288 (21.8) | | 67 (21.9) | |
| Group1, improved dietary habits | 931 (25.6) | 476 (23.6) | 375 (28.4) | | 80 (26.1) | |
| Group3, worsening dietary habits | 770 (21.1) | 433 (21.5) | 285 (21.6) | | 52 (17.0) | |
| Group4, deteriorating dietary habits | 1,033 (28.4) | 552 (27.4) | 374 (28.3) | | 107 (35.0) | |
| Age (years) | | | | < 0.001 | | 0.446 |
| ≤45 | 2,321 (63.7) | 1,314 (65.2) | 818 (61.9) | | 189 (61.8) | |
| 45–60 | 939 (25.8) | 470 (23.3) | 388 (29.3) | | 81 (26.5) | |
| ≥60 | 383 (10.5) | 231 (11.5) | 116 (8.8) | | 36 (11.8) | |
| Sex | | | | 0.236 | | 0.064 |
| Male | 1,896 (52.0) | 1,043 (51.8) | 712 (53.9) | | 141 (46.1) | |
| Female | 1,747 (48.0) | 972 (48.2) | 610 (46.1) | | 165 (53.9) | |
| Nationalities | | | | 0.302 | | 0.111 |
| Han | 3,306 (90.7) | 1,841 (91.4) | 1,194 (90.3) | | 271 (88.6) | |
| Non-han | 337 (9.3) | 174 (8.6) | 128 (9.7) | | 35 (11.4) | |
| Annual per capita family income | | | | 0.894 | | 0.722 |
| Low (<1,369.68$) | 1,138 (31.2) | 624 (31.0) | 418 (31.6) | | 96 (31.4) | |
| Middle (1,369.68–2,739.35 $) | 1,100 (30.2) | 617 (30.6) | 396 (30.0) | | 87 (28.4) | |
| High (>2,739.35$) | 1,405 (38.6) | 774 (38.4) | 508 (38.4) | | 123 (40.2) | |
| Geographic location | | | | <0.001 | | <0.001 |
| Liaoning | 1,205 (33.1) | 581 (28.8) | 473 (35.8) | | 151 (49.3) | |
| Heilongjiang | 938 (25.7) | 571 (28.3) | 323 (24.4) | | 44 (14.4) | |
| Jiangsu | 984 (27.0) | 622 (30.9) | 308 (23.3) | | 54 (17.6) | |
| Shandong | 516 (14.2) | 241 (12.0) | 218 (16.5) | | 57 (18.6) | |
| Marital status | | | | 0.005 | | 0.013 |
| Married | 3,128 (85.9) | 1,709 (84.8) | 1,149 (86.9) | | 270 (88.2) | |
| Unmarried | 108 (3.0) | 80 (4.0) | 26 (2.0) | | 2 (0.7) | |
| Divorced/separate/widowed | 407 (11.2) | 226 (11.2) | 147 (11.1) | | 34 (11.1) | |
| Years of education (years) | | | | <0.001 | | 0.065 |
| <9 | 2,688 (73.8) | 1,486 (73.7) | 961 (72.7) | | 241 (78.8) | |
| 9–12 | 637 (17.5) | 323 (16.0) | 268 (20.3) | | 46 (15.0) | |
| >12 | 318 (8.7) | 206 (10.2) | 93 (7.0) | | 19 (6.2) | |
| Drinking status | | | | 0.090 | | 0.043 |
| Current drinker | 1,973 (54.2) | 1,080 (53.6) | 748 (56.6) | | 145 (47.4) | |
| Never | 1,670 (45.8) | 935 (46.4) | 574 (43.4) | | 161 (52.6) | |
| Physical activities | | | | 0.006 | | 0.009 |
| Light | 152 (4.2) | 89 (4.4) | 49 (3.7) | | 14 (4.6) | |

*(Continued)*

TABLE 1 (Continued)

| Characteristics | Overall | Normal weight | Overweight trajectory | | Overweight upwards trajectory | |
|---|---|---|---|---|---|---|
| | ($n = 3,643$) | ($n = 2,115$) | ($n = 1,243$) | $P^a$ | ($n = 285$) | $P^b$ |
| Medium | 466 (12.8) | 221 (11.0) | 193 (14.6) | | 52 (17.0) | |
| Heavy | 3,025 (83.0) | 1,705 (84.6) | 1,080 (81.7) | | 240 (78.4) | |
| Smoking status | | | | 0.009 | | 0.009 |
| Current smoker | 1,060 (29.1) | 632 (31.4) | 358 (27.1) | | 70 (22.9) | |
| Ex-smoker | 558 (15.3) | 287 (14.2) | 226 (17.1) | | 45 (14.7) | |
| Never | 2,025 (55.6) | 1,096 (54.4) | 738 (55.8) | | 191 (62.4) | |
| **Energy (kcal/d)** | 1,762.5 (1,479.9, 2,074.0) | 1,748.8 (1,467.3, 2,078.4) | 1,783.3 (1,502.2, 2,073.0) | 0.076 | 1,769.5 (1,487.9, 2,076.5) | 0.658 |

[a]The difference test between the "Overweight" trajectory group and the "Normal weight" trajectory group.
[b]The difference test between the "Overweight upwards trajectory" trajectory group and the "Normal weight" trajectory group.
Energy is presented as number (proportion %). The others are presented as median (IQR). *P*-values were calculated using analysis of the Mann-Whitney *U*-test and Chi-square test for continuous and categorical variables, respectively.

each object and subsequently incorporated this variable into our multinomial logistic regression models. Then, multinomial logistic regression models were used to separately analyze the association between the BMI or WHR trajectory and the change trajectory patterns of LCD and LFD scores, with effects reported as odds ratios (*OR*) and 95% confidence intervals (*CI*).

Last, considering that the exclusion of participants who had diabetes at baseline or who had diabetes at baseline and all follow-up, years may affect our results, we conducted a sensitivity analysis in this population to consolidate our findings. To account for the potential selection bias of subject screening, we also performed inverse probability weighting (IPW). Further assessment of the impact of missing covariate data on the association between the change in LCDs or LFDs and adiposity trajectories and sensitivity analyses of the missing value samples was performed using the multiple imputation method. All analyses were performed in Stata (version 17.0) and R (version 4.2.2) software, and a two-sided test of $P < 0.05$ indicated statistical significance.

# 3 Results

Following the initial screening process, our study included 3,643 participants, all of whom were enrolled two or more times between 1997 and 2015. Table 1 lists the characteristics of the study attendees according to adiposity trajectory group. Participants with an upwards overweight trajectory more often had a diet trajectory of deteriorating dietary habits, and a lower education level, and were non-smokers. Table 2 presents the characteristics of the study participants according to the abdominal obesity trajectory group.

Compared with the no-abdominal-obesity group, the rapid growth of abdominal obesity had a higher proportion of deteriorating dietary habits, in older adults. They were more likely to be non-drinkers and non-smokers. The flowcharts depicting the process of sample selection can be found in Supplementary Figure S1.

## 3.1 Assessments of multi-trajectories of LCD and LFD scores

In the total sample of six waves of CHNS data, we identified four diverse diet score multitrajectories among participants based on the unhealthy LCD score, unhealthy LFD score, healthy LCD score, and healthy LFD score (Figure 1). The overall LCD and LFD score ranged from 0 to 30. A quarter of the participants (25.6%) fell into a diet trajectory characterized by sustained healthy dietary habits (Group 2, reference category). They were identified as having a high healthy LCD score and healthy LFD score, a low unhealthy LCD score at baseline and sustained change for the better, they included persons whose healthy LCD score increased from 12 to 17, whose healthy LFD score slowly increased from 20 to 21, whose unhealthy LCD score fluctuated around 8, and whose unhealthy LFDs score decreased from 16 to 12. A total of 909 participants (25.0%) were able to maintain improved dietary habits (Group 1). Of the participants, 770 individuals (21.1%) exhibited worsening dietary habits characterized by suboptimal dietary habits at baseline that persisted over time (Group 3). A total of 1,033 participants (28.4%) had deteriorating dietary habits, characterized by a change from previously good to poor dietary habits, which continued to worsen over time (Group 4).

## 3.2 Assessments of trajectory patterns of adiposity and abdominal obesity

Figures 2, 3 show adiposity and abdominal obesity from 1997 to 2015. Three patterns of adiposity change trajectory were identified based on the baseline level and rates of change in the BMI groups (Figure 2). The first pattern of adiposity trajectory featuring low stability of normal weight (score 2) during follow-up visits was named the "normal weight trajectory". The second pattern, characterized by an increase from normal weight to overweight (score from 2.5 to 3) in BMI groups during follow-up visits, was named the "overweight trajectory". The third pattern, which

TABLE 2 Characteristics of study participants by abdominal obesity trajectory group.

| Characteristics | Overall | No abdominal obesity | Slowly growth of abdominal obesity | | Rapidly growth of abdominal obesity | |
|---|---|---|---|---|---|---|
| | ($n$ = 3, 643) | ($n$ = 2, 104) | ($n$ = 938) | $P^a$ | ($n$ = 601) | $P^b$ |
| Trajectories | | | | 0.019 | | 0.022 |
| Group2, sustained healthy dietary habits | 909 (25.0) | 417 (25.7) | 181 (26.8) | | 311 (23.1) | |
| Group1, improved dietary habits | 931 (25.6) | 403 (24.8) | 163 (24.1) | | 365 (27.1) | |
| Group3, worsening dietary habits | 770 (21.1) | 377 (23.2) | 122 (18.1) | | 271 (20.1) | |
| Group4, deteriorating dietary habits | 1,033 (28.4) | 426 (26.2) | 209 (31.0) | | 398 (29.6) | |
| Age (years) | | | | 0.005 | | <0.001 |
| ≤45 | 2,321 (63.7) | 1,129 (69.6) | 472 (69.9) | | 720 (53.5) | |
| 45–60 | 939 (25.8) | 342 (21.1) | 165 (24.4) | | 432 (32.1) | |
| ≥60 | 383 (10.5) | 152 (9.4) | 38 (5.6) | | 193 (14.3) | |
| Sex | | | | 0.317 | | <0.001 |
| Male | 1,896 (52.0) | 917 (56.5) | 366 (54.2) | | 613 (45.6) | |
| Female | 1,747 (48.0) | 706 (43.5) | 309 (45.8) | | 732 (54.4) | |
| Nationalities | | | | 0.316 | | 0.038 |
| Han | 3,306 (90.7) | 1,490 (91.8) | 611 (90.5) | | 1,205 (89.6) | |
| Non-han | 337 (9.3) | 133 (8.2) | 64 (9.5) | | 140 (10.4) | |
| Annual per capita family income | | | | 0.112 | | 0.365 |
| Low (<1,369.68$) | 1,138 (31.2) | 502 (30.9) | 188 (27.9) | | 448 (33.3) | |
| Middle (1,369.68–2,739.35$) | 1,100 (30.2) | 498 (30.7) | 197 (29.2) | | 405 (30.1) | |
| High (>2,739.35$) | 1,405 (38.6) | 623 (38.4) | 290 (43.0) | | 492 (36.6) | |
| Geographic location | | | | 0.977 | | <0.001 |
| Liaoning | 1,205 (33.1) | 458 (28.2) | 193 (28.6) | | 554 (41.2) | |
| Heilongjiang | 938 (25.7) | 451 (27.8) | 185 (27.4) | | 302 (22.5) | |
| Jiangsu | 984 (27.0) | 462 (28.5) | 196 (29.0) | | 326 (24.2) | |
| Shandong | 516 (14.2) | 252 (15.5) | 101 (15.0) | | 163 (12.1) | |
| Marital status | | | | <0.001 | | <0.001 |
| Married | 3,128 (85.9) | 1,387 (85.5) | 613 (90.8) | | 1,128 (83.9) | |
| Unmarried | 108 (3.0) | 73 (4.5) | 6 (0.9) | | 29 (2.2) | |
| Divorced/separate/widowed | 407 (11.2) | 163 (10.0) | 56 (8.3) | | 188 (14.0) | |
| Years of education (years) | | | | 0.851 | | 0.187 |
| <9 | 2,688 (73.8) | 1,182 (72.8) | 489 (72.4) | | 1,017 (75.6) | |
| 9–12 | 637 (17.5) | 289 (17.8) | 126 (18.7) | | 222 (16.5) | |
| >12 | 318 (8.7) | 152 (9.4) | 60 (8.9) | | 106 (7.9) | |
| Drinking status | | | | 0.474 | | <0.001 |
| Current drinker | 1,973 (54.2) | 940 (57.9) | 380 (56.3) | | 653 (48.6) | |
| Never | 1,670 (45.8) | 683 (42.1) | 295 (43.7) | | 692 (51.4) | |
| Physical activities | | | | 0.007 | | <0.001 |
| Light | 152 (4.2) | 60 (3.7) | 21 (3.1) | | 71 (5.3) | |

*(Continued)*

10.3389/fpubh.2023.1227994

TABLE 2 (Continued)

| Characteristics | Overall | No abdominal obesity | Slowly growth of abdominal obesity | | Rapidly growth of abdominal obesity | |
|---|---|---|---|---|---|---|
| | ($n$ = 3, 643) | ($n$ = 2, 104) | ($n$ = 938) | $P^a$ | ($n$ = 601) | $P^b$ |
| Medium | 466 (12.8) | 189 (11.6) | 50 (7.4) | | 227 (16.9) | |
| Heavy | 3,025 (83.0) | 1,374 (84.7) | 604 (89.5) | | 1,047 (77.8) | |
| Smoking status | | | | 0.046 | | <0.001 |
| Current smoker | 1,060 (29.1) | 535 (33.0) | 191 (28.3) | | 334 (24.8) | |
| Ex-smoker | 558 (15.3) | 224 (13.8) | 112 (16.6) | | 222 (16.5) | |
| Never | 2,025 (55.6) | 864 (53.2) | 372 (55.1) | | 789 (58.7) | |
| **Energy (kcal/d)** | 1,762.5 (1,479.9, 2,074.0) | 1,789.9 (1,497.5, 2,096.1) | 1,818.5 (1,540.1, 2,128.5) | 0.007 | 1,714.6 (1,438.1, 2,007.3) | <0.001 |

[a]The difference test between the "Slowly growth of abdominal obesity" trajectory group and the "No abdominal obesity" trajectory group.
[b]The difference test between the "Rapidly growth of abdominal obesity" trajectory group and the "No abdominal obesity" trajectory group.
Data are presented as median (IQR) or number (proportion %). $P$-values were calculated using analysis of the Mann-Whitney $U$-test and Chi-square test for continuous and categorical variables, respectively.

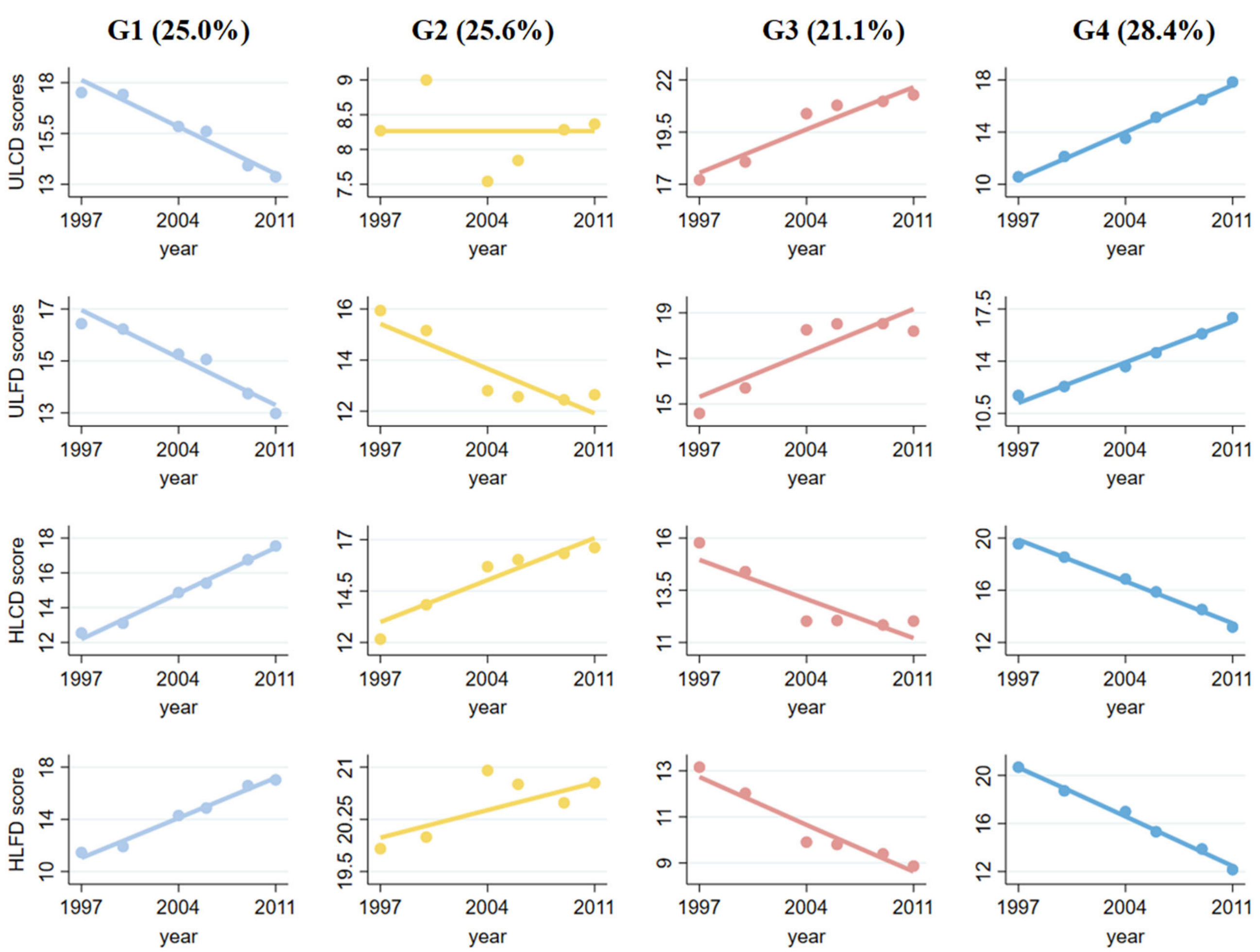



FIGURE 1
Multitrajectories of low-carbohydrate and low-fat diet scores among study populations. Source: CHNS 1997–2011. Solid lines represent the average estimated low-carbohydrate and low-fat diet scores over time. The dots represent the actual data, where we weighted each individual's responses based on posterior probabilities of group membership. Group 1 refers to the participants with unhealthy diet scores who sustained changes for the better; Group 2 refers to the participants with healthy diet scores who sustained changed for the better; Group 3 refers to the participants with moderate diet scores and persistent worsening; and Group 4 refers to the participants with healthy diet scores and persistent worsening.

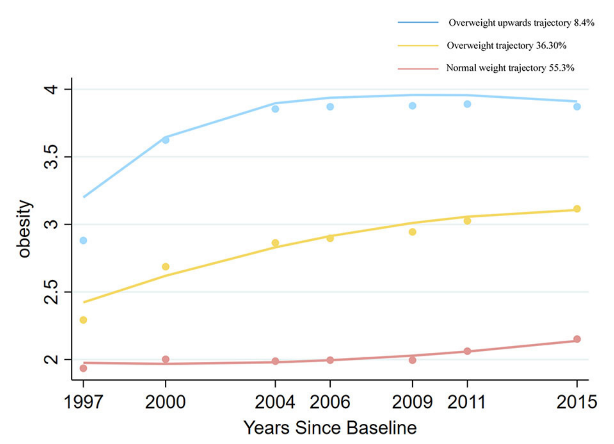



FIGURE 2
Change trajectories of adiposity measured by BMI groups. Source: CHNS 1997–2015.

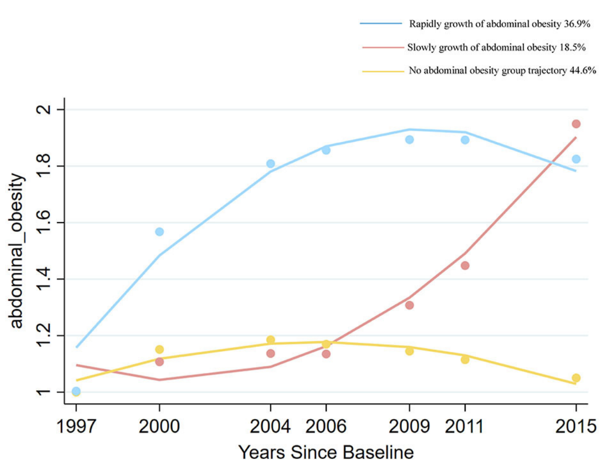



FIGURE 3
Change trajectories of abdominal obesity measured by waist to hip ratio groups. Source: CHNS 1997–2015.

was characterized by staying stable at around obesity (score 4) in BMI groups during follow-up visits, was named the "overweight upwards trajectory". We identified three abdominal obesity groups (Figure 3), labeled the "no abdominal-obesity group," "slow growth of abdominal obesity," and "rapid growth of abdominal obesity," respectively, according to the initial level and development trend of trajectories.

## 3.3 Associations between the adiposity trajectory and the change trajectory patterns of LCD and LFD scores

The results from multinomial logistic regression showed a significant association between the change trajectory patterns of LCD and LFD scores and adverse adiposity trajectory (adverse adiposity trajectory refers to "overweight trajectory" and "overweight upwards trajectory", "normal weight trajectory" as reference) (Figure 4). The group of participants with sustained healthy dietary habits as the reference category (Group 2), Group 1 (*OR* = 1.570, 95% CI, 1.331–1.852 in overweight; *OR* = 1.422, 95% CI, 1.177–1.718 in people with obesity), Group 3 (*OR* = 1.465, 95% CI, 1.237–1.734 in overweight; *OR* = 1.225, 95% CI, 1.032–1.454 in people with obesity) and Group 4 (*OR* = 1.310, 95% CI, 1.113–1.541 in overweight; *OR* = 1.580, 95% CI, 1.309–1.907 in obesity) significantly increased the risk of "overweight" and "overweight upwards".

## 3.4 Associations between the abdominal obesity trajectory and the change trajectory patterns of LCD and LFD scores

The change trajectory patterns of LCD and LFD scores were associated with an adverse abdominal obesity trajectory (adverse abdominal obesity trajectory refers to "rapid growth of abdominal obesity", and "no abdominal obesity" as the reference) (Figure 4). In the multinomial logistic regression analysis, compared with sustained healthy dietary habits, Group 1 (*OR* = 1.328, 95% *CI*, 1.131–1.559), Group 3 (*OR* = 1.207, 95% *CI*, 1.027–1.418), and Group 4 (*OR* = 1.373, 95% *CI*, 1.175–1.604) were associated with a higher degree of risk in "Rapidly growth of abdominal obesity". compared with sustained healthy dietary habits, Group 3 (*OR* = 0.726, 95% *CI*, 0.573–0.921) was associated with a lower degree of risk of "slow growth of abdominal obesity". No significant association was observed between other dietary trajectories and the slow growth of abdominal obesity.

## 3.5 Subgroup analysis

We further stratified by age and gender, and performed subgroup analysis. The subgroup analysis results were largely consistent with the main findings, except for individual groups which did not demonstrate statistical significance. The results of the subgroup analysis are shown in Figures 5, 6.

## 3.6 Sensitivity analyses

The results of our sensitivity analyses demonstrated the robustness of the main findings. First, in analyses using inverse-probability weighting to minimize the differences in participant characteristics, the analysis results were generally in line with the results of the main analyses (Supplementary Tables S5, S6). Second, following the multiple imputations of missing data, the results remained consistent with those obtained from the analytic samples, with no substantial differences in the direction or magnitude of the observed associations (Supplementary Tables S7, S8). Excluding participants with diabetes at baseline and those with diabetes at both baseline and follow-up years, the results were generally consistent with the main analysis (Supplementary Tables S9–S12).

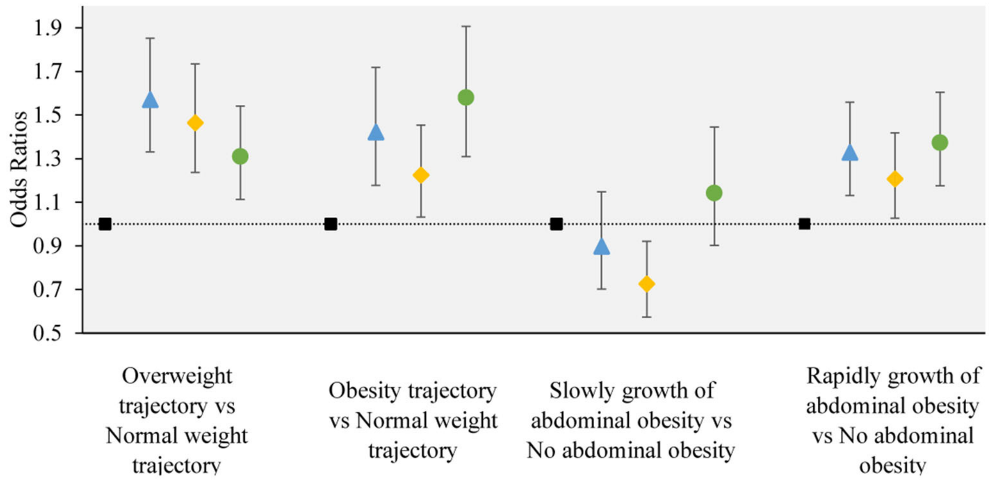



FIGURE 4
The associations between the obesity or abdominal obesity trajectory and the change trajectory patterns of low-carbohydrate and low-fat diet scores. Source: CHNS 1997–2015. Adjusted model: adjusted for sociodemographic factors, including sex, age, marital status, nationality, education level, family economic level, region, and lifestyle factors, including smoking status, drinking status, physical activity, and dietary energy. ■ refers to the sustained healthy dietary habits; ▲ refers to the improved dietary habits; ◆ refers to the worsening dietary habits; ● refers to the deteriorating dietary habits.

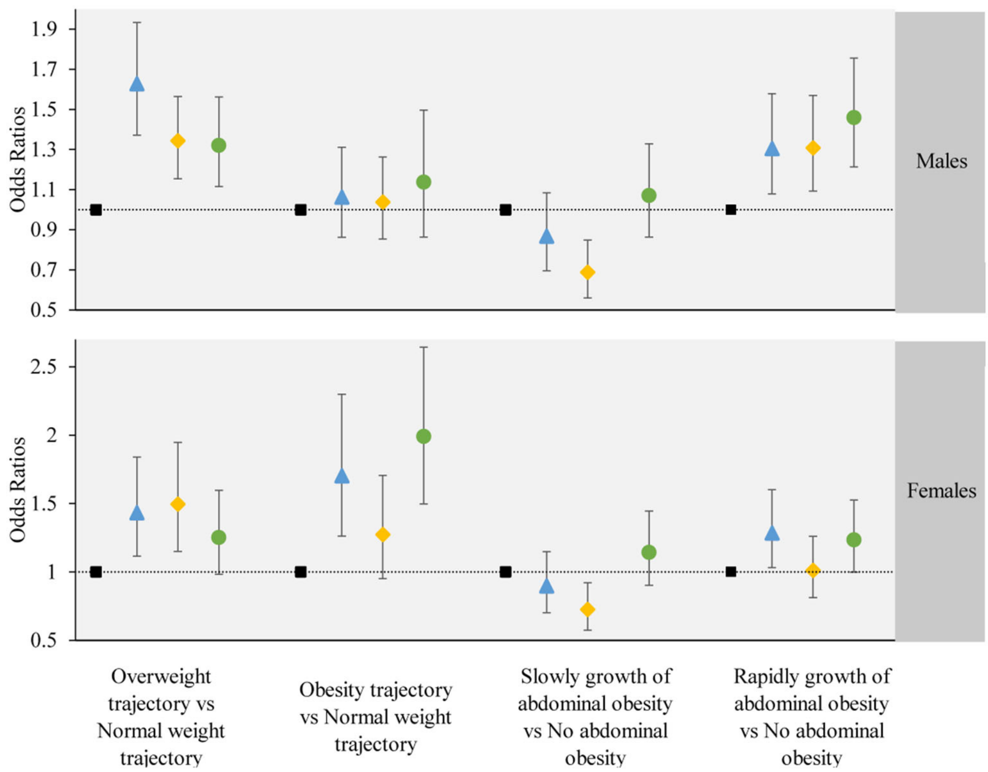



FIGURE 5
The associations between the obesity or abdominal obesity trajectory and the change trajectory patterns of low-carbohydrate and low-fat diet scores stratified by participant's gender. Source: CHNS 1997–2015. Adjusted model: adjusted for sociodemographic factors, including sex, age, marital status, nationality, education level, family economic level, region, and lifestyle factors, including smoking status, drinking status, physical activity, and dietary energy. ■ refers to the sustained healthy dietary habits; ▲ refers to the improved dietary habits; ◆ refers to the worsening dietary habits; ● refers to the deteriorating dietary habits.

10.3389/fpubh.2023.1227994

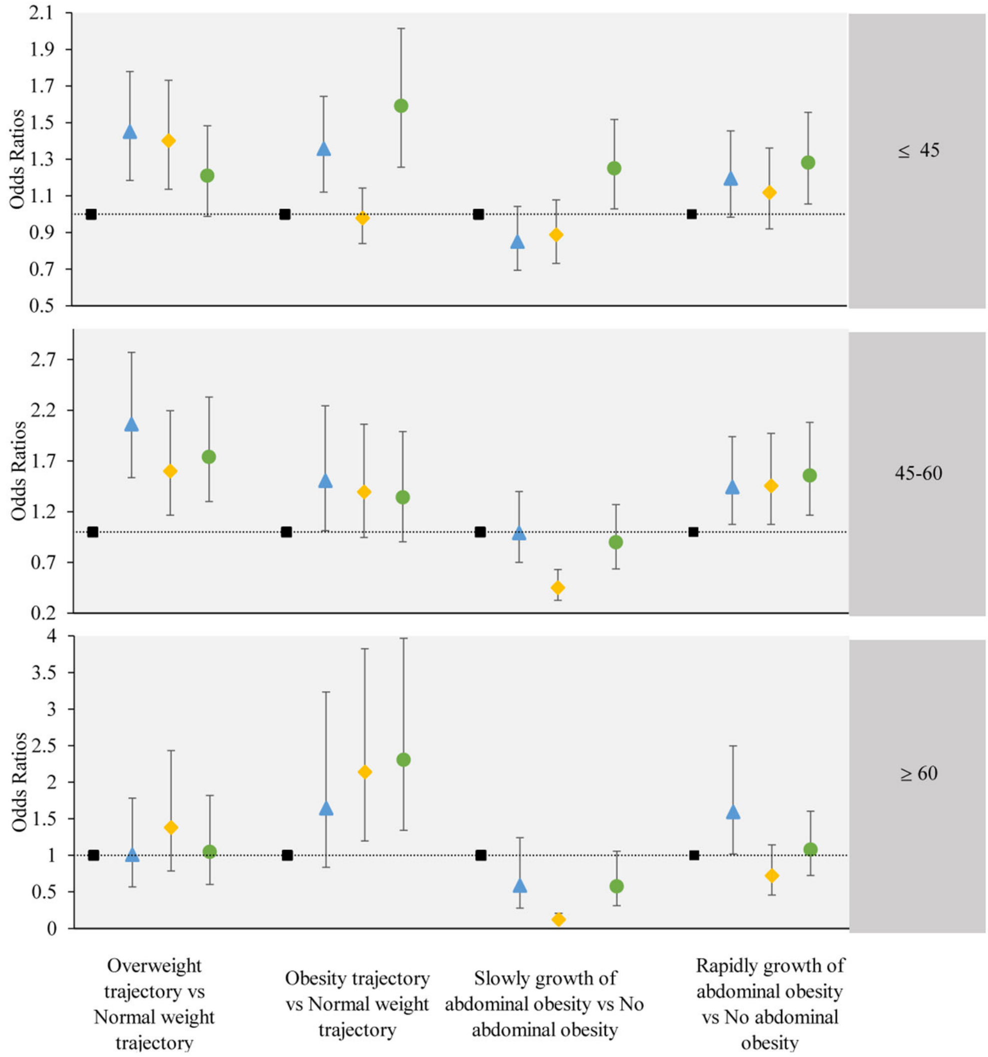



FIGURE 6
The associations between the obesity or abdominal obesity trajectory and the change trajectory patterns of low-carbohydrate and low-fat diet scores stratified by participant's age. Source: CHNS 1997–2015. Adjusted model: adjusted for sociodemographic factors, including sex, age, marital status, nationality, education level, family economic level, region, and lifestyle factors, including smoking status, drinking status, physical activity, and dietary energy. ■ refers to the sustained healthy dietary habits; ▲ refers to the improved dietary habits; ◆ refers to the worsening dietary habits; ● refers to the deteriorating dietary habits.

## 4 Discussion

Using a nationally representative sample of Chinese adults, this study identified three obesity and abdominal obesity trajectories that can dynamically assess the changes in obesity status in the Chinese population. In addition, four various trajectories of LCD and LFD scores were drawn according to the total and type of macronutrients. Approximately a quarter of the participants had healthy diet scores at baseline and sustained healthy diet scores, and the risk of adiposity was lowest in this group. The other diet trajectories include Group 1, Group 3, and Group 4. Group 1 was characterized by an unhealthy diet score at baseline, with sustained improvement, while Group 3 showed a moderate diet score at baseline but persistent worsening, and Group 4 had healthy diet scores at baseline but persistent worsening. These groups of participants had a higher risk of adverse obesity and abdominal obesity than those participants who had healthy diet scores at baseline and sustained changes for the better.

LCD and LFD, a composite score encompassing the three primary macronutrient sources, can effectively unveil macronutrient intake and its respective sources. The association between LCD and LFD diets and obesity has been studied in national and international research but is not conclusive. In a nationwide cross-sectional study, researchers found that a healthy LCD was associated with decreased odds of steatosis, while an unhealthy LFD was linked to increased odds of steatosis (27). Findings from 37,233 US adults demonstrated that unhealthy LCD and LFD scores were linked to higher mortality, while healthy LCD and LFD scores were related to lower mortality (13). One study using data from NHANES found a significant association between insistence on healthy LCDs and LFDs and a lower risk of mortality among adults with prediabetes, while an unhealthy number of points for both LCDs and LFDs tended to be associated with a higher risk of mortality (43). In contrast, a cross-sectional study conducted in Iran failed to establish a correlation between low-carbohydrate diets and increased levels of overweight and obesity (20).

In addition to inconsistent associations, previous studies have relied on single point measurements, and there is a lack of data based on multiple point measurements. We add to this literature by using a group-based multitrajectory method, which clusters distinct trajectory patterns considering more than one variable and considering its association with the trajectory of adiposity. We documented how the long-term trends between these scores are important to fully understand the quality and quantity of an individual's macronutrient intake, which can incorporate the intercorrelations between LCDs and LFDs and enhance the precision of personalized group membership probabilities. In addition, the state of obesity is not a static condition, but rather a dynamic process of change. We used repeated measures of overweight upwards trajectories covering more than 15 years rather than single-point measurements of overweight upwards trajectories to facilitate a comprehensive consideration of the dynamics. This strategy can describe in a straightforward manner how BMI and WHR may increase, decrease, or remain stable in different groups with varying initial BMI and WHR values. By mapping the BMI or WHR trajectories, it is intuitive to identify specific groups.

However, it is important to note that the association between slow growth of abdominal obesity and adverse dietary trajectories was not statistically significant and there was even a negative association in one diet trajectory. In contrast to other studies of a similar nature, this study reached inconsistent conclusions with other studies due to differences in assessment methodology, as few studies have examined dual trajectory associations (9, 44). The trajectory of slow growth of abdominal obesity was non-abdominal in the first few years of follow-up and did not become abdominal obesity until the last 2 years of follow-up when most of the participants had reached middle age. Obesity results from an imbalance between energy intake and energy expenditure. The gradual loss of muscle mass that occurs with age can potentially affect habitual energy expenditure and the energy imbalance that leads to the development of obesity (45). In addition, middle-aged and older adults have a lower metabolic rate than adolescents (46). As a result, middle-aged and older adults are at greater risk of obesity than their younger counterparts with an equivalent dietary intake. Obesity due to age-related metabolic decline may explain the lack of statistical significance of the association between poor dietary habits and slow-growing abdominal obesity.

Several possible mechanisms may clarify the association between unhealthy LCD and LFD scores with adiposity. Saturated fats have a high energy density, and may directly affect energy expenditure and storage. This further leads to an increased risk of adiposity and abdominal obesity. LCDs, such as refined grains and added sugars, could be associated with adiposity and dyslipidemia because of their high glycemic index (47, 48). High-quality carbohydrates, which include non-starchy vegetables, whole fruits, and whole grains, are rich in fiber and can slow glucose absorption (49). High-fiber diets give the feeling of fullness without overloading us with calories, which could lower the risk of the population being overweight or obese. Based on the given explanation, we can shed light on the lower risk of healthy LCD and LFD scores and the trajectories of adverse adiposity.

The main strengths of this study include repeating measures of BMI and WHR and a long follow-up and various dimensions for diet scores allowing the assessment of dietary intake use dynamic changes. Based on this nationally representative sample of Chinese adults, we mapped the trajectory of change in diet and adiposity which can reflect Chinese dietary intake and adiposity status from 1997 to 2011. Moreover, this study provides insight into the association between dietary intake and adiposity trends. We also undertook inverse-probability weighting and multiple imputations in the sensitivity analysis phase, which takes missing data into account, and the results from these analyses were consistent with the main findings. Our study also had some limitations. First, although the 24-h dietary review method is a frequently used dietary evaluation tool, self-reported dietary information is subject to potential recall bias. Second, this study cannot preclude residual confounding despite our adjustment for many covariates. Third, it is important to emphasize that our assessment of obesity was based on BMI and WHR, while other tools for assessing obesity, such as anthropometric indices, were not included in this study. However, it is undeniable that BMI and WHR are currently the more commonly used indicators to assess obesity (50). Further studies need to objectively evaluate dietary intake to confirm our findings, and more experimental studies are needed to explain the mechanism.

## 5 Conclusion

Our findings, based on a nationally representative longitudinal survey, identified four distinct multitrajectories of LCD and LFD scores and concluded that maintaining healthy LCDs and LFDs can markedly decrease the risk of adiposity. The findings underscore the necessity for population-representative research on the trajectory of dietary patterns, which can establish an evidentiary basis for the development of guidelines, policies, and intervention targets aimed at sustaining healthy food environments.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding authors: Siying Wu, Huangyuan Li, and Xiaoxu Xie.

## Ethics statement

The study was conducted according to the guidelines of the Declaration of Helsinki and was approved by the Institutional Review Board of the University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, United States (No. 07-1963). The National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention, approved the survey (No. 201524).

All subjects involved in the study gave their written informed consent.

## Author contributions

LZ and JG designed the research programs. LZ, XL, and XXu contributed to the data analysis. XL, XXu, and LY drafted the manuscript. SW, HL, and XXi reviewed the manuscript. All authors were involved in writing the paper and had final approval of the submitted and published versions and willing to share the study protocol and statistical code to generate the published results and data set with the journal editors.

## Funding

This research was funded by the National Natural Science Foundation of China (NSFC) (Grant number 82173553) and special funds for Education and Scientific Research of Directly Affiliated Institutions of Fujian Province (Grant number 21SCZZX003).

## Acknowledgments

We are grateful to the participants and staff of the CHNS for their contributions to the study. All data can be downloaded from the CHNS website (https://www.cpc.unc.edu/projects/china). All codes are available from the corresponding author on reasonable request.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1227994/full#supplementary-material

## References

1. World Health Organization. *Obesity and Overweight*. Available online at: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight (accessed September 28, 2023).

2. Saklayen MG. The Global Epidemic of the Metabolic Syndrome. *Curr Hypertens Rep*. (2018) 20:12. doi: 10.1007/s11906-018-0812-z

3. Brown KA. Metabolic pathways in obesity-related breast cancer. *Nat Rev Endocrinol*. (2021) 17:350–63. doi: 10.1038/s41574-021-00487-0

4. Lega IC, Lipscombe LL. Review: diabetes, obesity, and cancer-pathophysiology and clinical implications. *Endocr. Rev*. (2020) 41:33–52. doi: 10.1210/endrev/bnz014

5. Katta N, Loethen T, Lavie CJ, Alpert MA. Obesity and coronary heart disease: epidemiology, pathology, and coronary artery imaging. *Curr Probl Cardiol*. (2021) 46:100655. doi: 10.1016/j.cpcardiol.2020.100655

6. Powell-Wiley TM, Poirier P, Burke LE, Després JP, Gordon-Larsen P, Lavie CJ, et al. Obesity and cardiovascular disease: a scientific statement from the American Heart Association. *Circulation*. (2021) 143:e984–1010. doi: 10.1161/CIR.0000000000000973

7. Ruiz-Ortega M, Rayego-Mateos S, Lamas S, Ortiz A, Rodrigues-Diez RR. Targeting the progression of chronic kidney disease. *Nat Rev Nephrol*. (2020) 16:269–88. doi: 10.1038/s41581-019-0248-y

8. The Lancet Gastroenterology Hepatology. Obesity: another ongoing pandemic. *Lancet Gastroenterol Hepatol*. (2021) 6:411. doi: 10.1016/S2468-1253(21)00143-6

9. Zhang X, Zhang J, Du W, Su C, Ouyang Y, Huang F, et al. Multi-trajectories of macronutrient intake and their associations with obesity among Chinese adults from 1991 to 2018: a prospective study. *Nutrients*. (2021) 14. doi: 10.3390/nu14010013

10. Wang L, Zhou B, Zhao Z, Yang L, Zhang M, Jiang Y, et al. Body-mass index and obesity in urban and rural China: findings from consecutive nationally representative surveys during 2004-18. *Lancet*. (2021) 398:53–63. doi: 10.1016/S0140-6736(21)00798-4

11. Pan XF, Wang L, Pan A. Epidemiology and determinants of obesity in China. *Lancet Diabetes Endocrinol*. (2021) 9:373–92. doi: 10.1016/S2213-8587(21)00045-0

12. Afshin A, Forouzanfar MH, Reitsma MB, Sur P, Estep K, Lee A, et al. Health effects of overweight and obesity in 195 countries over 25 years. *N Engl J Med*. (2017) 377:13–27. doi: 10.1056/NEJMoa1614362

13. Shan Z, Guo Y, Hu FB, Liu L, Qi Q. Association of low-carbohydrate and low-fat diets with mortality among US adults. *JAMA Intern Med*. (2020) 180:513–23. doi: 10.1001/jamainternmed.2019.6980

14. Reynolds A, Mann J, Cummings J, Winter N, Mete E, Te Morenga L. Carbohydrate quality and human health: a series of systematic reviews and meta-analyses. *Lancet*. (2019) 393:434–45. doi: 10.1016/S0140-6736(18)31809-9

15. Ludwig DS, Hu FB, Tappy L, Brand-Miller J. Dietary carbohydrates: role of quality and quantity in chronic disease. *BMJ*. (2018) 361:k2340. doi: 10.1136/bmj.k2340

16. Warrier G, Incze MA. I want to lose weight: which diet is best? *JAMA Intern Med*. (2021) 181:1268. doi: 10.1001/jamainternmed.2021.3342

17. Tabibian S, Daneshzad E, Bellissimo N, Brett NR, Dorosty-Motlagh AR, Azadbakht L. Association between adherence to the dietary approaches to stop hypertension diet with food security and weight status in adult women. *Nutr Diet*. (2018) 75:481–7. doi: 10.1111/1747-0080.12440

18. Silveira EA, Noll PRES, Mohammadifard N, Rodrigues APS, Sarrafzadegan N, de Oliveira C. Which diets are effective in reducing cardiovascular and cancer risk in women with obesity? An integrative review. *Nutrients*. (2021) 13:3504. doi: 10.3390/nu13103504

19. Karimbeiki R, Namkhah Z, Alipoor E, Yaseri M, Hosseinzadeh-Attar MJ. The relationship between low-carbohydrate diet score, dietary insulin index and load with obesity in healthy adults. *Eat Weight Disord*. (2022) 27:3341–50. doi: 10.1007/s40519-022-01464-w

20. Jafari-Maram S, Daneshzad E, Brett NR, Bellissimo N, Azadbakht L. Association of low-carbohydrate diet score with overweight, obesity and cardiovascular disease risk factors: a cross-sectional study in Iranian women. *J Cardiovasc Thorac Res*. (2019) 11:216–23. doi: 10.15171/jcvtr.2019.36

21. Willems AEM, Sura-de Jong M, van Beek AP, Nederhof E, van Dijk G. Effects of macronutrient intake in obesity: a meta-analysis of low-carbohydrate and low-fat diets on markers of the metabolic syndrome. *Nutr Rev.* (2021) 79:429–44. doi: 10.1093/nutrit/nuaa044

22. Lei L, Huang J, Zhang L, Hong Y, Hui S, Yang J. Effects of low-carbohydrate diets versus low-fat diets on metabolic risk factors in overweight and obese adults: a meta-analysis of randomized controlled trials. *Front Nutr.* (2022) 9:935234. doi: 10.3389/fnut.2022.935234

23. Chawla S, Tessarolo Silva F, Amaral Medeiros S, Mekary RA, Radenkovic D. The effect of low-fat and low-carbohydrate diets on weight loss and lipid levels: a systematic review and meta-analysis. *Nutrients.* (2020) 12:3774. doi: 10.3390/nu12123774

24. Hu T, Mills KT, Yao L, Demanelis K, Eloustaz M, Yancy WS Jr, et al. Effects of low-carbohydrate diets versus low-fat diets on metabolic risk factors: a meta-analysis of randomized controlled clinical trials. *Am J Epidemiol.* (2012) 176(Suppl. 7):S44–54. doi: 10.1093/aje/kws264

25. Haufe S, Engeli S, Kast P, Böhnke J, Utz W, Haas V, et al. Randomized comparison of reduced fat and reduced carbohydrate hypocaloric diets on intrahepatic fat in overweight and obese human subjects. *Hepatology.* (2011) 53:1504–14. doi: 10.1002/hep.24242

26. Bian H, Hakkarainen A, Lundbom N, Yki-Järvinen H. Effects of dietary interventions on liver volume in humans. *Obesity.* (2014) 22:989–95. doi: 10.1002/oby.20623

27. Li X, Li M, Xu L, Zeng X, Zhang T, Yang H, et al. Associations between low-carbohydrate and low-fat diets and hepatic steatosis. *Obesity.* (2022) 30:2317–28. doi: 10.1002/oby.23551

28. Zhu Z, Yang X, Fang Y, Zhang J, Yang Z, Wang Z, et al. Trends and disparities of energy intake and macronutrient composition in China: a series of national surveys, 1982–2012. *Nutrients.* (2020) 12:2168. doi: 10.3390/nu12082168

29. Popkin BM, Du S, Zhai F, Zhang B. Cohort profile: The China Health and Nutrition Survey–monitoring and understanding socio-economic and health change in China, 1989-2011. *Int J Epidemiol.* (2010) 39:1435–40. doi: 10.1093/ije/dyp322

30. Wu C, Mi B, Luo W, Chen B, Ma J, Huang H, et al. Association between long-term changes in dietary percentage of energy from fat and obesity: evidence from over 20 years of longitudinal data. *Nutrients.* (2022) 14:3373. doi: 10.3390/nu14163373

31. Du S, Batis C, Wang H, Zhang B, Zhang J, Popkin BM. Understanding the patterns and trends of sodium intake, potassium intake, and sodium to potassium ratio and their effect on hypertension in China. *Am J Clin Nutr.* (2014) 99:334–43. doi: 10.3945/ajcn.113.059121

32. Halton TL, Willett WC, Liu S, Manson JE, Albert CM, Rexrode K, et al. Low-carbohydrate-diet score and the risk of coronary heart disease in women. *N Engl J Med.* (2006) 355:1991–2002. doi: 10.1056/NEJMoa055317

33. Akter S, Mizoue T, Nanri A, Goto A, Noda M, Sawada N, et al. Low carbohydrate diet and all cause and cause-specific mortality. *Clin Nutr.* (2021) 40:2016–24. doi: 10.1016/j.clnu.2020.09.022

34. Chen C, Lu FC. The guidelines for prevention and control of overweight and obesity in Chinese adults. *Biomed Environ Sci.* (2004) 17(Suppl.):1–36.

35. Song P, Li X, Bu Y, Ding S, Zhai D, Wang E, et al. Temporal trends in normal weight central obesity and its associations with cardiometabolic risk among Chinese adults. *Sci Rep.* (2019) 9:5411. doi: 10.1038/s41598-019-41986-5

36. Qian X, Su C, Zhang B, Qin G, Wang H, Wu Z. Changes in distributions of waist circumference, waist-to-hip ratio and waist-to-height ratio over an 18-year period among Chinese adults: a longitudinal study using quantile regression. *BMC Public Health.* (2019) 19:700. doi: 10.1186/s12889-019-6927-6

37. Su C, Zhao J, Wu Y, Wang H, Wang Z, Wang Y, et al. Temporal trends in dietary macronutrient intakes among adults in rural China from 1991 to 2011: findings from the CHNS. *Nutrients.* (2017) 9:227. doi: 10.3390/nu9030227

38. Deng Y, Paul DR. The relationships between depressive symptoms, functional health status, physical activity, and the availability of recreational facilities: a rural-urban comparison in middle-aged and older Chinese adults. *Int J Behav Med.* (2018) 25:322–30. doi: 10.1007/s12529-018-9714-3

39. World Health Organization. *Global Physical Activity Questionnaire (GPAQ) Analysis Guide.* Geneva (2012).

40. Nagin DS, Jones BL, Passos VL, Tremblay RE. Group-based multi-trajectory modeling. *Stat Methods Med Res.* (2018) 27:2015–23. doi: 10.1177/0962280216673085

41. Jones BL, Nagin DS. A note on a stata plugin for estimating group-based trajectory models. *Sociol Methods Res.* (2013) 42:608–13. doi: 10.1177/0049124113503141

42. Andruff H, Carraro N, Thompson AJ, Gaudreau P, Louvet B. Latent class growth modelling: a tutorial. *Quant Meth Psych.* (2009) 5:11–24. doi: 10.20982/tqmp.05.1.p011

43. Li L, Shan Z, Wan Z, Li R, Geng T, Lu Q, et al. Associations of lower-carbohydrate and lower-fat diets with mortality among people with prediabetes. *Am J Clin Nutr.* (2022) 116:206–15. doi: 10.1093/ajcn/nqac058

44. Zhang J, Wang H, Wang Z, Huang F, Zhang X, Du W, et al. Trajectories of dietary patterns and their associations with overweight/obesity among Chinese Adults: China Health and Nutrition Survey 1991–2018. *Nutrients.* (2021) 13:2835. doi: 10.3390/nu13082835

45. Wolfe RR. The underappreciated role of muscle in health and disease. *Am J Clin Nutr.* (2006) 84:475–82. doi: 10.1093/ajcn/84.3.475

46. Welch AA, Hayhoe RP, Cameron D. The relationships between sarcopenic skeletal muscle loss during ageing and macronutrient metabolism, obesity and onset of diabetes. *Proc. Nutr Soc.* (2020) 79:158–69. doi: 10.1017/S0029665119001150

47. Welsh JA, Sharma A, Abramson JL, Vaccarino V, Gillespie C, Vos MB. Caloric sweetener consumption and dyslipidemia among US adults. *JAMA.* (2010) 303:1490–7. doi: 10.1001/jama.2010.449

48. Vega-López S, Venn BJ, Slavin JL. Relevance of the glycemic index and glycemic load for body weight, diabetes, and cardiovascular disease. *Nutrients.* (2018) 10:1361. doi: 10.3390/nu10101361

49. Wall CR, Stewart AW, Hancox RJ, Murphy R, Braithwaite I, Beasley R, et al. Association between frequency of consumption of fruit, vegetables, nuts and pulses and BMI: analyses of the international study of asthma and allergies in childhood (ISAAC). *Nutrients.* (2018) 10:316. doi: 10.3390/nu10030316

50. Piqueras P, Ballester A, Durá-Gil JV, Martinez-Hervas S, Redón J, Real JT. Anthropometric indicators as a tool for diagnosis of obesity and other health risk factors: a literature review. *Front. Psychol.* (2021) 12:631179. doi: 10.3389/fpsyg.2021.631179

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 10 January 2024
DOI 10.3389/fpubh.2023.1329241

Check for updates

OPEN ACCESS

EDITED BY
Luis Suarez-Arrones,
Universidad Pablo de Olavide, Spain

REVIEWED BY
Azam Doustmohammadian,
Iran University of Medical Sciences, Iran
Fadwa Hammouh,
American University of Madaba, Jordan
Sofia Sousa,
University Porto, Portugal

*CORRESPONDENCE
Xu Meihong
✉ xumeihong@bjmu.edu.cn

†These authors have contributed equally to this work and share first authorship

RECEIVED 28 October 2023
ACCEPTED 11 December 2023
PUBLISHED 10 January 2024

CITATION
Zhixue L, Ying X, Zheng L, Yan M, Yanfang G, Dewang W, Weijun Y, Rencheng Z, Qing Y and Meihong X (2024) Status and associated factors of food and nutrition literacy among young adults aged 15–44 years in Shenzhen City, China.
*Front. Public Health* 11:1329241.
doi: 10.3389/fpubh.2023.1329241



# Status and associated factors of food and nutrition literacy among young adults aged 15–44 years in Shenzhen City, China

Li Zhixue[1†], Xu Ying[1†], Liu Zheng[1], Ma Yan[1], Guo Yanfang[1], Wang Dewang[1], Yu Weijun[1], Zhao Rencheng[1], Yuan Qing[1] and Xu Meihong[2*]

[1]Department of Chronic Disease Prevention and Control, Shenzhen Baoan Center for Chronic Diseases Control, Shenzhen, China, [2]Department of Nutrition and Food Hygiene, School of Public Health, Peking University, Beijing, China

**Background:** Food and nutrition literacy (FNL) plays an important role in young adults' dietary habits and nutrition. This study aimed to investigate FNL status and its associated factors among young adults aged 15–44 years in Shenzhen.

**Methods:** A cross-sectional survey of 5,390 participants was conducted in June 2021. FNL was measured using the Food and Nutrition Literacy Questionnaire for Chinese Adults (FNLQ). A generalized linear model was employed to analyze the factors associated with FNL.

**Results:** The median FNL score (total score = 100) was 68.00, which was below the adequate level of 80. FNL was divided into the two different domains of knowledge and skills, with significantly different scoring rate of 85.30 and 67.77%, respectively. The overall proportion of respondents with adequate FNL was 19.52%. The FNL score was significantly higher among the participants who were female ($\beta = 2.665$; 95% confidence interval [CI]: 2.031–3.299) and with higher education levels ($\beta$ ranging from 5.632 [CI: 3.845–7.419] to 10.756 [CI: 8.973–12.538]), healthcare-related work experience ($\beta = 4.197$; CI: 3.557–4.837) and a higher economic status ($\beta$ ranging from 0.753 [CI: 0.079–1.426] to 6.217 [CI: 5.208–7.227]). Those who were divorced or with an unknown marital status ($\beta = -8.438$; CI: −9.701, −7.175), abnormal body mass index (thin [$\beta = -2.115$; CI: −3.063, −1.166], overweight [$\beta = -1.427$; CI: −2.254, −0.600]), and suffering from chronic diseases (single disease [$\beta = -3.483$; CI: −4.485, −2.480], multimorbidity [$\beta = -5.119$; CI: −5.912, −4.327]) had significantly lower FNL scores.

**Conclusion:** Generally, the level of FNL among young adults in Shenzhen, China, was relatively low. Thus, nutrition education programs targeted at promoting improved FNL status call for additional emphasis, especially in subgroups with lower scores.

KEYWORDS

**China, Shenzhen, food and nutrition literacy, young adults, associated factors**

# 1 Introduction

Chinese dietary patterns and diet-related behaviors have undergone significant transitions in the past few decades, with recent changes trending toward diversification and modernization (1, 2). The problem of malnutrition, which mainly manifests as the coexistence of insufficient and unbalanced nutrition intake, has thus become more prominent. Consequently, nutrition-related chronic diseases have been susceptible to rapid growth (3). Nutritional deficiencies was estimated to affect 8.31% of Chinese. At the same time, 34.8% of Chinese adults were overweight and 14.1% were obese (4). Food and nutrition literacy (FNL) is defined as an individual's ability to obtain, understand, and process food and nutrition information and apply nutrition knowledge (5). It is regarded as a specific form of health literacy (6). FNL affects dietary behavior and nutrition intake, which leads to nutritional status disparities and further health impacts (7). Recent studies have suggested that malnutrition is closely related to FNL and poor dietary behavior (8). Specifically, individuals with low FNL are at a high risk of diet-related chronic diseases, such as diabetes/hyperglycemia, hypertension, coronary heart disease and stroke (9). It is worth noting that both FNL and dietary behavior can be improved by nutrition education and management (8). Thus, improving FNL has been regarded as an effective strategy to promote nutritional status and health.

In 2020, the frequency of adequate health literacy among the Chinese population increased from 6.48%, as recorded in 2008, to 23.15%, indicating a great improvement over the past 10 years (10). However, the current evaluation and monitoring system for health literacy in China is unable to evaluate the content of FNL. These existing measures do not accurately, objectively, or comprehensively reflect the status of FNL (11). At present, an established set of FNL assessment tools have been widely used among the general population outside of China, such as the Nutrition Literacy Scale (NLS) (12), the Nutrition Literacy Assessment Instrument (13), the Evaluation Instrument of Nutrition Literacy in Adults (14), and the Japan Nutrition Literacy Scale (15). However, due to significant differences in dietary habits, socioeconomic development, and cultural backgrounds, the above FNL assessment tools are not suitable for China's distinctive national conditions. Accordingly, some studies have used self-designed questionnaires to explore the status of nutrition knowledge and practice, as well as its correlation with chronic diseases, including diabetes/hyperglycemia, hypertension, and dyslipidemia (9, 16). However, there is still a lack of recognized evaluation methods and tools for assessing FNL for Chinese adults. In this regard, the FNLQ was established as having good validity and reliability (Cronbach's $\alpha = 0.893$, $\chi^2/DF = 4.750$, root mean square error of approximation [RMSEA] = 0.048, goodness-of-fit index [GFI] = 0.891 and adjusted goodness-of-fit index [AGFI] = 0.876). Thus, the FNLQ could be considered a promising scale for assessing the FNL of Chinese adults (17).

Shenzhen is one of the youngest and fastest growing cities in China. Unprecedented social and economic development in Shenzhen has led to significant changes in dietary patterns, which have largely contributed to the high prevalence of nutrition-related chronic diseases (e.g., excess body weight and dyslipidemia) (18, 19). Furthermore, the FNL status of young adults and its correlates remain to be examined in Shenzhen. Therefore, this study aimed to investigate and analyze the status of FNL and its associated factors using the FNLQ among young adults aged 15–44 years in Shenzhen. The findings are expected to assist public health authorities in developing strategies for FNL promotion based on sound references and theoretical foundations.

# 2 Materials and methods

## 2.1 Data collection

In June 2021, a stratified sampling approach was employed to recruit participants from each district of Shenzhen. The number of sample was determined according to the population's proportion of gender and age. The study participants were citizens aged 15–44 living in Shenzhen, China, who were willing to participate in the survey. Participants were asked to complete an online survey anonymously and independently. All participants were informed about the study, and consent was obtained before completing the survey. Cross-checking was conducted to eliminate invalid questionnaires due to a lack of information or implausible answers. The study was approved by the Human Research Ethics Committee of the Shenzhen Baoan Center for Chronic Diseases Control (approval number: SZBACCDC-2021013).

## 2.2 Measures

The questionnaire mainly included two sections: (1) the first section asked for basic information about the residents, namely their gender, nationality, age, educational level, marital status, health-related work experience, economic status, body height and weight, and chronic disease history; and (2) the second section comprised a 20-component survey of FNLQ, which consisted of two domains (knowledge and skills) and four dimensions (food and nutrition knowledge) [component 1–4], selecting food [component 5–10], preparing food [component 11–13], eating [component 14–20] (see Table 1). The questionnaire was developed and validated for Chinese adults, as reported elsewhere (17).

The FNLQ included 50 questions, with a total possible score of 100 points. The questions included 5-point Likert-type questions (e.g., for a statement such as, "Good dietary patterns are the foundation of adequate nutrition," respondents could indicate that they strongly disagree, disagree, do not know, agree, or strongly agree) and multiple-choice questions with only one right answer (e.g., "What is the approximate weight of a ping-pong-ball-sized egg?"). The higher the score, the higher the FNL level of the respondents. An FNL score higher than 80 was considered to indicate an adequate level of FNL. The scores of the different domains and dimensions were converted into scoring rates for comparison as follows:

$$\text{Domain scoring rate} = \sum \text{score of the domain for every respondent} / \left(\begin{array}{l}\text{full score of the domain}^{*}\text{ the}\\ \text{number of respondents}\end{array}\right)$$

$$\text{Dimension scoring rate} = \sum \text{score of the dimension for every respondent} / \left(\begin{array}{l}\text{full score of the}\\ \text{dimension}^{*}\text{ the number}\\ \text{of respondents}\end{array}\right)$$

TABLE 1 The scores of the core items of food and nutrition literacy.

| Domain | Dimension | No. | Components | Number of questions | Total score | M ($P_{25}$–$P_{75}$) | Scoring rate (%) |
|---|---|---|---|---|---|---|---|
| Knowledge | Food and nutrition knowledge | 1 | Understanding that a healthy diet should be followed at every stage of life. | 2 | 4 | 2.00 (1.00–2.00) | 85.93 |
| | | 2 | Understanding that a rational diet is an important basis for maintaining health and avoiding disease. | 2 | 4 | 2.00 (1.00–2.00) | 85.57 |
| | | 3 | Knowing about food classification, sources, and main nutritional characteristics. | 2 | 4 | 3.50 (2.00–4.00) | 84.22 |
| | | 4 | Choosing a healthy diet and enjoy your food. | 1 | 2 | 2.00 (1.00–2.00) | 86.58 |
| Skills | Selecting food | 5 | Making your own food, eating out less and sharing meals with family. | 2 | 4 | 4.00 (2.00–4.00) | 85.28 |
| | | 6 | Being able to choose safe and hygienic food stores and restaurants. | 2 | 4 | 3.00 (1.00–5.00) | 50.12 |
| | | 7 | Being able to judge food quality and to choose fresh and healthy food. | 1 | 2 | 2.00 (0.00–2.00) | 57.03 |
| | | 8 | Being able to read and understand food nutrition labels. | 3 | 6 | 3.00 (1.00–5.00) | 50.50 |
| | | 9 | Paying attention to nutrition and health information, identifying, and applying the right information. | 3 | 6 | 3.50 (1.00–6.00) | 59.16 |
| | | 10 | Being able to choose healthy food and fortified food correctly. | 3 | 6 | 4.00 (1.50–5.00) | 58.25 |
| | Preparing food | 11 | Being able to estimate food portion size. | 2 | 4 | 3.00 (1.00–4.00) | 67.60 |
| | | 12 | Being able to match food rationally. | 1 | 2 | 2.00 (0.00–2.00) | 52.02 |
| | | 13 | Being able to store, prepare, process, and cook food in an appropriate manner. | 8 | 16 | 9.50 (5.50–14.00) | 59.65 |
| | Eating | 14 | Eating regular meals and having a good breakfast. | 1 | 2 | 2.00 (0.50–2.00) | 82.55 |
| | | 15 | Eating a variety of foods, mainly grains, eating more fruits and vegetables, and drinking plenty of water. | 5 | 10 | 8.00 (4.5–10.00) | 76.91 |
| | | 16 | Eating appropriate amount of fish, poultry, eggs, lean meat, and adequate milk and beans. | 2 | 4 | 3.00 (1.50–4.00) | 74.13 |
| | | 17 | Eating less salt and less oil, controlling sugar, and limiting alcohol. | 3 | 6 | 3.50 (2.00–6.00) | 59.20 |
| | | 18 | Preparing meals on demand, eating in a civilized manner, and eliminating waste. | 2 | 4 | 4.00 (2.00–4.00) | 86.21 |
| | | 19 | Respecting different food cultures and paying attention to table manners. | 1 | 2 | 2.00 (1.00–2.00) | 85.95 |
| | | 20 | Balance eating and movement, measure and evaluate your weight regularly. | 5 | 10 | 6.50 (4.00–9.50) | 66.71 |
| Total | | | | 50 | 100 | 68.00 (44.50–87.00) | 67.15 |

## 2.3 Statistical analysis

After checking all the questionnaires and excluding the invalid ones, all data were imported into the Statistical Package for the Social Sciences 24.0 software program (SPSS, Inc., Chicago, Illinois, USA) for statistical analysis. As the FNL score did not exhibit a normal distribution, it was represented as median and percentile 25 and 75 (M[$P_{25}$–$P_{75}$]). The Wilcoxon rank sum test and Kruskal–Wallis test were applied to compare the median differences. Categorical variables were reported by frequencies and percentages of distribution. A chi-square test was used to examine whether the distribution of categorical variables between the groups was significantly different, and Spearman's correlation coefficient was calculated to examine the bivariate association between the different domains of FNL. Generalized linear and logistic linear regression analyses were used to explore the factors related to FNL. The statistical significance level was set at $p < 0.05$.

# 3 Results

## 3.1 Demographic characteristics of the study participants

This investigation included 5,390 valid questionnaires, of which 53.19% (2867) and 46.81% (2523) were completed by males and females, respectively, with an average age of 33.68 ± 4.60 years. The majority of the respondents was 35–44 years old (57.24%; $n = 3{,}085$), and they were mainly Han Chinese (99.54%; $n = 5{,}365$). Educational level was mainly junior college/undergraduate and above (64.25%; $n = 3{,}463$), followed by junior high school/senior high school or secondary specialized school (32.19%; $n = 1{,}735$). Most of the respondents were married (76.81%, $n = 4{,}140$). A total of 47.83% ($n = 2{,}578$) had health-related work experience. According to the BMI cutoff in the dietary guidelines for Chinese residents (2016) (20), 12.76% ($n = 672$) and 17.38% ($n = 915$) of the respondents were thin (BMI = 23.9–27.9) and overweight (BMI > 24), respectively (see Table 2 for additional information).

## 3.2 Food and nutrition literacy status

As shown in Table 1, the median FNL score was 68.00 (44.50, 87.00). The overall proportion of respondents with adequate FNL was 19.52% (1,052/5,390). Among the FNL domain, the scoring rate for knowledge was 85.30%, which was significantly higher than that of skill (67.77%). For the skill dimensions, the scoring rate for selecting food was the lowest (58.78%), followed by preparing food (60.40%) and then eating (72.89%) ($p < 0.05$) (Figure 1).

TABLE 2 Demographic characteristics of study participants ($N = 5{,}390$).

| Demographic characteristics | | *n* | % |
|---|---|---|---|
| Gender | Male | 2,867 | 53.19 |
| | Female | 2,523 | 46.81 |
| Age group (year) | 15–24 | 333 | 6.18 |
| | 25–34 | 1972 | 36.59 |
| | 35–44 | 3,085 | 57.24 |
| Educational level | Primary school and below | 192 | 3.56 |
| | Junior high school/senior high school or secondary specialized school | 1735 | 32.19 |
| | Junior college/undergraduate or above | 3,463 | 64.25 |
| Marital status | Unmarried | 848 | 15.73 |
| | Married | 4,140 | 76.81 |
| | Others | 402 | 7.46 |
| Ethnicity | Han | 5,365 | 99.54 |
| | Minority | 25 | 0.46 |
| Healthcare-related work experience | Yes | 2,578 | 47.83 |
| | No | 2,812 | 52.17 |
| Family income *per capita* (CNY/month) | ≤ 13,000 | 2,846 | 52.80 |
| | 13,000 ~ 24,000 | 1906 | 35.36 |
| | ≥ 24,000 | 638 | 11.84 |
| BMI group | Thin | 672 | 12.76 |
| | Normal | 3,678 | 69.86 |
| | Overweight | 915 | 17.38 |
| Chronic diseases | None | 3,509 | 65.10 |
| | Single disease | 589 | 10.93 |
| | Multimorbidity | 1,292 | 23.97 |

Chronic diseases (suffering from two diseases at the same time was judged as multimorbidity, including dyslipidemia, diabetes or elevated blood sugar, hypertension, cancer and other malignant tumors, chronic lung diseases like bronchitis, emphysema, pulmonary heart disease, liver diseases, heart disease, stroke, kidney disease, stomach disease or digestive system disease, emotional or other mental problems, etc.).

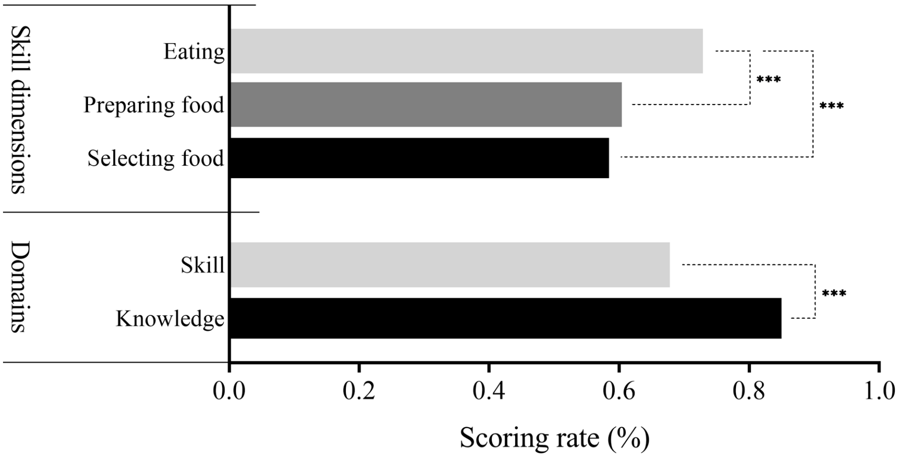



FIGURE 1
Scoring rate among different dimensions of FNL. *$p < 0.05$; **$p < 0.01$; **$p < 0.001$.

TABLE 3 Spearman correlation coefficients among the domains and dimensions of FNL ($N = 5,390$).

| Variables | | Total FNL and its domains | | | Skill dimensions | | |
|---|---|---|---|---|---|---|---|
| | | Total FNL | Knowledge | Skills | Selecting food | Preparing food | Eating |
| Total FNL and its domains | Total FNL | – | 0.698** | 0.996** | 0.891** | 0.840** | 0.747** |
| | Knowledge | 0.698** | – | 0.642** | 0.484** | 0.422** | 0.698** |
| | Skill | 0.996** | 0.642** | – | 0.903** | 0.855** | 0.729** |
| Skill dimensions | Selecting food | 0.891** | 0.484** | 0.903** | – | 0.783** | 0.456** |
| | Preparing food | 0.840** | 0.422** | 0.855** | 0.783** | – | 0.373** |
| | Eating | 0.747** | 0.698** | 0.729** | 0.456** | 0.373** | – |

–, no data; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

In terms of selecting food, the scoring rate for the components of "being able to read and understand food nutrition labels" and "being able to choose safe and hygienic food stores and restaurants" were the lowest, with scoring rates of 50.50 and 50.12%, respectively. In terms of preparing food, the scoring rate for the component of "being able to match food rationally" was the lowest at 52.02%. In terms of eating, the scoring rate for the components of "eating less salt and less oil, controlling sugar, and limiting alcohol" and "balance eating and movement; measure and evaluate your weight regularly" were the lowest, with scoring rates of 59.20 and 66.71%, respectively (Table 1).

As shown in Table 3, a significant correlation was found between total FNL and knowledge ($r = 0.698$) and skills ($r = 0.996$). The correlation coefficients between total FNL and each dimension ranged from 0.698 to 0.891 ($p < 0.05$). Higher skill scores were significantly correlated with higher knowledge scores ($r = 0.642$). The correlation coefficients between each dimension ranged from 0.373 to 0.903 ($p < 0.05$).

## 3.3 Distribution of food and nutrition literacy

As presented in Figure 2, both the FNL scores and the proportion of participants with adequate FNL were significantly higher in participants with the following characteristics: female (versus male), nonsmokers (versus smokers), higher level of education, married or never married, (versus divorced and other marital status), healthcare-related work experience (versus no such experience), higher family income, normal BMI (versus abnormal BMI < 18.5 or ≥ 24.0), and no chronic disease (versus suffering from chronic diseases) ($p < 0.05$). The FNL score was also significantly higher in participants aged 25–34 years compared to those aged 15–24 years and 35–44 years.

## 3.4 Multivariate analysis of food and nutrition literacy

The multivariate analysis showed that the FNL scores of females were higher than those of males ($\beta = 2.665$, CI: 2.031–3.299). A higher educational level ($\beta$ ranging from 5.632 [CI: 3.845–7.419] to 10.756 [CI: 8.973–12.538]) and higher family income ($\beta$ ranging from 0.753 [CI: 0.079–1.426] to 6.217 [CI: 5.208–7.227]) were also associated with an increased FNL score. The FNL scores of those who had never married ($\beta = -1.309$, CI: −2.255, −0.364) and those who were divorced or had another unknown marital status ($\beta = -8.438$; CI: −9.701, −7.175) were lower than those who were married. Health-related work experience was correlated with a higher FNL score compared to those without such experience ($\beta = 4.197$, CI:

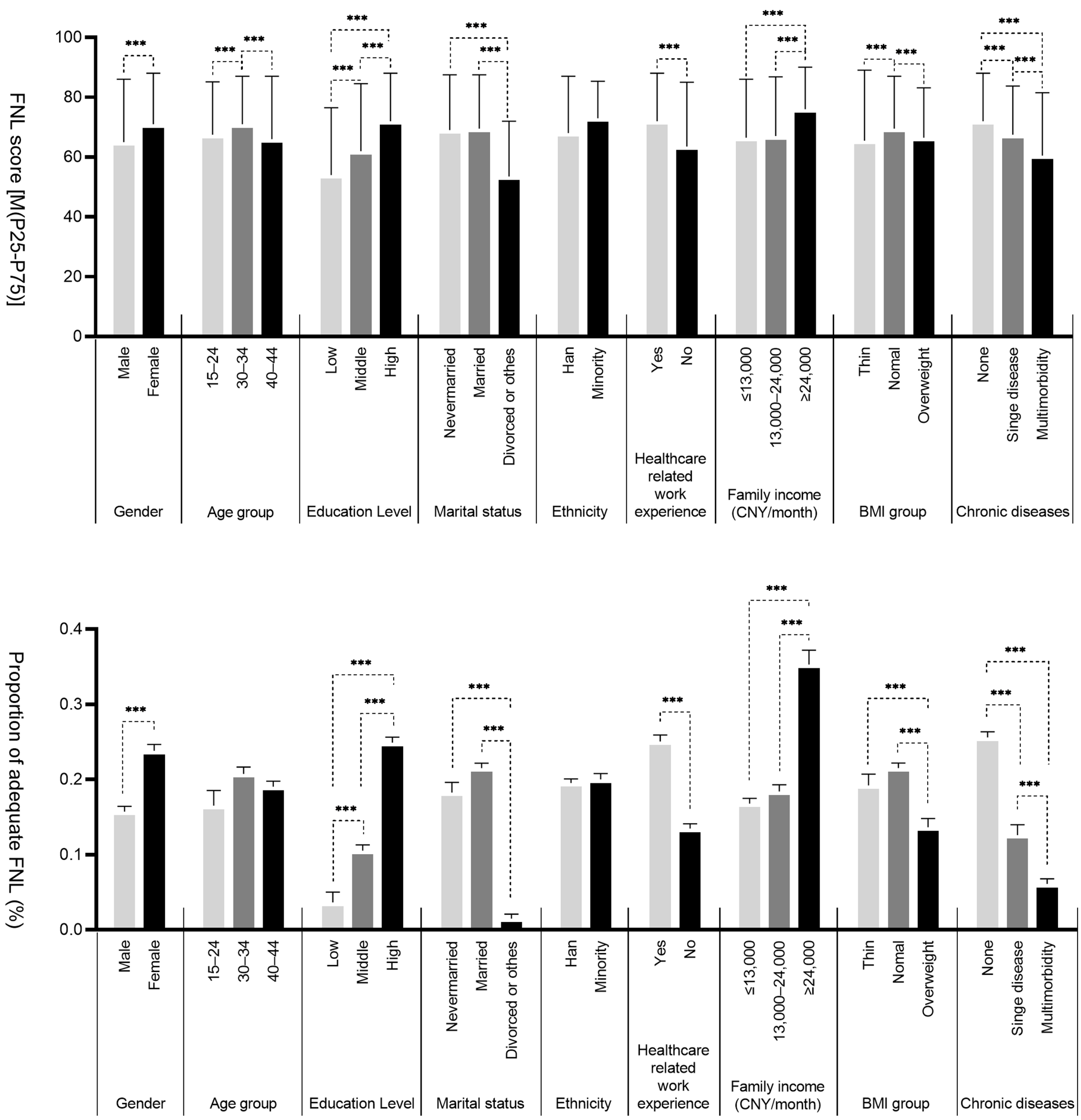



FIGURE 2
Distribution of FNL in young adults aged 15-44 in Shenzhen. Education level (Low: Primary school and below, Middle: Junior high school/senior high school or secondary specialized school, High: Junior college/undergraduate and above); Family income (Monthly income per capita = total family income/total number of family members, CNY: Chinese yuan); Chronic disease (Suffering from the two diseases at the same time were judged as multimorbidity, including dyslipidemia, diabetes or elevated blood sugar, hypertension, cancer and other malignant tumors, chronic lung diseases such as bronchitis, emphysema, pulmonary heart disease, liver diseases, heart disease, stroke, kidney disease, stomach disease or digestive system disease, emotional, and mental problems, etc.); **p* < 0.05; ***p* < 0.01; ****p* < 0.001.

3.557–4.837). The highest FNL score was also shown in the normal BMI group versus the abnormal BMI group (thin [$\beta=-2.115$; CI: $-3.063$, $-1.166$], overweight [$\beta=-1.427$; CI: $-2.254$, $-0.600$]). Suffering from a chronic disease decreased the FNL score compared to those who were healthy (singe disease [$\beta=-3.483$; CI: $-4.485$, $-2.480$], multimorbidity [$\beta=-5.119$; CI: $-5.912$, $-4.327$]).

Similarly, adequate FNL was more likely to be associated with being female, well-educated, having a stable marital status (never married or married), having healthcare-related work experience, having a higher family income, having a normal BMI, and not suffering from a chronic disease. Otherwise, participants with the lower age was were less likely to have adequate FNL (Table 4).

# 4 Discussion

FNL is an important content indicator of health literacy (11). It is also an essential factor in improving nutrition status and in preventing

TABLE 4 Multivariate analysis of FNL among young adults aged 15–44 in Shenzhen ($N = 5,390$).

| Demographic characteristics | Total FNL score[a] | | | Adequate FNL[b] | | |
|---|---|---|---|---|---|---|
| | $\beta$ (95% CI) | Wald $\chi^2$ | p value | OR (95% CI) | Wald $\chi^2$ | p value |
| Gender (Male) | Reference | | | Reference | | |
| Female | 2.665 (2.031–3.299) | 67.841 | < 0.001 | 1.475 (1.270–1.714) | 25.946 | < 0.001 |
| Age group (Year) (15–24) | Reference | | | Reference | | |
| 25–34 | 1.541 (0.145–2.937) | 4.680 | 0.031 | 0.614 (0.431–0.875) | 7.272 | 0.007 |
| 35–44 | 1.401 (−0.024–2.826) | 3.713 | 0.054 | 0.738 (0.630–0.864) | 14.263 | < 0.001 |
| Educational level (Primary school and below) | Reference | | | Reference | | |
| Junior high school/senior high school or secondary specialized school | 5.632 (3.845–7.419) | 38.169 | < 0.001 | 2.218 (1.004–4.900) | 3.880 | 0.049 |
| Junior college/undergraduate and above | 10.756 (8.973–12.538) | 139.892 | < 0.001 | 4.465 (2.041–9.769) | 14.036 | < 0.001 |
| Marital status (Married) | Reference | | | Reference | | |
| Never married | −1.309 (−2.255– −0.364) | 7.364 | 0.007 | 0.758 (0.606–0.949) | 5.833 | 0.016 |
| Divorced or others | −8.438 (−9.701– −7.175) | 171.410 | < 0.001 | 0.106 (0.047–0.242) | 28.560 | < 0.001 |
| Ethnicity (Minority) | Reference | | | Reference | | |
| Han | 1.112 (−3.344–5.567) | 0.239 | 0.625 | 0.823 (0.292–2.316) | 0.136 | 0.712 |
| Healthcare-related work experience (No) | Reference | | | Reference | | |
| Yes | 4.197 (3.557–4.837) | 165.291 | < 0.001 | 1.689 (1.449–1.969) | 45.033 | < 0.001 |
| Family income (CNY/month) (≤ 13,000) | Reference | | | Reference | | |
| 13,000–24,000 | 0.753 (0.079–1.426) | 4.799 | 0.028 | 1.099 (0.934–1.294) | 1.287 | 0.257 |
| ≥ 24,000 | 6.217 (5.208–7.227) | 145.648 | < 0.001 | 2.440 (1.981–3.006) | 70.455 | < 0.001 |
| BMI group (Normal) | Reference | | | Reference | | |
| Thin | −2.115 (−3.063–-1.166) | 19.084 | <0.001 | 0.836 (0.665–1.051) | 2.346 | 0.126 |
| Overweight | −1.427 (−2.254, −0.600) | 11.444 | < 0.001 | 0.645 (0.519–0.801) | 15.776 | < 0.001 |
| Chronic diseases (None) | Reference | | | Reference | | |
| Single disease | −3.483 (−4.485, −2.480) | 46.374 | < 0.001 | 0.448 (0.344–0.583) | 35.431 | < 0.001 |
| Multimorbidity | −5.119 (−5.912, −4.327) | 160.163 | < 0.001 | 0.277 (0.216–0.357) | 99.919 | < 0.001 |

[a]Multivariate linear regression model; [b]Logistic regression model; CNY: Chinese yuan: Chronic diseases (suffering from two diseases at the same time was judged as multimorbidity, including dyslipidemia, diabetes or elevated blood sugar, hypertension, cancer and other malignant tumors, chronic lung diseases like bronchitis, emphysema, pulmonary heart disease, liver diseases, heart disease, stroke, kidney disease, stomach disease or digestive system disease, emotional or other mental problems, etc.).

and controlling nutrition-related chronic diseases (21–24). In this study, the FNLQ was used to analyze the FNL of young adults aged 15–44 and its related factors in Shenzhen, China. The results showed that the median FNL score was only 68.00, which is below the minimum adequate level of 80. Accordingly, the probability of obtaining an adequate FNL score was only 19.52%, which indicates that the FNL status of young adults in this region needs further improvement. In addition, gender, age, educational level, marital status, healthcare-related work experience, family income, BMI classification, and health status were evaluated as factors related to FNL.

FNL has been divided into functional FNL, interactive FNL, and critical FNL (6). People are expected not only to master nutrition knowledge and skills, but also to exhibit the ability to make good decisions and address more complex nutrition issues as they arise (6, 25, 26). Therefore, FNL is regarded as an integral part of nutrition education programs and is crucial for health promotion (27). Our results revealed a significantly moderate correlation between knowledge score and total FNL score ($r = 0.698$) and skill score ($r = 0.642$). The necessity of food and nutrition knowledge as a prerequisite for dietary changes (28), although insufficient, calls for more emphasis on nutrition educational programs. However, the scoring rate for skills were lower than that for knowledge. Thus, improving skills might be a key strategy for upgrading the status of FNL. It is worth noting that a significant but poor correlation was found between preparing food and eating ($r = 0.373$) among the skill dimensions. Comprehensive intervention measures should be taken to improve each dimension of skills more evenly.

In the dimension of selecting food, the scoring rate for the components of "being able to read and understand food nutrition labels" and "being able to choose safe and hygienic food stores and restaurants" were the lowest. Food labels include accurate information about expiration dates, ingredient lists, and the nutritional value of foods (29). They have been designed to help Chinese consumers understand food and nutrition information, which is expected to enable them to choose healthy foods. However, food labels are rarely used by Chinese consumers when shopping for food (30). The results of a review study showed that Chinese commercial and residential food handlers had insufficient food safety knowledge, especially in the areas of foodborne pathogens and safe food-handling practices. It is thus necessary to improve the public's capacity to exercise food safety (31). Thus, future FNL-promoting programs should pay attention to skills assessment, which should focus on food and nutrition information acquisition, decision making, and safe practices.

In addition to making the appropriate food selections, preparing food is also an important part of balanced nutrient intake. Food categories, eating frequency, and cooking methods are gradually increasing and diversifying in China (1, 32). To improve diet-related behaviors, the 2022 Dietary Guidelines for Chinese residents have proposed reasonable food collocation which mainly refers to: following a healthy dietary pattern, and mastering the simple principles of food diversity, collocations between the staple and subsidiary food, coarse and fine grain, animal and vegetarian food, food with various colors, etc. (33). In terms of preparing food, the scores for the component "being able to match food rationally" were the lowest. This indicates that awareness of food collocation is poor among young adults in Shenzhen. According to the literature, dietary collocation and the daily intake of foods can notably be improved after a nutrition education intervention (34). Thus, we need to pay greater attention to addressing these weaker links in the preparing food dimension.

In another study, FNL was found to predict adherence to healthy/unhealthy dietary patterns (35). In the dimension of eating, the scores for the components of "eating less salt and less oil, controlling sugar, and limiting alcohol" and "balance eating and movement; measure and evaluate your weight regularly" were the lowest. According to the literature, the macronutrient composition of the diets consumed by Chinese adults has shifted toward fats, and sodium intake remains high (1, 32). Moreover, the intake of foods high in added sugar has increased (32). Under the increasing prevalence of alcohol use, low physical activity, and high BMIs, the disease burden attributed to these factors in China showed an overall upward trend from 1990 to 2019 (36). Therefore, further promoting the "China Healthy Lifestyle for All" project (where healthy lifestyles include salt, oil, and sugar reduction and healthy weight maintenance) is an important strategy to improve the FNL of young adults (37).

The results of our study showed that females had higher FNL levels than males. Chinese females are often responsible for taking care of their families and housework, including recipe and food selection and preparation (15, 38). Thus, they have more opportunities to learn, master, and use nutrition-related information and services more actively. Similarly, married people showed higher FNL scores, indicating that they may apply dietary knowledge into practice due to their own or their family's nutrition and health (39). At present, the average age of the permanent population in Shenzhen is less than 35 years, and youth may be more included to neglect nutrition and health knowledge due to factors such as a fast-paced work environment and the lack of nutrition education curricula. The young age group in our study had low FNL scores, which highlights the need for special attention to be directed toward this group. Higher educational level and economic status were also positively associated with FNL. Consistent results have been reported in several other studies (15, 40, 41). Furthermore, a review of the available literature indicates that abnormal BMI and suffering from a chronic disease have been associated with a low probability of achieving a high level of FNL (9, 17, 42), which is also consistent with our findings. Thus, these factors should be included in key publicity and education initiatives.

To the best of our knowledge, this is the first study to assess the FNL status of young adults in Shenzhen using a valid multidimensional tool. However, several limitations need to be noted. First, its cross-sectional design makes it impossible to interpret the direction of associations. Moreover, our results are based on an online investigation of the respondents' self-reported measures. Therefore, memory and reporting biases were possible. However, they may have been partly overcome by the large sample size, as well as by the anonymity and confidentiality of the data. Finally, this study was conducted among young adults aged 15–44 in Shenzhen, and the participants showed a relatively high education level. Therefore, its results may not be generalized to other age groups or different populations.

In conclusion, the present study showed that young adults in Shenzhen have relatively low FNL, especially in the food and nutrition-related skill dimensions. Among the possible associated factors examined, age, gender, educational level, health-related work experience, family income, marital status, BMI group, and health status were all significantly correlated with FNL. Further studies are recommended to identify other possible factors related to FNL. For example, FNL may be affected by social support levels that were not assessed in the present study (15). Nutrition education programs with content pertaining to food and nutrition knowledge, skills, and behaviors call for additional development emphasis. The findings have also highlighted the need for future studies focusing on FNL-promoting interventions for young adults in Shenzhen.

## Author contributions

LiZ: Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing, Funding acquisition. XY: Conceptualization, Resources, Validation, Writing – review & editing. LiuZ: Resources, Validation, Writing – review & editing. MY: Investigation, Methodology, Writing – review & editing. GY: Investigation, Methodology, Writing – review & editing. WD: Investigation, Methodology, Writing – review & editing. YW: Investigation, Methodology, Writing – review & editing. ZR: Investigation, Methodology, Writing – review & editing. YQ: Project administration, Resources, Supervision, Writing – review & editing. XM: Conceptualization, Project administration, Resources, Supervision, Validation, Writing – review & editing.

## Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## References

1. Bu T, Tang D, Liu Y, Chen D. Trends in dietary patterns and diet-related behaviors in China. *Am J Health Behav*. (2021) 45:371–83. doi: 10.5993/ajhb.45.2.15

2. Zhang J, Wang Z, Du W, Huang F, Jiang H, Bai J, et al. Twenty-five-year trends in dietary patterns among Chinese adults from 1991 to 2015. *Nutrients*. (2021) 13:1327. doi: 10.3390/nu13041327

3. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the global burden of disease study 2019. *Lancet*. (2020) 396:1204–22. doi: 10.1016/s0140-6736(20)30925-9

4. Chen K, Shen Z, Gu W, Lyu Z, Qi X, Mu Y, et al. Prevalence of obesity and associated complications in China: a cross-sectional, real-world study in 15.8 million adults. *Diabetes Obes Metab*. (2023) 25:3390–9. doi: 10.1111/dom.15238

5. Zoellner J, Connell C, Bounds W, Crook L, Yadrick K. Nutrition literacy status and preferred nutrition communication channels among adults in the lower Mississippi Delta. *Prev Chronic Dis*. (2009) 77:144–7. doi: 10.1016/j.pec.2009.03.008

6. Krause C, Sommerhalder K, Beer-Borst S, Abel T. Just a subtle difference? Findings from a systematic review on definitions of nutrition literacy and food literacy. *Health Promot Int*. (2018) 33:378–89. doi: 10.1093/heapro/daw084

7. Cassar AM, Denyer GS, O'Connor HT, Gifford JA. A qualitative investigation to underpin the development of an electronic tool to assess nutrition literacy in Australians adults. *Nutrients*. (2018) 10:251. doi: 10.3390/nu10020251

8. Carbone ET, Zoellner JM. Nutrition and health literacy: a systematic review to inform nutrition research and practice. *J Acad Nutr Diet*. (2012) 112:254–65. doi: 10.1016/j.jada.2011.08.042

9. Wang S, Wu Y, Shi M, He Z, Hao L, Wu X. Association between nutrition and health knowledge and multiple chronic diseases: a large cross-sectional study in Wuhan, China. *Nutrients*. (2023) 15:2096. doi: 10.3390/nu15092096

10. Li Y, Lv X, Liang J, Dong H, Chen C. The development and Progress of health literacy in China. *Front Public Health*. (2022) 10:1034907. doi: 10.3389/fpubh.2022.1034907

11. Li MX, Zhu WL, Xu YJ, Ma GS. Research and application of assessment tools for Residents' nutrition literacy. *Zhonghua Yu Fang Yi Xue Za Zhi*. (2020) 54:1031–4. doi: 10.3760/cma.j.cn112150-20200303-00236

12. Gibbs HD, Camargo J, Owens S, Gajewski B, Cupertino AP. Measuring nutrition literacy in Spanish-speaking Latinos: an exploratory validation study. *J Immigr Minor Health*. (2018) 20:1508–15. doi: 10.1007/s10903-017-0678-1

13. Gibbs H, Chapman-Novakofski K. Establishing content validity for the nutrition literacy assessment instrument. *Prev Chronic Dis*. (2013) 10:E109. doi: 10.5888/pcd10.120267

14. Yuen EYN, Thomson M, Gardiner H. Measuring nutrition and food literacy in adults: a systematic review and appraisal of existing measurement tools. *Health Lit Res Pract*. (2018) 2:e134–60. doi: 10.3928/24748307-20180625-01

15. Aihara Y, Minai J. Barriers and catalysts of nutrition literacy among elderly Japanese people. *Health Promot Int*. (2011) 26:421–31. doi: 10.1093/heapro/dar005

16. Huang MC, Lin KD, Chen HJ, Wu YJ, Chang CI, Shin SJ, et al. Validity of a short food frequency questionnaire assessing macronutrient and Fiber intakes in patients of Han Chinese descent with type 2 diabetes. *Int J Environ Res Public Health*. (2018) 15:1142. doi: 10.3390/ijerph15061142

17. Zhang Y, Zhang Z, Xu M, Aihemaitijiang S, Ye C, Zhu W, et al. Development and validation of a food and nutrition literacy questionnaire for Chinese adults. *Nutrients*. (2022) 14:1933. doi: 10.3390/nu14091933

18. Yang W, Xiao J, Yang Z, Ji L, Jia W, Weng J, et al. Serum lipids and lipoproteins in Chinese men and women. *Circulation*. (2012) 125:2212–21. doi: 10.1161/circulationaha.111.065904

19. Ni WQ, Liu XL, Zhuo ZP, Yuan XL, Song JP, Chi HS, et al. Serum lipids and associated factors of dyslipidemia in the adult population in Shenzhen. *Lipids Health Dis*. (2015) 14:71. doi: 10.1186/s12944-015-0073-7

20. Wang SS, Lay S, Yu HN, Shen SR. Dietary guidelines for Chinese residents (2016): comments and comparisons. *J Zhejiang Univ Sci B*. (2016) 17:649–56. doi: 10.1631/jzus.B1600341

21. Sarkar U, Fisher L, Schillinger D. Is self-efficacy associated with diabetes self-management across race/ethnicity and health literacy? *Diabetes Care*. (2006) 29:823–9. doi: 10.2337/diacare.29.04.06.dc05-1615

22. Blanchard CM, Courneya KS, Stein K. Cancer Survivors' adherence to lifestyle behavior recommendations and associations with health-related quality of life: results from the American Cancer Society's Scs-ii. *J Clin Oncol*. (2008) 26:2198–204. doi: 10.1200/jco.2007.14.6217

23. Williams MV, Baker DW, Parker RM, Nurss JR. Relationship of functional health literacy to Patients' knowledge of their chronic disease. A study of patients with hypertension and diabetes. *Arch Intern Med*. (1998) 158:166–72. doi: 10.1001/archinte.158.2.166

24. Safeer RS, Cooke CE, Keenan J. The impact of health literacy on cardiovascular disease. *Vasc Health Risk Manag*. (2006) 2:457–64. doi: 10.2147/vhrm.2006.2.4.457

25. Velardo S. The nuances of health literacy, nutrition literacy, and food literacy. *J Nutr Educ Behav*. (2015) 47:385–9.e1. doi: 10.1016/j.jneb.2015.04.328

26. Naigaga DA, Pettersen KS, Henjum S, Guttersrud Ø. Assessing Adolescents' perceived proficiency in critically evaluating nutrition information. *Int J Behav Nutr Phys Act*. (2018) 15:61. doi: 10.1186/s12966-018-0690-4

27. Truman E, Bischoff M, Elliott C. Which literacy for health promotion: health, food, nutrition or media? *Health Promot Int*. (2020) 35:432–44. doi: 10.1093/heapro/daz007

28. Nelson SA, Nickols-Richardson SM. A systematic review of peer nutrition education in childhood and adolescence. *Health Behav Policy Rev*. (2014) 1:247–64. doi: 10.14485/HBPR.1.4.1

29. Fisher G. Nutrition labeling reduces valuations of food through multiple health and taste channels. *Appetite*. (2018) 120:500–4. doi: 10.1016/j.appet.2017.09.013

30. Zhang J, Zhai L, Osewe M, Liu A. Analysis of factors influencing food nutritional labels use in Nanjing, China. *Foods*. (2020) 9:796. doi: 10.3390/foods9121796

31. Chen H, Feng Y. Moving forward to the future: a review of microbial food safety education in China. *Foodborne Pathog Dis*. (2021) 18:547–66. doi: 10.1089/fpd.2020.2889

32. Zhai FY, Du SF, Wang ZH, Zhang JG, Du WW, Popkin BM. Dynamics of the Chinese diet and the role of Urbanicity, 1991–2011. *Obes Rev*. (2014) 15 Suppl 1:16–26. doi: 10.1111/obr.12124

33. Chinese Nutrition Society. *Dietary guidelines for Chinese residents: 2022*. Beijing: People's Medical Publishing Press. (2022). p. 7–9

34. Shahril MR, Wan Dali WP, Lua PL. A 10-week multimodal nutrition education intervention improves dietary intake among university students: cluster randomised controlled trial. *J Nutr Metab*. (2013) 2013:658642:1–11. doi: 10.1155/2013/658642

35. Taylor MK, Sullivan DK, Ellerbeck EF, Gajewski BJ, Gibbs HD. Nutrition literacy predicts adherence to healthy/unhealthy diet patterns in adults with a nutrition-related chronic condition. *Public Health Nutr*. (2019) 22:2157–69. doi: 10.1017/s1368980019001289

36. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the global burden of disease study 2019. *Lancet*. (2020) 396:1223–49. doi: 10.1016/s0140-6736(20)30752-2

37. Wu F, Zhang L, Guo W, Wang M, Gao Y, Liu D, et al. Evaluation of China healthy lifestyle for all interventions based on re-aim framework – China, 2007-2020. *China CDC Wkly*. (2022) 4:403–6. doi: 10.46234/ccdcw2022.091

38. Michou M, Panagiotakos DB, Lionis C, Costarelli V. Socioeconomic inequalities in relation to health and nutrition literacy in Greece. *Int J Food Sci Nutr*. (2019) 70:1007–13. doi: 10.1080/09637486.2019.1593951

39. Gibbs HD, Kennett AR, Kerling EH, Yu Q, Gajewski B, Ptomey LT, et al. Assessing the nutrition literacy of parents and its relationship with child diet quality. *J Nutr Educ Behav*. (2016) 48:505–9.e1. doi: 10.1016/j.jneb.2016.04.006

40. Dallongeville J, Marécaux N, Cottel D, Bingham A, Amouyel P. Association between nutrition knowledge and nutritional intake in middle-aged men from northern France. *Public Health Nutr*. (2001) 4:27–33. doi: 10.1079/phn200052

41. De Vriendt T, Matthys C, Verbeke W, Pynaert I, De Henauw S. Determinants of nutrition knowledge in young and middle-aged Belgian women and the association with their dietary behaviour. *Appetite*. (2009) 52:788–92. doi: 10.1016/j.appet.2009.02.014

42. Zeng M, Zhu Y, Cai Z, Xian J, Li S, Wang T, et al. Nutrition literacy of middle school students and its influencing factors: a cross-sectional study in Chongqing, China. *Front Public Health*. (2022) 10:807526. doi: 10.3389/fpubh.2022.807526

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 08 February 2024
DOI 10.3389/fpubh.2024.1339149

Check for updates

OPEN ACCESS

EDITED BY
Luis Suarez-Arrones,
Universidad Pablo de Olavide, Spain

REVIEWED BY
Jingyuan Xiong,
Sichuan University, China
Octavian Vasiliu,
Dr. Carol Davila University Emergency Military Central Hospital, Romania

*CORRESPONDENCE
Shaokang Wang
shaokangwang@seu.edu.cn

RECEIVED 15 November 2023
ACCEPTED 26 January 2024
PUBLISHED 08 February 2024

CITATION
Jin X, Zhu J, Wang N, Sun L, Yu J, Wang S and Sun G (2024) Eating behavior during pregnancy mediates the association between depression and diet quality--a new strategy for intervention in pregnancy.
*Front. Public Health* 12:1339149.
doi: 10.3389/fpubh.2024.1339149



# Eating behavior during pregnancy mediates the association between depression and diet quality--a new strategy for intervention in pregnancy

Xingyi Jin[1], Jian Zhu[2], Niannian Wang[1], Lingzhen Sun[2], Junhui Yu[1], Shaokang Wang[1,3]* and Guiju Sun[1]

[1]Key Laboratory of Environmental Medicine and Engineering of Ministry of Education, Department of Nutrition and Food Hygiene, School of Public Health, Southeast University, Nanjing, China, [2]Danyang Maternal and Child Health Hospital, Danyang, Zhenjiang, China, [3]Department of Public Health, School of Medicine, Xizang Minzu University, Xianyang, China

**Background:** Depression can result in changes in eating behavior and decrease the quality of eating. It has been shown that maternal depression during pregnancy can result in malnutrition, which can have adverse effects on the pregnancy and the offspring. There is currently no clear association between depression and diet.

**Methods:** Five hundred and forty-nine pregnant women recruited from Danyang Maternal and Child Health Hospital in Jiangsu Province participated in this study and were administered the Intuitive Eating Scale-2 (IES-2), Edinburgh Post-natal Depression Scale (EPDS), Pregnancy Stress Scale (PPS), Self-rating Anxiety Scale (SAS), and Dietary Guidelines Adherence Index for Pregnant Women during Pregnancy (CDGCI-PW). The nutritional software collected dietary records for three consecutive days in mid-pregnancy to calculate dietary intake and nutrients that support energy production. The mediation analyses were conducted using SPSS 24.0 macro PROCESS.

**Results:** The relationship between depressive symptoms during pregnancy and diet quality was moderated primarily by two aspects of eating behavior, "Reliance on Hunger and Satiety Cues" (RHS) and "Body-Food Choice Congruence" (BFC). Depressive symptoms (EPDS scores) showed a negative correlation with RHS, BFC, and RHS, and BFC showed a positive correlation with diet quality, yielding a significant specific indirect effect. The multiple mediation model explained 14.7% of the variance in the diet quality.

**Conclusion:** This study highlights the important role of eating behaviors during pregnancy in the relationship between depressive symptoms (EPDS scores) and diet quality, and provides preliminary evidence for feasible ways pregnant women with depressive symptoms can improve diet quality, promote maternal and child health, and reduce depression.

KEYWORDS

pregnancy, nutrient, depression, eating behavior, diet, mediation analysis

# 1 Introduction

During pregnancy, depression is one of the most common mental disorders (1–3). It can potentially impact the mother's and unborn child's health and well-being. The diet of mothers has been negatively impacted by depression according to several studies (4, 5). A recent cohort study of Chinese pregnant women found an inverse association between prenatal depression and mothers' dietary patterns (6). Furthermore, poor diet quality is often detrimental to pregnant women. Pregnant women who consume low-quality diets are more likely to suffer from metabolic disorders and experience poor pregnancy outcomes (7–9). Moreover, it affects the development of their offspring (10, 11).

An irrational diet, obesity, and malnutrition are associated with gestational diabetes among Chinese mothers (12, 13). Research has demonstrated that pregnant women who consume higher-quality diets have offspring who possess better visual–spatial skills, intelligence, executive function, and behavior regulation abilities (14, 15). The importance of improving the diet of pregnant women is therefore paramount.

The importance of nutritional interventions during pregnancy has been demonstrated in numerous studies. In previous studies, the majority of nutrition interventions were dietitian-prepared meals, regular dietetic follow-up, and nutrient supplements. There has been little research on the motivation and changes in eating behavior of pregnant women themselves. Monitoring and developing healthy eating behaviors are equally important as a strategy for nutritional intervention during pregnancy. The Intuitive Eating Measurement Scale was developed by Tylka et al. to measure eating behavior and motivation. There are four different aspects of intuitive eating covered by the IES-2. "Unconditional Permission to Eat (UPE)" describes the behavior of eating whatever food is desired at the time. There is no classification of foods into allowed and forbidden items. UPE can be considered an anti-diet attitude. The "Eating for Physical Rather Than Emotional Reasons (EPR)" score assesses the ability to eat when physically hungry rather than relying on food to cope with negative emotions. According to EPR, eating styles are not influenced by emotional states. "Reliance on Hunger and Satiety Cues" (RHS) can be defined as the ability to regulate food intake by paying attention to hunger and satiety cues. RHS is characterized by the perception of physiological states. "Body-Food Choice Congruence" (BFC) refers to the selection of a healthy and tasty diet that is compatible with an individual's bodily needs. The concept of gentle nutrition aims to honor the health and function of the body by extending intuitive eating (16). This study suggests that the IES scale should be understood as four related, but distinct dietary behaviors in a population of pregnant women rather than as a single score (17). Several studies have demonstrated that higher depressive states are associated with lower intuitive eating behaviors and that low eating behaviors result in lower dietary quality (17–19).

Currently, nutrition interventions are inconsistent, and many studies do not collect eating behavior changes. In other words, participants' dietary perceptions or behaviors may change as soon as they enter a nutrition intervention study. Thus, the final outcome of the intervention may not be the result of just the intervention, but rather a combination of intuitive eating and positive eating accompanied by the intervention. The results of a recent study in 2023 indicate that simple changes in eating behavior alone can also influence nutritional quality without any intervention (20). An analysis of three European country pairs conducted in 2018 found an association between positive eating and both depressive symptoms and depressive disorders (21). Therefore, the purpose of this study was to investigate whether intuitive eating behaviors mediate the relationship between depressive states during pregnancy and diet quality in a population of pregnant women.

# 2 Materials and methods

## 2.1 Study design

The study was conducted at the Maternal and Child Health Hospital in Danyang City, Jiangsu Province, China. At the time of their first hospital visit following the diagnosis of pregnancy, all pregnant women in the region receive a Maternal and Child Health Card issued by the government. Women who were first-time cardholders were recruited and followed by nutritionists one-on-one during 20–25 weeks of gestation (when gestational diabetes screening was conducted). The sociodemographic information contained in the electronic records of the hospital is partial. The inclusion criteria for the study population were as follows: pregnant women diagnosed with a singleton pregnancy within the first 18 weeks of gestation; residing in Danyang and planning to give birth locally within the next year; voluntarily participating in the cohort study with informed consent; and capable of understanding and responding to the questionnaire accurately. The exclusion criteria were as follows: pregnant women under 18 years of age; pregnant women with previous diagnoses of syphilis, AIDS, anemia, cardiopulmonary disease, metabolic disorders, or psychological disorders; pregnant women with polycythemia vera. The study excluded 64 participants who were unable to complete the dietary questionnaire. A total of 549 pregnant women participated in this study between October 2022 and November 2023. They completed a baseline survey and a mid-pregnancy follow-up. The study was approved by the School of Public Health of Southeast University and Danyang Maternal and Child Health Hospital for ethical review.

## 2.2 Measures

### 2.2.1 Intuitive eating

The IES-2 consists of 23 items that are rated on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree" (16). A total of six items have been reverse-coded. There is an average score calculated for each of the four subscales and for the entire scale. The IES-2 was developed to assess four constructs thought to make up intuitive eating, including unconditional permission to eat (UPE; 6 items, e.g., "I tried to avoid certain foods high in fat, carbohydrates, or calories"), eating for physical rather than emotional reasons [EPR;8 items, e.g., "I usually stopped eating when I felt full (not overstuffed)"], reliance on hunger and satiety cues to determine when and how much to eat (RHS;6 items, e.g., "I could tell when I was slightly full") and Body-Food Choice Congruence (BFC; 3 items, e.g., "I mostly eat foods that give my body energy and stamina."). The Cronbach alphas for the Intuitive Eating-2 scale in the current sample were 0.78.

### 2.2.2 Depression

Perinatal depression symptoms were evaluated according to the 10-item Edinburgh Postnatal Depression Scale (EPDS) (22). This is a self-reported scale originally developed for postpartum women and has since been validated for use with pregnant women to identify the risk for perinatal depression. The participants were asked to select the response that best reflected their current situation over the past 7 days. Each item was scored on a 4-point scale ranging from 0 to 3 (0 = most of the time/very often to 3 = never/not at all). Negatively stated items were reversed-scored so that higher scores indicated a higher level of perinatal depression. A total score above 13 indicates depression levels consistent with depressive disorders. In this analysis, we used the total EPDS score as a continuous measure of perinatal depression status within the last week. The depressive group was defined as those with EPDS scores greater than 13, and the healthy group was defined as those with EPDS scores below 13. The Cronbach alphas for the depression subscales of the EPDS in the current sample were 0.82.

### 2.2.3 Anxiety

The widely used Zung's Self-rating Anxiety Scale (SAS) was used to assess anxiety symptoms (23). Anxiety symptoms are measured by 20 self-reported items on the SAS. Some of the items were worded symptomatically positive rated on a 4–1 scale (a little of the time, some of the time, a good part of the time, and most of the time), and others symptomatically negative rated on a 1–4 scale. A standardized scoring algorithm defines anxiety symptoms, with a total score range of 20–80. A score of >50 on the SAS indicates anxiety disorder risk. In this analysis, we used the total SAS score as a continuous measure of perinatal anxiety status within the last week. The Cronbach alphas for the anxiety subscales of the SAS in the current sample were 0.85.

### 2.2.4 Pregnancy stress

The Pregnancy Stress Scale (PPS), developed by Chan Changhui and some other researchers in the 1990s, was used to analyze the level and source of stress (24). There are 30 items in the PPS scale, which are categorized as follows: factor 1, stress induced by identification with parental roles, including 15 items; factor 2, stress induced by ensuring the health and safety of mother and child, including 8 items; factor 3, stress induced by physical activity and changes in appearance, including four items; factor 4, the remaining 3 items are other factors that have not been classified. There were four options for each item, including "not at all," "a little," "often," and "always." Scores were 0, 1, 2, and 3, and the total score was the sum of the scores for all entries, the higher the psychological stress, the higher the score. In this analysis, we used the total PPS score as a measure of perinatal stress status within the last week. The Cronbach alphas for the pregnancy stress subscales of the PPS in the current sample were 0.95.

### 2.2.5 Pregnancy dietary quality

The Dietary Guidelines Adherence Index for Pregnant Women during Pregnancy (CDGCI-PW) is a clinical evaluation tool to establish and assess the dietary quality of pregnant women based on the Dietary Guidelines for Chinese Residents (2016). The mid and later-pregnancy dietary scale consists of 13 items, including 5 core questions and 8 general questions. According to the Chinese Dietary Guidelines for mid and late-pregnancy, the questionnaire includes all recommended food groups and intakes. Each question is scored according to the proportion of food in the dietary tower. The details of this scale can be found in other studies (25). In general, the higher the index scores, the higher the proportion of pregnant women who consume all types of food within the recommended range and the lower the proportion who consume less than the recommended range. Based on the total score of the scale, it was possible to understand the difference between the dietary intake of pregnant women and the national dietary recommendations, as well as evaluate the overall quality of a pregnant woman's diet at mid and later pregnancy.

### 2.2.6 Dietary intake assessment

An individual dietary assessment will be provided by a dietitian during each woman's mid-pregnancy. During mid-pregnancy, pregnant women are required to bring their dietary records for three consecutive days to the hospital for their routine checkup. Recording researchers conducted a three-day, 72-h dietary review survey using the DaYingJia Intelligent Dietary Management System software, which determined the average daily dietary intake type, dietary intake, the intake of the three major energy-supporting nutrients (carbohydrates, proteins, and fats), and the percentage of energy supplied by those nutrients.

## 2.3 Statistical analysis

Data were analyzed using Hayes's (2013) PROCESS macro model 4 for SPSS 24.0 (26). Correlations were assessed by Pearson correlation coefficients between model variables (27) (27). A Bonferroni correction was conducted. There was no evidence of multicollinearity between the facets of intuitive eating (tolerance: 0.715–0.889, variance inflation factor: 1.124–1.398). Due to significant correlations between study variables and week, anxiety, and stress, these variables were included in the models as covariates of both the mediator and the outcome (26). Path analyses were conducted using ordinary least squares (OLS) regression analysis. Due to the IES-2 factor structure with four first-order latent factors and a second-order intuitive eating factor (16, 28), both a simple and a multiple mediation analysis were carried out. A multiple-mediator model has several advantages. It can provide a more accurate assessment of a mediation effect (29) and it allows the paths of each mediator to be examined with regard to the outcome while all other mediators are controlled (26). We used 10,000 bootstrap samples (percentile and 95% CI). Bootstrapping is a resampling method in which samples are repeatedly taken from the data set (with replacement) to estimate the sampling distribution of the indirect effect, and with that, to calculate the confidence interval for the indirect effect (26, 30). In contrast to normal theory approaches such as the Sobel test, bootstrapping does not make assumptions about the sampling distribution of the indirect effect. Therefore, a bootstrap confidence interval yields more accurate inferences and has more power (26, 31). If the 95% percentile bootstrap confidence interval for the indirect effect does not include zero, it is considered significant at the $p < 0.05$ level. Following Hayes (2013), unstandardized regression coefficients are reported. Specific analytical models can be found in Figures 1A,B.

# 3 Results

## 3.1 Baseline characteristics of study participants

In this study, a total of 549 individuals were included, of whom 242 had data on early pregnancy, mid-pregnancy, and late pregnancy, and 307 had data on mid-pregnancy only. Table 1 indicates that the mean age of the study participants was 30 years (SD = 4.81), the mean

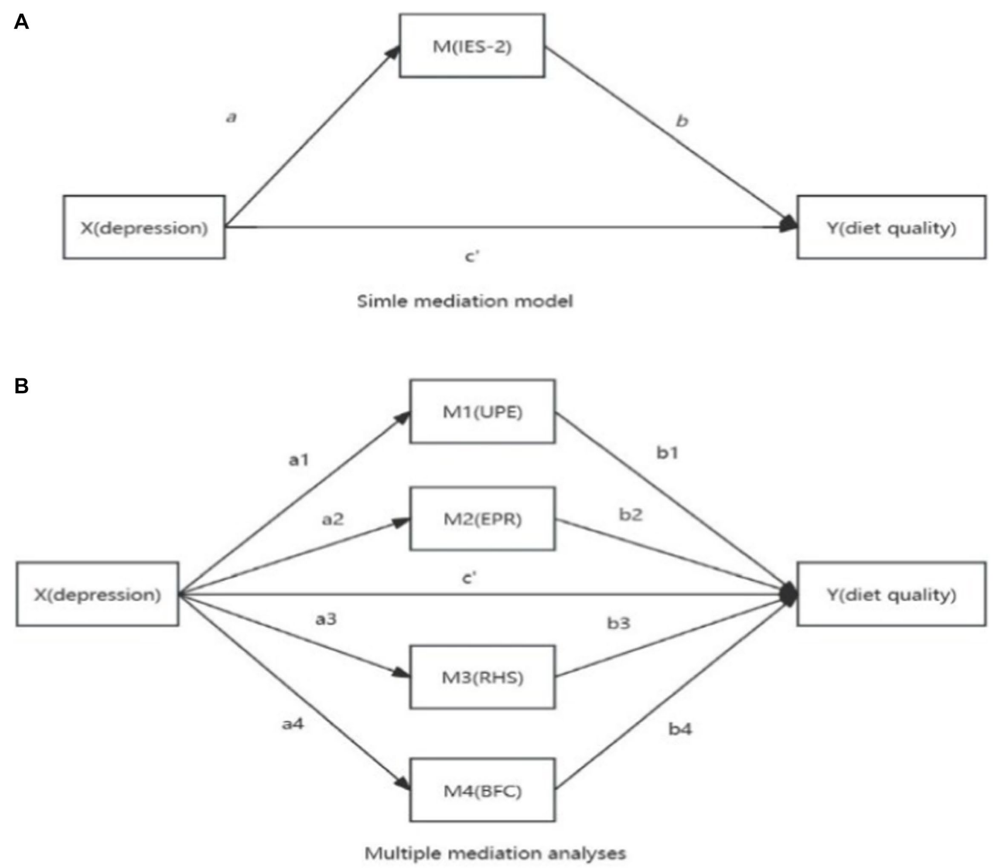



FIGURE 1
Analysis of two models (**A** and **B**).

BMI level at mid-pregnancy was 24.60 kg/m$^2$, and the mean gestation week at mid-pregnancy was 24.19 (SD = 2.2). In the study, 88.8% of participants completed secondary school or technical college, 59.1% had a household income ranging from 3,000 to 7,000 CNY per month, 63.9% worked, 90% had never smoked, 59.5% had never exercised, 95.6% took folic acid, 43.3% did not take any other nutritional supplements other than folic acid, 42.5% did not experience constipation, 62.1% slept regularly, and 25.8% considered themselves to have good sleeping quality. Furthermore, the mean scores for depressive symptoms (EPDS scores) (SAS score), anxiety (EPDS score), stress (PPS score), and diet quality (CDGCI-PW score) during mid-pregnancy were 5.1, 23.73, 23.03, and 3.46 (SD = 4.53, 6.98, 8.40, and 0.52 respectively).

## 3.2 Depressive symptoms and diet

Further research was conducted on 246 pregnant women who completed a recorded dietary questionnaire mid-pregnancy for three days (72 h) in Table 2. The results of the study showed that 17 pregnant women experienced significant depressive symptoms (EPDS score $\geq$ 13) during their pregnancy. A statistically significant difference was not found between the two groups of pregnant women at baseline (age, gestational week, pre-pregnancy body mass index, current body mass index, literacy level, and economic level), see Table 1. Compared to pregnant women without mid-pregnancy depressive symptoms, pregnant women with mid-pregnancy depressive symptoms consumed a more varied diet ($p = 0.02$, higher fruit intake ($p = 0.006$), more livestock and meat ($p = 0.043$), and fewer soybeans and nuts ($p = 0.001$)). There was no significant difference between the two groups in terms of the proportion of energy supplied by carbohydrates, proteins, and fats. However, both total carbohydrate and protein intake were significantly higher in the depressed group than in the health group ($p = 0.005, 0.016$). Depressive symptoms (EPDS scores) scored lower on the "Reliance on Hunger and Satiety Cues" scale ($p = 0.032$). The quality of diet was worse in both mid and late-pregnancy than in the health group ($p = 0.05, 0.006$).

## 3.3 Intuitive eating behavior and diet quality

Table 3 shows the association between intuitive eating behaviors during mid-pregnancy and diet quality in mid and late-pregnancy. According to the crude model, mid-pregnancy intuitive eating behavior scores, UPE scores, EPR scores, and RHS scores were significantly related to late-pregnancy diet quality ($p = 0.029, 0.015, 0.032, 0.018$). There was a significant association between the mid-pregnancy RHS score and the BFC score ($p = 0.050, 0.031$) after adjustment for confounders. There was a significant association between the total intuitive eating score, the UPE score, and the RHS score in late pregnancy ($p = 0.049, 0.028$, and $0.006$).

TABLE 1 Baseline characteristics of the study sample of pregnant women ($n = 549$).

| | Total | EPDS score [c] < 13 ($n = 515$) | EPDS score [c] ≥ 13 ($n = 30$) | $p$-value |
|---|---|---|---|---|
| | Mean [SD] or % ($n$) | Mean [SD] or % ($n$) | mean [SD] or % ($n$) | |
| **Age (years)** | 30 [4.81] | 31 [4.72] | 29 [4.93] | 0.451 |
| **Height (m)** | 160 [14.28] | 159.15 [14.65] | 160.36 [4.19] | 0.652 |
| **Weight before pregnancy (kg)** | 59.49 [12.83] | 59.58 [12.9] | 55.25 [7.13] | 0.112 |
| **Weight in mid-pregnancy (kg)** | 64.46 [10.97] | 64.65 [10.88] | 61.41 [13.08] | 0.193 |
| **Gestation week in early pregnancy (w)** [b] | 11.35 [2.08] | / | / | / |
| **Gestation week in mid-pregnancy (w)** | 24.19 [2.2] | 24.12 [1.94] | 25.4 [1.99] | **<0.001** |
| **Education (%)** | | | | 0.677 |
| Vocational high school and below | 35 (6.4%) | 34 (6.6%) | 1 (3.3%) | |
| College and secondary school | 483 (88.8%) | 455 (88.3%) | 28 (93.3%) | |
| Undergraduate and above | 26 (4.8%) | 25 (4.8%) | 1 (3.3%) | |
| **Monthly disposable household income (%)** | | | | 0.741 |
| More than 10,000 CNY | 87 (15.9%) | 84 (16.3%) | 3 (10%) | |
| 7,000–10,000 CNY | 102 (18.7%) | 93 (18.1%) | 9 (30%) | |
| 3,000–7,000 CNY | 325 (59.1%) | 310 (60.1%) | 15 (50%) | |
| Less than 3,000 CNY | 29 (5.3%) | 26 (86.6%) | 3 (10%) | |
| **Work (%)** | | | | 0.960 |
| No | 198 (35.8%) | 186 (36.11%) | 12 (40%) | |
| Yes | 351 (63.9%) | 333 (64.6%) | 18 (60%) | |
| **Smoking (%)** | | | | 0.061 |
| No, and no second-hand smoke | 497 (90.5%) | 468 (90.8%) | 29 (96.6%) | |
| No, and have second-hand smoke | 46 (9%) | 46 (8.9%) | 0 (0.0%) | |
| Used to smoke, but now quit | 3 (0.5%) | 2 (0.38%) | 1 (3.33%) | |
| **Physical activity (%)** | | | | 0.461 |
| No | 327 (59.56%) | 312 (60.5%) | 15 (50%) | |
| Exercise all the time before pregnancy | 82 (14.93%) | 76 (14.75%) | 6 (20%) | |
| Start exercising in early pregnancy | 33 (9.45%) | 26 (5.0%) | 5 (16.6%) | |
| Start exercising in mid-pregnancy | 107 (19.48%) | 103 (20%) | 4 (13.3%) | |
| **Body mass index before pregnancy (kg/m$^2$)** | 24.48 [9.74] | 24.54 [9.83] | 21.78 [2.64] | 0.127 |
| **Body mass index in mid-pregnancy (kg/m$^2$)** | 24.60 [4.83] | 25.29 [4.81] | 23.84 [5.05] | 0.577 |
| **Folic acid intake status (%)** | | | | 0.553 |
| No | 24 (4.4%) | 22 (4.3%) | 2 (3.3%) | |
| Yes | 525 (95.6%) | 497 (96.5%) | 28 (93.3%) | |
| **Other nutrient intake (%)** [a] | | | | 0.730 |
| No | 238 (43%) | 226 (43.8%) | 12 (40%) | |
| Yes | 311 (57%) | 293 (56.8%) | 18 (60%) | |
| **Constipation (%)** | | | | 0.590 |
| No | 232 (42.5%) | 220 (42.7%) | 12 (40%) | |
| 1–3 times per week | 266 (48.2%) | 252 (48.9%) | 14 (46.6%) | |
| 4–6 times per week | 35 (6.4%) | 32 (6.2%) | 3 (10%) | |
| Every time | 16 (2.9%) | 15 (2.9%) | 1 (3.3%) | |
| **Sleeping rhythm (%)** | | | | 0.060 |
| Irregularly, with night shifts | 16 (2.9%) | 14 (2.7%) | 2 (6.7%) | |
| Irregularly, sleeping at home at will | 191 (35%) | 172 (33.3%) | 19 (63.3%) | |

*(Continued)*

TABLE 1 (Continued)

| | Total | EPDS score [c] < 13 (*n* = 515) | EPDS score [c] ≥ 13 (*n* = 30) | *p*-value |
|---|---|---|---|---|
| Regularly | 342 (62.1%) | 333 (64.0%) | 9 (30%) | |
| **Depressive score in early pregnancy, EPDS score [b]** | 5.00 [5.15] | / | / | |
| **Depressive symptoms in early pregnancy, EPDS score [b]** | 17 (6.9%) | / | / | |
| **Depressive score in mid-pregnancy, EPDS score** | 5.10 [4.53] | 4.46 [3.73] | 16.07 [2.62] | **<0.001** |
| **Depressive symptoms in mid-pregnancy, EPDS score** | 30 (5.5%) | / | / | |
| **Anxiety score in mid-pregnancy, SAS score** | 23.73 [6.98] | 23.35 [6.78] | 30.20 [7.36] | **<0.001** |
| **Anxiety symptoms in mid-pregnancy, SAS score** | 1 (0.2%) | 0 | 1 | / |
| **Stress symptoms in mid-pregnancy, PPS score** | 23.03 [8.45] | 22.48 [7.9] | 30.20 [7.73] | **<0.001** |
| **Diet quality in early pregnancy, CDGCI-PW score [b]** | 46.90 [17.65] | / | / | |
| **Diet quality in mid-pregnancy, CDGCI-PW score** | 46.81 [14.24] | 42.86 [14.68] | 37.47 [12.92] | **0.044** |
| **Diet quality in late pregnancy, CDGCI-PW score [b]** | 67.86 [9.77] | / | / | |
| **Intuitive Eating Scale-2 score in mid-pregnancy** | 3.46 [0.52] | 3.48 [0.49] | 3.33 [0.57] | 0.068 |
| UPE | 3.24 [0.54] | 3.25 [0.53] | 3.17 [0.64] | 0.047 |
| EPR | 3.11 [0.43] | 3.13 [0.38] | 3.10 [0.43] | 0.074 |
| RHS | 3.71 [0.58] | 3.73 [0.52] | 3.43 [0.57] | **0.005** |
| BFC | 3.80 [0.57] | 3.81 [0.56] | 3.60 [0.65] | **0.046** |

SD, standard deviation; EPDS, Edinburgh Post-natal Depression Scale; PPS, Pregnancy Stress Scale; SAS, Self-rating Anxiety Scale; CDGCI-P, dietary guidelines adherence index for pregnant women during pregnancy; IES2, Intuitive Eating Scale-2; EPR, eating for physical rather than emotional reasons; UPE, unconditional permission to eat; RHS, Reliance on hunger and satiety cues; BFC, body-food choice congruence.
[a]Did not take any other nutritional supplements besides folic acid.
[b]*n* = 246 due to missing values.
[c]Based on mid-pregnancy EPDS score.
Bold indicates $p < 0.05$.

## 3.4 Association of depression, intuitive eating, and diet quality

We further mediated the analysis with 549 pregnant women who provided mid-pregnancy information to assess the associations between depressive symptoms (EPDS scores), intuitive eating behaviors, and diet quality. The following Table 4 presents a summary of descriptive statistics and correlational data. There was a significant negative correlation between depressive symptoms and stress and the RHS and BFC. UPE and anxiety were significantly correlated. There was a significant positive correlation between diet quality and the IES-2 total score, RHS, and BFC, and a significant negative correlation between diet quality and depressive symptoms and anxiety. A significant correlation was found between depressive symptoms and gestation week among the sociodemographic variables. There was no association between BMI during pregnancy and variables (IES-2, EPR, UPE, RHS, BFC, depressive symptoms (EPDS scores), stress, anxiety, diet quality, GWG, and week).

### 3.4.1 Simple mediation analyses

The results of simple mediation analysis are shown in Table 5. A significant positive association was found between IES-2 and diet quality and a significant negative relationship was found between depressive symptoms and diet quality when anxiety, stress, and gestational week were taken into account. There was no association between depressive symptoms (EPDS scores) and IES-2, however. As the percentile bootstrap confidence interval contained zero, the indirect effect was not statistically significant.

### 3.4.2 Multiple mediation analyses

Based on previous research, the IES-2 scale is not likely to lead to uniform behavior in pregnant women (the total score is meaningless), but instead should be divided into four subscales. This has also been demonstrated by other special groups. As a result, we divided the IES-2 scale into four subscales and conducted multiple mediation analyses.

The multiple mediation analysis, after controlling for gestational week, anxiety, and stress, indicated a significant total indirect effect (Table 6). In the relationship between depressive symptoms during pregnancy and diet quality, RHS and BFC were the primary moderators. Depressive symptoms showed a negative correlation with RHS, BFC, and RHS, and BFC showed a positive correlation with diet quality, yielding a significant specific indirect effect. The confidence interval for the contrast between the specific indirect effects of EPR and UPE included zero, indicating that the specific indirect effects of EPR and UPE did not statistically differ from each other. Meanwhile, depressive symptoms showed a negative correlation with diet quality (Table 7). Therefore, it is an indirect mediation model and the multiple mediation model explained 14.7% of the variance in the diet quality.

## 4 Discussion

This study investigated whether eating behaviors during pregnancy are associated with depressive symptoms and diet quality in pregnant women for the first time. In this study, preliminary simple mediation analyses indicated there was no relationship between

TABLE 2 Associations between depressive symptoms and eating status, intuitive eating behaviors.

| | Health group (*n* = 229) | Depression group[a] (*n* = 17) | *P-value* |
|---|---|---|---|
| **Number of species** | | | |
| Daily Ingredients | 14.31 (5.91) | 21 (9.35) | **0.020** |
| Grains | 2.82 (1.76) | 3.8 (1.92) | 0.233 |
| Vegetables and fruits | 4.3 (1.97) | 6 (2.34) | 0.067 |
| Meat, fish and seafood | 2.63 (1.22) | 2.8 (1.30) | 0.790 |
| Dairy, legumes, and nuts | 1.48 (1.03) | 1.60 (1.51) | 0.801 |
| **Food intake (g)** | | | |
| Grains | 301.99 (183.37) | 384.26 (200.18) | 0.335 |
| Potatoes | 63.18 (54.83) | 103.5 (65.32) | 0.243 |
| Vegetables and mushrooms | 200.46 (153.54) | 194.88 (277.71) | 0.940 |
| Fruits | 214.11 (115.86) | 389 (169.80) | **0.006** |
| Livestock and poultry meat | 120.39 (113.68) | 257.76 (95.34) | **0.043** |
| Egg | 82.97 (41.40) | 76.02 (32.83) | 0.716 |
| Soybeans and nuts | 89 (1.5) | 7.75 (8.9) | **0.000** |
| Aquatic products | 86.78 (68.31) | 167.4 (215.8) | 0.183 |
| Milk and dairy products | 233.77 (89.31) | 313.87 (134.11) | 0.107 |
| Fast food | 81.16 (78.97) | 92.2 (70.42) | 0.848 |
| **Intake of energy-supporting nutrients** | | | |
| Carbohydrates as a percentage of total energy | 54.07 (8.86) | 58.23 (11.08) | 0.317 |
| Protein as a percentage of total energy | 17.90 (3.20) | 18.40 (4.71) | 0.748 |
| Fat as a percentage of total energy | 28.01 (7.98) | 23.36 (10.37) | 0.216 |
| Carbohydrate intake | 218.55 (68.74) | 313.62 (113.80) | **0.005** |
| Protein intake | 69.93 (21.06) | 95.46 (42.20) | **0.016** |
| Fat intake | 50.28 (22.89) | 52.33 (28.5) | 0.848 |
| **IES-2 score in mid-pregnancy** | 16.86 (2.19) | 16.64 (2.06) | 0.610 |
| UPE | 20.12 (1.87) | 20.14 (2.03) | 0.977 |
| EPR | 24.18 (3.63) | 25.57 (2.50) | 0.321 |
| RHS | 11.52 (1.63) | 10.14 (1.57) | **0.032** |
| BFC | 11.63 (1.64) | 10.71 (2.14) | 0.166 |
| **Quality of diet (CDGCI-PW score)** | | | |
| Early Pregnancy | 48.05 (19.94) | 47.50 (20.31) | 0.947 |
| Mid-Pregnancy | 52.19 (14.70) | 41.43 (11.97) | **0.050** |
| Late Pregnancy | 69.67 (9.85) | 57.00 (10.65) | **0.006** |

SD, standard deviation; CDGCI-PW, dietary guidelines adherence index for pregnant women during pregnancy; IES-2, Intuitive Eating Scale-2; EPR, eating for physical rather than emotional reasons; UPE, unconditional permission to eat; RHS, Reliance on hunger and satiety cues; BFC, body-food choice congruence.
[a]Depression = EPDS score > 13.
Bold indicates $p < 0.05$.

intuitive eating behaviors, depressive symptoms (EPDS scores), and diet quality. According to previous studies, Daundasekara et al. concluded that subscales should be used rather than the total scale score to describe pregnant women's eating behaviors (17). Therefore, we conducted multiple analyses. The results indicated that the RHS and BFC mediated the relationship between depressive symptoms and diet quality and that depressive symptoms can directly influence diet quality. The relationship between depressive symptoms and diet quality was mediated by certain eating behaviors during pregnancy.

In the association between depressive symptoms and dietary intake, our study showed the opposite results to previous studies, which indicated that depressive symptoms were lower in those with high fruit and vegetable intake (32–34). But our research shows, the depressed group consumed more fruits and food groups than the health group but consumed less legumes. There was no difference between the depressed and health groups regarding the three macronutrient energy supply ratios, but carbohydrate and protein intake was greater in the depressed group. Furthermore, women who were classified as depressed in mid-pregnancy had poorer diet quality in the early, mid, and late stages of pregnancy compared to the health group. Even though the diet quality of the two groups was similar in the early stages of pregnancy, a significant difference was observed in

TABLE 3 Association of intuitive eating behaviors in mid-pregnancy with diet quality in mid and late-pregnancy.

| | Crude model[a] | | | Adjusted model[b] | | | | |
|---|---|---|---|---|---|---|---|---|
| | Beta | *t* | *p* | Beta | *t* | *p* | 95%CI | |
| **Mid-pregnancy intuitive eating behaviors and mid-pregnancy diet quality** | | | | | | | | |
| IES-2 | −0.302 | −0.625 | 0.533 | −0.618 | −1.111 | 0.269 | −1.918 | 0.541 |
| UPE | −0.002 | −0.012 | 0.991 | 0.167 | 0.769 | 0.443 | −1.931 | 4.377 |
| EPR | 0.243 | 0.811 | 0.419 | 0.322 | 0.941 | 0.349 | −1.303 | 3.655 |
| RHS | 0.306 | 1.938 | 0.055 | 0.315 | 1.864 | **0.050** | 0.168 | 5.380 |
| BFC | 0.244 | 1.437 | 0.153 | 0.405 | 2.187 | **0.031** | 0.312 | 6.415 |
| **Mid-pregnancy intuitive eating behaviors and late-pregnancy diet quality** | | | | | | | | |
| IES-2 | −1.190 | −2.218 | **0.029** | −1.243 | −1.935 | **0.049** | −2.007 | −0.027 |
| UPE | 0.504 | 2.462 | **0.015** | 0.546 | 2.238 | **0.028** | 0.330 | 5.576 |
| EPR | 0.723 | 2.175 | **0.032** | 0.686 | 1.738 | 0.086 | −0.260 | 3.868 |
| RHS | 0.448 | 2.403 | **0.018** | 0.460 | 2.777 | **0.006** | 0.801 | 4.788 |
| BFC | 0.214 | 1.164 | 0.247 | 0.272 | 1.291 | 0.200 | −0.875 | 4.121 |

IES2, Intuitive Eating Scale-2; EPR, eating for physical rather than emotional reasons; UPE, unconditional permission to eat; RHS: Reliance on hunger and satiety cues; BFC, body-food choice congruence.

[a]Crude model did not adjust for any confounding factors. [b]Adjusted model adjusted for age, week, education, prenatal BMI, mid-pregnancy BMI, folic acid intake status, constipation, sleeping rhythm, sleeping quality, smoke, anxiety, and stress.

Bold indicates $p < 0.05$.

TABLE 4 The intercorrelations between model variables.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. IES-2 | 1 | | | | | | | | | | | |
| 2. EPR | 0.827** | 1 | | | | | | | | | | |
| 3. UPE | 0.508** | 0.330** | 1 | | | | | | | | | |
| 4. RHS | 0.542** | 0.147** | 0.012 | 1 | | | | | | | | |
| 5. BFC | 0.632** | 0.270** | 0.067 | 0.495** | 1 | | | | | | | |
| 6. Depression | −0.046 | 0.075 | 0.046 | −0.208** | −0.138** | 1 | | | | | | |
| 7. Stress | −0.037 | 0.057 | 0.041 | −0.171** | −0.104* | 0.490** | 1 | | | | | |
| 8. Anxiety | 0.045 | 0.086* | −0.015 | −0.041 | 0.031 | 0.321** | 0.509** | 1 | | | | |
| 9. Diet quality | 0.223** | 0.078 | 0.032 | 0.266** | 0.287** | −0.145** | −0.080 | 0.139** | 1 | | | |
| 10.GWG | 0.067 | 0.078 | 0.006 | 0.058 | 0.001 | 0.077 | 0.139 | 0.090 | −0.046 | 1 | | |
| 11. Week | −0.037 | −0.002 | −0.004 | −0.070 | −0.046 | 0.109* | 0.076 | 0.029 | −0.042 | 0.064 | 1 | |
| 12. BMI (mid-pregnancy) | −0.047 | −0.024 | 0.007 | −0.079 | −0.036 | −0.049 | −0.041 | −0.042 | −0.014 | 0.120 | −0.026 | 1 |

IES2, Intuitive Eating Scale-2; EPR, eating for physical rather than emotional reasons; UPE, unconditional permission to eat; RHS, reliance on hunger and satiety cues; BFC, body-food choice congruence; GWG, gestational weight gain; BMI, body mass index.

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

the late stages. In addition, intuitive eating behaviors have an impact on the quality of the diet during the second and third trimesters of pregnancy. As a result, according to previous research, individuals with high levels of neuroticism are highly likely to engage in binge eating behaviors (35). Although eating disorder behaviors were not measured in our study. However, based on the diet of the depressed group, we found that carbohydrates and proteins were significantly higher, while the energy supply ratio of both was the same. Moreover, the depressed group consumes a greater variety of diets, but scores lower in terms of quality. Therefore, we presumed that the depressed group had a higher and unhealthy dietary intake and was more likely to have binge eating symptoms.

Although studies have shown that people with high fruit intake have less depression, most studies have not set a maximum fruit intake and have used people with low fruit intake as controls. In addition, some of the studies did not examine vegetables and fruits separately but combined them into one option. Though fruit is considered a "healthy food" in common sense, excessive consumption of fruit does not constitute a "healthy" diet. The consumption of high glycemic index fruits, in particular, can result in an increase in blood sugar levels or even the development of gestational diabetes in pregnant women. Women who are pregnant may pay more attention to "healthy" foods than those who are not pregnant. The general population may select ultra-processed sweets when overeating is

TABLE 5 Results for the pathways and model summary information in the simple.

| | | IES2 (M) | | | | DQ (Y) | | |
|---|---|---|---|---|---|---|---|---|
| | | coeff | *t* | *p* | | coeff | *t* | *p* |
| Depression (X) | a | −0.053 | −0.847 | 0.397 | *c'* | −0.482 | −3.269 | 0.001 |
| IES (M) | | / | / | / | *b* | 0.496 | 4.913 | <0.001 |
| Cov (week) | | −0.089 | −0.714 | 0.475 | | −0.116 | −0.394 | 0.693 |
| Cov (stress) | | −0.040 | −1.083 | 0.279 | | −0.199 | −2.280 | 0.023 |
| Cov (anxiety) | | 0.073 | 1.778 | 0.075 | | 0.487 | 5.034 | <0.001 |
| | | | | | | | | |
| | | $R^2$ | 0.009 | | | $R^2$ | 0.110 | |
| | | *F* | 1.251 | | | *F* | 13.374 | |

IES2, Intuitive Eating Scale-2; DQ, diet quality.

TABLE 6 Indirect effects of depression on diet quality through the facets of intuitive eating.

| | | | 95% Percentile confidence interval | |
|---|---|---|---|---|
| Mediator | Parameter estimate | SE | Lower | Upper |
| Total | −0.144 | 0.053 | −0.255 | −0.045 |
| UPE | −0.004 | 0.010 | −0.011 | 0.032 |
| EPR | −0.001 | 0.010 | −0.024 | 0.020 |
| RHS | −0.076 | 0.035 | −0.157 | −0.020 |
| BFC | −0.070 | 0.035 | −0.151 | −0.010 |

EPR, eating for physical rather than emotional reasons; UPE, unconditional permission to eat; RHS, reliance on hunger and satiety cues; BFC, body-food choice congruence.

prevalent, while pregnant women may prefer "healthy" sweets like fruit. A study of pregnant women showed that sweet consumption was more reflective of a tendency to ignore satiety (36). As a result, we do not believe that it is reasonable to combine vegetables and fruits on this point, as they differ in this regard. Those who suffer from depression and lose their appetite may also be more inclined to consume sugary foods rather than fewer vegetables (37, 38).

It has been shown in our research that negative emotions also influence eating behaviors and that all three kinds of emotions – depression, anxiety, and stress – influence each other. This is consistent with previous research (39). Although depression anxiety stress are all negative emotions, the three are not the same (40). In our study, both depressive symptoms and stress scores were correlated with RHS and BFC scores, but anxiety scores were only correlated with EPR scores. It has been demonstrated in previous studies that binge eating is more common in individuals suffering from depression or anxiety and less common in more stressed individuals (41, 42). This may be due to the fact that our study measured pregnancy stress. Among pregnant women, stress from pregnancy might be a contributing factor to the development of depression. Therefore, the consistency of the association was reflected in this study. In addition, our study did not observe the effects of gestational weight gain, gestational week, BMI, and eating behaviors, but there was an association between gestational week and depressive symptoms. The reason for this may be that the weight gain during pregnancy was not significant. Nevertheless, the gestational week is a reflection of the course of pregnancy. As time passes, depressive symptoms may become more pronounced as we reach the latter stages of pregnancy. The risk of prenatal depression increases as the pregnancy progresses and clinically significant depressive symptoms are common in the mid and late trimester (43). In order to further understand the importance of observing this part in the latter stages of pregnancy, it is necessary to differentiate between different trimesters of pregnancy.

According to our study, depressive symptoms (EPDS scores) is associated with fewer intuitive eating behaviors and poorer diet quality, as well as fewer intuitive eating behaviors associated with poorer diet quality. Depressive symptoms have been shown to influence eating behaviors such as emotional eating and eating disorders (44). Furthermore, they may not be able to follow their self-imposed hunger to eat or stop eating, which can also be reflected in the RHS scale. However, for mothers who are unable to reduce their intake of food and tend to reject unhealthy, high-sugar foods, conflicting eating behaviors may result. Depression during pregnancy and diet may be biologically related (45). In pregnancy, depression scores have been associated with reductions in dairy products, sweetened beverages, sugar, and packaged snacks, increased magnesium intake, increased non-core foods intake, and decreases in core food and fruit intake (4). Due to this, BFC was more evident during the same time period in studies of pregnant women participating in intuitive eating programs. Furthermore, our study showed that lower intuitive eating behaviors in mid-pregnancy predicted poorer diet quality in late pregnancy. Most current studies, however, are cross-sectional and cannot predict future diet quality because they are limited to contemporaneous data.

Previous studies have focused primarily on depression and diet quality without considering dietary behaviors within the population (46, 47). Our study demonstrated that, during mid-pregnancy, pregnant women's RHS and BFC eating behaviors were associated with depressive symptoms (EPDS scores) and diet quality. The results of a recent study suggest that eating behaviors may mediate the relationship between satiety and dietary intake and that interventions targeting hunger and satiety may help prevent binge eating (48). As part of our study, the RHS was a subscale measuring whether pregnant participants adhered to hunger and satiety during mid- and late pregnancy, with the RHS demonstrating a significant association with diet quality during this period. During pregnancy, women undergo significant physical, physiological, and immunological changes, making them more susceptible to

10.3389/fpubh.2024.1339149

TABLE 7 Results for the pathways and model summary information in the multiple mediation model to explain diet quality.

| Antecedent | | M1 (UPE) | | | | M2 (EPR) | | | | M3 (RHS) | | | | M4 (BFC) | | | | Y (DQ) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | coeff. | SE | *p* | | coeff. | SE | *p* | | coeff. | SE | *p* | | coeff. | SE | *p* | | coeff. | SE | *p* |
| X (depression) | $a_1$ | 0.014 | 0.017 | 0.423 | $a_2$ | 0.043 | 0.038 | 0.257 | $a_3$ | −0.0636 | 0.0184 | **0.001** | $a_4$ | −0.047 | 0.018 | **0.011** | $c'$ | −0.509 | 0.150 | **0.001** |
| $M_1$ (UPE) | | / | / | / | | / | / | / | | / | / | / | | / | / | / | $b_1$ | 0.288 | 0.370 | 0.437 |
| $M_2$ (EPR) | | / | / | / | | / | / | / | | / | / | / | | / | / | / | $b_2$ | −0.033 | 0.179 | 0.855 |
| $M_3$ (RHS) | | / | / | / | | / | / | / | | / | / | / | | / | / | / | $b_3$ | 1.197 | 0.384 | **0.002** |
| $M_4$ (BFC) | | / | / | / | | / | / | / | | / | / | / | | / | / | / | $b_4$ | 1.504 | 0.391 | **0.001** |
| Cov (week) | | −0.008 | 0.035 | 0.814 | | −0.017 | 0.076 | 0.8205 | | −0.0393 | 0.0369 | 0.288 | | −0.025 | 0.037 | −0.663 | | −0.075 | 0.291 | 0.796 |
| Cov (stress) | | 0.009 | 0.011 | 0.371 | | −0.002 | 0.023 | 0.9075 | | −0.0257 | 0.0109 | 0.019 | | −0.022 | 0.011 | 0.052 | | −0.159 | 0.086 | 0.066 |
| Cov (anxiety) | | −0.012 | 0.011 | 0.295 | | 0.035 | 0.025 | 0.1554 | | 0.019 | 0.0121 | 0.115 | | 0.031 | 0.012 | 0.012 | | 0.459 | 0.095 | <0.001 |
| | | $R^2$ | 0.005 | | | $R^2$ | 0.019 | | | $R^2$ | 0.0559 | | | $R^2$ | 0.033 | | | $R^2$ | 0.148 | |
| | | F | 0.631 | | | *F* | 1.357 | | | *F* | 8.0123 | | | *F* | 4.636 | | | *F* | 11.601 | |
| | | P | 0.641 | | | *P* | 0.247 | | | *P* | **<0.001** | | | *P* | **<0.001** | | | *P* | **<0.001** | |

EPR, eating for physical rather than emotional reasons; UPE, unconditional permission to eat; RHS, reliance on hunger and satiety cues; BFC, body-food choice congruence.
Bold indicates $p < 0.05$.

nutritional deficiencies (4). When women are not pregnant, they focus on maintaining a healthy body image and self-image, and they may be more concerned about their hunger to avoid nutritional deficiencies. As a result, pregnant women may be more inclined to follow their body hunger. Other similar studies have focused on the mediating role of positive eating behaviors (49, 50). A recent study found a similar relationship between intuitive eating and positive thinking, for example in choosing healthy foods (51). Therefore, our study provides some support for previous mediational modeling studies that suggest positive-thought eating mediates the association between negative emotions and eating.

In addition, nutritional psychiatry is emerging as a very promising field, and numerous studies have demonstrated that nutrition can improve mental health. As a result, reverse causality may exist (52, 53). In a study by Namely et al., people who had previously suffered from depression and sought treatment scored higher on eating patterns, and those unaware of their depression scored lower. Participants in our study were pregnant women who had never been screened for depressive symptoms (EPDS scores) and who had not received any psychological assistance before participation. Therefore, our study falls under the category of assessing the effect of depressive symptoms on eating behavior and dietary intake without knowing whether a person is depressed. In some studies, the results may not have been significant because some of the study populations knew they had depressive symptoms before being observed in their eating behaviors, so they may have altered their eating behaviors subjectively. This resulted in confounding and did not reflect depression's impact on both. The effects of nutritional interventions may be bidirectional in the real world. In our opinion, this may not matter, since improved eating behaviors could reduce the negative effects of depressive symptoms during pregnancy while improving the quality of the diet during pregnancy and encouraging the development of healthy children. In addition to traditional nutritional interventions, we believe pregnant women should be educated about eating behaviors. These two strategies are essential for ensuring good nutritional status during pregnancy and promoting the health of the mother and child. The approach is also more economically advantageous from a socio-economic standpoint.

Our limitations are, first, that while we collected diet quality during pregnancy, we did not measure dietary behaviors in late pregnancy. As a result, even though we observed a correlation between dietary behaviors in mid-pregnancy and diet quality during late pregnancy, we were not able to find a correlation between dietary behaviors during late pregnancy and diet quality. As a result of the special characteristics of pregnancy, pregnant women's dietary behaviors may change more rapidly than the general population during pregnancy. Consequently, we do not believe that mid-pregnancy dietary behaviors can replace late-pregnancy dietary behaviors. In addition, we did not measure emotional eating, binge eating behavior, or personality traits in pregnant women. The results of the study indicate that people with severe depressive symptoms are highly likely to experience binge eating disorder symptoms. Eating behaviors influenced by personality traits were not assessed in this study. We also failed to measure social family support for pregnant women, as this can also affect depression. Lastly, the limitation of this study is the lack of a clinical diagnosis of depression (54). However, the EPDS is a widely used screening tool for postpartum depression, having been validated against clinical interviews in the setting where the present study was carried out, and with good psychometric properties (54). In the future, we believe that it is possible to conduct prospective studies in the early, middle, and late phases of pregnancy, as well as during the postpartum period, which will allow us to observe the changes in dietary behaviors over time. Consequently, it is possible to obtain more convincing evidence to discuss the effects of depression during pregnancy on eating behavior and quality, as well as to investigate the bidirectional causal role that nutrition plays in depression. The effectiveness of traditional interventions can be compared to develop new strategies for pregnancy interventions in the future.

## 5 Conclusion

This study highlights the important role of eating behaviors during pregnancy in terms of the relationship between depression and diet quality and provides preliminary evidence for possible ways to achieve higher diet quality in pregnant women with depressive symptoms. In particular, for pregnant women with some depressive tendencies, promoting maternal and offspring health by encouraging intuitive eating behaviors as a nutritional intervention is a useful and economical strategy. Future studies of intuitive eating behaviors could be conducted in more pregnant women populations to gain more insight into the temporal and causal relationships between depression and diet quality.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by the School of Public Health of Southeast University and Danyang Maternal and Child Health Hospital for ethical review. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

XJ: Data curation, Investigation, Methodology, Software. JZ: Writing – review & editing, Funding acquisition, Investigation, Software, Supervision. NW: Conceptualization, Investigation, Software. LS: Writing – review & editing, Conceptualization, Investigation, Software. JY: Writing – review & editing, Conceptualization, Investigation, Software. SW: Writing – review & editing, Funding acquisition, Project administration, Resources, Validation, Visualization. GS: Writing – review & editing, Project administration, Validation, Visualization.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This study was funded by the Jiangsu Danyang Science and Technology Project Key Research and Development Plan Project (Social Development) (No. SSF202212), China Health Promotion Foundation (No. z093001) and Chinese Nutrition Society (No. CNS- HPNK2022-140).

## Acknowledgments

We are grateful for the support of the team from Southeast University and Danyang Maternal and Child Health Hospital.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## References

1. Deligiannidis KM, Meltzer-Brody S, Gunduz-Bruce H, Doherty J, Jonas J, Li S, et al. Effect of zuranolone vs placebo in postpartum depression: a randomized clinical trial. *JAMA Psychiatry*. (2021) 78:951–9. doi: 10.1001/jamapsychiatry.2021.1559

2. Becker M, Weinberger T, Chandy A, Schmukler S. Depression during pregnancy and postpartum. *Curr Psychiatry Rep*. (2016) 18:32. doi: 10.1007/s11920-016-0664-7

3. Gavin N, Gaynes B, Lohr K, Meltzer-Brody S, Gartlehner G, Swinson T. Perinatal depression: a systematic review of prevalence and incidence. *Obstet Gynecol*. (2005) 106:1071–83. doi: 10.1097/01.AOG.0000183597.31630.db

4. Avalos LA, Caan B, Nance N, Zhu Y, Li D, Quesenberry C, et al. Prenatal depression and diet quality during pregnancy. *J Acad Nutr Diet*. (2020) 120:972–84. doi: 10.1016/j.jand.2019.12.011

5. Pina-Camacho L, Jensen SK, Gaysina D, Barker ED. Maternal depression symptoms, unhealthy diet and child emotional–behavioural dysregulation. *Psychol Med*. (2015) 45:1851–60. doi: 10.1017/S0033291714002955

6. Zhan Y, Zhao Y, Qu Y, Yue H, Shi Y, Chen Y, et al. Longitudinal association of maternal dietary patterns with antenatal depression: evidence from the chinese pregnant women cohort study. *J Affect Disord*. (2022) 308:587–95. doi: 10.1016/j.jad.2022.04.028

7. Brantsæter AL, Haugen M, Samuelsen SO, Torjusen H, Trogstad L, Alexander J, et al. A dietary pattern characterized by high intake of vegetables, fruits, and vegetable oils is associated with reduced risk of preeclampsia in nulliparous pregnant norwegian women. *J Nutr*. (2009) 139:1162–8. doi: 10.3945/jn.109.104968

8. Hofmeyr G, Lawrie T, Atallah Á, Torloni M. Calcium supplementation during pregnancy for preventing hypertensive disorders and related problems. *Cochrane Database Syst Rev*. (2018) 10:CD001059. doi: 10.1002/14651858

9. Karimipour Z, Sharifi N, Seydkhani H, Sayadi H, Jalilian M. Lifestyle intervention for gestational diabetes prevention in rural woman of shoush city. *J Educ Health Prom*. (2021) 10:172. doi: 10.4103/jehp.jehp_1072_20

10. Adu-Afarwuah S, Young RR, Lartey A, Okronipa H, Ashorn P, Ashorn U, et al. Supplementation with small-quantity lipid-based nutrient supplements does not increase child morbidity in a semiurban setting in Ghana: a secondary outcome noninferiority analysis of the international lipid-based nutrient supplements (ilins)–dyad randomized controlled trial. *J Nutr*. (2020) 150:382–93. doi: 10.1093/jn/nxz243

11. Iannotti L, Tielsch J, Black M, Black R. Iron supplementation in early childhood: health benefits and risks. *Am J Clin Nutr*. (2006) 84:1261–76. doi: 10.1093/ajcn/84.6.1261

12. Ma RCW, Lin X, Jia W. Causes of type 2 diabetes in China. *Lancet Diab Endocrinol*. (2014) 2:980–91. doi: 10.1016/S2213-8587(14)70145-7

13. Miller V, Webb P, Micha R, Mozaffarian D. Defining diet quality: a synthesis of dietary quality metrics and their validity for the double burden of malnutrition. *Lancet Planet Health*. (2020) 4:e352–70. doi: 10.1016/S2542-5196(20)30162-5

14. Mahmassani HA, Switkowski KM, Scott TM, Johnson EJ, Rifas-Shiman SL, Oken E, et al. Maternal intake of lutein and zeaxanthin during pregnancy is positively associated with offspring verbal intelligence and behavior regulation in mid-childhood in the project viva cohort. *J Nutr*. (2021) 151:615–27. doi: 10.1093/jn/nxaa348

15. Mahmassani HA, Switkowski KM, Scott TM, Johnson EJ, Rifas-Shiman SL, Oken E, et al. Maternal diet quality during pregnancy and child cognition and behavior in a us cohort. *Am J Clin Nutr*. (2022) 115:128–41. doi: 10.1093/ajcn/nqab325

16. Tylka TL, Kroon Van Diest AM. The intuitive eating scale–2: item refinement and psychometric evaluation with college women and men. *J Couns Psychol*. (2013) 60:137–53. doi: 10.1037/a0030893

17. Daundasekara SS, Beasley AD, O'Connor DP, Sampson M, Hernandez D, Ledoux T. Validation of the intuitive eating scale for pregnant women. *Appetite*. (2017) 112:201–9. doi: 10.1016/j.appet.2017.02.001

18. Linardon J, Tylka TL, Fuller TM. Intuitive eating and its psychological correlates: ameta-analysis. *Int J Eat Disord*. (2021) 54:1073–98. doi: 10.1002/eat.23509

19. Martin-Wagar CA, Heppner H. Adaptive depends on context: an examination of the intuitive eating scale-2 in an eating disorder sample. *Appetite*. (2023) 180:106349. doi: 10.1016/j.appet.2022.106349

20. Dogan BG, Tengilimoglu-Metin MM. Does mindful eating affect the diet quality of adults? *Nutrition*. (2023) 110:112010. doi: 10.1016/j.nut.2023.112010

21. Winkens L, van Strien T, Brouwer I, Penninx B, Visser M, Lähteenmäki L. Associations of mindful eating domains with depressive symptoms and depression in three european countries. *J Affect Disord*. (2018) 228:26–32. doi: 10.1016/j.jad.2017.11.069

22. Cox JL, Holden JM, Sagovsks R. Detection of postnatal depression. *Br J Psychiatry*. (1987) 150:782–6. doi: 10.1192/bjp.150.6.782

23. Zung W. A self-rating depression scale. *Arch Gen Psychiatry*. (1965) 12:63–70. doi: 10.1001/archpsyc.1965.01720310065008

24. Chen C, Chen H, Huang T. Stressors associated with pregnancy as perceived by pregnant women during three trimesters. *Gaoxiong Yi Xue Ke Xue Za Zhi*. (1989) 9:505–9.

25. Ding Y, Xu F, Zhong C, Tong L, Li F, Li Q, et al. Association between chinese dietary guidelines compliance index for pregnant women and risks of pregnancy complications in the tongji maternal and child health cohort. *Nutrients*. (2021) 13:829. doi: 10.3390/nu13030829

26. Hayes AF. *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York, NY: The Guilford press (2013).

27. Cohen J. Quantitative methods in psychology. *Psychol Bull*. (1992) 112:155–9. doi: 10.1038/141613a0

28. Ruzanska UA, Warschburger P. Psychometric evaluation of the german version of the intuitive eating scale-2 in a community sample. *Appetite*. (2017) 117:126–34. doi: 10.1016/j.appet.2017.06.018

29. Fritz MS, MacKinnon DP. Required sample size to detect the mediated effect. *Psychol Sci*. (2007) 18:233–9. doi: 10.1111/j.1467-9280.2007.01882.x

30. Field A. *Discovering statistics using ibm spss statistics*. *4th* ed. Los Angeles, London, New Delhi, Singapore, Washington DC: Sage (2013).

31. Miočević M, O'Rourke H, MacKinnon D, Brown H. Statistical properties of four effect-size measures for mediation models. *Behav Res Methods*. (2018) 50:285–301. doi: 10.3758/s13428-017-0870-1

32. Dharmayani P, Mishra GD, Mihrshahi S. Fruit and vegetable consumption and depression symptoms in young women: results from 1973 to 1978 cohort of the australian longitudinal study on women's health. *Eur J Nutr*. (2022) 61:4167–78. doi: 10.1007/s00394-022-02926-8

33. Liu X, Yan Y, Li F, Zhang D. Fruit and vegetable consumption and the risk of depression: a meta-analysis. *Nutrition*. (2016) 32:296–302. doi: 10.1016/j.nut.2015.09.009

34. Mihrshahi S, Dobson AJ, Mishra GD. Fruit and vegetable consumption and prevalence and incidence of depressive symptoms in mid-age women: results from the australian longitudinal study on women's health. *Eur J Clin Nutr*. (2015) 69:585–91. doi: 10.1038/ejcn.2014.222

35. Robinson L, Zhang Z, Jia T, Bobou M, Roach A, Campbell I, et al. Association of genetic and phenotypic assessments with onset of disordered eating behaviors and comorbid mental health problems among adolescents. *JAMA Netw Open*. (2020) 3:e2026874. doi: 10.1001/jamanetworkopen.2020.26874

36. Lipsky LM, Burger KS, Faith MS, Shearrer GE, Nansel TR. Eating in the absence of hunger is related to worse diet quality throughout pregnancy. *J Acad Nutr Diet*. (2021) 121:501–6. doi: 10.1016/j.jand.2020.09.037

37. Payne ME, Steck SE, George RR, Steffens DC. Fruit, vegetable, and antioxidant intakes are lower in older adults with depression. *J Acad Nutr Diet*. (2012) 112:2022–7. doi: 10.1016/j.jand.2012.08.026

38. Whitaker KM, Sharpe PA, Wilcox S, Hutto BE. Depressive symptoms are associated with dietary intake but not physical activity among overweight and obese women from disadvantaged neighborhoods. *Nutr Res*. (2014) 34:294–301. doi: 10.1016/j.nutres.2014.01.007

39. Fernández MS, Pilatti A, Pautassi RM. Eating-to-cope motives and uncontrolled eating as mediators between negative emotional states and food addiction among argentinean young adults. *Int J Ment Health Addict*. (2022) 18:1–19. doi: 10.1007/s11469-022-00934-7

40. Goyal M, Singh S, Sibinga E, Gould N, Rowland-Seymour A, Sharma R, et al. Meditation programs for psychological stress and well-being: a systematic review and meta-analysis. Jama. *Intern Med*. (2015) 174:357–68. doi: 10.1001/jamainternmed.2013.13018

41. Burgess EE, Turan B, Lokken KL, Morse A, Boggiano MM. Profiling motives behind hedonic eating. Preliminary validation of the palatable eating motives scale. *Appetite*. (2014) 72:66–72. doi: 10.1016/j.appet.2013.09.016

42. Macht M, Mueller J. Immediate effects of chocolate on experimentally induced mood states. *Appetite*. (2007) 49:667–74. doi: 10.1016/j.appet.2007.05.004

43. Sheeba B, Nath A, Metgud CS, Krishna M, Venkatesh S, Vindhya J, et al. Prenatal depression and its associated risk factors among pregnant women in Bangalore: a hospital based prevalence study. *Front Public Health*. (2019) 7:108. doi: 10.3389/fpubh.2019.00108

44. Konttinen H, Männistö S, Sarlio-Lähteenkorva S, Silventoinen K, Haukkala A. Emotional eating, depressive symptoms and self-reported food consumption. A population-based study. *Appetite*. (2010) 54:473–9. doi: 10.1016/j.appet.2010.01.014

45. Leung BMY, Kaplan BJ. Perinatal depression: prevalence, risks, and the nutrition link—a review of the literature. *J Am Diet Assoc*. (2009) 109:1566–75. doi: 10.1016/j.jada.2009.06.368

46. Hutchesson MJ, Gough C, Müller AM, Short CE, Whatnall MC, Ahmed M, et al. Ehealth interventions targeting nutrition, physical activity, sedentary behavior, or obesity in adults: a scoping review of systematic reviews. *Obes Rev*. (2021) 22:e13259. doi: 10.1111/obr.13295

47. Paans N, Gibson-Smith D, Bot M, Strien T, Brouwer I, Visser M, et al. Depression and eating styles are independently associated with dietary intake. *Appetite*. (2019) 134:103–10. doi: 10.1016/j.appet.2018.12.030

48. Jacob R, Provencher V, Panahi S, Tremblay A, Drapeau V. Eating behaviour traits mediate the association between satiety responsiveness and energy intake among individuals with overweight and obesity. *Appetite*. (2023) 180:106373. doi: 10.1016/j.appet.2022.106373

49. Winkens L, Strien T, Brouwer IA, Penninx B, Visser M. Mindful eating and change in depressive symptoms: mediation by psychological eating styles. *Appetite*. (2018) (2019) 133:204–11. doi: 10.1016/j.appet.2018.11.009

50. Winkens L, Elstgeest L, van Strien T, Penninx B, Visser M, Brouwer IA. Does food intake mediate the association between mindful eating and change in depressive symptoms? *Public Health Nutr*. (2020) 23:1532–42. doi: 10.1017/S1368980019003732

51. Małachowska A, Jeżewska-Zychowicz M. Polish adaptation and validation of the intuitive (ies-2) and mindful (mes) eating scales—the relationship of the concepts with healthy and unhealthy food intake (a cross-sectional study). *Nutrients*. (2022) 14:1109. doi: 10.3390/nu14051109

52. Jacka FN, Cherbuin N, Anstey KJ, Butterworth P. Does reverse causality explain the relationship between diet and depression? *J Affect Disord*. (2015) 175:248–50. doi: 10.1016/j.jad.2015.01.007

53. Lai CCW, Boag S. The association between gut-health promoting diet and depression: a mediation analysis. *J Affect Disord*. (2023) 324:136–42. doi: 10.1016/j.jad.2022.12.095

54. Santos I, Matijasevich A, Tavares B, Barros A, Botelho I, Lapolli C, et al. Validation of the Edinburgh postnatal depression scale (epds) in a sample of mothers from the 2004 Pelotas birth cohort study. *Cad Saude Publica*. (2007) 23:2577–88. doi: 10.1590/s0102-311x2007001100005

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 21 March 2024
DOI 10.3389/fpubh.2024.1368069

Check for updates

OPEN ACCESS

EDITED BY
Alejandro Galán-Mercant,
University of Cádiz, Spain

REVIEWED BY
Aureliusz Kosendiak,
Wroclaw Medical University, Poland
Karolina Sobczyk,
Medical University of Silesia, Poland

*CORRESPONDENCE
Maria Puiu
maria_puiu@umft.ro

RECEIVED 09 January 2024
ACCEPTED 11 March 2024
PUBLISHED 21 March 2024

CITATION
Onofrei L-M, Puiu M, Chirita-Emandi A and Serban CL (2024) A comprehensive analysis concerning eating behavior associated with chronic diseases among Romanian community nurses.
*Front. Public Health* 12:1368069.
doi: 10.3389/fpubh.2024.1368069



# A comprehensive analysis concerning eating behavior associated with chronic diseases among Romanian community nurses

Lidia-Manuela Onofrei[1], Maria Puiu[1,2]*, Adela Chirita-Emandi[1,2] and Costela Lacrimioara Serban[2,3,4]

[1]Department of Microscopic Morphology Genetics Discipline, Center of Genomic Medicine, "Victor Babes" University of Medicine and Pharmacy Timisoara, Timisoara, Romania, [2]Regional Center of Medical Genetics Timis, Clinical Emergency Hospital for Children "Louis Turcanu", part of ERN ITHACA, Timisoara, Timis, Romania, [3]Department of Functional Sciences, Discipline of Public Health, "Victor Babes" University of Medicine and Pharmacy Timisoara, Timisoara, Romania, [4]Department of Functional Sciences, Discipline of Public Health, Center for Translational Research and Systems Medicine, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania

**Introduction:** Lifestyle factors, including inadequate eating patterns, emerge as a critical determinant of chronic disease. Apart from caring for patients, nurses should also take an active role in monitoring and managing their own health. Understanding the intricate relationship between nurses' eating behavior and managing their own health is crucial for fostering a holistic approach to healthcare, therefore our study aimed to evaluate eating behavior and demographic factors influencing chronic disease prevalence in a sample of community nurses from Romania.

**Methods:** Between October–November 2023, 1920 community nurses were invited to answer an online survey, using an advertisement in their professional network. Of them, 788 responded. In the survey, which included a semi-quantitative food frequency questionnaire with 53 food items, the Intuitive Eating Survey 2 (IES-2), and demographic items were used.

**Results:** A multivariate model was built for the prediction of the association between eating behavior and other factors associated with chronic diseases. The majority of participants were females (95.1%), with the largest age group falling between 40 and 49.9years (48.2%). Regarding the EFSA criteria for adequate carbohydrate and fat intake, 20.2% of the group have a high intake of carbohydrates, respectively, 43.4% of the group have a high intake of fat. Analysis of chronic diseases indicated that 24.9% of individuals reported at least one diagnosis by a physician. The presence of chronic disease was associated with a low level of perceived health status, with an OR=3.388, 95%CI (1.684–6.814), compared to those reporting excellent or very good perceived health status. High stress had an OR=1.483, 95%CI (1.033–2.129). BMI had an OR=1.069, 95%CI (1.032–1.108), while low carbohydrate diet score had an OR=0.956, 95%CI (0.920–0.992). Gender and IES-2 did not significantly contribute to the model, but their effect was controlled.

**Discussion:** By unraveling the intricate interplay between nutrition, lifestyle, and health outcomes in this healthcare cohort, our findings contribute valuable insights for the development of targeted interventions and support programs tailored to enhance the well-being of community nurses and, by extension, the patients they support.

KEYWORDS

chronic diseases, non-communicable diseases, community nurses, eating behavior, high carbohydrate diet, low carbohydrate diet score, intuitive eating

# 1 Introduction

Lifestyle factors, notably inadequate eating patterns, emerge as pivotal determinants influencing the onset and progression of chronic diseases (1). Inadequate dietary patterns have emerged as significant contributors to the development of obesity and various diseases of civilization, presenting a pressing public health concern globally. These dietary patterns, characterized by excessive intake of energy-dense foods high in sugars, unhealthy fats, and processed ingredients, coupled with insufficient consumption of nutrient-rich whole foods, have been closely linked to the rising prevalence of obesity and overweight populations. Furthermore, such dietary habits are implicated in the onset and progression of chronic diseases such as type 2 diabetes, cardiovascular diseases, hypertension, and certain cancers (2–4).

Nurses play a vital role in chronic disease management, serving as frontline healthcare providers. Their responsibilities encompass patient education, monitoring, and coordination of care to enhance patient outcomes. Nurses often facilitate lifestyle interventions, medication adherence, and provide emotional support to individuals with chronic conditions. Their holistic approach addresses not only the physical aspects of the disease but also the psychological and social components, promoting a patient-centered care model. The collaborative efforts of nurses contribute significantly to the overall well-being and quality of life of individuals living with chronic diseases (5, 6).

Beyond their dedicated roles in patient care, nurses should actively participate in monitoring and managing their own health. Nurses must maintain adequate eating behavior for several reasons. Firstly, nurses play a pivotal role in promoting health, and their own well-being sets an example for others. Secondly, proper nutrition contributes to sustained energy levels, enhancing nurses' ability to meet the physical and mental demands of their profession. Additionally, adequate eating behavior is linked to overall health, reducing the risk of chronic diseases that could affect job performance. Lastly, nurses with healthy eating habits are better equipped to educate and guide patients on lifestyle choices, creating a positive impact on public health (1, 7, 8).

Recognizing the intricate relationship between nurses' eating behavior and their overall well-being is paramount for fostering a comprehensive and proactive approach to healthcare (9). In light of this, our study delves into the evaluation of eating behavior and demographic factors influencing chronic disease diagnosis, focusing specifically on a sample of community nurses from Romania. This research aims to unravel the nuanced connections between nurses' lifestyles, eating habits, and their susceptibility to chronic conditions, offering valuable insights for promoting individual health and advancing healthcare practices.

# 2 Methods

## 2.1 Participants

In Romania, community nurses play a crucial role in providing medical and nursing care to patients outside of traditional hospital settings. Their main objective is to enhance access to quality medico-social services for the population, particularly for vulnerable groups. This involves offering preventive, curative, and recovery medical services and managing complex cases of chronic or rare diseases. Between October–November 2023, out of the 1920 community nurses (90% females) employed in Romania, 788 participants willingly took part in this study, resulting in a response rate of 41.1%.

## 2.2 Procedure

The recruitment of participants for our research project took place in October–November 2023 through an advertisement on a professional network and a national work platform targeting community nurses in Romania. We used the Google Forms platform to embed the questionnaire link in the advertisement. The introductory page of the questionnaire provided details about the study's purpose, estimated completion time, instruments used, and anticipated outcomes. Participants were required to answer all questions, and their explicit agreement was necessary to gain access to survey. Only those who completed the entire questionnaire were permitted to submit the form. A flow-diagram depicting important aspects of the procedure is presented in Figure 1.

Our study protocol received approval from the Research Ethics Committee of Victor Babes University of Medicine and Pharmacy (Approval No. 30/31.03.2022). Participants voluntarily consented to participate, adhering to the principles outlined in the Helsinki Declaration throughout the study.

### 2.2.1 Nutritional assessment

Our nutritional assessment involved using a validated FFQ (10, 11), which included 53 different food items. This questionnaire was designed to gather information about food intake over the course of last 30 days. For each item, we investigated the frequency and usual amount of consumption. Additional questions regarding specific items were asked to estimate the quantity of fat or added sugar. The Romanian version of the FFQ is available as a supplementary material (Supplementary material 1). We converted the intakes to grams using household scale guidelines (12) and calculated energy and macronutrient intakes for each individual using a specialized computer program. Finally, we transformed macronutrient intakes into a percentage of contribution to the total energy consumed.

To determine adherence to a low carbohydrate diet, a score called the low carbohydrate diet (LCD) score was calculated, using deciles of the percentage of macronutrients (13, 14). The score for carbohydrates ranged from one to ten, with the lowest decile receiving the highest score of 10, and the highest decile receiving the lowest score of one. For fat and protein, the lowest decile received a score of one, and the highest decile received a score of 10. The individual scores for each macronutrient were then added to get the LCD score, which can range from 3 to 30, with higher scores indicating better adherence to a low carbohydrate diet. European Food and Safety Authority (EFSA) recommendations (15) for adequate intake, were used to create two variables for individual meeting or not the recommended intake for carbohydrates and fat, using the contributing percentage of each of the macronutrients to total energy intake.

The Intuitive Eating Scale-2 (IES-2) is the most widely used measure to assess intuitive eating (16) and was recently validated in Romanian (17). It consists of 23 items. Items 4, 5, 6, 11–23 are scored Strongly Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly

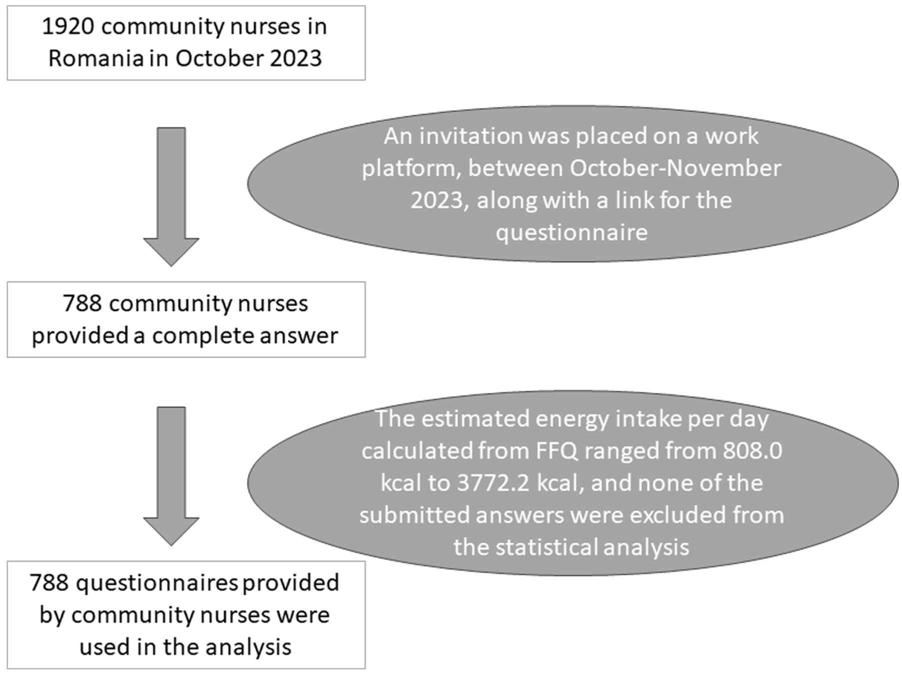



FIGURE 1
Flow-chart of the recruitment and quality check of questionnaires.

Agree = 5 and for items 1, 2, 3, 7, 8, 9, and 10 the scoring is reversed. The IES-2 score is obtained by adding all the individual item scores and then by division to the number of items (23 items). Higher scores on the IES-2 indicate a greater ability to eat intuitively. The Romanian version of the IES-2 is available as a supplementary material (Supplementary material 2).

In addition to the aforementioned instruments, the study also included questions regarding gender, age, relationship status (5 categories), education level, using International Standard Classification of Education (ISCED) (18), self-perceived health status (5 levels), years of experience as a community nurse, and self-perceived stress levels. Stress levels were rated on a 10-point scale, with higher values indicating higher levels of stress. Moreover, community nurses were requested to assess their height and weight through measurement, as well as to indicate the existence of chronic diseases and provide diagnoses of such diseases, which were set by physicians. Participants were presented with a dropdown list of seven chronic diseases that have a significant impact on public health and are heavily influenced by lifestyle choices (1). These diseases included hypertension, heart failure, ischemic heart disease, type 2 diabetes, obesity, asthma, and chronic obstructive pulmonary disease. Additionally, participants were given the option to provide an open response and list any other chronic diseases that have been diagnosed by their physicians. For those who reported one or more diagnoses, a follow-up question was asked regarding their treatment of the chronic disease (s).

## 2.3 Data management and statistics

Data transformations and statistical analyses were performed using IBM SPSS version 21. All submitted participant responses were included in the analysis. Height and weight were self-reported, but nurses were asked to report a measurement not older than 3 months. Height and weight were further used for the calculation of body mass index (BMI; BMI = weight (kg)/height (m)$^2$). The nutritional status of the participants was determined using the following BMI thresholds: underweight (BMI below 18.5 kg/m$^2$), normal weight (18.5–24.9 kg/m$^2$), overweight (25–29.9 kg/m2) and obese (over 30 kg/m$^2$). Other variables were categorized as such: age was split into 3 groups: <=40 years, 40–49.9 years and > =50 years; relationship status was dichotomized: in a relationship versus alone; education was divided into 2 levels, equivalent to ISCED 4 or less, ISCED 5 or above; self-perceived health status was categorized into 2 levels: excellent or very good health status vs. lower levels of perception; years of experience as a community nurse were split into 3 groups: <5 years, 5–9.9 years and > =10 years; self-perceived stress levels were split into tertiles and highest tertile was used to define the variable high levels of stress.

Normal distribution was tested using the Kolmogorov-Smirnoff test. Mean and standard deviation (SD) were used to present continuous variables. Absolute and relative frequencies were used for categorical variables. Statistical significance was determined by a $p$-value < 0.05. To compare means, ANOVA with Sidak correction was utilized. To compare proportions, the Mann–Whitney test was used for the comparison of 2 factors, and the Kruskal–Wallis test was used for the comparison of 3 factors. Bonferroni correction was used to assess the statistical significance when multiple Mann–Whitney tests were applied. Demographic and nutritional intake quality data, including LCD score and intuitive eating score, were used in a regression analysis model to determine the association with the presence of at least a chronic disease diagnosis established by a physician.

TABLE 1 Descriptive statistics of the sample of community nurses per presence of a diagnosis of chronic disease and total ($N = 788$).

| Variables | | Diagnosis of chronic disease | | *p*-value | Total |
|---|---|---|---|---|---|
| | | No | Yes | | |
| Gender* | Male | 29 (4.9%) | 10 (5.2%) | 0.834 | 39 (4.9%) |
| | Female | 568 (95.1%) | 181 (94.8%) | | 749 (95.1%) |
| Age categories* | <=40 years | 230 (38.5%) | 32 (16.8%) | <0.001 | 262 (33.2%) |
| | 40–49.9 years | 282 (47.2%) | 98 (51.3%) | | 380 (48.2%) |
| | >=50 years | 85 (14.2%) | 61 (31.9%) | | 146 (18.5%) |
| Work as a community nurse* | <5 | 201 (33.7%) | 41 (21.5%) | <0.001 | 242 (30.7%) |
| | 5–9.9 years | 201 (33.7%) | 57 (29.8%) | | 258 (32.7%) |
| | >=10 years | 195 (32.7%) | 93 (48.7%) | | 288 (36.5%) |
| Excellent or very good perceived health status* | No | 483 (80.9%) | 181 (94.8%) | <0.001 | 664 (84.3%) |
| | Yes | 114 (19.1%) | 10 (5.2%) | | 124 (15.7%) |
| With partner* | No | 74 (12.4%) | 21 (11.0%) | 0.605 | 95 (12.1%) |
| | Yes | 523 (87.6%) | 170 (89.0%) | | 693 (87.9%) |
| Education ISCED 4 or less* | No | 157 (26.3%) | 41 (21.5%) | 0.180 | 198 (25.1%) |
| | Yes | 440 (73.7%) | 150 (78.5%) | | 590 (74.9%) |
| BMI categories* | Underweight | 14 (2.3%) | 3 (1.6%) | <0.001 | 17 (2.2%) |
| | Normal weight | 273 (45.7%) | 50 (26.2%) | | 323 (41.0%) |
| | Overweight | 208 (34.8%) | 78 (40.8%) | | 286 (36.3%) |
| | Obese | 102 (17.1%) | 60 (31.4%) | | 162 (20.6%) |
| Age (years)** | Mean (SD) | 42.3 (7.7) | 47.1 (7.0) | <0.001 | 43.4 (7.8) |
| Worked as a community nurse (years)** | Mean (SD) | 9.1 (6.6) | 11.3 (6.5) | <0.001 | 8.0 (6.6) |
| Stress level (1 to10)* | Mean (SD) | 5.2 (2.6) | 5.9 (2.5) | 0.001 | 5.4 (2.6) |
| BMI ($kg/m^2$)** | Mean (SD) | 25.9 (4.7) | 28.4 (5.4) | <0.001 | 26.5 (5.0) |

*Mann–Whitney test, ***t*-test.

## 3 Results

Out of the sample, the majority were females, making 95.1% (749). The largest age group in the sample was 40–49.9 years old, consisting of 380 individuals (48.2%). A significant proportion of the nurses, 36.5% had worked as community nurses for more than 10 years, while 32.7% had worked between 5–9.9 years. The mean age of the whole group was 43.4 years with a standard deviation of 7.8 years, ranging from 22 to 65 years old. On average, the group had worked as community nurses for 8 years, ranging from 0 to 22 years (Table 1).

Regarding personal status and education, most of the nurses were in a relationship, comprising 87.9% or 693 individuals, and 74.9% had obtained at most an ISCED 4 diploma. Only 15.7% or 124 individuals reported an excellent or very good perceived health status. The mean BMI of the group was 26.5 $kg/m^2$. Among the participants, 36.3% were overweight, 20.6% were classified as obese, 2.2% were underweight and 41.0% had a normal weight (Table 1). Using the presence/absence of chronic disease as a factor, no significant differences were found between the different categories in the following variables: gender ($p = 0.834$), social status ($p = 0.605$), and education level ($p = 0.180$). However, the group with the chronic disease did exhibit higher age [47.1 (7.0) vs. 42.3 (7.7)] and experience as community nurses [11.3 (6.5) vs. 9.1 (6.6)], than those without chronic disease. Additionally, the group with chronic diseases reported greater stress levels and perceived their health status to be lower. In terms of nutrition status, those with chronic disease had a higher reported BMI of 28.4 (5.4) $kg/m^2$, than those without chronic disease which had a mean of 25.9 (4.7) $kg/m^2$, the difference being significant (Table 1).

In terms of chronic diseases, 24.9% or 191 individuals reported having at least one diagnosed by a physician. Among all community nurses, 16.5% had one chronic disease, 4.6% had two, and 3.2% had three or more. The community nurses reported several diagnoses of chronic diseases, with hypertension being the most prevalent at 9.8% (77 cases). This was followed by obesity at 4.4% (35 cases), thyroid diseases at 3.8% (30 cases), and dyslipidemia at 3.7% (29 cases). Type II diabetes had a prevalence of 2.2% with 17 cases, while heart failure and ischemic heart disease recorded 1.9% (15 cases) and 1.6% (13 cases) point prevalence, respectively. Asthma had a point prevalence of 1.4% (11 cases), while other diseases had significantly lower point prevalence (data not shown).

In regards to chronic disease treatment, it is noteworthy that only 22 out of 191 individuals (11.5%) who reported a chronic condition did not adhere to their prescribed treatment plan. Interestingly, all of these non-adherers reported only a single chronic condition. Additionally, it is worth mentioning that for both heart failure and ischemic heart disease, all patients followed their prescribed treatment plan.

## 3.1 Eating behavior evaluation

The mean (SD) LCD score was 16.5 (6.8) with a range from a minimum of 3 and a maximum of 29 points. The mean (SD) IES-2 score, on the other hand, was 3.3 (0.3), ranging from a minimum of 1.91 to a maximum of 4.13 points. Energy intake ranged from a minimum of 808.0 kcal to a maximum of 3772.2 kcal, with a mean and a standard deviation of 1917.9 (612.6) kcal. In terms of EFSA's recommended intake, 481 individuals, or 61%, meet the suggested proportion of carbohydrate intake, while 56.6% of the overall group meet the recommended proportion of fat intake. However, it's worth noting that 18.8% of the group, or 148 individuals, have a low intake of carbohydrates, while 20.2% of the group, or 159 individuals, have a high intake of carbohydrates. Additionally, 43.4% of the group have a high intake of fat.

Based on the LCD score tertiles, the medium carbohydrate intake group shows a significantly higher IES-2 score ($p < 0.001$), but only when compared to the high carbohydrate group. Additionally, the medium carbohydrate group features the highest proportions of EFSA recommended carbohydrate intake, while the high carbohydrate group has the highest proportion of recommended fat intake ($p < 0.001$). Those in the high carbohydrate intake group have a higher prevalence of chronic diseases ($p = 0.001$), while those in the low carbohydrate intake group have a higher prevalence of excellent or very good perceived health status ($p = 0.002$). It's worth noting that education level ($p = 0.649$), high-stress level ($p = 0.127$), total energy intake ($p = 0.960$), age ($p = 0.227$), experience as a community nurse ($p = 0.568$), and BMI ($p = 0.983$) are not influenced by the tertiles of LCD score (Table 2).

When dividing participants into tertiles based on their IES-2 scores, we found that the recommended carbohydrate intake proportions were similar across all groups ($p = 0.331$). However, those who achieved the recommended fat intake were more prevalent in the top tertile of intuitive eating ($p = 0.045$). Furthermore, individuals in the highest tertile tended to perceive their health status as excellent or very good ($p < 0.001$), had greater experience as a community nurse ($p = 0.003$), were older ($p = 0.002$), had a lower BMI ($p < 0.001$) and had lower energy intake ($p < 0.001$) than those in the lower tertiles. The presence of chronic disease, level of education, and high-stress levels remained consistent across all IES-2 tertiles (Table 3).

TABLE 2 Macronutrient intake and demographic variables by tertiles of LCD score (*N* = 788).

| Eating behavior and demographic variables | | Tertiles of LCD score | | | |
|---|---|---|---|---|---|
| | | High carbohydrate intake | Medium carbohydrate intake | Low carbohydrate intake | *p*-value |
| Carbohydrate recommended intake n (%)* | Low | 0 (0.0%) | 10 (4.5%) | 138 (47.8%) | <0.001 |
| | recommended | 117 (42.5%) | 214 (95.5%) | 150 (51.9%) | |
| | high | 158 (57.5%) | 0 (0.0%) | 1 (0.3%) | |
| Fat recommended intake n (%)* | low | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | <0.001 |
| | recommended | 260 (94.5%) | 142 (63.4%) | 44 (15.2%) | |
| | high | 15 (5.5%) | 82 (36.6%) | 245 (84.8%) | |
| Chronic diseases diagnosed by physician n (%)* | No | 189 (31.7%) | 171 (28.6%) | 237 (39.7%) | 0.001 |
| | Yes | 86 (45.0%) [a] | 53 (27.7%) [b] | 52 (27.2%) [b] | |
| Excellent or very good perceived health status n (%)* | No | 241 (36.3%) | 187 (28.2%) | 236 (35.5%) | 0.002 |
| | Yes | 34 (27.4%) [a] | 37 (29.8%) [a] | 53 (42.7%) [b] | |
| High perceived stress level n (%)* | No | 156 (32.5%) | 147 (30.6%) | 177 (36.9%) | 0.127 |
| | Yes | 119 (38.6%) | 77 (25.0%) | 112 (36.4%) | |
| Education ISCED 4 or less n (%)* | No | 64 (23.3%) | 60 (26.8%) | 74 (25.6%) | 0.649 |
| | Yes | 211 (76.7%) | 164 (73.2%) | 215 (74.4%) | |
| IES-2 score mean (SD)** | | 3.24 (0.33) [a] | 3.32[b] (0.27) | 3.31 (0.28) [b] | 0.002 |
| Energy intake (Kcal) mean (SD)** | | 1925.7 (653.5) | 1910.1 (603.8) | 1916.6 (580.2) | 0.960 |
| Age (years) mean (SD) ** | | 43.87 (7.80) | 43.82 (8.06) | 42.74 (7.68) | 0.227 |
| Experience as a Community nurse (years) mean (SD) mean (SD) ** | | 10.04 (7.51) | 9.02 (5.86) | 9.61 (6.30) | 0.568 |
| BMI (kg/m$^2$) mean (SD) ** | | 26.61 (5.25) | 26.50 (4.73) | 26.51 (4.91) | 0.983 |

LCD, low carbohydrate diet score; IES-2, Intuitive Eating Scale 2; ISCED, International Standard Classification of Education; SD, standard deviation.
*Kruskal-Wallis test followed if significant by Mann Whitney tests with Bonferroni correction for multiple comparisons **ANOVA with Sidak adjustment [a,b] similar superscript letters denote no statistically significant between groups. Different superscript letters denote significant differences between groups, after Bonferroni or respective Sidak correction.

TABLE 3 Macronutrient intake and demographic variables by tertiles of IES-2 score (*N* = 788).

| Eating behavior and demographic variables | | Tertiles of IES-2 score | | | |
|---|---|---|---|---|---|
| | | Low tertile | Medium tertile | High tertile | *p*-value |
| Carbohydrate recommended intake n (%)* | low | 51 (19.0%) | 51 (18.6%) | 46 (18.7%) | 0.331 |
| | recommended | 151 (56.3%) | 170 (62.0%) | 160 (65.0%) | |
| | high | 66 (24.6%) | 53 (19.3%) | 40 (16.3%) | |
| Fat recommended intake n (%)* | low | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0.045 |
| | recommended | 140 (52.2%) | 152 (55.5%) | 154 (62.6%) | |
| | high | 128 (47.8%) | 122 (44.5%) | 92 (37.4%) | |
| Chronic diseases diagnosed by physician n (%)* | No | 208 (77.6%) | 196 (71.5%) | 193 (78.5%) | 0.127 |
| | Yes | 60 (22.4%) | 78 (28.5%) | 53 (21.5%) | |
| Excellent or very good perceived health status n (%)* | No | 234 (87.3%) | 245 (89.4%) | 185 (75.2%) | <0.001 |
| | Yes | 34 (12.7%) [a] | 29 (10.6%) [a] | 61 (24.8%) [b] | |
| High perceived stress level n (%)* | No | 157 (58.6%) | 168 (61.3%) | 155 (63.0%) | 0.582 |
| | Yes | 111 (41.4%) | 106 (38.7%) | 91 (37.0%) | |
| Education ISCED 4 or less n (%)* | No | 54 (20.1%) | 73 (26.6%) | 71 (28.9%) | 0.058 |
| | Yes | 214 (79.9%) | 201 (73.4%) | 175 (71.1%) | |
| Energy intake (Kcal) mean (SD)** | | 2008.1 (623.7) [a] | 1959.8 (620.3) [a] | 1773.0 (566.4) [b] | <0.001 |
| Age (years) mean (SD)** | | 42.04 (7.84) [a] | 44.23 (7.45) [b] | 44.08 (8.08) [b] | 0.002 |
| Experience as a Community nurse (years) mean (SD) | | 8.46 (5.81) [a] | 10.31 (6.53) [b] | 10.02 (7.42) [b] | 0.003 |
| BMI (kg/m$^2$) mean (SD)** | | 27.40 (5.26) [a] | 26.86 (4.99) [a,b] | 25.26 (4.37) [b] | <0.001 |

IES-2 Intuitive Eating Scale 2, ISCED—International Standard Classification of Education, SD—standard deviation, *Kruskal-Wallis test followed if significant by Mann Whitney tests with Bonferroni correction for multiple comparisons **ANOVA with Sidak adjustment [a,b]similar superscript letters denote no statistically significant between groups. Different superscript letters denote significant differences between groups, after Bonferroni or respective Sidak correction.

TABLE 4 Prediction model for the association of demographic and eating habits to the presence of a diagnosis of chronic disease (*N* = 788).

| Factors | OR | 95% confidence interval for OR | |
|---|---|---|---|
| | | Lower | Upper |
| Gender (Male vs. Female) | 0.930 | 0.408 | 2.119 |
| High Stress (Yes vs. No) | 1.483 | 1.033 | 2.129 |
| IES-2 score | 0.858 | 0.464 | 1.586 |
| LCD score | 0.969 | 0.944 | 0.995 |
| Excellent or very good perceived health status (No vs. Yes) | 3.388 | 1.684 | 6.814 |
| BMI (kg/m$^2$) | 1.069 | 1.032 | 1.108 |
| Age (years) | 1.089 | 1.062 | 1.117 |
| Constant | 0.001 | | |

Logistic regression chi-square = 112.3, degrees of freedom = 7, $p < 0.001$, Independent variable: Diagnosis of at least one chronic disease. Independent variables: Gender (Male vs Female), High Stress (Yes vs No), IES-2 score, LCD score, Excellent or very good perceived health status (Yes vs No), BMI (kg/m2), Age (years).

## 3.2 Prediction model for chronic disease

We used a prediction model to analyze the connection between demographic variables, IES-2, and LCD score concerning the diagnosis of at least one chronic disease, set by a physician. Table 4 displays the OR and 95% confidence intervals of each predictor fitted in the model. Our findings indicate that a low level of perceived health status has the strongest association with the presence of diagnosis of chronic diseases, with an OR of 3.388, 95%CI 1.684–6.814, compared to those reporting excellent or very good perceived health status. High stress has an OR of 1.483, 95%CI 1.033–2.129. BMI had an OR of 1.069, 95%CI 1.032–1.108, while LCD score had an OR of 0.956, 95%CI 0.920–0.992. While other social demographic factors did not significantly contribute to the model, they were still taken into account (Table 4).

# 4 Discussion

To the best of our knowledge, this is the first study to shed light on the eating habits concerning chronic diseases in community nurses from Romania. This assessment is important for future programs targeting improvement in eating habits in community nurses, with personal benefits, but also for their patients' benefits, because being able to provide nutrition screening and appropriate nutrition advice is essential to improve healthy eating and subsequent health outcomes of their patients.

The trend of chronic diseases in Europe is marked by a significant rise in prevalence, posing substantial challenges to healthcare systems. Lifestyle factors, including sedentary behavior and poor dietary habits, contribute to the increasing burden of diseases such as diabetes, cardiovascular conditions, and obesity. Aging populations further amplify this trend, as chronic diseases are often more prevalent in older demographics (19, 20). In our analysis, we found that among individuals with an age range from 22 to 65 years, the point prevalence of any chronic disease was 24.2%, and for those with more than two chronic diseases, it was 7.8%.

This increase in multimorbidity among adults under the age of 65 challenges the traditional perception that chronic conditions primarily affect older populations. Overall, the prevalence of multimorbidity across Europe is estimated to be 39.2% with a 95% confidence interval of 33.2–45.2%, with higher prevalences in Europe in women 43.4% (24.8–50.0), compared to men 37.4% (31.7–55.1) (21). The burden of multimorbidity not only impacts individual well-being but also poses significant challenges to healthcare systems in terms of management and resource allocation (21, 22).

According to our study, the predictive model for the association between demographics and eating habits with chronic disease diagnosis found that individuals diagnosed with chronic disease tend to experience higher levels of stress, perceive their health status as poor, have an older age and higher BMI, and consume more carbohydrates compared to those without a diagnosis.

Individuals diagnosed with chronic conditions often report a lower perceived health status, reflecting the multifaceted impact of these conditions on well-being. The psychological and emotional burden associated with chronic diseases can contribute to a negative perception of overall health (23). Conversely, those with a positive perception of health may exhibit better coping mechanisms and adherence to healthcare recommendations. Understanding the interplay between chronic diseases and subjective health assessments is crucial for comprehensive health management and targeted interventions (24).

While age is not a modifiable factor, factors such as high levels of stress, high BMI, and low food intake quality can be improved. Incorporating mindfulness practices, like meditation and deep breathing exercises, can effectively reduce stress levels, promoting mental well-being (25, 26). The management of BMI can include practicing a regular exercise routine, including both aerobic and strength-training exercises, which are a key strategy for promoting weight loss and improving overall physical health (27). Interventions providing education plus personalized advice and feedback empower individuals to make healthier food choices, emphasizing a balanced diet rich in fruits, vegetables, whole grains, and lean proteins to enhance overall food quality (28). Behavioral interventions, such as goal-setting and self-monitoring, can foster sustainable lifestyle changes, aiding in stress reduction, BMI management, and the adoption of healthier eating habits (1). Systemic interventions to improve walkability, access to healthy food and sport facilities are equally important (29).

Our investigation of the eating habits of community nurses analyzed both the quality of their food intake using the Low Carbohydrate Diet (LCD) score, which is a score based on deciles of macronutrients, as well as their intuitive eating habits with the Intuitive Eating Score 2 (IES-2) index. Our findings revealed that community nurses with a high carbohydrate intake had a much higher prevalence of chronic disease (45.0%) compared to those in the middle (27.7%) and low carbohydrate diet tertiles (27.2%), but no effect was found between LCD score and BMI.

Low-carbohydrate diets have gained popularity due to their effectiveness in achieving short-term weight loss, which is further enhanced when coupled with high-protein diets (30, 31). However, recent studies have yielded inconsistent findings regarding their long-term impact on diabetes (32, 33). Though useful and popular for short-term weight loss and short-term reduction in cardiovascular risk factors (34), diets low in carbohydrates and high in fat, especially saturated fat put a supplementary risk for all-cause mortality (33–35). On the other hand, increased consumption of dietary carbohydrate intake is associated with an increased risk of cardiovascular disease, the risk increasing by 1.02 times for every 5% rise in dietary carbohydrate consumption (36). The ARIC cohort showed a U-shaped all-cause mortality, with the lowest risk of mortality in diets with 50–55% energy from carbohydrates (37). The source of fat and protein further modulated the increased mortality in high and low percentages of energy from carbohydrates, with plant sources having a protective effect and animal-derived fat or protein having a detrimental effect on all-cause mortality (37).

Intuitive eating is a holistic approach to nutrition that prioritizes one's body cues over external diet rules. By listening to and trusting internal signals, such as hunger and fullness, one can develop a mindful and non-restrictive relationship with food that promotes overall well-being and a healthier relationship with eating. Recent meta-analyses have found that those who practice intuitive eating tend to have a lower BMI (38) and a higher quality diet (39). In our study, higher levels of intuitive eating were linked to lower BMI levels and lower energy intake and higher percentage of adequate intake of fat. We discovered that nurses in the highest tertile of intuitive eating had significantly lower BMI values of 25.26 (4.37), compared to those in the lowest tertile of intuitive eating, who had BMI values of 27.40 (5.26). Additionally, energy intake was found to be associated with tertiles of intuitive eating score, with the highest tertile of intuitive eating being linked to lower energy intake with a mean of 1773.0 (566.4) kcal when compared to other tertiles 2008.1 (623.7) kcal, respective 1959.8 (620.3) kcal.

Our research has shown that community nurses with more age and experience tend to have higher intuitive scores. This may be attributed to the fact that as individuals age, they develop a greater understanding of their body and personal preferences, leading to a more refined and knowledgeable approach to intuitive eating. The principles of intuitive eating are in line with mindfulness techniques, which encourage individuals to be fully present and aware of their eating habits (40). Our investigation did not uncover any previous studies utilizing the Intuitive Eating Scale 2 (IES-2) specifically among nurses.

Nurses often experience high levels of occupational stress due to demanding workloads, long hours, and the emotionally charged nature of their profession, impacting their mental well-being and work performance (41, 42). Chronic stress triggers physiological responses that can contribute to the development and exacerbation of chronic diseases, including cardiovascular conditions and metabolic disorders (43, 44). Stress often influences unhealthy coping behaviors, such as poor dietary choices and lack of exercise, which are linked to the development of chronic conditions like obesity and diabetes (43, 45). The interplay between chronic stress and chronic diseases forms a complex cycle, where stress exacerbates the conditions, and the presence of chronic diseases can, in turn, amplify stress levels, highlighting the importance of holistic approaches to health management (44).

The Body Mass Index (BMI) analysis in Europe reveals an increasing prevalence of overweight and obesity across diverse populations (46, 47). Elevated BMI is closely linked to the rising incidence of chronic diseases, including diabetes, cardiovascular conditions, and certain cancers. The NCD Risk Factor Collaboration reports a mean BMI of 27.3 (26.3–27.7) kg/m$^2$ for Romania, which is comparable to our sample's BMI of 26.5 (5.0) kg/m$^2$. The prevalence of obesity in the community nurse cohort, measured by weight and height, is 20.6% and the prevalence of combined overweight and obesity is 56.9%, consistent with other estimates (48). There is a significant difference in the prevalence of the diagnosis of obesity reported by nurses in the chronic diseases section of just 4.4% and the prevalence obtained from measurements of 20.6%. The missed diagnosis of obesity remains a prevalent concern in healthcare, as it often goes unrecognized due to societal misconceptions and biases. Healthcare providers may not consistently assess or address obesity during routine examinations, leading to underdiagnosis in both adult and child populations (49–51). The consequences of missed obesity diagnoses include delayed intervention and increased risk for associated health conditions such as diabetes, cardiovascular diseases, and mental health issues (52, 53).

According to our study, hypertension exhibited the highest point prevalence (9.8%) among chronic reported diseases. The prevalence of hypertension (in males and females) has doubled worldwide between 1990 and 2019 (54). According to the same review (54), in Romania, the prevalence of hypertension is 43.9% (with 95% CI 35.1–52.8) with a detection awareness of 74.6% (with 95%CI 61.8–85.4). The alarming increase in hypertension diagnosis highlights an unsettling trend in multimorbidity. Hypertension frequently acts, along with heart diseases, and diabetes, as a primary contributor in later multimorbidity (55).

Treatment non-adherence in our group was 11.5% of all patients with a chronic disease. Non-adherence to treatment poses a significant risk to multimorbidity, as individuals with chronic conditions may experience worsening health outcomes when failing to follow prescribed medical plans. The complex interplay of multiple chronic diseases can exacerbate if treatments are not consistently adhered to, leading to increased morbidity and complications (56, 57). Poor adherence to medication regimens, lifestyle modifications, and regular health check-ups may contribute to the progression and development of additional chronic conditions. Addressing non-adherence is crucial in preventing the cascade of health issues associated with multimorbidity, highlighting the importance of patient education, support systems, and healthcare interventions to promote treatment compliance (1, 55).

Our study has certain limitations, such as self-reporting bias and selection bias. The self-reported bias pertains not only to the nutrition evaluation, but also to the reported diagnosis of chronic disease. It is important to note that the design of this study was cross sectional, which means that no causality can be established between eating patterns and the presence of chronic diseases. Instead, the findings can only be interpreted as associations. Although the response rate of our study was good, it is common knowledge that individuals who participate in nutrition studies are typically more interested in nutrition and healthy living than those who do not participate. There is a predominantly female cohort, however this is concordant with the prevalence of female community nurses in Romania.

The present study on the eating habits and health profiles of community nurses in Romania provides comprehensive insights, which may serve as a foundation for future research endeavors. Given the findings of this study, several key areas warrant further attention. Longitudinal studies could clarify on the dynamic nature of dietary patterns, stress levels, and chronic disease diagnoses among nurses over time, thereby facilitating a deeper understanding of their interchange. Moreover, comparative research across diverse healthcare settings and regions could provide valuable insights into the factors influencing these outcomes.

Additionally, intervention studies targeting modifiable factors identified in this research, such as stress reduction techniques, healthy weight management strategies, and nutritional education programs, could be explored to assess their effectiveness in promoting overall well-being among healthcare professionals. Such research would not only benefit the healthcare professionals but also the patients they serve. It is widely acknowledged that the health of healthcare professionals is directly linked to the quality of care that patients receive, and therefore, interventions that improve the health and well-being of healthcare professionals can have a positive impact on patient outcomes (58, 59).

Lastly, collaborative efforts between healthcare institutions, policymakers, and researchers are essential to develop and implement tailored programs that prioritize the health and resilience of nurses, thereby contributing to the mitigation of the burden of chronic diseases within healthcare systems. The implementation of such programs would require a concerted effort and the development of strategies that are feasible, sustainable, and evidence-based. Overall, these research endeavors can contribute significantly to the advancement of knowledge in this field and ultimately lead to positive health outcomes for healthcare professionals and patients alike.

## 5 Conclusion

This study provides a comprehensive insight into the eating habits and health profiles of community nurses in Romania, uncovering noteworthy associations between dietary patterns, stress levels, and chronic disease diagnoses. The prevalence of chronic diseases among this population, particularly hypertension, underscores the importance of targeted interventions for healthcare professionals. Notably, the study identifies modifiable factors, including stress, BMI, and dietary habits based on high carbohydrate diets, offering potential avenues for personalized health interventions. The findings emphasize the need for holistic strategies, encompassing stress reduction, healthy weight management, and nutritional education to enhance overall well-being. As healthcare systems struggle with the increasing burden of chronic diseases, these insights contribute to the development of tailored programs that prioritize the health and resilience of healthcare providers.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by the Research Ethics Committee of Victor Babes University of Medicine and Pharmacy. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

L-MO: Conceptualization, Investigation, Writing – original draft, Methodology. MP: Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing. AC-E: Conceptualization, Data curation, Methodology, Writing – review & editing. CS: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft.

## Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

## Acknowledgments

The authors want to thank the community nurses who provided an answer to the survey for their invaluable contribution and commitment to advancing healthcare knowledge.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## References


1. Guerreiro MP, Brito Félix I, Moreira Marques M. *A practical guide on behaviour change support for self-managing chronic disease*. Cham: Springer International Publishing (2023).

2. Jayedi A, Soltani S, Abdolshahi A, Shab-Bidar S. Healthy and unhealthy dietary patterns and the risk of chronic disease: an umbrella review of meta-analyses of prospective cohort studies. *Br J Nutr*. (2020) 124:1133–44. doi: 10.1017/S0007114520002330

3. Pan B, Wu Y, Yang Q, Ge L, Gao C, Xun Y, et al. The impact of major dietary patterns on glycemic control, cardiovascular risk factors, and weight loss in patients with type 2 diabetes: a network meta-analysis. *J Evid-Based Med*. (2019) 12:29–39. doi: 10.1111/jebm.12312

4. English LK, Ard JD, Bailey RL, Bates M, Bazzano LA, Boushey CJ, et al. Evaluation of dietary patterns and all-cause mortality: A systematic review. *JAMA Netw Open*. (2021) 4:e2122277. doi: 10.1001/jamanetworkopen.2021.22277

5. Stephen C, McInnes S, Halcomb E. The feasibility and acceptability of nurse-led chronic disease management interventions in primary care: an integrative review. *J Adv Nurs*. (2018) 74:279–88. doi: 10.1111/jan.13450

6. Wagner EH. The role of patient care teams in chronic disease management. *BMJ*. (2000) 320:569–72. doi: 10.1136/bmj.320.7234.569

7. Swanson M, Wong ST, Martin-Misener R, Browne AJ. The role of registered nurses in primary care and public health collaboration: a scoping review. *Nurs Open*. (2020) 7:1197–07. doi: 10.1002/nop2.496

8. Iriarte-Roteta A, Lopez-Dicastillo O, Mujika A, Ruiz-Zaldibar C, Hernantes N, Bermejo-Martins E, et al. Nurses' role in health promotion and prevention: a critical interpretive synthesis. *J Clin Nurs*. (2020) 29:3937–49. doi: 10.1111/jocn.15441

9. Marko S, Wylie S, Utter J. Enablers and barriers to healthy eating among hospital nurses: a systematic review. *Int J Nurs Stud*. (2023) 138:104412. doi: 10.1016/j.ijnurstu.2022.104412

10. Haftenberger M, Heuer T, Heidemann C, Kube F, Krems C, Mensink GB. Relative validation of a food frequency questionnaire for national health and nutrition monitoring. *Nutr J*. (2010) 9:36. doi: 10.1186/1475-2891-9-36

11. Serban CL, Banu AM, Putnoky S, Butica SI, Niculescu MD, Putnoky S. Relative validation of a four weeks retrospective food frequency questionnaire versus 7-day paper-based food Records in Estimating the intake of energy and nutrients in adults. *Nutr Diet Suppl [Internet]*. (2021). doi: 10.2147/NDS.S310260

12. Nutrition C for FS and A. Guidance for industry: guidelines for determining metric equivalents of household measures. FDA (2023) Available at: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-guidelines-determining-metric-equivalents-household-measures

13. de Koning L, Fung TT, Liao X, Chiuve SE, Rimm EB, Willett WC, et al. Low-carbohydrate diet scores and risk of type 2 diabetes in men 123. *Am J Clin Nutr*. (2011) 93:844–50. doi: 10.3945/ajcn.110.004333

14. Halton TL, Willett WC, Liu S, Manson JE, Albert CM, Rexrode K, et al. Low-carbohydrate-diet score and the risk of coronary heart disease in women. *N Engl J Med*. (2006) 355:1991–02. doi: 10.1056/NEJMoa055317

15. EFSA (European Food Safety Authority). Dietary reference values for nutrients: summary report. *EFSA Supp Publ*. (2017) 14:92, e15121. doi: 10.2903/sp.efsa.2017.e15121

16. Tylka TL, Kroon Van Diest AM. The intuitive eating Scale-2: item refinement and psychometric evaluation with college women and men. *J Couns Psychol*. (2013) 60:137–53. doi: 10.1037/a0030893

17. Vintilă M, Todd J, Goian C, Tudorel O, Barbat CA, Swami V. The Romanian version of the intuitive eating Scale-2: assessment of its psychometric properties and gender invariance in Romanian adults. *Body Image*. (2020) 35:225–36. doi: 10.1016/j.bodyim.2020.09.009

18. International Standard Classification of Education (ISCED) Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_Standard_Classification_of_Education_(ISCED) (Accessed December 30, 2023).

19. Brennan P, Perola M, van Ommen GJ, Riboli E. Chronic disease research in Europe and the need for integrated population cohorts. *Eur J Epidemiol*. (2017) 32:741–9. doi: 10.1007/s10654-017-0315-2

20. Hajat C, Stein E. The global burden of multiple chronic conditions: a narrative review. *Prev Med Rep*. (2018) 12:284–93. doi: 10.1016/j.pmedr.2018.10.008

21. Chowdhury SR, Das DC, Sunna TC, Beyene J, Hossain A. Global and regional prevalence of multimorbidity in the adult population in community settings: a systematic review and meta-analysis. *eClinicalMed*. (2023) 57:101860. doi: 10.1016/j.eclinm.2023.101860

22. Marengoni A, Angleman S, Melis R, Mangialasche F, Karp A, Garmen A, et al. Aging with multimorbidity: a systematic review of the literature. *Ageing Res Rev*. (2011) 10:430–9. doi: 10.1016/j.arr.2011.03.003

23. Axon DR, Jang A, Son L, Pham T. Determining the association of perceived health status among United States older adults with self-reported pain. *Aging Health Res*. (2022) 2:100051. doi: 10.1016/j.ahr.2021.100051

24. Cheng C, Inder K, Chan SWC. Coping with multiple chronic conditions: an integrative review. *Nurs Health Sci*. (2020) 22:486–97. doi: 10.1111/nhs.12695

25. Geiger C, Cramer H, Dobos G, Kohl-Heckl WK. A systematic review and meta-analysis of mindfulness-based stress reduction for arterial hypertension. *J Hum Hypertens*. (2023) 37:161–9. doi: 10.1038/s41371-022-00764-z

26. David Creswell J, Lindsay EK, Villalba DK, Chin B. Mindfulness training and physical health: mechanisms and outcomes. *Psychosom Med*. (2019) 81:224–32. doi: 10.1097/PSY.0000000000000675

27. LeBlanc ES, Patnode CD, Webber EM, Redmond N, Rushkin M, O'Connor EA. Behavioral and pharmacotherapy weight loss interventions to prevent obesity-related morbidity and mortality in adults: updated evidence report and systematic review for the US preventive services task force. *JAMA*. (2018) 320:1172–91. doi: 10.1001/jama.2018.7777

28. Whatnall MC, Patterson AJ, Ashton LM, Hutchesson MJ. Effectiveness of brief nutrition interventions on dietary behaviours in adults: a systematic review. *Appetite*. (2018) 120:335–47. doi: 10.1016/j.appet.2017.09.017

29. Jiang Q, Forseth B, Fitzpatrick L, Laroche HH, Hampl S, Davis AM, et al. Prospective associations of neighborhood healthy food access and walkability with weight status in a regional pediatric health system. *Int J Behav Nutr Phys Act*. (2023) 20:113. doi: 10.1186/s12966-023-01514-1

30. Maula A, Kai J, Woolley AK, Weng S, Dhalwani N, Griffiths FE, et al. Educational weight loss interventions in obese and overweight adults with type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials. *Diabet Med*. (2020) 37:623–35. doi: 10.1111/dme.14193

31. Clifton PM, Condo D, Keogh JB. Long term weight maintenance after advice to consume low carbohydrate, higher protein diets – A systematic review and meta analysis. *Nutr Metab Cardiovasc Dis*. (2014) 24:224–35. doi: 10.1016/j.numecd.2013.11.006

32. Huntriss R, Campbell M, Bedwell C. The interpretation and effect of a low-carbohydrate diet in the management of type 2 diabetes: a systematic review and meta-analysis of randomised controlled trials. *Eur J Clin Nutr*. (2018) 72:311–25. doi: 10.1038/s41430-017-0019-4

33. Churuangsuk C, Lean MEJ, Combet E. Low and reduced carbohydrate diets: challenges and opportunities for type 2 diabetes management and prevention. *Proc Nutr Soc*. (2020) 79:498–13. doi: 10.1017/S0029665120000105

34. Qin P, Suo X, Chen S, Huang C, Wen W, Lin X, et al. Low-carbohydrate diet and risk of cardiovascular disease, cardiovascular and all-cause mortality: a systematic review and meta-analysis of cohort studies. *Food Funct*. (2023) 14:8678–91. doi: 10.1039/D3FO01374J

35. Noto H, Goto A, Tsujimoto T, Noda M. Low-carbohydrate diets and all-cause mortality: a systematic review and Meta-analysis of observational studies. *PLoS One*. (2013) 8:e55030. doi: 10.1371/journal.pone.0055030

36. Qin P, Huang C, Jiang B, Wang X, Yang Y, Ma J, et al. Dietary carbohydrate quantity and quality and risk of cardiovascular disease, all-cause, cardiovascular and cancer mortality: a systematic review and meta-analysis. *Clin Nutr*. (2023) 42:148–65. doi: 10.1016/j.clnu.2022.12.010

37. Seidelmann SB, Claggett B, Cheng S, Henglin M, Shah A, Steffen LM, et al. Dietary carbohydrate intake and mortality: a prospective cohort study and meta-analysis. *Lancet Public Health*. (2018) 3:e419–28. doi: 10.1016/S2468-2667(18)30135-X

38. Van Dyke N, Drinkwater EJ. Review article relationships between intuitive eating and health indicators: literature review. *Public Health Nutr*. (2014) 17:1757–66. doi: 10.1017/S1368980013002139

39. Hensley-Hackett K, Bosker J, Keefe A, Reidlinger D, Warner M, D'Arcy A, et al. Intuitive eating intervention and diet quality in adults: a systematic literature review. *J Nutr Educ Behav*. (2022) 54:1099–15. doi: 10.1016/j.jneb.2022.08.008

40. Serban DM, Serban CL, Ursoniu S, Putnoky S, Moleriu RD, Putnoky S. Mindful eating questionnaire: validation and reliability in Romanian adults. *Int J Environ Res Public Health*. (2022) 19:10517. doi: 10.3390/ijerph191710517

41. Khamisa N, Peltzer K, Ilic D, Oldenburg B. Work related stress, burnout, job satisfaction and general health of nurses: a follow-up study. *Int J Nurs Pract*. (2016) 22:538–45. doi: 10.1111/ijn.12455

42. Sarafis P, Rousaki E, Tsounis A, Malliarou M, Lahana L, Bamidis P, et al. The impact of occupational stress on nurses' caring behaviors and their health related quality of life. *BMC Nurs*. (2016) 15:56. doi: 10.1186/s12912-016-0178-y

43. Agorastos A, Chrousos GP. The neuroendocrinology of stress: the stress-related continuum of chronic disease development. *Mol Psychiatry*. (2022) 27:502–13. doi: 10.1038/s41380-021-01224-9

44. Kivimäki M, Steptoe A. Effects of stress on the development and progression of cardiovascular disease. *Nat Rev Cardiol*. (2018) 15:215–29. doi: 10.1038/nrcardio.2017.189

45. Hill D, Conner M, Clancy F, Moss R, Wilding S, Bristow M, et al. Stress and eating behaviours in healthy adults: a systematic review and meta-analysis. *Health Psychol Rev*. (2022) 16:280–04. doi: 10.1080/17437199.2021.1923406

46. Stival C, Lugo A, Odone A, van den Brandt PA, Fernandez E, Tigova O, et al. Prevalence and correlates of overweight and obesity in 12 European countries in 2017–2018. *Obes Facts*. (2022) 15:655–65. doi: 10.1159/000525792

47. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. *Lancet*. (2016) 387:1377–96. doi: 10.1016/S0140-6736(16)30054-X

48. Overweight and obesity BMI statistics. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Overweight_and_obesity_-_BMI_statistics (Accessed December 30, 2023).

49. Kim EG, Kaelber DC. Phenotypic prevalence of obesity and metabolic syndrome among an underdiagnosed and underscreened population of over 50 million children and adults. *Front Genet*. (2022) 13:961116. doi: 10.3389/fgene.2022.961116

50. Kapoor A, Kim J, Zeng X, Harris ST, Anderson A. Weighing the odds: assessing underdiagnosis of adult obesity via electronic medical record problem list omissions. *Digit Health*. (2020) 6:91871. doi: 10.1177/2055207620918715

51. Lydecker JA, Grilo CM. The missed diagnosis and Mis-diagnosis of pediatric obesity. *Psychother Psychosom*. (2017) 86:173–4. doi: 10.1159/000452501

52. Valenzuela PL, Carrera-Bastos P, Castillo-García A, Lieberman DE, Santos-Lozano A, Lucia A. Obesity and the risk of cardiometabolic diseases. *Nat Rev Cardiol*. (2023) 20:475–94. doi: 10.1038/s41569-023-00847-5

53. Safaei M, Sundararajan EA, Driss M, Boulila W, Shapi'i A. A systematic literature review on obesity: understanding the causes & consequences of obesity and reviewing various machine learning approaches used to predict obesity. *Comput Biol Med*. (2021) 136:104754. doi: 10.1016/j.compbiomed.2021.104754

54. Zhou B, Carrillo-Larco RM, Danaei G, Riley LM, Paciorek CJ, Stevens GA, et al. Worldwide trends in hypertension prevalence and progress in treatment and control from 1990 to 2019: a pooled analysis of 1201 population-representative studies with 104 million participants. *Lancet*. (2021) 398:957–80. doi: 10.1016/S0140-6736(21)01330-1

55. Kudesia P, Salimarouny B, Stanley M, Fortin M, Stewart M, Terry A, et al. The incidence of multimorbidity and patterns in accumulation of chronic conditions: a systematic review. *J Multimorb Comorbidity*. (2021) 11:10328. doi: 10.1177/26335565211032880

56. Tazzeo C, Zucchelli A, Vetrano DL, Demurtas J, Smith L, Schoene D, et al. Risk factors for multimorbidity in adulthood: a systematic review. *Ageing Res Rev*. (2023) 91:102039. doi: 10.1016/j.arr.2023.102039

57. Foley L, Larkin J, Lombard-Vance R, Murphy AW, Hynes L, Galvin E, et al. Prevalence and predictors of medication non-adherence among people living with multimorbidity: a systematic review and meta-analysis. *BMJ Open*. (2021) 11:e044987. doi: 10.1136/bmjopen-2020-044987

58. Oberg E, Frank E. Physicians' health practices strongly influence patient health practices. *J R Coll Physicians Edinb*. (2009) 39:290–1. doi: 10.4997/JRCPE.2009.422

59. Holtzclaw L, Arlinghaus KR, Johnston CA. The health of health care professionals. *Am J Lifestyle Med*. (2020) 15:130–2. doi: 10.1177/1559827620977065

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 15 May 2024
DOI 10.3389/fpubh.2024.1358423

Check for updates

OPEN ACCESS

EDITED BY
Javier Benítez-Porres,
University of Málaga, Spain

REVIEWED BY
David Jean Simon,
Université Panthéon Sorbonne, France
Audrius Dėdelė,
Vytautas Magnus University, Lithuania

*CORRESPONDENCE
Seyyed Reza Sobhani
✉ Seyyedrezasobhani@gmail.com

RECEIVED 19 December 2023
ACCEPTED 29 April 2024
PUBLISHED 15 May 2024

CITATION
Irankhah K, Asadimehr S, Kiani B, Jamali J, Rezvani R and Sobhani SR (2024) Investigating the role of the built environment, socio-economic status, and lifestyle factors in the prevalence of chronic diseases in Mashhad: PLS-SEM model. *Front. Public Health* 12:1358423. doi: 10.3389/fpubh.2024.1358423



# Investigating the role of the built environment, socio-economic status, and lifestyle factors in the prevalence of chronic diseases in Mashhad: PLS-SEM model

Kiyavash Irankhah[1,2], Soheil Asadimehr[1], Behzad Kiani[3], Jamshid Jamali[2,4], Reza Rezvani[1] and Seyyed Reza Sobhani[1,2]*

[1]Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran, [2]Social Determinants of Health Research Center, Mashhad University of Medical Sciences, Mashhad, Iran, [3]UQ Center for Clinical Research, The University of Queensland, Brisbane, QLD, Australia, [4]Department of Biostatistics, School of Health, Social Determinants of Health Research Center, Mashhad University of Medical Sciences, Mashhad, Iran

**Background:** Chronic diseases remain a significant contributor to both mortality and disability in our modern world. Physical inactivity and an unhealthy diet are recognized as significant behavioral risk factors for chronic diseases, which can be influenced by the built environment and socio-economic status (SES). This study aims to investigate the relationship between the built environment, SES, and lifestyle factors with chronic diseases.

**Methods:** The current study was conducted in Mashhad's Persian cohort, which included employees from Mashhad University of Medical Sciences (MUMS). In the study, 5,357 participants from the cohort were included. To assess the state of the built environment in Mashhad, a Geographic Information System (GIS) map was created for the city and participants in the Persian Mashhad study. Food intake and physical exercise were used to assess lifestyle. A food frequency questionnaire (FFQ) was used to assess food intake. To assess food intake, the diet quality index was computed. To assess the link between variables, the structural model was created in accordance with the study's objectives, and partial least square structural equation modeling (PLS-SEM) was utilized.

**Results:** The chronic diseases were positively associated with male sex ($p < 0.001$), married ($p < 0.001$), and higher age ($p < 0.001$). The chronic diseases were negatively associated with larger family size ($p < 0.05$), higher SES ($p < 0.001$), and higher diet quality index (DQI) ($p < 0.001$). No significant relationship was found between chronic disease and physical activity.

**Conclusion:** Food intake and socioeconomic status have a direct impact on the prevalence of chronic diseases. It seems that in order to reduce the prevalence of chronic diseases, increasing economic access, reducing the class gap and increasing literacy and awareness should be emphasized, and in the next step, emphasis should be placed on the built environment.

KEYWORDS

**chronic diseases, built environment, socio-economic status, food intake, physical activity**

# Introduction

Globally, chronic illnesses are a leading source of mortality and disability. Cardiovascular disorders (heart attacks and strokes), cancers, chronic respiratory disorders, diabetes, chronic liver and kidney problems, and obesity are a few examples of chronic diseases (1, 2). These are responsible for 42 million deaths worldwide each year and for a large share of the disease's burden (1, 3). Premature fatalities are defined as those that occur before the age of 70, such as the 17 million deaths caused by chronic diseases (4). In low- and middle-income nations, mortality from chronic diseases accounts for over three-quarters of all deaths (5, 6). According to the DALY index, 74% of deaths globally in 2019 were caused by chronic diseases, which also accounted for 64% of the global disease burden (7).

The identification of primary risk factors and population-level management of these disorders are essential components of chronic disease prevention (8). The four primary behavioral risk factors for chronic disease are alcohol use, smoking, poor diet, and inactivity. Blood lipid disorders, obesity, high blood pressure, and excessive blood sugar are the four biological risk factors. The emergence and aggravation of metabolic and physiological risk factors are significantly influenced by behavioral risk factors. But modifying these lifestyle choices can assist in managing these risk factors and reducing the burden of disease (9).

Excess energy consumption from high-calorie and low-nutrient density products (10), high consumption of sugar (11), sodium (12) and trans fatty acids (13), and poor consumption of dietary fiber (14), omega-3 (13), fruits and vegetables (15) all raise the risk of chronic diseases. Physical activity can lower the risk of chronic diseases by improving obesity and weight loss and strengthening the body's antioxidant systems (16). People with lower socioeconomic level are also more vulnerable to chronic disease risk factors (17). Aside from an individual's economic status, the built environment and physical characteristics of their residences can influence physical activity and food intake, both of which are factors that influence chronic diseases (18).

Chronic diseases currently place the greatest strain on Iran's health-care system. According to WHO statistics, chronic diseases caused 82% of deaths in Iran in 2020 (43% cardiovascular diseases, 16% cancers, and 23% other) (19). Physical inactivity increased among Iranian adults from 39% in 2011 to 51.3% in 2021 (20–22). Every year, over 330,000 Iranians relocate to cities, which increases the need for basic infrastructure (23, 24). One of the factors influencing the rise in the prevalence of chronic diseases as a result of lifestyle changes is urbanization (1). Sedentary lifestyles and restricted availability to fresh meals are frequently associated with urbanization, particularly in less developed nations (25–27).

Iranians consume a diet low in protein, vegetables, and fruits and high in carbohydrates, especially bread and rice. In cities, there has also been a rise in the consumption of fast food and unhealthy snacks (28). The average salt consumption in the population is 9.52 grams per day, roughly double the World Health Organization guideline (29). Furthermore, in 2020, Iran's *per capita* sugar consumption was 3.5 times higher than the advised level (30, 31). Among Iranian adults, highly processed foods account for over half of their daily calorie consumption (32). Examining these elements as a whole is essential given the established links between socioeconomic position, built environment, lifestyle and chronic diseases (28).

Although these relationships have been studied previously, there is still a lack of research on the combined effect of these connections on chronic diseases, especially in Iran and more specifically in Mashhad, the country's second-largest city. Therefore, the main goal of this research is to clarify the complex connections between the built environment, diet, socioeconomic status, physical activity, and chronic diseases in Mashhad University of Medical Sciences staff members. Our goal is to obtain a thorough understanding of the factors that contribute to chronic diseases by investigating these interconnected aspects. This information will be useful in developing preventive strategies and health interventions.

# Methods

## Data and sample size

This cross-sectional study was conducted in the Mashhad Persian cohort study, which included Iranian citizens who were employed by Mashhad University of Medical Sciences, lived in Mashhad, and were between the ages of 30 and 70.

Each participant in the Persian Cohort Center provides written informed permission, which is obtained through the use of reliable personal identity documents. Samples of biological material are collected after registration, since participants are required to arrive fasting. The measurement of anthropometric traits comes next. Following the interview, the participants fill out three questionnaires on general health, medicine, and diet (29).

Based on a prevalence rate of 51.3%, a response rate of 90%, and a design effect of 1.5, a total sample size of 4,266 was calculated (22). Given that a larger sample size improves the accuracy of PLS-SEM estimations (30), we chose a sample size of 5,357 participants from the available Mashhad Persian cohort for the investigation. The research ethics committee of Mashhad University of Medical Sciences accepted this work with the number IR.MUMS.fm.REC.1396.620.

## Exposure measurement

Height (in centimeters), weight (in kilograms), waist, hip and wrist circumferences (in centimeters) were measured using Seca meters and scales following the protocols of the US National Institutes of Health (31).

The general questionnaire yielded the variables of age, gender, education, marital status, and number of family members. Furthermore, physical activity was assessed using a generic questionnaire. Participants' physical activity was measured in MET-h/day (29). The general questionnaire looks at demographics, socioeconomic situation, occupational status, and exercise levels. This questionnaire is filled out by experts.

The wealth score index (WSI) and education (32) were used to assess socioeconomic position. The wealth score index (WSI) for each

Abbreviations: SES, socio-economic status; FFQ, food frequency questionnaire; DALY, disability-adjusted life year; DQI, diet quality index; GIS, geographic information system; PLS-SEM, partial least squares structural equation modeling; MCA, morphological component analysis; WSI, wealth score index; LUM, land use mix; OSR, open space ratio; PTS, proportion of public transit supply; NMT, proportion of non-motorized transportation; RAR, road area ratio; SAR, sidewalk area ratio; PAR, pavement area ratio; MRIR, main road intersection ratio; PBR, pedestrian bridges ratio; MUMS, Mashhad University of Medical Sciences.

person was calculated using morphological component analysis (MCA) based on the following variables: [access to a freezer, access to a washing machine, access to a dishwasher, access to a computer, access to the Internet access to a motorcycle, access to a car (no access, access to a car with a price of <50 million Tomans and access to a car with a price of >50 million Tomans), access to a vacuum cleaner, type of color TV (black and white TV or color TV) regular vs. plasma color TV], owning a mobile phone, owning a computer or laptop, lifetime international travel (never, pilgrimage only, both pilgrimage and non-pilgrimage).

Nutritionists are trained to complete the nutrition questionnaire. This questionnaire looks at meal frequency, eating patterns, food preparation, and storage practices. The diet quality index (DQI) and a 134-part semi-quantitative food frequency questionnaire (FFQ) (33) which ask about the amount of people's usual consumption of each food during the year before the date of the interview, were used to determine food consumption. Participants reported their daily, weekly, monthly or yearly use of each item, as well as the portion consumed each time, based on portion sizes pertaining to each item. Actual dishes, cups and utensils, as well as several portion size models were used for a more precise portion size estimation. In addition, a 64-picture album including standard portions for selected items was used whenever needed (34). The Diet Quality Index is a technique for assessing the overall quality of a person's dietary intake by grading food or nutrients, as well as lifestyle, in accordance with existing nutritional guidelines. This index's key components are diversity, sufficiency, moderation, and balance, which were calculated separately (35). Diet quality index, a higher score indicates a higher diet quality.

Food diversity considers the intake of five essential food groups: cereals, vegetables, fruits, dairy and legumes, meats. Each group consumed earns 3 points, resulting in a maximum diversity score of 15 and a minimum of zero. Adequacy evaluates the consumption of eight vital food items, such as vegetables, fruits, grains, fiber, protein, iron, calcium, and vitamin C. Scores range from 0 to 5 based on the percentage of daily requirements, yielding a maximum adequacy score of 40 and a minimum of zero. Dietary adequacy assesses five items including total fat, saturated fat, cholesterol, sodium, and foods with minimal nutritional value. Scores range from 0 to 6, reflecting the percentage of daily recommended intake. The maximum suitability score is 30, while the minimum is zero. Nutritional balance analyzes macronutrient and fatty acid ratios, with scores ranging from 0 to 6 and 0 to 4, respectively. This results in a maximum balance score of 10 and a minimum of zero (35).

Population density, land use mix, access to walking space and pavement area, access to public transportation, area of roads and main intersections, and access to various types of shops and restaurants such as supermarkets, bakeries, fruit and vegetable shops, fast food outlets, coffee shops, and grills were all used to evaluate the built environment. Each feature was measured in proportion to the area of the neighborhood, the data and number of the variables were obtained from municipal maps. Mashhad has 175 neighborhoods, according to the municipality's urban division. The map was then produced using a geographic information system (GIS).

## Outcome measurement

Medical history, reproductive history (women), medication history, family medical history, oral and dental health (past and current), personal habits (smoking, alcohol and drug use) (past and current), blood pressure and pulse measurement, and physical examination are all examined. The physician completes this questionnaire, and the ailments of the participants are diagnosed by the physician. Chronic diseases included cardiovascular disease, diabetes, cancer, chronic renal disease, liver disease, lung disease, and obesity. Chronic patients were participants who had at least one of these disorders (29).

## Statistical analysis

SPSS 26 was used for data analysis, and ArcGIS 10.6 was used to examine the built environment. We also used Smart PLS 3.2.8 to simulate partial least squares structural equations. The data was analyzed using descriptive statistics such as frequency, mean, and standard deviation. For comparing quantitative variables with normal distributions, the independent t-test was used, and for comparing quantitative variables with non-normal distributions, the Mann–Whitney test was utilized. To compare qualitative variables, the chi-square test was performed. The mean and standard deviation were used to convey quantitative data, whereas frequencies and percentages were used to express qualitative data. To examine the link between latent variables, partial least squares structural equation modeling (PLS-SEM) was utilized.

The bootstrapping algorithm was used to examine the significance of the association between possible variables. The coefficient of determination (R2), path coefficient, and effect size (f2) were all evaluated as part of the internal model quality study. R2 was used to assess the structural model's explanatory and predictive capacity, with values ranging from 0 to 1. R2 values of 0.19, 0.33, and 0.67 were proposed by Urbach and Ahleman for small, medium, and strong explanatory powers, respectively. Cohen's suggested f2 values for weak, medium, and strong effects are 0.02, 0.15, and 0.35, respectively. Path coefficient values range from −1 to +1, with a coefficient closer to 1 suggesting a stronger positive or negative connection (30, 36).

# Results

In our current study, we enrolled 5,357 participants from the Mashhad Persian cohort study. Among them, 2,413 were men (45%) and 2,944 were women (55%). Within this cohort, 2,247 individuals had chronic diseases, while 3,110 were in good health. Table 1 provides a summary of key findings: the average age of the participants was 43.76 ± 8.00 years, and each participant had an average of 4 family members. Additionally, 4,586 people were married, while 771 people were single. From a socio-economic perspective, 4,408 participants held a university education, 680 individuals had a diploma, 262 people had education below a diploma, and only 10 individuals were illiterate. The average wealth index in the studied population was −0.01 ± 0.98. In addition, in this table, information on the participants' physical activity and food intake is provided.

Between healthy participants and chronic illness groups, demographic and socioeconomic factors related to physical activity and food consumption were evaluated. When compared to the chronic disease group, the healthy group had a considerably higher number of female participants, a higher number of single individuals, a higher education level, a higher average physical activity, and a

TABLE 1 Data characteristics: chronic disease and healthy participants.

| Variables (n) | | Total (5,357) | Chronic disease (2,247) | Healthy participants (3,110) | *p*-value |
|---|---|---|---|---|---|
| Gender | Men [*n* (%)] | 2,413 (45%) | 1,052 (44%) | 1,361 (56%) | <0.05 |
| | Women [*n* (%)] | 2,944 (55%) | 1,195 (41%) | 1749 (59%) | |
| Age (mean years) | | 43.76 ± 8.00 | 45.94 ± 8.93 | 42.19 ± 6.83 | <0.001 |
| Family size (mean number) | | 3.44 ± 1.06 | 3.45 ± 1.05 | 3.43 ± 1.05 | 0.64 |
| Marital | Single [*n* (%)] | 771 (14%) | 262 (34%) | 509 (66%) | <0.001 |
| | Married [*n* (%)] | 4,586 (86%) | 1985 (43%) | 2,601 (57%) | |
| Social economic | | | | | |
| Education | Illiterate [*n* (%)] | 10 (0.18%) | 7 (70%) | 3 (30%) | <0.001 |
| | Under diploma [*n* (%)] | 262 (5%) | 161 (61%) | 110 (39%) | |
| | Diploma [*n* (%)] | 680 (13%) | 335 (49%) | 345 (51%) | |
| | University [*n* (%)] | 4,405 (82%) | 1744 (40%) | 2,661 (60%) | |
| Wealth index | | −0.01 ± 0.98 | −0.02 ± 1.00 | −0.01 ± 0.97 | 0.83 |
| Physical activity | | | | | |
| Physical activity (MET-h/day) | | 38.86 ± 5.57 | 38.50 ± 6.06 | 39.11 ± 5.51 | <0.001 |
| Food intake | | | | | |
| Energy (Cal/day) | | 2414.62 ± 673.26 | 2425.34 ± 682.32 | 2408.01 ± 664.05 | 0.33 |
| Cereals (gr/day) | | 468.91 ± 358.52 | 473.31 ± 364.30 | 465.64 ± 355.82 | 0.44 |
| Vegetables (gr/day) | | 367.79 ± 194.91 | 388.00 ± 204.57 | 353.16 ± 186.31 | <0.001 |
| Fruits (gr/day) | | 456.35 ± 277.32 | 486.52 ± 296.44 | 434.57 ± 260.55 | <0.001 |
| Dairy (gr/day) | | 387.12 ± 233.78 | 394.81 ± 241.48 | 381.53 ± 227.96 | <0.05 |
| Legumes and nuts (gr/day) | | 63.18 ± 44.29 | 63.85 ± 43.34 | 62.69 ± 44.98 | 0.34 |
| Meats (gr/day) | | 116.98 ± 57.93 | 116.20 ± 57.59 | 117.52 ± 58.18 | 0.41 |
| Sugars (gr/day) | | 134.12 ± 115.74 | 133.29 ± 121.08 | 134.69 ± 111.74 | 0.66 |
| Fats (gr/day) | | 27.78 ± 19.30 | 26.58 ± 18.24 | 28.81 ± 19.99 | <0.001 |
| Varity | | 14.91 ± 2.76 | 14.89 ± 2.78 | 14.92 ± 2.74 | 0.73 |
| Adequacy | | 26.97 ± 4.95 | 27.10 ± 4.85 | 26.87 ± 5.03 | 0.11 |
| Moderation | | 13.50 ± 5.95 | 13.88 ± 6.14 | 13.32 ± 5.80 | <0.001 |
| Balance | | 0.49 ± 1.00 | 0.51 ± 1.01 | 0.48 ± 0.99 | 0.27 |
| Diet quality index | | 55.86 ± 7.71 | 56.37 ± 7.82 | 55.50 ± 7.61 | <0.001 |

Quantitative variables, values are reported as mean ± standard deviation and qualitative variables are reported as number (percentage). Independent *t*-test and chi-square test were used to compare variables between two groups.

higher consumption of fat. In comparison to the healthy group, the chronic illness group had a considerably larger percentage of illiterates, a higher average age, a poorer diet quality score, lower moderation, and lower consumption of vegetables, fruits, and dairy products.

Table 2 provides insights into the environmental access and food availability for participants within their neighborhood. The differences in built environment features between the two groups were explored (Table 2). The chronic disease group had considerably higher values for land use mix, pedestrian bridges ratio, access to supermarkets ratio, and access to coffee shop juice ratio.

Figure 1 depicts Mashhad's environmental access map by neighborhood. In comparison to other places, the western areas and the city center have more environmental accessibility.

Figure 2 depicts Mashhad's food access map by neighborhood. Restaurants, fruits and vegetables, fast food, and juice were more readily available in the western regions. Northern areas had greater access to bakeries. Supermarkets and grills were more accessible in central regions.

Table 3 shows the bivariate association patterns of the built environment, socioeconomic status, diet quality index, and physical activity with the state of chronic diseases (hidden variables). Chronic disease was significantly associated with married persons, higher environmental access, higher access to unhealthy food stores, and older age, and adversely associated with higher socioeconomic position, higher diet quality index, and higher number of family members.

The combined model is depicted in Figure 3. There was a positive relationship between chronic disease and older age [$b$ ($SD$) = 0.322 (0.014), $p < 0.001$], male sex [$b$ ($SD$) = 0.058 (0.013), $p < 0.001$], and married status [$b$ ($SD$) = 0.044 (0.011), $p < 0.001$]. Higher diet quality

TABLE 2 Environmental access and food access separately from the chronic disease and healthy participants.

| Variables (n) | Total (5,357) | Chronic disease (2,247) | Healthy participants (3,110) | *P*-value |
|---|---|---|---|---|
| *Environmental access* | | | | |
| Land use mix | 0.0022 ± 0.00 | 0.0022 ± 0.00 | 0.0021 ± 0.00 | <0.05 |
| Open space ratio | 0.43 ± 1.28 | 0.45 ± 1.32 | 0.42 ± 1.25 | 0.51 |
| Public transportation supply | 39.86 ± 51.12 | 40.51 ± 50.40 | 39.41 ± 51.65 | 0.44 |
| Non-motorized transport | 181.60 ± 56.76 | 182.98 ± 55.71 | 181.63 ± 57.43 | 0.14 |
| Road area ratio | 29.46 ± 7.80 | 29.60 ± 7.70 | 29.36 ± 7.87 | 0.29 |
| Sidewalk area ratio | 8.68 ± 7.43 | 8.60 ± 6.83 | 8.73 ± 7.84 | 0.51 |
| Pavement area ratio | 588.19 ± 804.48 | 594.29 ± 861.55 | 583.68 ± 760.96 | 0.64 |
| Main road intersection ratio | 15.39 ± 17.84 | 15.53 ± 17.59 | 15.30 ± 18.02 | 0.66 |
| Pedestrian bridges ratio | 2.17 ± 2.34 | 2.26 ± 2.41 | 2.01 ± 2.28 | <0.05 |
| *Food access* | | | | |
| Access to restaurants | 7.63 ± 4.70 | 7.78 ± 4.72 | 7.53 ± 4.68 | 0.06 |
| Access to supermarkets | 7.97 ± 4.40 | 8.12 ± 4.45 | 7.86 ± 4.36 | < 0.05 |
| Access to fast food | 8.71 ± 5.79 | 8.69 ± 5.66 | 8.72 ± 5.88 | 0.86 |
| Access to fruit and vegetables | 5.58 ± 3.16 | 5.62 ± 3.16 | 5.54 ± 3.16 | 0.36 |
| Access to bakery | 4.46 ± 2.93 | 4.45 ± 2.96 | 4.47 ± 2.92 | 0.77 |
| Access to coffee shop | 6.37 ± 5.40 | 6.57 ± 5.40 | 6.23 ± 5.39 | < 0.05 |
| Access to grill | 5.02 ± 3.30 | 5.02 ± 3.25 | 5.02 ± 3.33 | 0.99 |

Quantitative variables, values are reported as mean ± standard deviation. Independent *t*-test was used to compare variables between two groups.

index [*b* (*SD*) = −0.026 (0.012), $p < 0.001$], higher socioeconomic level [*b* (*SD*) = −0.097 (0.016), $p < 0.001$], and larger family size [*b* (*SD*) = −0.036 (0.012), $p < 0.05$] were found to have a negative correlation with chronic disease. Physical activity had no relationship with chronic illness.

Male sex [*b* (*SD*) = −0.072 (0.012), $p < 0.001$] and older age [*b* (*SD*) = −0.089 (0.014), $p < 0.001$] showed a negative link with a greater diet quality score, whereas socioeconomic level, availability to healthy food stores, and access to unhealthy food stores did not.

Physical activity was unrelated to gender, age, financial level, environmental accessibility, or family size.

Access to healthy food shops was positively related to older age [*b* (*SD*) = 0.071 (0.012), $p < 0.001$] and higher socioeconomic status [*b* (*SD*) = 0.098 (0.014), $p < 0.001$], whereas access to unhealthy food stores did not relate to age or socioeconomic status. Environmental accessibility was positively related to older age [*b* (*SD*) = 0.135 (0.021), $p < 0.001$] and better socioeconomic level [*b* (*SD*) = 0.132 (0.023), $p < 0.001$].

Male sex [*b* (*SD*) = 0.191 (0.011), $p < 0.001$] and married status [*b* (*SD*) = 0.028 (0.011), $p < 0.05$] were related to greater socioeconomic position. Finally, older age [*b* (*SD*) = −0.308 (0.013), $p < 0.001$] had a negative relationship with socioeconomic position, although family size was not.

Figure 3 depicts the coefficient of determination (R2), which reflects the predictive model's strength in identifying factors influencing chronic diseases. This model could account for 13.7% of the variance in chronic disease, 1.1% in diet quality index, 0.1% in physical activity, 2.4% in environmental access, 1% in access to healthy food stores, 0.5% in access to unhealthy food stores, and 12.2% in economic status. The effect sizes (f2) for all variables in the model were small, with no evidence of strong or moderate impacts.

Table 4 shows the results of the indirect effects. The examination of indirect effects found that older age was associated with chronic disease indirectly ($\beta = 0.032$, $p < 0.001$) via food intake and socioeconomic status. Furthermore, older age was associated with better environmental access ($\beta = -0.041$, $P < 0.001$) and greater availability to healthy food stores ($\beta = -0.030$, $p < 0.001$) via socioeconomic level. Through the diet quality index and socioeconomic level, male sex was found to be indirectly associated to chronic disease ($\beta = -0.007$, $p < 0.001$). Furthermore, through socioeconomic position, male sex was indirectly related to higher diet quality index ($\beta = -0.002$, $p < 0.001$), larger environmental access ($\beta = 0.012$, $p < 0.001$), and higher access to healthy food stores ($\beta = 0.009$, $p < 0.001$). Through socioeconomic level, married people were indirectly associated with chronic disease ($\beta = -0.003$, $P < 0.05$), more environmental access ($\beta = 0.004$, $p < 0.05$), and greater access to healthy food shops ($\beta = 0.003$, $p < 0.05$).

## Discussion

This cross-sectional study delves into the intricate interplay among chronic diseases, the built environment, socioeconomic status, dietary habits, and physical activity, employing a structural equation model. Highlighting the pivotal role of individual behaviors like physical activity and diet in chronic disease development, the model underscores the profound impact of the built environment on health outcomes. Furthermore, it sheds light on how socioeconomic status influences both the environment and lifestyle choices. The study's

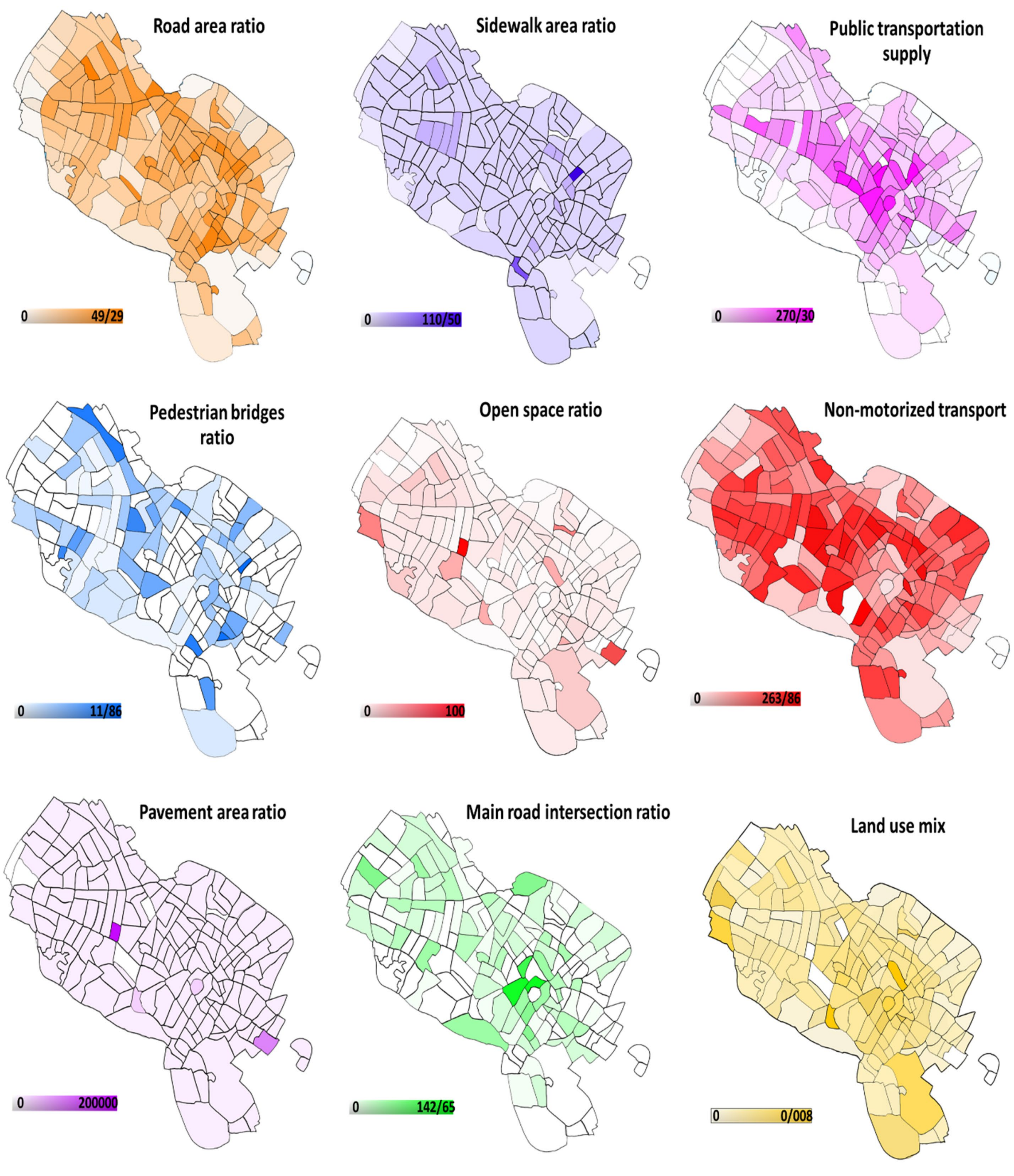



FIGURE 1
The environmental access map of Mashhad by neighborhoods.

findings reveal a higher incidence of chronic diseases among men, married individuals, and the older adult, contrasted with a lower prevalence among those from larger families, higher socioeconomic strata, and with healthier dietary habits.

According to the current study, higher diet quality is inversely connected to the risk of chronic diseases. Our findings are comparable with those of Hlaing et al. (37), who conducted research in Australia. According to this study, improved diet quality is inversely related to chronic disease outcomes in middle-aged Australian women. Furthermore, the findings of our study are consistent with the findings of Imelda Angeles et al. (38), in the Philippines, who found that consuming meat, sugary drinks, rice, and fish is connected with an increased risk of cardiovascular disease. Excessive calorie intake, processed meats, sugary drinks, refined carbohydrates, sugars, and fats can all raise the risk of chronic diseases (39, 40). Excessive consumption of simple carbohydrates, refined grains, saturated and trans fats, and sodium can result in dyslipidemia, hypertension, insulin resistance, and endothelial dysfunction (41–44). Mashhad's

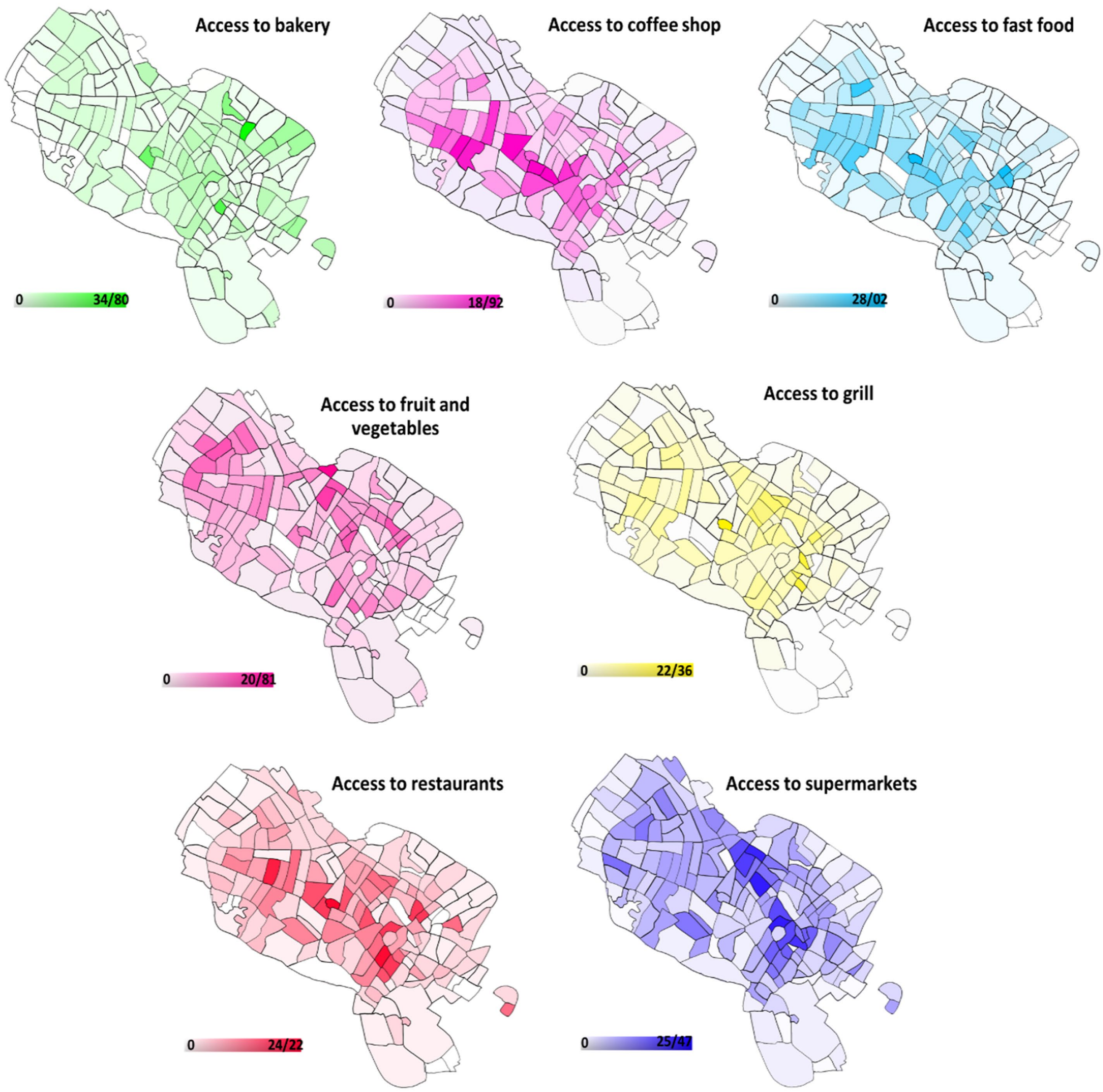



FIGURE 2
The food access map of Mashhad by neighborhoods.

culinary culture is rich and diverse, reflecting the broader Iranian cuisine. Traditional Iranian dishes are often centered around rice, bread and meat. However, with modernization and urbanization, there has been a shift toward more processed and fast foods, which are often high in unhealthy fats, sugars, and sodium.

According to the findings of this study, socioeconomic level has a negative association with the chance of getting chronic diseases. The findings are congruent with those of Shams et al. (8), Emami et al. (45), Moradi et al. (46), and Yaya et al. (47). A higher socioeconomic level provides more access to open spaces, physical activity facilities, and healthy food options, which leads to increased physical activity and improved diet quality, lowering the risk of chronic diseases (48, 49). Conversely, low socioeconomic status is associated with increased inactivity, smoking, alcohol consumption and unhealthy food choices, leading to an increased risk of chronic diseases (50–52). Lower socioeconomic status is also linked to poor education, insufficient nutrition knowledge, poor access to healthcare and seeking care at non-curable stages of the disease (53). Spending on cigarettes, tobacco and alcohol also reduces food budgets, depriving individuals of healthy and fresh foods (51).

The present study showed that physical activity is not related to the state of chronic diseases. The result obtained is contrary to most studies that state that physical activity and the chance of chronic diseases have an inverse relationship (54–56). Several variables could explain the ambiguous association between physical exercise and chronic diseases. The participants' chronic conditions had already been diagnosed at the time of examination, and they had most likely received the appropriate instruction to change their lifestyle (29). The technique employed to assess physical activity may have been inaccurate. Furthermore, in the city of Mashhad, poor socioeconomic

TABLE 3 Descriptive analysis for the relationship between built environment, socioeconomic status, diet quality index and physical activity with chronic disease status: bivariate correlation.

| latent variable | SES | Chronic disease | Marital status | Family size | Gender | DQI | Environmental access | Age | Healthy food stores | Unhealthy food stores | P. A |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SES | 1 | −0.195** | 0.001 | 0.044** | 0.122** | 0.001 | 0.089** | −0.320** | 0.075** | 0.049** | −0.016 |
| Chronic disease | | 1 | 0.029* | −0.068** | −0.001 | −0.054** | 0.029* | 0.352** | 0.016 | 0.025* | −0.003 |
| Marital status | | | 1 | 0.201** | −0.245** | 0.018 | 0.005 | 0.024* | 0.000 | 0.000 | −0.025* |
| Family size | | | | 1 | −0.065** | 0.023 | −0.031** | −0.098** | −0.004 | −0.028* | 0.018 |
| Gender | | | | | 1 | −0.063** | −0.013 | −0.127** | 0.024* | −0.007 | −0.011 |
| DQI | | | | | | 1 | −0.026* | −0.073** | −0.002 | −0.003 | 0.019 |
| Environmental access | | | | | | | 1 | 0.093** | 0.276** | 0.207** | −0.009 |
| Age | | | | | | | | 1 | 0.040** | 0.031** | −0.010 |
| Healthy food stores | | | | | | | | | 1 | 0.256** | 0.005 |
| Unhealthy food stores | | | | | | | | | | 1 | 0.007 |
| P. A | | | | | | | | | | | 1 |

**The correlation is significant at the 0.01 level. *Correlation is significant at the 0.05 level. Correlations between quantitative variables were calculated using Pearson correlation, while the correlation between a binary nominal variable and a continuous variable was calculated using the Point-Biserial Correlation test.

conditions can make it difficult for people to participate in physical activity programs or sports clubs due to cost or time constraints (57–59). Undesirable socioeconomic conditions can also result in psychological pressure and stress, lowering motivation and energy for physical exercise (60). Additionally, Mashhad's status as a religious city in Iran introduces unique cultural and religious factors that could potentially hinder certain groups from engaging in physical activity, despite the presence of available facilities (61).

In the present study, no correlation was observed between the built environment and chronic diseases. The obtained result is contrary to most studies (62–64). Our findings are consistent with the findings of Maike Schulz et al. (65) in Germany, who investigated the influence of the built environment on risk factors and health behavior. The study found no association between green space or street design and health (65). In the context of Mashhad, several factors may contribute to this lack of correlation. Inadequate active transportation infrastructure, poor public transportation quality, and personal preference for personal autos over public transportation may have contributed to the lack of a link between the built environment and chronic diseases (66, 67). Additionally, the study focused on neighborhood facilities, assuming individuals used them, which may not always be the case. Personal preference, cost-effective grocery shopping outside the neighborhood and extensive marketing from stores outside the neighborhood may have influenced individuals' facility use despite having access within the neighborhood (68, 69).

## Policy implication of findings

This study highlights the direct impact of socioeconomic status and dietary habits on the development of chronic diseases. Moreover, socioeconomic status significantly influences dietary choices. These findings underscore the importance of implementing targeted policies to mitigate the risk factors associated with chronic illnesses. By adopting these policy measures, governments and stakeholders can collaboratively strive to alleviate the burden of chronic diseases and foster healthier lifestyles within communities, thereby enhancing overall public health outcomes.

Improving Socioeconomic Conditions: Acknowledging the intricate connection between socioeconomic status and the risk of chronic diseases, elevating individuals' socioeconomic status emerges as a pivotal strategy for preventing and mitigating chronic illnesses. Policy initiatives should concentrate on bridging socioeconomic disparities to facilitate equitable access to nutritious food, avenues for physical activity, and healthcare services. Initiatives aimed at poverty alleviation, educational enhancements, and fostering employment opportunities hold promise in fostering improved overall health outcomes (70–72).

Nutritional Education and Promotion: Given the inverse relationship between diet quality and chronic diseases, policymakers can prioritize nutritional education initiatives to improve food literacy and promote healthy eating habits. This could involve public awareness campaigns, nutritional education programs in schools, and community-based interventions aimed at increasing access to and knowledge of healthy food options (73–75).

Enhancing Food and Nutrition Literacy: Given the concerning findings indicating low levels of food and nutrition literacy in Iran (76, 77), it's evident that many individuals, particularly those with low

10.3389/fpubh.2024.1358423

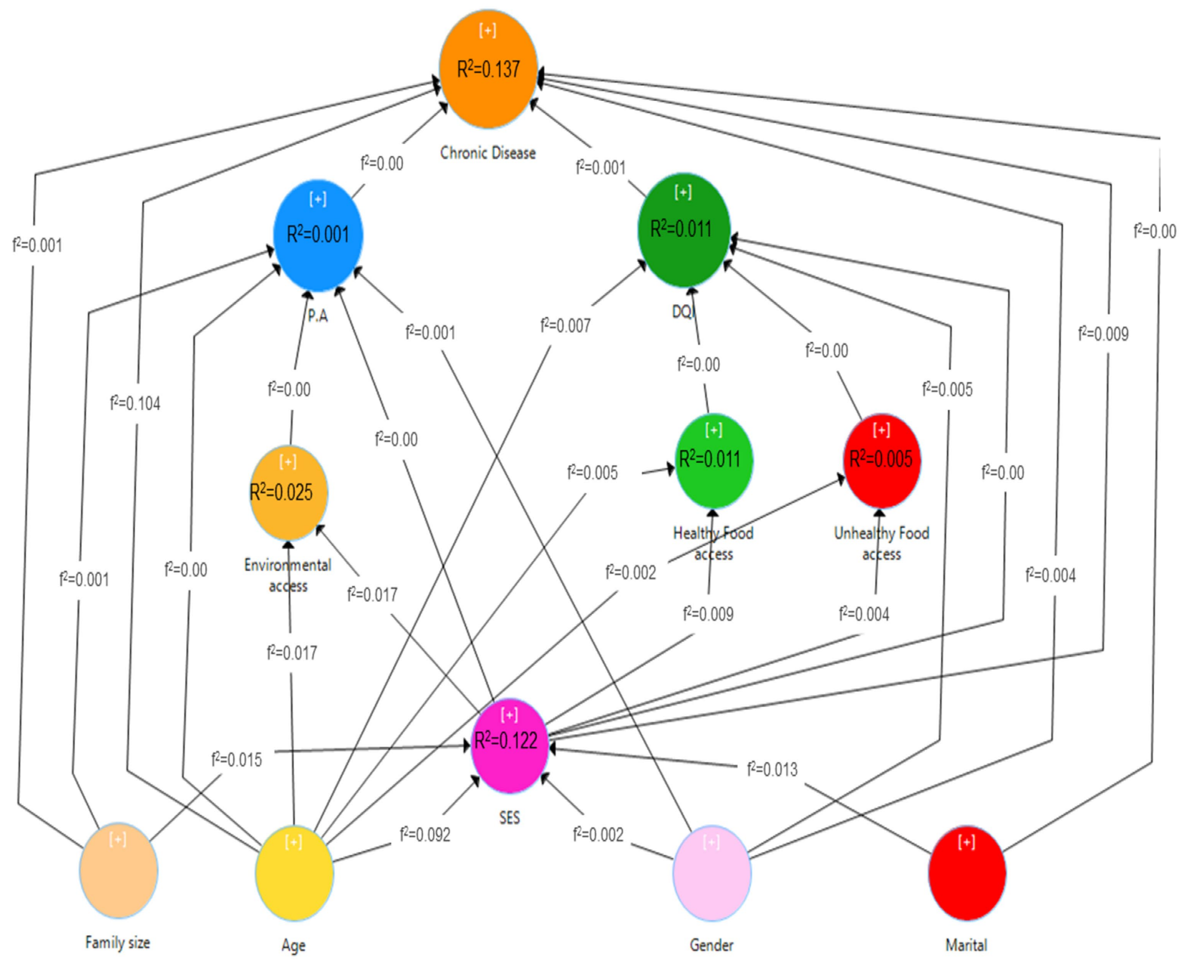



FIGURE 3
Path analysis model of the relationship between built environment, socio-economic status, diet quality index and physical activity with the status of chronic diseases.

incomes, may lack access to accurate information regarding healthy eating habits and the correlation between diet and chronic diseases (53). To address this issue, policymakers must prioritize investments in initiatives aimed at enhancing nutritional knowledge and awareness among the populace. This may entail integrating comprehensive nutrition education into school curricula, establishing resources for nutritional counseling, and ensuring widespread access to reliable and precise nutritional information for the general public (78, 79).

Promoting Physical Activity: Despite the lack of correlation found in the study, physical activity remains a crucial factor in preventing chronic diseases. Policymakers can implement strategies to encourage physical activity, such as building and maintaining recreational facilities, providing incentives for active transportation, and promoting community-based exercise programs (80, 81).

Creating Healthy Built Environments: While the study did not find a direct association between the built environment and chronic diseases, policymakers can still prioritize urban planning strategies that promote active living. This could include designing walkable neighborhoods, enhancing public transportation infrastructure, and increasing access to green spaces for recreational activities (82, 83).

Utilizing Economic Incentives: Policymakers can leverage economic mechanisms such as subsidies and taxes to encourage healthy behaviors and discourage unhealthy ones. For example, subsidies could be provided for healthy food options, while taxes could be imposed on sugary beverages or unhealthy food products (84, 85).

## Strength and limitation

The study benefits from the utilization of a diverse range of influential variables for chronic diseases and employs partial least squares structural equation modeling, enhancing its robustness. However, the cross-sectional design poses limitations in establishing causal relationships between the built environment, socioeconomic characteristics, nutritional consumption, physical activity, and chronic diseases. Notably, the study lacks consideration of participants' socio-economic status, including job, income, and housing status, which could offer a more comprehensive understanding of the socio-economic landscape. Moreover, behavioral and cultural factors were not accounted for in the study; their intricate roles in access and food choices warrant further exploration. Also, the data about diseases are self-reported.

Regarding the assessment of the built environment, municipal data was utilized, yet its potential limitations in comprehensiveness

TABLE 4 The indirect effect of the relationship between the built environment, socio-economic status, diet quality index and physical activity with the status of chronic diseases.

| Path | β | P-value | Relationships | Indirect effect | | Total effect | |
|---|---|---|---|---|---|---|---|
| | | | | β | P-value | β | p-value |
| Age → DQI → Chronic disease | 0.002 | 0.04 | Age → Chronic disease | 0.032 | 0.000 | 0.354 | <0.001 |
| Age → SES → Chronic disease | 0.030 | <0.001 | | | | | |
| Age → SES → DQI | 0.006 | 0.11 | Age → DQI | 0.006 | 0.114 | −0.083 | <0.001 |
| Age → SES → Environmental access | −0.041 | <0.001 | Age → Environmental access | −0.041 | 0.000 | 0.094 | <0.001 |
| Age → SES → Healthy food stores | −0.030 | <0.001 | Age → Healthy food stores | −0.030 | 0.000 | 0.041 | <0.001 |
| | | | Age → SES | | | −0.308 | <0.001 |
| | | | DQI → Chronic disease | | | −0.026 | 0.03 |
| Family size → SES → Chronic disease | −0.001 | 0.25 | Family size → Chronic disease | −0.001 | 0.268 | −0.037 | 0.001 |
| Gender → DQI → Chronic disease | 0.002 | 0.06 | Gender → Chronic disease | −0.007 | 0.001 | 0.051 | <0.001 |
| Gender → SES → Chronic disease | −0.009 | <0.001 | | | | | |
| Gender → SES → DQI | −0.002 | 0.12 | Gender → DQI | −0.002 | 0.123 | −0.074 | <0.001 |
| Gender → SES → Environmental access | 0.012 | <0.001 | Gender → Environmental access | 0.012 | 0.000 | 0.012 | <0.001 |
| Gender → SES → Healthy food stores | 0.009 | <0.001 | Gender → Healthy food stores | 0.009 | 0.000 | 0.009 | <0.001 |
| | | | Gender → SES | | | 0.091 | <0.001 |
| Marital status → SES → Chronic disease | −0.003 | 0.02 | Marital status → Chronic disease | −0.003 | 0.024 | −0.003 | <0.001 |
| Marital status → SES → Environmental access | 0.004 | 0.02 | Marital status → Environmental access | 0.004 | 0.022 | 0.004 | 0.02 |
| Marital status → SES → Healthy food stores | 0.003 | 0.02 | Marital status → Healthy food stores | 0.003 | 0.023 | 0.003 | 0.02 |
| | | | Marital status → SES | | | 0.028 | 0.01 |
| | | | SES → Chronic disease | 0.000 | 0.335 | −0.097 | <0.001 |
| | | | SES → Environmental access | | | 0.132 | <0.001 |
| | | | SES → Healthy food stores | | | 0.098 | <0.001 |

The indirect effect of the relationship between the variables was measured using PLS-SEM. A significance level of $P < 0.05$ was considered.

and currency should be acknowledged. This data may not be up-to-date and may not include all stores. Future studies may benefit from supplementing such data with questionnaires, interviews, or network buffers for a more nuanced evaluation. Additionally, it's crucial to recognize that the study's participant pool, limited to employees of Mashhad University of Medical Sciences, may not fully represent the broader Mashhad community.

Furthermore, the model's explanatory power is modest, accounting for only 13.7% of chronic diseases. This underscores the need for additional research to explore the new links and factors influencing chronic diseases comprehensively.

## Conclusion

Cultural, environmental, economic, and lifestyle factors all have an impact on chronic diseases. The current study found that, in addition to its direct effect, socioeconomic position influences the prevalence of chronic diseases via its effect on food intake. It was also shown that nutrition is associated with the presence of chronic diseases. Policymakers and planners should create supportive economic, social, and cultural systems to prevent and minimize chronic diseases, such as by raising food and nutrition literacy, encouraging physical exercise, lowering poverty, and providing universal insurance coverage. These strategies have the potential to lower the prevalence of chronic diseases and improve community health.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by Mashhad University of Medical Sciences IR.MUMS.fm.REC.1396.620. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

KI: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Writing – original draft, Writing – review & editing. SA: Data curation, Investigation, Methodology, Software, Writing – original draft. BK: Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing – review & editing. JJ: Formal analysis, Investigation, Methodology, Software, Writing – review & editing. RR: Funding acquisition, Project administration, Resources, Writing – review & editing. SS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This study was extracted from a research project, approved on 21/02/2018 by Mashhad University of Medical Sciences (code: 960234), and sponsored by the University Research Council.

## Acknowledgments

The authors appreciate the cooperation and assistance of the University Vice Chancellor for Research.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1358423/full#supplementary-material

## References

1. Organization WH. Non-communicable diseases Available at: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases (2021).

2. Organization WH. The top 10 causes of death. Available at: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death2021

3. Organization WH. Non-communicable diseases Available at: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases (2023).

4. Shrivastava SR, Shrivastava PS, Ramasamy J. Implementing the World Health Organization's package of essential non-communicable disease interventions in primary care settings. *J Scient Soc.* (2017) 44:165. doi: 10.4103/jss.JSS_30_17

5. Hamzehkhani MS, Zahiri M, Haghighizadeh MH, Dehcheshmeh NF. Evaluating the quality of Iran's package of essential non-communicable (IraPEN) disease in the eastern health Center of Ahvaz: viewpoints of the referring patients. *Arch Pharm Pract.* (2020) 1:62.

6. S M. Global status report on noncommunicable diseases 2014. Available at: http://www.who.int/nmh/publications/ncd-status-report-2014/en/2014

7. Organization WH. Preventing non-communicable diseases (NCDs) by reducing environmental risk factors. Available at: https://www.who.int/publications/i/item/WHO-FWC-EPE-17.01 (2017).

8. Shams L, Nasiri T, Meskarpour AM. Relationship between socioeconomic status and non-communicable diseases risk factors: a case study in north of Iran. *Iran J Epidemiol.* (2022) 17:340–52.

9. Martin-Diener E, Meyer J, Braun J, Tarnutzer S, Faeh D, Rohrmann S, et al. The combined effect on survival of four main behavioural risk factors for non-communicable diseases. *Prev Med.* (2014) 65:148–52. doi: 10.1016/j.ypmed.2014.05.023

10. Egger G, Dixon J. Beyond obesity and lifestyle: a review of 21st century chronic disease determinants. *Biomed Res Int.* (2014) 2014:1–12. doi: 10.1155/2014/731685

11. Barclay AW, Petocz P, McMillan-Price J, Flood VM, Prvan T, Mitchell P, et al. Glycemic index, glycemic load, and chronic disease risk—a meta-analysis of observational studies. *Am J Clin Nutr.* (2008) 87:627–37. doi: 10.1093/ajcn/87.3.627

12. Carrera-Bastos P, Fontes-Villalba M, O'Keefe JH, Lindeberg S, Cordain L. The western diet and lifestyle and diseases of civilization. *Res Rep Clin Cardiol.* (2011) 2:15–35. doi: 10.2147/RRCC.S16919

13. Danaei G, Ding EL, Mozaffarian D, Taylor B, Rehm J, Murray CJ, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *PLoS Med.* (2009) 6:e1000058. doi: 10.1371/journal.pmed.1000058

14. Salas-Salvadó J, Farrés X, Luque X, Narejos S, Borrell M, Basora J, et al. Effect of two doses of a mixture of soluble fibres on body weight and metabolic variables in overweight or obese patients: a randomised trial. *Br J Nutr.* (2008) 99:1380–7. doi: 10.1017/S0007114507868528

15. CfDCa Prevention. National Health and Nutrition Examination Survey. Available at: http://www.cdc.gov/nchs/nhanes.htm2018

16. Willett W, Koplan J, Nugent R, Dusenbury C, Puska P, Gaziano T. *Chapter 44. Prevention of chronic disease by means of diet and lifestyle changes (table 44.2). Disease control priorities in developing countries.* New York and Washington, DC: Oxford University Press and the World Bank (2006).

17. Williams J, Allen L, Wickramasinghe K, Mikkelsen B, Roberts N, Townsend N. A systematic review of associations between non-communicable diseases and socioeconomic status within low-and lower-middle-income countries. *J Glob Health.* (2018) 8:020409. doi: 10.7189/jogh.08.020409

18. Garden FL, Jalaludin BB. Impact of urban sprawl on overweight, obesity, and physical activity in Sydney, Australia. *J Urban Health.* (2009) 86:19–30. doi: 10.1007/s11524-008-9332-5

19. Ahmadi A, Shirani M, Khaledifar A, Hashemzadeh M, Solati K, Kheiri S, et al. Non-communicable diseases in the southwest of Iran: profile and baseline data from the Shahrekord PERSIAN cohort study. *BMC Public Health.* (2021) 21:2275. doi: 10.1186/s12889-021-12326-y

20. Koohpayehzadeh J, Etemad K, Abbasi M, Meysamie A, Sheikhbahaei S, Asgari F, et al. Gender-specific changes in physical activity pattern in Iran: national surveillance of risk factors of non-communicable diseases (2007–2011). *Int J Public Health.* (2014) 59:231–41. doi: 10.1007/s00038-013-0529-3

21. Sahebkar M, Heidarian Miri H, Noormohammadpour P, Akrami R, Mansournia N, Tavana B, et al. Prevalence and correlates of low physical activity in the Iranian population: national survey on non-communicable diseases in 2011. *Scand J Med Sci Sports*. (2018) 28:1916–24. doi: 10.1111/sms.13082

22. Nejadghaderi SA, Ahmadi N, Rashidi M-M, Ghanbari A, Noori M, Abbasi-Kangevari M, et al. Physical activity pattern in Iran: Findings from STEPS 2021. *Front. Public Health*. (2023) 10:1036219. doi: 10.3389/fpubh.2022.1036219

23. Iran SCo. Our Iran. Migration from village to city. Available at: https://www.amar.org.ir/2018

24. Alizadeh S, Mehdi A, Mahdian Bahnamiri M. Investigating healthy City indices in the zone 2 of Qom City. Socio-cultural development. *Studies*. (2012) 1:76–99.

25. Riha J, Karabarinde A, Ssenyomo G, Allender S, Asiki G, Kamali A, et al. Urbanicity and lifestyle risk factors for cardiometabolic diseases in rural Uganda: a cross-sectional study. *PLoS Med*. (2014) 11:e1001683. doi: 10.1371/journal.pmed.1001683

26. Popkin BM. Rural areas drive the global weight gain. *Nature*. (2019) 569:200–1. doi: 10.1038/d41586-019-01182-x

27. Juma K, Juma PA, Shumba C, Otieno P, Asiki G. Non-communicable diseases and urbanization in African cities: a narrative review. *Pub Health Dev Count Chall Opportunit*. (2019):31–50. doi: 10.5772/intechopen.89507

28. Sobhani SR, Eini-Zinab H, Rezazadeh A. Assessing the changes in Iranian household food basket using National Household Budget and expenditure survey data, 1991–2017. *Int J Prev Med*. (2021) 12:148. doi: 10.18502/ijph.v51i4.9254

29. Poustchi H, Eghtesad S, Kamangar F, Etemadi A, Keshtkar AA, Hekmatdoost A, et al. Prospective epidemiological research studies in Iran (the PERSIAN cohort study): rationale, objectives, and design. *Am J Epidemiol*. (2018) 187:647–55. doi: 10.1093/aje/kwx314

30. Hoyle RH. *Structural equation modeling: Concepts, issues, and applications*. Sage Publications, Inc. Sage (1995).

31. CfDCa P. National Health and nutrition examination survey (NHANES) Anthropometry Procedures Manual. Available at: https://stacks.cdc.gov/view/cdc/50334 (2007).

32. Khamseh ME, Sepanlou SG, Hashemi-Madani N, Joukar F, Mehrparvar AH, Faramarzi E, et al. Nationwide prevalence of diabetes and prediabetes and associated risk factors among Iranian adults: analysis of data from PERSIAN cohort study. *Diabet Therapy*. (2021) 12:2921–38. doi: 10.1007/s13300-021-01152-5

33. Willett WC, Sampson L, Stampfer MJ, Rosner B, Bain C, Witschi J, et al. Reproducibility and validity of a semiquantitative food frequency questionnaire. *Am J Epidemiol*. (1985) 122:51–65. doi: 10.1093/oxfordjournals.aje.a114086

34. Eghtesad S, Hekmatdoost A, Faramarzi E, Homayounfar R, Sharafkhah M, Hakimi H, et al. Validity and reproducibility of a food frequency questionnaire assessing food group intake in the PERSIAN cohort study. *Front Nutr*. (2023) 10:10. doi: 10.3389/fnut.2023.1059870

35. Project I. *Data4Diets: building blocks for diet-related food security analysis Tufts University*. Boston, MA. Available at: https://inddex.nutrition.tufts.edu/data4diets: (2018).

36. Urbach N, Ahlemann F. Structural equation modeling in information systems research using partial least squares. *J Infor Technol Theory Applicat*. (2010) 11:2.

37. Hlaing-Hlaing H, Dolja-Gore X, Tavener M, James EL, Hodge AM, Hure AJ. Diet quality and incident non-communicable disease in the 1946–1951 cohort of the Australian longitudinal study on Women's health. *Int J Environ Res Public Health*. (2021) 18:11375. doi: 10.3390/ijerph182111375

38. Angeles-Agdeppa I, Sun Y, Tanda KV. Dietary pattern and nutrient intakes in association with non-communicable disease risk factors among Filipino adults: a cross-sectional study. *Nutr J*. (2020) 19:1–13. doi: 10.1186/s12937-020-00597-x

39. Alberti KGMM, Zimmet P, Shaw J. Metabolic syndrome—a new world-wide definition. A consensus statement from the international diabetes federation. *Diabet Med*. (2006) 23:469–80. doi: 10.1111/j.1464-5491.2006.01858.x

40. Budreviciute A, Damiati S, Sabir DK, onder K, Schuller-Goetzburg P, Plakys G, et al. Management and prevention strategies for non-communicable diseases (NCDs) and their risk factors. *Front Public Health*. (2020) 8:788. doi: 10.3389/fpubh.2020.574111

41. Berry C, Brosnan MJ, Fennell J, Hamilton CA, Dominiczak AF. Oxidative stress and vascular damage in hypertension. *Curr Opin Nephrol Hypertens*. (2001) 10:247–55. doi: 10.1097/00041552-200103000-00014

42. Giovannucci E. Diet, body weight, and colorectal cancer: a summary of the epidemiologic evidence. *J Women's Health*. (2003) 12:173–82. doi: 10.1089/154099903321576574

43. Hadi HA, Suwaidi JA. Endothelial dysfunction in diabetes mellitus. *Vasc Health Risk Manag*. (2007) 3:853–76. doi: 10.2147/vhrm.s12187424

44. Versari D, Daghini E, Virdis A, Ghiadoni L, Taddei S. Endothelial dysfunction as a target for prevention of cardiovascular disease. *Diabetes Care*. (2009) 32:S314–21. doi: 10.2337/dc09-S330

45. Emamian MH, Alami A, Fateh M. Socioeconomic inequality in non-communicable disease risk factors in Shahroud, Iran. *Iran J Epidemiol*. (2011) 7:44–51.

46. Moradi G, Mohammad K, Majdzadeh R, Ardakani HM, Naieni KH. Socioeconomic inequality of non-communicable risk factors among people living in Kurdistan Province, Islamic Republic of Iran. *Int J Prev Med*. (2013) 4:671–83.

47. Yaya S, Uthman OA, Ekholuenetale M, Bishwajit G. Socioeconomic inequalities in the risk factors of non-communicable diseases among women of reproductive age in Sub-Saharan Africa: a multi-country analysis of survey data. *Front Public Health*. (2018) 6:307. doi: 10.3389/fpubh.2018.00307

48. Gebel K, Bauman A, Owen N. Correlates of non-concordance between perceived and objective measures of walkability. *Ann Behav Med*. (2009) 37:228–38. doi: 10.1007/s12160-009-9098-3

49. Koohsari MJ, Nakaya T, Hanibuchi T, Shibata A, Ishii K, Sugiyama T, et al. Local-area walkability and socioeconomic disparities of cardiovascular disease mortality in Japan. *J Am Heart Assoc*. (2020) 9:e016152. doi: 10.1161/JAHA.119.016152

50. Wang D, Dai X, Mishra SR, Lim CC, Carrillo-Larco RM, Gakidou E, et al. Association between socioeconomic status and health behaviour change before and after non-communicable disease diagnoses: a multicohort study. *Lancet Public Health*. (2022) 7:e670–82. doi: 10.1016/S2468-2667(22)00157-8

51. Allen L, Williams J, Townsend N, Mikkelsen B, Roberts N, Foster C, et al. Socioeconomic status and non-communicable disease behavioural risk factors in low-income and lower-middle-income countries: a systematic review. *Lancet Glob Health*. (2017) 5:e277–89. doi: 10.1016/S2214-109X(17)30058-X

52. Ciapponi A. *Systematic review of the link between tobacco and poverty*. Geneva, Switzerland: World Health Organization. Institute for Clinical Effectiveness and Health Policy (2011).

53. Vellakkal S, Subramanian S, Millett C, Basu S, Stuckler D, Ebrahim S. Socioeconomic inequalities in non-communicable diseases prevalence in India: disparities between self-reported diagnoses and standardized measures. *PLoS One*. (2013) 8:e68219. doi: 10.1371/journal.pone.0068219

54. Keralis JM, Javanmardi M, Khanna S, Dwivedi P, Huang D, Tasdizen T, et al. Health and the built environment in United States cities: measuring associations using Google street view-derived indicators of the built environment. *BMC Public Health*. (2020) 20:1–10. doi: 10.1186/s12889-020-8300-1

55. Phan L, Yu W, Keralis JM, Mukhija K, Dwivedi P, Brunisholz KD, et al. Google street view derived built environment indicators and associations with state-level obesity, physical activity, and chronic disease mortality in the United States. *Int J Environ Res Public Health*. (2020) 17:3659. doi: 10.3390/ijerph17103659

56. Creatore MI, Glazier RH, Moineddin R, Fazli GS, Johns A, Gozdyra P, et al. Association of neighborhood walkability with change in overweight, obesity, and diabetes. *JAMA*. (2016) 315:2211–20. doi: 10.1001/jama.2016.5898

57. Cassou B, Deriemaeker P, Tafflet M. Economic crisis and physical activity: a review of the literature. *BMC Public Health*. (2017):17.

58. Brownson RC, Boehmer TK, Luke DA. Declining rates of physical activity in the United States: what are the contributors? *Annu Rev Public Health*. (2005) 26:421–43. doi: 10.1146/annurev.publhealth.26.021304.144437

59. Sfm C, Van Cauwenberg J, Maenhout L, Cardon G, Lambert E, Van Dyck D. Inequality in physical activity, global trends by income inequality and gender in adults. *Int J Behav Nutr Phys Act*. (2020) 17:1–8. doi: 10.1186/s12966-020-01039-x

60. Levecque K, Van Rossem R, De Boyser K, Van de Velde S, Bracke P. Economic hardship and depression across the life course: the impact of welfare state regimes. *J Health Soc Behav*. (2011) 52:262–76. doi: 10.1177/0022146510394861

61. Adlakha D, Parra DC. Mind the gap: gender differences in walkability, transportation and physical activity in urban India. *J Transp Health*. (2020) 18:100875. doi: 10.1016/j.jth.2020.100875

62. Lee EY, Choi J, Lee S, Choi BY. Objectively measured built environments and cardiovascular diseases in middle-aged and older Korean adults. *Int J Environ Res Public Health*. (2021) 18:1861. doi: 10.3390/ijerph18041861

63. Wu H, Wang H, Liu D, Cao Y, Qu Y. The impact of the neighborhood built environment on the commuting patterns and health of patients with chronic diseases: a case study of Changshu, China. *Sustain For*. (2022) 14:11201. doi: 10.3390/su141811201

64. Reis WP, Ghamsary M, Galustian C, Galust H, Herring P, Gaio J, et al. Childhood obesity: is the built environment more important than the food environment? *Clin Med Insights Pediat*. (2020) 14:117955652093212. doi: 10.1177/1179556520932123

65. Schulz M, Romppel M, Grande G. Built environment and health: a systematic review of studies in Germany. *J Public Health*. (2018) 40:8–15. doi: 10.1093/pubmed/fdw141

66. Eriksson L, Friman M, Gärling T. Perceived attributes of bus and car mediating satisfaction with the work commute. *Transp Res A Policy Pract*. (2013) 47:87–96. doi: 10.1016/j.tra.2012.10.028

67. Goopy S, Chapman J, Kassan A, McCormack G, O'Brien M, Silversides H, et al. Culture, identity, and walkability: determining patterns of walking behavior in a high-risk population (breakout presentation). *J Transp Health*. (2017) 7:S21–2. doi: 10.1016/j.jth.2017.11.035

68. Walker RE, Keane CR, Burke JG. Disparities and access to healthy food in the United States: a review of food deserts literature. *Health Place*. (2010) 16:876–84. doi: 10.1016/j.healthplace.2010.04.013

69. Cummins S, Flint E, Matthews SA. New neighborhood grocery store increased awareness of food access but did not alter dietary habits or obesity. *Health Aff*. (2014) 33:283–91. doi: 10.1377/hlthaff.2013.0512

70. Adler NE, Newman K. Socioeconomic disparities in health: pathways and policies. *Health Aff*. (2002) 21:60–76. doi: 10.1377/hlthaff.21.2.60

71. Sallis JF, Floyd MF, Rodríguez DA, Saelens BE. Role of built environments in physical activity, obesity, and cardiovascular disease. *Circulation*. (2012) 125:729–37. doi: 10.1161/CIRCULATIONAHA.110.969022

72. Kraft P, Kraft B. Explaining socioeconomic disparities in health behaviours: a review of biopsychological pathways involving stress and inflammation. *Neurosci Biobehav Rev*. (2021) 127:689–708. doi: 10.1016/j.neubiorev.2021.05.019

73. Control CfD, Prevention. School health guidelines to promote healthy eating and physical activity. *MMWR Recommendat Report*. (2011) 60:1–76.

74. Dudley DA, Cotton WG, Peralta LR. Teaching approaches and strategies that promote healthy eating in primary school children: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. (2015) 12:28. doi: 10.1186/s12966-015-0182-8

75. Chaudhary A, Sudzina F, Mikkelsen BE. Promoting healthy eating among Young people-a review of the evidence of the impact of school-based interventions. *Nutrients*. (2020) 12:2894. doi: 10.3390/nu12092894

76. Yarmohammadi P, Morowatisharifabad MA, Rahaei Z, Khayyatzadeh SS, Madadizadeh F. Nutrition literacy and its related demographic factors among workers of Taraz steel company, Chaharmahal and Bakhtiari, Iran. *Front Public Health*. (2022) 10:911619. doi: 10.3389/fpubh.2022.911619

77. Ashoori M, Omidvar N, Eini-Zinab H, Shakibazadeh E, Doustmohamadian A, Abdar-Esfahani B, et al. Food and nutrition literacy status and its correlates in Iranian senior high-school students. *BMC Nutr*. (2021) 7:19. doi: 10.1186/s40795-021-00426-2

78. Scazzocchio B, Varì R, d'Amore A, Chiarotti F, Del Papa S, Silenzi A, et al. Promoting Health and Food Literacy through Nutrition Education at Schools: The Italian Experience with MaestraNatura Program. *Nutrients*. (2021) 13:1547. doi: 10.3390/nu13051547

79. West EG, Lindberg R, Ball K, McNaughton SA. The Role of a Food Literacy Intervention in Promoting Food Security and Food Literacy—OzHarvest's NEST Program. *Nutrients*. (2020) 12:2197. doi: 10.3390/nu12082197

80. Tuso P. Strategies to increase physical activity. *Perm J*. (2015) 19:84–8. doi: 10.7812/TPP/14-242

81. OECD, Organization WH. *Policy options to increase physical activity*. Available at: https://www.oecd.org/health/step-up-tackling-the-burden-of-insufficient-physical-activity-in-europe-500a9601-en.htm (2023).

82. OECD, Organization WH. Policy options to increase physical activity. Available at:. (2023) https://www.oecd.org/health/step-up-tackling-the-burden-of-insufficient-physical-activity-in-europe-500a9601-en.htm

83. Capolongo S, Rebecchi A, Dettori M, Appolloni L, Azara A, Buffoli M, et al. Healthy design and urban planning strategies, actions, and policy to achieve Salutogenic cities. *Int J Environ Res Public Health*. (2018) 15:2698. doi: 10.3390/ijerph15122698

84. Brown C, Laws C, Leonard D, Campbell S, Merone L, Hammond M, et al. Healthy choice rewards: a feasibility trial of incentives to influence consumer food choices in a remote Australian aboriginal community. *Int J Environ Res Public Health*. (2019) 16:112. doi: 10.3390/ijerph16010112

85. Vlaev I, King D, Darzi A, Dolan P. Changing health behaviors using financial incentives: a review from behavioral economics. *BMC Public Health*. (2019) 19:1059. doi: 10.1186/s12889-019-7407-8

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 30 May 2024
DOI 10.3389/fpubh.2024.1411724



OPEN ACCESS

EDITED BY
Pascal Izzicupo,
University of Studies G. d'Annunzio Chieti and Pescara, Italy

REVIEWED BY
Kommi Kalpana,
Manav Rachna International Institute of Research and Studies (MRIIRS), India
Anastasios Vamvakis,
Hellenic Mediterranean University, Greece

*CORRESPONDENCE
Mai A. Khatib
✉ mkhatib@kau.edu.sa

RECEIVED 03 April 2024
ACCEPTED 14 May 2024
PUBLISHED 30 May 2024

CITATION
Khatib MA, Aljaaly EA, Hafiz MS, Alamri A and Alzahrani W (2024) The risk of low energy availability among athlete females in Saudi Arabia: a cross-sectional study.
*Front. Public Health* 12:1411724.
doi: 10.3389/fpubh.2024.1411724



# The risk of low energy availability among athlete females in Saudi Arabia: a cross-sectional study

Mai A. Khatib[1,2,3]*, Elham A. Aljaaly[1,4], Maryam S. Hafiz[1], Alkhuzama Alamri[1] and Wejdan Alzahrani[1]

[1]Department of Clinical Nutrition, Faculty of Applied Medical Sciences, King Abdulaziz University, Jeddah, Saudi Arabia, [2]Food, Nutrition, and Lifestyle Unit, King Fahd Medical Research Center, King Abdulaziz University, Jeddah, Saudi Arabia, [3]Obesity Unit, King Abdulaziz University Hospital, King Abdulaziz University, Jeddah, Saudi Arabia, [4]Adult Podiatric Adolescent Obesity Clinic, MNT Unit, King Abdulaziz University Hospital, King Abdulaziz University, Jeddah, Saudi Arabia

**Introduction:** Low energy availability (LEA) is a state of inadequate energy reserves that results from a negative energy balance. This condition can lead to severe health risks such as amenorrhea and osteoporosis. Various causes for LEA, such as eating disorders and exercise addiction, have been reported in the literature. However, data in Saudi Arabia are lacking. This cross-sectional study measures the prevalence of LEA, eating disorders, and exercise addiction among adult females in Saudi Arabia and identifies possible associated risk factors.

**Methods:** The sample comprised 119 female athletes who filled out an online survey adapted from the LEA in Females Questionnaire, the Eating Disorder Examination Questionnaire, and the Exercise Addiction Inventory.

**Results:** Participants showed a high prevalence of LEA (66.4%), eating disorder (33.6%), and exercise addiction (10.1%), confirming the association between normal weight and LEA in females living in Saudi Arabia ($p < 0.00$).

**Discussion and conclusion:** With an increasing number of females in the country interested in following a healthy lifestyle, there is a need to raise the awareness of the population on the issues of LEA, eating disorders, and exercise addiction and their effects on the body by developing educational programs about energy intake and healthy physical activity routines.

KEYWORDS

**exercise addiction, eating disorders, female athlete triad, amenorrhea, relative energy deficiency in sport**

## Introduction

Energy availability is the dietary energy left over to support physiological functions after deducting energy expenditure from exercise (1). Inadequate intake and/or excessive expenditure of energy may lead to a state known as low energy availability (LEA), where the body's ability to support optimal physiological function is compromised (2). Endurance athletes typically exhibit LEA resulting from altered dietary habits and/or high energy expenditure brought on by body dissatisfaction, the notion that becoming lighter will enhance performance and social pressure to maintain a particular appearance. Additionally, athletes may feel pressure from their teammates, coach, or social media (2). It has been suggested that energy savings may serve as a helpful indicator of LEA. In competitive female cyclists, poor aerobic performance and relative energy shortage were both linked to female riders with ratios of measured resting energy expenditure to predicted resting energy expenditure (mREE/pREE) below 0.9, which are associated with LEA (3). Low energy availability in female endurance athletes who do not have disordered eating behavior is common, and studies have stated that it is more common among athletes engaging in weight-sensitive sports when in comparison with sedentary controls (4).

Low Energy Availability in Females (LEAF), particularly, leads to undesirable conditions such as poor resting energy expenditure and disruption of a variety of hormonal, metabolic, and functional features; although both genders can develop LEA, which lowers endurance, raises the risk of injury, and depletes glycogen stores (5). As a result, the body attempts to conserve energy, through metabolic changes that maintain homeostasis by decreasing energy expenditure (3). Reduced macronutrient intake in athletes may result in a decline in their physiological capacity for bone production, maintenance of muscle mass, repair of damaged tissue, and recovery after injury (6). Furthermore, during periods of intense exercise training, glycogen stores may not be adequately restored especially when carbohydrate consumption prior the exercise was not insufficient. Moreover, protein needs might also increase since the protein reserves could be utilized as a substitute source of energy. Additionally, micronutrients are necessary for the growth of bones and muscles, the replacement of erythrocytes, and the availability of cofactors for the control of metabolic reactions that produce energy (6). For this reason, a well-balanced and diverse diet that provides all macronutrient needs as well as vitamins, minerals, and sufficient energy should be maintained (7). Insufficient availability of energy results in reduction of energy expenditure by stopping bodily functions, including menstrual periods, hence the main concern will be survival (7). Functional hypothalamic amenorrhea is known as the menstruation absence caused by supressed axis of hypothalamus to ovaries with absence of organic or anatomical reasons (8). It is potentially reversible and frequently manifests itself in conditions of stress, rapid weight loss, and overexertion (8). Usually, secondary amenorrhea, or previously regular menses that cease for at least 3 months or menses already irregular that cease for at least 6 months, calls for evaluation (9). Psychological variables in eating patterns, as in disordered eating, may cause LEA, although LEA in turn can cause severe psychological suffering (10). The two factors, amenorrhea and eating disorders, that come with LEA are also important components called female athlete triad (FAT) (10). The FAT, which includes amenorrhea, osteoporosis, and an eating disorder, was initially identified in 1992 (11). Currently, it has been proposed that the FAT can be defined as the existence of one or more elements in females participating in sports (11). Screening tools for early detection of FAT/LEA symptoms are crucial to protect young athletes from long-term harm brought on by the development potential risks connected to FAT/LEA (12). Several quantitative measurements can be used to test for LEAF, including body compositional analysis, bone mineral density, basal energy expenditure, and day-to-day dietary recall (12). Moreover, a qualitative instrument can be utilized such as the Low Energy Availability in Females Questionnaire (LEAF-Q) (12). It was once thought that the triad only affected professional athletes, but we now know that it can even affect women who are not athletes (11).

Moreover, early detection of factors associated with LEA can aid in preventing deterioration in performance and health and in planning protection and proper nutritional intervention programs (10). Specifically, disordered eating behavior was commonly shown among weight-sensitive athletes and considered a significant risk factor for developing LEA (2, 13), although LEA among female endurance athletes without disordered eating was also shown to be common (14). The gold standard for detecting the behavioral symptoms of disordered eating is Eating Disorder Examination Questionnaire (EDE-Q) 6.0 (15, 16).

Physical activity, universally recognized as a healthy habit, has the potential to develop into an unhealthy preoccupation, referred to as exercise addiction (17). The primary addiction to exercise is characterized by exercise addiction that does not accompany disordered eating; while secondary, which can develop in conjunction with eating disorders or because of them (18). Low energy availability can result from either type, but it is still unknown how exercise addiction, separate from disordered eating, contributes to the development of LEA (13, 19). Also, exercise addiction not only runs the risk of causing considerable bodily harm, but those who struggle with this addiction also prioritize exercise over their relationships with family and friends, their health, and their careers (17). Assessment for the risk of exercise addiction is often neglected by health care professionals (17). However, it can be screened for using the Exercise Addiction Inventory Questionnaire (EAI-Q), which is a quick and easy. Based on the available literature on LEAF, more research is required to investigate the link connecting disordered eating behavior to exercise addiction with LEAF, especially in Saudi Arabia that has seen an increasing numbers of females of reproductive age participating in sports. Therefore, the main purpose of this study was to measure the prevalence of LEAF, exercise addiction, and eating disorders among females in Saudi Arabia and to identify the association between LEAF in female athletes with exercise addiction, body mass index, and eating disorders. This will help to understand the magnitude of this problem in the society and aid the Ministry of Health in developing proper approaches and educational programs about appropriate energy intake in addition to helping to understand the effect of healthy food intake and good exercise at the population level.

# Materials and methodology

## Participants

The sample size was calculated using Epi Info 7.2.4.0 (CDC, Atlanta). Based on the female population in Saudi Arabia in 2022, with an 80% confidence level, 50% expected frequency, and a 5% margin of error, the estimated sample size required for this study was 164 participants. Recruitment took place through the snowball sampling method. Invitations were sent electronically via social media outlets. We included female athletes [who perform 5 h per week or more (20)] from any region of the country, age 18–50 years old, who had no medical conditions that could cause LEA. We excluded women who are active yet perform $<5$ h per week, females of menopausal period, females with history of any chronic disease and/or who have taken hormonal replacement therapy over the past year, women taking medication that affects bone mineral density, and pregnant or breastfeeding females prior or at during the study.

## Measures

The study was cross-sectional that was conducted from September 2022 until June 2023, female athletes filled out an online questionnaire adapted from three previously validated and published questionnaires (14, 21, 22) concerned with energy availability in females, exercise addiction, and the evaluation of disordered eating behavior in physically active females. The questionnaire also collected demographic data including age, educational level, profession, height, weight, BMI, medical background, use of medications, and smoking (Table 1).

Prior to the study, all four sections of the tool were reviewed, modified, and refined by an expert panel of seven clinical and sports nutrition professionals. The expert panel also observed and approved the translation of the tool into Arabic. To confirm the questionnaire's validity and reliability, it was pilot tested on seven students, who were similar in age to the study population, following the same inclusion criteria, results of which are included in the analysis. The tool was shared with participants all over the country electronically through social media platforms [WhatsApp, X (formerly Twitter), and Instagram] using a poster with the survey barcode.

## Ethical approval

The ethical approval for the study was obtained from the Unit of Biomedical Ethics at King Abdulaziz University (Reference number: FAMS-EC2023-01). Strict confidentiality was upheld for the sample and the data collected. Data were de-identified during evaluation, analysis, and any publication. Electronically signed consent was obtained from all participants prior enrolment in the study and answering questions.

## Statistical analysis

Statistical analysis was carried out using IBM SPSS Statistics (Version 23.0) with double -tailed significance level set at $p \leq 0.05$. The data was inspected and verified as non-normally distributed using one sample Kolmogorov–Smirnov test ($p < 0.01$), thus the Wilcoxon rank-sum test and score and Mann-Whitney *U*-test were used. The results are presented as median and interquartile range (Q1 at 25% and Q3 at 75%). We used chi-square test to investigate possible differences among categorical variables in two independent groups. Finally, we used logistic regression to identify potential risk factors for LEA, defined as a LEAF-Q score $\geq$ or $<$ 8 as the dependent variable. Odds ratios and confidence intervals were used to investigate possible associations among logistic regression model. Variables were expressed as numbers and percentages. To reinforce clear and thorough reporting, the study followed the STROBE checklist (23).

# Results

## Sociodemographic factors

The total number of responses to the questionnaire received was 184. However, only 119 responses were considered in the analysis after excluding responses with no training status or respondents who did not fulfill the criterion used to define athletes (exercising for five or more hours per week) (20), which is crucial when using the LEAF questionnaire as it was validated for use with female athletes (12, 14) (see Table 1 for sociodemographic data). Average participant age was 21.92 ± 4.54 years. Average body mass index (BMI) was 22.68 ± 3.82 kg/m$^2$ (63.90% had a normal BMI). Only five participants were smokers.

## Energy availability risk score

Seventy-nine participants scored 8 or higher on the LEAF-Q (66.4%), qualifying them to be at risk for LEA, and the difference was statistically significant from the number of participants at low risk (40 participants, 33.6%), $p < 0.001$. Forty participants scored 2.5 or higher on the EDE-Q, qualifying them to be statistically significant at risk for eating disorders (33.6%; $p < 0.001$). Twelve participants had statistically significant risk for exercise addiction with a score of 24 or higher on the EAI-Q, $p < 0.001$. Among the participants with LEA ($n = 79$), four (3.3%) were classified as having primary exercise addiction, 6 (5.0%) had secondary exercise addiction, and 20 (16.8%) had disordered eating without exercise addiction.

We found no significant relationship between LEA and eating disorders ($p > 0.05$), although 40% of subjects that were at greater risk of LEA also scored 2.5 or higher on the EDE-Q (Table 2). No relationship was found between LEA and exercise addiction either ($p > 0.05$), although 12.7% of subjects that were at greater risk of LEA also scored 24 or higher on the EAI-Q (Table 3). The results revealed a significant association between having a BMI in the normal or underweight range and being at risk for LEA ($p < 0.05$), as 11.2% of the participants who were underweight according to BMI and 63.2% of participants with normal weight were at greater risk for LEA (LEAF-Q score ≥ 8; Table 4). Logistic regression analysis has revealed that low BMIs were at greater risk of LEA (OR = 0.29; $p \leq 0.01$), meaning that BMI can be considered a contributing factor for LEAF (Table 5). There was no statistically significant association between LEA and any of the other variables (Table 5).

# Discussion

The main objective of our study was to measure the prevalence of LEA among active adult females in Saudi Arabia and to identify the contributing factors associated with LEAF. The study found a significant correlation between BMI and LEA; lower BMI status was more prevalent with participants at greater risk for LEA. Our study showed that 66.4% of female athletes were at high

TABLE 1 Participant sociodemographic and lifestyle characteristics and Low Energy Availability in Females (LEAF) scores ($N = 119$).

| Factor | | All $N = 119$ | LEAF-Q score < 8 $n = 40$ | LEAF-Q score ≥ 8 $n = 79$ | p-value |
|---|---|---|---|---|---|
| Age | | 21.92 ± 4.54 | 22.78 ± 5.12 | 21.49 ± 4.18 | 0.17 |
| Education (%) | Below secondary school | 4.2 | 7.5 | 2.5 | 0.08 |
| | Secondary school | 29.4 | 25 | 31.6 | |
| | Bachelor | 60.5 | 55 | 63.3 | |
| | Postgraduate | 5.9 | 12.5 | 2.5 | |
| Employment (%) | Full time | 9.2 | 10 | 8.9 | 0.65 |
| | Part time | 9.2 | 12.5 | 7.6 | |
| | Unemployed | 81.5 | 77.5 | 83.5 | |
| Do you have any medical background? (%) | Yes | 26.9 | 32.5 | 24.1 | 0.64 |
| | No | 73.1 | 67.5 | 75.9 | |
| BMI | Underweight | 10.9 | 10 | 11.4 | 0.05* |
| | Normal | 63.9 | 50 | 70.9 | |
| | Overweight | 17.6 | 30 | 11.4 | |
| | Obese | 7.6 | 10 | 6.3 | |
| Height (cm) | | 159 ± 6.13 | 161.08 ± 5.55 | 158 ± 6.18 | 0.007** |
| Weight (kg) | | 57.47 ± 10.74 | 60.92 ±10.21 | 55.73 ± 10.65 | 0.01* |
| BMI | | 22.68 ± 3.82 | 23.49 ± 3.77 | 22.28 ±3.80 | 0.1 |
| Exercise (hours/week) | | 5.14 ± 2.39 | 5.05 ± 2.57 | 5.19 ± 2.31 | 0.76 |
| Do you smoke? (%) | Yes | 4.2 | 2.5 | 5.1 | 0.51 |
| | No | 95.8 | 97.5 | 94.9 | |
| Do you use any medication (excluding oral contraceptives)? (%) | Yes | 7.6 | 5.0 | 8.9 | 0.45 |
| | No | 92.4 | 95.0 | 91.1 | |
| LEAF score | | 9.57 ± 3.95 | 5.47 ± 1.44 | 11.65 ± 3.09 | <0.001*** |
| EDE global score | | 2.14 ± 1.21 | 2.18 ± 1.23 | 2.11 ± 1.21 | 0.76 |
| EAI score | | 18.77 ± 3.94 | 18.07 ± 3.77 | 19.12 ± 4.01 | 0.16 |

Data are represented as mean and standard deviation for continuous data and percentage for nominal data. LEAF-Q score ≥ 8 indicates at risk for LEA. LEAF is the dependent variable (low risk and at risk). Wilcoxon rank-sum and chi-square tests were used.

BMI, body mass index; LEAF-Q, Low Energy Availability in Females Questionnaire; EDE, Eating Disorder Examination; EAI, Exercise Addiction Inventory.

*$p \le 0.05$.

**$p \le 0.01$.

***$p \le 0.001$.

risk for LEA, which is similar to 65 and 62.2% cases of LEA in female athletes reported by Fahrenholtz et al. (4) and Melin et al. (14), respectively. However, a lower percentage (31%) was reported by Carr et al. (24), and a higher percentage (79.5%) was reported by Jesus et al. (24, 25). These discrepancies could be related to the different types of sports practiced and the level of activity (26). Despite the reasons associated with LEA, the high prevalence indicates vulnerability of the studied group of females to LEA, which can, consequently, lead to a rise of symptoms related to FAT and relative energy deficiency in sport (RED-S) syndromes (19).

For the majority of female athletes, LEA results unintentionally from appetite suppression post exercise (19, 27), low energy diets (28), An insufficient understanding of ideal sports nutrition (16, 29–31) along with impacts of LEA (32–35), or a busy lifestyle with inadequate time or access to food (29, 36, 37). On the other hand, insufficient balance between caloric intake and expenditure resulting in LEA may lead intentionally in pursuit of optimizing body mass and composition, to avoid gaining weight while downtime, or as a result of eating disorders or exercise dependence and/or addiction (36, 38), although, as previously mentioned, female endurance athletes can have LEA without

TABLE 2 Relationship between eating disorders and Low Energy Availability in Females score.

| EDE-Q | LEAF-Q | | | | *p*-value |
|---|---|---|---|---|---|
| | <8 | | ≥8 | | |
| | No. | % | No. | % | |
| <2.5 (%) | 26 | 65.0% | 53 | 67.1% | 0.82 |
| ≥2.5 (%) | 14 | 35.0% | 26 | 32.9% | |
| Total | 40 | 100.0% | 79 | 100.0% | |

EDE-Q scores ≥ 2.5 indicate individuals at risk for eating disorders. LEAF-Q scores ≥ 8 indicate individuals at risk for LEA. LEAF score is the dependent variable (low risk and at risk).
Chi-square test was used.
EDE-Q, Eating Disorders Evaluation Questionnaire; LEAF-Q, Low Energy Availability in Females Questionnaire.

TABLE 3 Relationship between exercise addiction and Low Energy Availability in Females score.

| EAI score | LEAF-Q score | | | | *p*-value |
|---|---|---|---|---|---|
| | <8 | | ≥8 | | |
| | No. | % | No. | % | |
| <24 | 38 | 95.0% | 69 | 87.3% | 0.19 |
| ≥24 | 2 | 5.0% | 10 | 12.7% | |
| Total | 40 | 100.0% | 79 | 100.0% | |

EAI scores ≥ 24 indicate that the individual is at risk of exercise addiction. LEAF-Q scores ≥ 8 indicate individuals at risk of LEA. LEAF score is the dependent variable (low risk and at risk). Chi-square test was used.
EAI, Exercise Addiction Inventory; LEAF-Q, Low Energy Availability in Females Questionnaire.

disordered eating (39). Nevertheless, the present study showed prevalence rates of 32.9 and 12.7% for eating disorders and EA, respectively, among female athletes at high risk for LEA. On the other hand, data analysis revealed no significant association between eating disorders and LEA or between exercise addiction and LEA. This comes contrary to what is published in the literature. Fahrenholtz et al. (4) demonstrated that participants at greater risk for LEA also had high scores for both disordered eating and exercise addiction when compared with participants at low risk (4). This can explain the high prevalence of LEA (62.2%) in their study, since availability of energy results from energy intake and expenditure, and, thus, both disordered eating and exercise addiction should be considered when examining for LEA (4). Collectively, our results suggest a high prevalence of eating disorders and exercise addiction in women, which is concerning.

There are primary and secondary forms of exercise dependence. When it is caused by disordered eating or is associated with it, the condition is secondary (40). However, if it occurs without accompanying symptoms of disordered eating, it is primary exercise dependence (41–44). In the latter, the person exercises continuously for the sole purpose of psychological gratification that results from the exercise itself no other pathologies (40). The current findings show that among the athletes with LEA ($n$ = 79, 66.4%), primary exercise addiction was found in 3.3%, 5.0% had secondary exercise addiction, and 16.8% had disordered eating without exercise addiction. Disordered eating is known as a reason that can cause LEA (19, 45); however, how exercise dependence causes LEA in the absence of disordered eating has not yet been explored. Preliminary studies have pointed to an increase in biochemical markers that indicate LEA (13, 46). However, these results are limited. It is possible that reduced availability of energy may contribute to the eating disorders in secondary exercise dependence. It is crucial, therefore, when developing interventions for athletes with RED-S syndrome to examine both dietary and exercise patterns.

In the present study, a rough measure of BMI was used with the intention to generally investigate the association between BMI and LEA among the population of female athletes. The current findings showed lower BMIs in athletes at greater risk for LEA comparing with athletes at low risk. Moreover, using regression analysis, LEA was found to be influenced by BMI. This could be logically expected, as athletes generally perceive excess fat as a major limiting factor in sport performance and that a higher skeletal muscle mass promotes strength and power (47). Thus, athletes might intentionally decrease their intake in order to reach the desired shape and/or optimal body composition (48). One can speculate from this point of view that LEA is not exclusive to a certain weight group and that it can be suspected even in people of normal weight. This highlights how important it is to promote healthy dietary habits and a positive body image among female athletes, since the current findings showed that most of the athletes at risk for LEA presented a healthy BMI. Although the current outcomes are in line with those of Fahrenholtz et al. and Christo et al. (4, 49), other reports disagree with them (14, 28). This conflict can only suggest that BMI cannot be used alone when screening for LEA, given the potential metabolic compensatory mechanisms and that other measurements of body composition should be used to carefully identify malnutrition and examine athletic health and performance (50–52). Further research is recommended to elucidate this relationship.

The novelty in this study is the identified prevalence of LEA, eating disorders, along with exercise addiction among females residing in the various regions of Saudi Arabia. The outcomes of the current research emphasize the importance of the topic and reinforce the need for larger future studies that allow for the detection of comparable differences among the different regions of the country. Due to the cross-sectional design of the study, it was not possible to identify the correlation's direction and, hence, causality. Moreover, hence the data collection involved self-reporting, it might be prone to response bias, denial, and erroneous reporting in studies. Overestimation or underestimation of anthropometric data and food intake was also an issue. Future studies should include measuring the nutritional knowledge of the participated females and categorizing the participated females according to the type of sport practiced during analysis and risk association, since athletes in weight categories of aesthetic sports manipulate their weight when compared to other type of sports. In conclusion, this study showed a high prevalence of LEA (66.4%), eating disorders (33.6%), and exercise addiction (10.1%) and confirmed the association between normal weight and LEA in females living in Saudi Arabia. The high percentage of the affected population elicits the need to raise awareness among

TABLE 4 Relationship between BMI and Low Energy Availability in Females score.

| | | LEAF group | | | | Total | | |
|---|---|---|---|---|---|---|---|---|
| | | No | | Yes | | | | |
| | | No. | % | No. | % | No. | % | *p*-value |
| BMI level | Underweight | 4 | 10.0% | 9 | 11.4% | 13 | 10.9% | 0.05* |
| | Normal | 20 | 50.0% | 56 | 70.9% | 76 | 63.9% | |
| | Overweight | 12 | 30.0% | 9 | 11.4% | 21 | 17.6% | |
| | Obese | 4 | 10.0% | 5 | 6.3% | 9 | 7.6% | |
| Total | 40 | 100.0% | 79 | 100.0% | 119 | 100.0% | | |

BMI < 18.5 indicates underweight; between 18.5 and 25 indicates normal weight; between 25 and 30 indicates overweight; >30 indicates obesity. LEAF-Q scores ≥ 8 indicate individuals at risk for LEA. LEAF score is the dependent variable (low risk and at risk).
BMI, body mass index; LEAF-Q, Low Energy Availability in Females Questionnaire.
Chi-square test was used.
*$p \leq 0.05$.

TABLE 5 Risk factors for low energy availability.

| | | OR | 95% CI | | *p*-value |
|---|---|---|---|---|---|
| | | | Lower | Upper | |
| Independent variable | BMI | 0.295 | 0.124 | 0.704 | 0.006* |
| | EAI | 2.75 | 0.573 | 13.222 | 0.20 |
| | EDE | 0.91 | 0.409 | 2.031 | 0.82 |

The dependent variable is low energy availability in females score. A binary logistic test was conducted.
OR, odds ratio; CI, confidence interval; BMI, body mass index; EAI, Exercise Addiction Inventory; EDE, Eating Disorder Examination.
*$p \leq 0.01$.

females, especially with the increasing trends of practicing sports and following a healthy lifestyle in the country. Further, larger studies should follow to assess the causative relationship between LEA and eating disorders, exercise addiction, and BMI in both genders. The results of the current study should be used as rough estimates for future studies comparing prevalence rates with other Gulf, and neighboring, countries. They will also help the Ministry of Health in developing proper educational programs and approaches for appropriate energy intake as well as understanding the effect of healthy food intake and good exercise at the population level.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Author contributions

MK: Conceptualization, Formal analysis, Resources, Supervision, Writing – original draft, Writing – review & editing. EA: Data curation, Investigation, Methodology, Supervision, Visualization, Writing – review & editing. MH: Methodology, Project administration, Supervision, Visualization, Writing – review & editing. AA: Investigation, Methodology, Writing – original draft, Writing – review & editing. WA: Investigation, Methodology, Writing – original draft, Writing – review & editing.

## Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

## Acknowledgments

The authors thank Dina Qahwaji, Haneen Najjar, Shoug Alashmali, and Doaa Alyoubi for their assistance with co-supervising the bachelor degree students while conducting this research. The authors would also like to thank all the volunteers who took part in the study.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

# References


1. Areta JL, Taylor HL, Koehler K. Low energy availability: history, definition and evidence of its endocrine, metabolic and physiological effects in prospective studies in females and males. *Eur J Appl Physiol.* (2021) 121:1–21. doi: 10.1007/s00421-020-04516-0

2. Wasserfurth P, Palmowski J, Hahn A, Krüger K. Reasons for and consequences of low energy availability in female and male athletes: social environment, adaptations, and prevention. *Sports Med.* (2020) 6:44. doi: 10.1186/s40798-020-00275-6

3. Jurov I, Keay N, Spudić D, Rauter S. Inducing low energy availability in trained endurance male athletes results in poorer explosive power. *Eur J Appl Physiol.* (2022) 122:503–13. doi: 10.1007/s00421-021-04857-4

4. Fahrenholtz IL, Melin AK, Wasserfurth P, Stenling A, Logue D, Garthe I, et al. Risk of low energy availability, disordered eating, exercise addiction, and food intolerances in female endurance athletes. *Front Sports Act Living.* (2022) 4:869594. doi: 10.3389/fspor.2022.869594

5. Ishibashi A, Kojima C, Tanabe Y, Iwayama K, Hiroyama T, Tsuji T, et al. Effect of low energy availability during three consecutive days of endurance training on iron metabolism in male long distance runners. *Physiol Rep.* (2020) 8:e14494. doi: 10.14814/phy2.14494

6. Kontele I, Vassilakou T. Nutritional risks among adolescent athletes with disordered eating. *Children.* (2021) 8:80715. doi: 10.3390/children8080715

7. Ryterska K, Kordek A, Załeska P. Has menstruation disappeared? Functional hypothalamic amenorrhea-what is this story about? *Nutrients.* (2021) 13:82827. doi: 10.3390/nu13082827

8. Master-Hunter T, Heiman DL. Amenorrhea: evaluation and treatment. *Am Fam Physician.* (2006) 73:1374–82.

9. Klein DA, Paradise SL, Reeder RM. Amenorrhea: a systematic approach to diagnosis and management. *Am Fam Physician.* (2019) 100:39–48.

10. Melin AK, Heikura IA, Tenforde A, Mountjoy M. Energy availability in athletics: health, performance, and physique. *Int J Sport Nutr Exerc Metab.* (2019) 29:152–64. doi: 10.1123/ijsnem.2018-0201

11. Witkoś J, Hartman-Petrycka M. The Female Athlete Triad-the impact of running and type of diet on the regularity of the menstrual cycle assessed for recreational runners. *PeerJ.* (2022) 10:e12903. doi: 10.7717/peerj.12903

12. Łuszczki E, Jagielski P, Bartosiewicz A, Kuchciak M, Dereń K, Stolarczyk A, et al. The LEAF questionnaire is a good screening tool for the identification of the Female Athlete Triad/Relative Energy Deficiency in Sport among young football players. *PeerJ.* (2021) 9:e12118. doi: 10.7717/peerj.12118

13. Monica Klungland T, Ida Lysdahl F, Mia Beck L, Thomas Birkedal S, Anna Katarina M. Exercise dependence, eating disorder symptoms and biomarkers of Relative Energy Deficiency in Sports (RED-S) among male endurance athletes. *Br Med J Open Sport Exer Med.* (2019) 5:e000439. doi: 10.1136/bmjsem-2018-000439

14. Melin A, Tornberg AB, Skouby S, Faber J, Ritz C, Sjödin A, et al. The LEAF questionnaire: a screening tool for the identification of female athletes at risk for the female athlete triad. *Br J Sports Med.* (2014) 48:540–5. doi: 10.1136/bjsports-2013-093240

15. Guest T. Using the eating disorder examination in the assessment of bulimia and anorexia: issues of reliability and validity. *Soc Work Health Care.* (2000) 31:71–83. doi: 10.1300/J010v31n04_05

16. Sim A, Burns SF. Review: questionnaires as measures for low energy availability (LEA) and relative energy deficiency in sport (RED-S) in athletes. *J Eat Disord.* (2021) 9:41. doi: 10.1186/s40337-021-00396-7

17. Griffiths MD, Szabo A, Terry A. The exercise addiction inventory: a quick and easy screening tool for health practitioners. *Br J Sports Med.* (2005) 39:e30. doi: 10.1136/bjsm.2004.017020

18. Kuikman MA, Mountjoy M, Burr JF. Examining the relationship between exercise dependence, disordered eating, and low energy availability. *Nutrients.* (2021) 13:82601. doi: 10.3390/nu13082601

19. Mountjoy M, Sundgot-Borgen JK, Burke LM, Ackerman KE, Blauwet C, Constantini N, et al. IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. *Br J Sports Med.* (2018) 52:687. doi: 10.1136/bjsports-2018-099193

20. McKinney J, Velghe J, Fee J, Isserow S, Drezner JA. Defining athletes and exercisers. *Am J Cardiol.* (2019) 123:532–5. doi: 10.1016/j.amjcard.2018.11.001

21. Terry A, Szabo A, Griffiths M. The exercise addiction inventory: a new brief screening tool. *Addict R . Theory.* (2004) 12:489–99. doi: 10.1080/16066350310001637363

22. Fairburn CG, Beglin SJ. Assessment of eating disorder psychopathology: interview or self-report questionnaire. *Int J Eating Disord.* (1994) 16:363–70.

23. Lachat C, Hawwash D, Ocké MC, Berg C, Forsum E, Hörnell A, et al. Strengthening the reporting of observational studies in epidemiology-nutritional epidemiology (STROBE-nut): an extension of the STROBE statement. *PLoS Med.* (2016) 13:e1002036. doi: 10.1371/journal.pmed.1002036

24. Carr A, McGawley K, Govus A, Andersson EP, Shannon OM, Mattsson S, et al. Nutritional intake in elite cross-country skiers during two days of training and competition. *Int J Sport Nutr Exerc Metab.* (2019) 29:273–81. doi: 10.1123/ijsnem.2017-0411

25. Jesus F, Castela I, Silva AM, Branco PA, Sousa M. Risk of low energy availability among female and male elite runners competing at the 26th European Cross-Country Championships. *Nutrients.* (2021) 13:30873. doi: 10.3390/nu13030873

26. Hoch AZ, Pajewski NM, Moraski L, Carrera GF, Wilson CR, Hoffmann RG, et al. Prevalence of the female athlete triad in high school athletes and sedentary students. *Clin J Sport Med.* (2009) 19:421–8. doi: 10.1097/JSM.0b013e3181b8c136

27. Howe SM, Hand TM, Larson-Meyer DE, Austin KJ, Alexander BM, Manore MM. No effect of exercise intensity on appetite in highly-trained endurance women. *Nutrients.* (2016) 8:223. doi: 10.3390/nu8040223

28. Melin A, Tornberg Å B, Skouby S, Møller SS, Sundgot-Borgen J, Faber J, et al. Energy availability and the female athlete triad in elite endurance athletes. *Scand J Med Sci Sports.* (2015) 25:610–22. doi: 10.1111/sms.12261

29. Benardot D. Energy thermodynamics revisited: energy intake strategies for optimizing athlete body composition and performance. *Pensar En Movimiento.* (2013) 11:1–14. doi: 10.15517/pensarmov.v11i2.10841

30. Trakman GL, Forsyth A, Devlin BL, Belski R. A systematic review of athletes' and coaches' nutrition knowledge and reflections on the quality of current nutrition knowledge measures. *Nutrients.* (2016) 8:90570. doi: 10.3390/nu8090570

31. Heikkilä M, Valve R, Lehtovirta M, Fogelholm M. Nutrition knowledge among young Finnish endurance athletes and their coaches. *Int J Sport Nutr Exerc Metab.* (2018) 28:522–7. doi: 10.1123/ijsnem.2017-0264

32. Folscher LL, Grant CC, Fletcher L, Janse van Rensberg DC. Ultra-marathon athletes at risk for the Female Athlete Triad. *Sports Med Open.* (2015) 1:29. doi: 10.1186/s40798-015-0027-7

33. Condo D, Lohman R, Kelly M, Carr A. Nutritional intake, sports nutrition knowledge and energy availability in Female Australian Rules Football Players. *Nutrients.* (2019) 11:50971. doi: 10.3390/nu11050971

34. Logue DM, Madigan SM, Melin A, Delahunt E, Heinen M, Donnell SM, et al. Low energy availability in athletes 2020: an updated narrative review of prevalence, risk, within-day energy balance, knowledge, and impact on sports performance. *Nutrients.* (2020) 12:30835. doi: 10.3390/nu12030835

35. Tosi M, Maslyanskaya S, Dodson NA, Coupey SM. The Female Athlete Triad: a comparison of knowledge and risk in adolescent and young adult figure skaters, dancers, and runners. *J Pediatr Adolesc Gynecol.* (2019) 32:165–9. doi: 10.1016/j.jpag.2018.10.007

36. Burke LM, Lundy B, Fahrenholtz IL, Melin AK. Pitfalls of conducting and interpreting estimates of energy availability in free-living athletes. *Int J Sport Nutr Exerc Metab.* (2018) 28:350–63. doi: 10.1123/ijsnem.2018-0142

37. Logue DM, Mahony L, Corish CA, Tobin D, Doherty R, O'Higgins G, et al. Athletes' and coaches' perceptions of nutritional advice: eating more food for health and performance. *Nutrients.* (2021) 13:61925. doi: 10.3390/nu13061925

38. Gibbs JC, Williams NI, De Souza MJ. Prevalence of individual and combined components of the female athlete triad. *Med Sci Sports Exerc.* (2013) 45:985–96. doi: 10.1249/MSS.0b013e31827e1bdc

39. Melin A, Tornberg ÅB, Skouby S, Møller SS, Faber J, Sundgot-Borgen J, et al. Low-energy density and high fiber intake are dietary concerns in female endurance athletes. *Scand J Med Sci Sports.* (2016) 26:1060–71. doi: 10.1111/sms.12516

40. Cook B, Hausenblas H, Freimuth M. Exercise addiction and compulsive exercising: relationship to eating disorders, substance use disorders, and addictive disorders. In: Brewerton TD, Dennis AB, editors. *Eating Disorders, Addictions and Substance Use Disorders: Research, Clinical and Treatment Perspectives*. New York, NY: Springer-Verlag Publishing/Springer Nature (2014). p. 127–44.

41. Blaydon MJ, Linder KJ, Kerr JH. Metamotivational characteristics of exercise dependence and eating disorders in highly active amateur sport participants. *Pers Individ Dif.* (2004) 36:1419–32. doi: 10.1016/S0191-8869(03)00238-1

42. Blaydon MJ, Lindner KJ. Eating disorders and exercise dependence in triathletes. *Eat Disord.* (2002) 10:49–60. doi: 10.1080/106402602753573559

43. Cook B, Luke R. Primary and secondary exercise dependence in a sample of cyclists. *Int J Ment Health Addict.* (2017) 15:444–51. doi: 10.1007/s11469-017-9745-z

44. McNamara J, McCabe MP. Striving for success or addiction? Exercise dependence among elite Australian athletes. *J Sports Sci.* (2012) 30:755–66. doi: 10.1080/02640414.2012.667879

45. Mountjoy M, Sundgot-Borgen J, Burke L, Carter S, Constantini N, Lebrun C, et al. The IOC consensus statement: beyond the Female Athlete Triad–Relative Energy Deficiency in Sport (RED-S). *Br J Sports Med.* (2014) 48:491–7. doi: 10.1136/bjsports-2014-093502

46. Lichtenstein MB, Andries A, Hansen S, Frystyk J, Støving RK. Exercise addiction in men is associated with lower fat-adjusted leptin levels. *Clin J Sport Med.* (2015) 25:138–43. doi: 10.1097/JSM.0000000000000110

47. Pyne DB, Anderson ME, Hopkins WG. Monitoring changes in lean mass of elite male and female swimmers. *Int J Sports Physiol Perform.* (2006) 1:14–26. doi: 10.1123/ijspp.1.1.14

48. Fairburn CG. *Cognitive Behavior Therapy and Eating Disorders*. New York, NY: Guilford Press (2008). p. 324.

49. Christo K, Cord J, Mendes N, Miller KK, Goldstein MA, Klibanski A, et al. Acylated ghrelin and leptin in adolescent athletes with amenorrhea, eumenorrheic athletes and controls: a cross-sectional study. *Clin Endocrinol.* (2008) 69:628–33. doi: 10.1111/j.1365-2265.2008.03237.x

50. Bosy-Westphal A, Schautz B, Later W, Kehayias JJ, Gallagher D, Müller MJ. What makes a BIA equation unique? Validity of eight-electrode multifrequency BIA to estimate body composition in a healthy adult population. *Eur J Clin Nutr.* (2013) 67(Suppl.1):S14–21. doi: 10.1038/ejcn.2012.160

51. Aragon AA, Schoenfeld BJ, Wildman R, Kleiner S, VanDusseldorp T, Taylor L, et al. International society of sports nutrition position stand: diets and body composition. *J Int Soc Sports Nutr.* (2017) 14:16. doi: 10.1186/s12970-017-0174-y

52. Achamrah N, Colange G, Delay J, Rimbert A, Folope V, Petit A, et al. Comparison of body composition assessment by DXA and BIA according to the body mass index: a retrospective study on 3655 measures. *PLoS ONE.* (2018) 13:e0200465. doi: 10.1371/journal.pone.0200465

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 06 June 2024
DOI 10.3389/fpubh.2024.1401254



OPEN ACCESS

EDITED BY
Luis Suarez-Arrones,
Universidad Pablo de Olavide, Spain

REVIEWED BY
Aureliusz Kosendiak,
Wroclaw Medical University, Poland
Gonzalo Saco-Ledo,
European University of Madrid, Spain

*CORRESPONDENCE
Hyun-Young Park
✉ hypark65@korea.kr

RECEIVED 15 March 2024
ACCEPTED 20 May 2024
PUBLISHED 06 June 2024

CITATION
Park JH and Park H-Y (2024) Sex-based differences in the association of resistance training levels with the risk of hypertension. *Front. Public Health* 12:1401254.
doi: 10.3389/fpubh.2024.1401254



# Sex-based differences in the association of resistance training levels with the risk of hypertension

Jae Ho Park[1] and Hyun-Young Park[2]*

[1]Division of Population Health Research, Department of Precision Medicine, Korea National Institute of Health, Korea Disease Control and Prevention Agency, Cheongju, Republic of Korea, [2]Korea National Institute of Health, Korea Disease Control and Prevention Agency, Cheongju, Republic of Korea

**Introduction:** Hypertension is a primary risk factor for cardiovascular disease and all-cause mortality. This study investigated sex-based differences in the association between the risk of hypertension and resistance training (RT) levels, including training frequency and period.

**Methods:** We enrolled 162,102 participants from nationwide Korean cohorts. The training period (months) and frequency (per week) of RT were used to investigate the presence of an inverse dose–response relationship between RT levels and the risk of hypertension. Multiple logistic regression models were used to evaluate the risk of hypertension in relation to RT levels.

**Results:** The prevalence of hypertension in the study population was 36.28% in men and 26.94% in women. Performing RT was associated with an 8% reduction in the risk of hypertension in women but not in men. In women, performing RT for 3–4 days/week, compared with not performing RT, reduced the risk of hypertension by 11%, even after adjusting for covariates, including RT time per week and period. However, in men, no significant association was observed between training frequency and the risk of hypertension. We also evaluated the risk of hypertension by simultaneously considering both the RT frequency and period. Performing RT for 3–4 days/week and ≥5 days/week were markedly related to 14 and 11% hypertension risk reduction, respectively, in women who had been performing RT for at least 6 months.

**Conclusion:** Given that no inverse dose–response association was observed between RT frequency and hypertension risk, engaging in RT for 3–4 days/week for at least 6 months is recommended for women. Further longitudinal studies are needed to verify sex-based differences in the antihypertensive effects of regular RT.

KEYWORDS
**hypertension, exercise, resistance training, sex differences, population study**

## 1 Introduction

Hypertension or high blood pressure (BP) is a primary risk factor for cardiovascular disease (CVD) and all-cause mortality (1, 2). According to the World Health Organization (WHO), the prevalence of hypertension has increased globally, and an estimated 1.4 billion people, almost one-fifth of the world's population, suffer from hypertension (3). In Korea, one of the fastest-aging countries in the world, the prevalence of hypertension among the older adult has increased from 62 to 66% in women and from 49 to 59% in men over the last decade (4). Consequently, increasing interest in preventive and therapeutic strategies for hypertension has been observed.

Recent hypertension guidelines recommend participating in moderate-intensity aerobic exercise training for at least 150 min per week to prevent and/or manage hypertension (5, 6). In recent meta-analyses, aerobic exercise training effectively reduced both systolic BP (SBP) and diastolic BP (DBP) in patients with hypertension (7, 8). Current guidelines also recommend performing resistance training (RT), which causes the major muscle groups in the body to work against external resistance, for 2–3 days per week to improve musculoskeletal fitness, blood glucose levels, insulin sensitivity, and BP (5, 6, 9). However, unlike aerobic exercise, the antihypertensive effects of RT remain unclear and controversial. Recent meta-analysis has shown that regular RT significantly reduces SBP and DBP in both individuals with prehypertension and hypertension (10). However, in another meta-analysis, significant BP-lowering effects were observed in participants who performed RT for 3 times per week compared with RT 2 times per week, and only moderate-intensity RT among other training intensities, including low- and high-intensity, was effective in reducing both SBP and DBP (11). Several randomized controlled trials (RCTs) have also reported no significant BP-lowering effects after 8 weeks of progressive (from low- to moderate-intensity) RT for 2 days per week (12), 13 weeks of moderate-intensity RT for 3 days per week (13), and 8 weeks of high-intensity RT for 3 days per week (14). Therefore, the BP-lowering effects of RT have been reported to be inconsistently dependent on training variables, including RT frequency and intensity. A few epidemiological studies have investigated the association between regular RT and the risk of hypertension beyond its BP-lowering effect. Although a recent cohort study revealed that regular RT for more than 1 day per week was associated with a significant hypertension risk reduction (15), this study did not consider a potential sex-based difference in the association between the variables and the presence of an inverse graded dose–response association according to RT levels, such as training frequency and period.

In the United States, the proportion of adults who perform RT for 2 days or more per week has increased by 5.4% among men (from 25.7 to 31.1%) and 6% among women (from 18.3 to 24.3%) over the past decade (16). As the sex gap in RT participation rates has reduced, a growing interest has been observed in the investigation of sex-based differences in the antihypertensive effect of RT. However, to the best of our knowledge, few studies have investigated these sex-based differences. Recent meta-analytical evidence has reported that regular RT significantly reduces both SBP and DBP in women but not in men (11). According to a longitudinal study, including RT in the physical activity (PA) schedule of participants who met the current PA guideline (≥150 min/week of moderate-intensity PA) further reduced the risk of incident hypertension by 35% in women but not in men (17). In contrast, higher levels of muscular strength, a major outcome of long-term RT, are markedly associated with a reduced risk of hypertension in both sexes (18, 19). Considering these contradictory results, further studies are necessary to investigate sex-based differences in the antihypertensive effects of RT. In particular, further research on specific RT levels, such as training frequency and period, for an antihypertensive effect according to sex is needed to provide sex-specific recommendations.

Therefore, the purpose of the present study was to investigate the association between RT regularity and hypertension risk reduction using data from large nationwide cohorts in Korea. We further aimed to examine the presence of an inversely graded dose–response relationship between RT levels (i.e., training frequency and period) and the risk of hypertension.

# 2 Materials and methods

## 2.1 Study participants

The present study used data from the Korean Genome and Epidemiology Study (KoGES), conducted by the Korea National Institute of Health. The KoGES is a consortium project consisting of 6 prospective cohort studies and aims to investigate the environmental and genetic etiologies of non-communicable chronic diseases in Korea, including hypertension, diabetes mellitus, CVD, and cancer (20). In this study, we used 2003–2013 data from the KoGES Health Examinee study, which included 173,202 urban residents aged 40–79 years, the KoGES Cardiovascular Disease Association study, which included 28,337 rural residents aged 40–91 years, and the fourth wave of the KoGES Ansan and Ansung study conducted in 2007–2008, which included 6,688 participants aged 44–76 years who lived in Ansan (an urban area) and Ansung (a rural area). All participants underwent face-to-face surveys and physical examinations were conducted by trained medical staff. A detailed description of these cohort studies has been provided previously (20).

Among the 208,227 participants from the 3 cohorts, the following were excluded from this study: those with a clinical history of CVD and any type of cancer ($n = 14{,}485$), those without data on BP ($n = 1{,}111$), those without data on PA levels ($n = 6{,}367$), those without data on RT parameters ($n = 16{,}150$), and those without data on covariates ($n = 8{,}012$). A total of 162,102 participants (105,820 women) were included in the final analysis (Figure 1). This study was approved by the Institutional Review Board of the Korea National Institute of Health, Korea Disease Control and Prevention Agency (Approval No. KDCA-2024-02-12-P-01).

## 2.2 Measurement of RT levels

All participants completed questionnaires regarding details of their RT levels. RT was defined as any training program involving muscle contraction against external resistance such as body weight, weight machines, barbells, and dumbbells. The frequency (per week), training time (min/week), and training period (months) of RT were assessed to examine RT levels. Regular RT was defined as participating in an RT program for more than 1 day per week. Participants were divided into 2 groups based on the regularity of RT: "non-RT (not performing RT)" and "RT (performing RT)." To investigate the presence of an inversely graded dose–response relationship between RT levels and the risk of hypertension, the training period and frequency of RT were analyzed. Based on the frequency of RT, participants were categorized into one of the following 4 subgroups: "non-RT (not performing RT)," "1–2 days/week," "3–4 days/week," and "≥5 days/week." Based on the RT training period, participants were also classified into one of the following 3 subgroups: "non-RT (not performing RT)," "<6 months," and "≥6 months." Finally, as shown in Figure 2, the participants were divided into one of the 7 groups

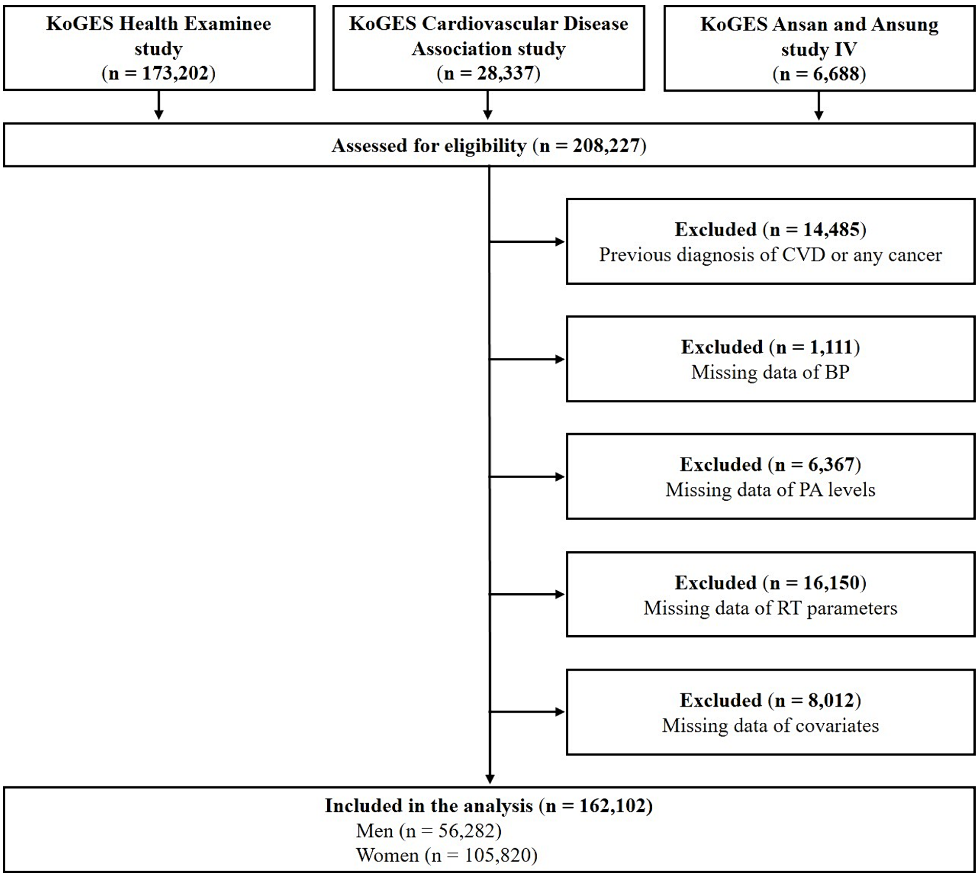



FIGURE 1
Flow diagram of participant inclusion and exclusion. CVD, cardiovascular disease; BP, blood pressure; PA, physical activity; RT, resistance training.

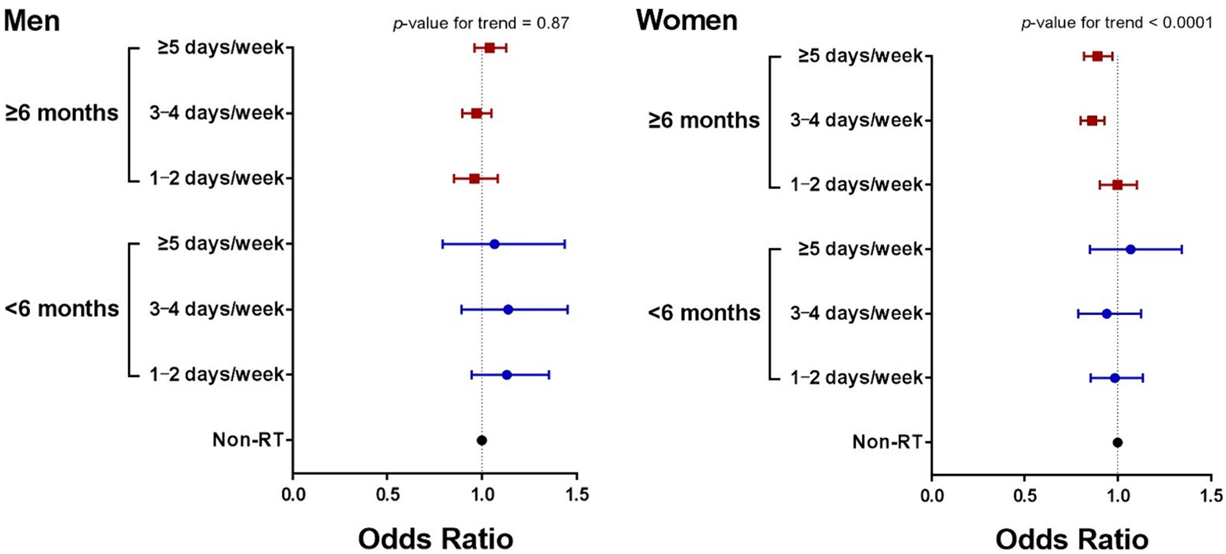



FIGURE 2
Odds ratios for hypertension prevalence according to period and frequency of RT. Adjusted for age, drinking, smoking, educational level, BMI, T-Chol, eGFR, PA time, and diabetes mellitus. RT, resistance training; BMI, body mass index; T-Chol, total cholesterol; eGFR, estimated glomerular filtration rate; PA, physical activity.

indicated above by simultaneously considering the training period and frequency of RT.

## 2.3 Definition of hypertension

Hypertension was defined based on a previous diagnosis by a physician, current use of antihypertensive drugs, SBP ≥140 mmHg, or DBP ≥90 mmHg. Trained healthcare providers measured BPs using standard methods. SBP and DBP were obtained by averaging two readings from the arm with the highest SBP after the participant had rested for 5 min in a seated position.

## 2.4 Covariates

Sociodemographic and health-related factors, including age, sex, educational level, drinking and smoking habits, PA time, body mass index (BMI), waist circumference (WC), diabetes mellitus status, and laboratory parameters, were included in our analyses. Educational level was divided into elementary school graduates or lower, middle or high school graduates, and college graduates or higher. Drinking and smoking habits were classified as "never," "former," and "current." PA time was defined as the total time (min/week) spent engaging in moderate-intensity leisure-time PA in a typical week. Moderate-intensity leisure-time PA was defined as participation in sports or engagement in exercises that resulted in sweating.

Anthropometric data including height, body weight, and WC were measured by trained healthcare providers using standardized methods. BMI was calculated as body weight (kg) divided by height (m) squared (kg/m$^2$). Blood samples were collected after an overnight fasting period of 8 h. Biochemical assays were performed to determine the total cholesterol (T-Chol), high-density lipoprotein cholesterol (HDL-C), triglyceride (TG), fasting blood glucose (FBG), and creatinine levels. The estimated glomerular filtration rate (eGFR) was calculated using the following formula, with creatinine expressed in mg/dL (21): eGFR (mL/min per 1.73 m$^2$) = 175 × (creatinine)$^{-1.154}$ × (age)$^{-0.203}$ × (0.742, if female). Diabetes mellitus was defined based on a previous diagnosis by a physician, current use of antidiabetic medications, including insulin and oral hypoglycemic agents, FBG ≥126 mg/dL, or glycated hemoglobin ≥6.5%. Detailed information on the biochemical analyses is described in a previous study (20).

## 2.5 Statistical analysis

All statistical analyses were conducted using SAS software (version 9.4; SAS Institute, Cary, North Carolina, United States). Participant characteristics are presented as descriptive statistics. Continuous variables are presented as mean ± standard deviation, whereas categorical variables are expressed as absolute frequencies and percentages (%). The chi-squared test was used to determine intergroup differences in educational level, drinking and smoking habits, RT regularity, and prevalence of hypertension and diabetes mellitus. Independent *t*-tests were used to compare age, PA time, BMI, WC, SBP, DBP, T-Chol, HDL-C, TG, FBG, creatinine, and eGFR between the groups.

Multiple logistic regression models were used to evaluate the odds ratios (ORs) and 95% confidence intervals (CIs) for hypertension prevalence. The models were adjusted for age, drinking, smoking, educational level, BMI, T-Chol level, eGFR, PA time, RT time (min/week), RT period (months), and diabetes mellitus status. Subgroup analyses were performed for each sex to investigate the association between the risk of hypertension and performance of long-term RT (≥6 months) for 3 or more days/week, considering age (<65 and ≥65 years), educational level (≤middle school and ≥high school), current drinking habits (no and yes), smoking status (never and ever), BMI (<25 and ≥25 kg/m$^2$), and diabetes mellitus status (no and yes). The *p*-value for the interaction was estimated to assess the consistency of the associations across the subgroups. All tests were two-tailed, and statistical significance was set at a *p*-value < 0.05.

# 3 Results

A total of 162,102 participants (105,820 women) were included in the analysis. Table 1 shows the characteristics of the study participants based on RT regularity and sex. The proportions of men and women engaging in regular RT were 15.84 and 13.84%, respectively. In women, the prevalence of hypertension was significantly lower in the RT group than in the non-RT group, whereas in men, no significant difference in the prevalence of hypertension was observed. In both sexes, the RT group showed markedly lower mean age, WC, TG, and FBG and lower proportions of never drinkers, current smokers, and patients with diabetes mellitus than the non-RT group. In contrast, the RT group exhibited significantly higher PA time, HDL-C, and a higher proportion of individuals with a high educational level (≥college) than the non-RT group. In men, compared with the non-RT group, the RT group was significantly associated with higher BMI and creatinine levels but lower eGFR. Women in the RT group had a markedly lower BMI but higher eGFR than women in the non-RT group. SBP, DBP, and T-Chol levels were significantly lower in the RT group than in the non-RT group in women but not in men.

The characteristics of the study participants based on hypertension status and sex are shown in Supplementary Table 1. The prevalence of hypertension in our study population was 36.28 and 26.94% in men and women, respectively. In both sexes, the hypertension group compared with the normotensive group was significantly associated with higher mean age, PA time, BMI, WC, TG, FBG, creatinine, and prevalence of diabetes mellitus, but lower HDL-C, eGFR, and proportion of a high educational level (≥college), and current smokers. Among men, the hypertension group showed a markedly higher prevalence of current drinkers than the normotensive group. In women, compared with the normotensive group, the hypertension group had significantly lower proportions of current drinkers and individuals engaging in regular RT, but higher T-Chol levels.

Table 2 shows the association between RT regularity and risk of hypertension after adjusting for covariates. Men had a significantly longer training time ($p < 0.01$) and period ($p < 0.0001$), as well as a markedly higher training frequency ($p < 0.0001$) and rate of a long-term RT program (≥6 months; $p < 0.0001$) than women. However,

TABLE 1 Characteristics of study participants based on RT regularity and sex.

| Variables | Men ($n$ = 56,282) | | $p$-value | Women ($n$ = 105,820) | | $p$-value |
|---|---|---|---|---|---|---|
| | non-RT ($n$ = 47,365) | RT ($n$ = 8,917) | | non-RT ($n$ = 91,172) | RT ($n$ = 14,648) | |
| **Age** (years) | 54.07 ± 8.81 | 53.05 ± 8.38 | <0.0001 | 53.02 ± 8.23 | 50.85 ± 7.46 | <0.0001 |
| **Educational level**, n (%) | | | <0.0001 | | | <0.0001 |
| ≤Elementary school | 6,810 (14.38) | 493 (5.53) | | 23,848 (26.16) | 1,665 (11.37) | |
| Middle/high school | 25,535 (53.91) | 4,472 (50.15) | | 52,621 (57.71) | 9,171 (62.61) | |
| ≥College | 15,020 (31.71) | 3,952 (44.32) | | 14,703 (16.13) | 3,812 (26.02) | |
| **Drinking habit**, n (%) | | | <0.0001 | | | <0.0001 |
| Never drinker | 9,733 (20.55) | 1,501 (16.83) | | 61,420 (67.37) | 8,970 (61.24) | |
| Ex-drinker | 3,188 (6.73) | 608 (6.82) | | 1,776 (1.95) | 353 (2.41) | |
| Current drinker | 34,444 (72.72) | 6,808 (76.35) | | 27,976 (30.68) | 5,325 (36.35) | |
| **Smoking habit**, n (%) | | | <0.0001 | | | <0.0001 |
| Never smoker | 12,993 (27.43) | 2,595 (29.10) | | 87,831 (96.33) | 14,203 (96.96) | |
| Ex-smoker | 17,779 (37.54) | 4,095 (45.92) | | 1,109 (1.22) | 202 (1.38) | |
| Current smoker | 16,593 (35.03) | 2,227 (24.98) | | 2,232 (2.45) | 243 (1.66) | |
| **PA time** (min/week) | 144.04 ± 226.12 | 284.59 ± 248.01 | <0.0001 | 117.51 ± 193.93 | 265.24 ± 227.03 | <0.0001 |
| **BMI** (kg/m$^2$) | 24.33 ± 2.81 | 24.58 ± 2.58 | <0.0001 | 23.82 ± 3.03 | 23.34 ± 2.71 | <0.0001 |
| **WC** (cm) | 85.84 ± 7.65 | 85.50 ± 7.19 | <0.0001 | 79.10 ± 8.42 | 77.17 ± 7.62 | < 0.0001 |
| **SBP** (mmHg) | 125.85 ± 15.11 | 125.84 ± 14.75 | 0.93 | 121.54 ± 15.94 | 118.79 ± 15.18 | < 0.0001 |
| **DBP** (mmHg) | 79.10 ± 10.04 | 79.30 ± 9.89 | 0.08 | 75.31 ± 10.07 | 74.03 ± 9.82 | <0.0001 |
| **T-Chol** (mg/dL) | 194.48 ± 34.80 | 194.69 ± 33.10 | 0.58 | 200.48 ± 35.94 | 198.14 ± 34.91 | <0.0001 |
| **HDL-C** (mg/dL) | 48.91 ± 12.03 | 50.61 ± 11.89 | <0.0001 | 55.18 ± 12.88 | 58.28 ± 13.21 | <0.0001 |
| **TG** (mg/dL) | 155.56 ± 112.19 | 146.54 ± 105.41 | <0.0001 | 117.31 ± 77.66 | 103.97 ± 64.83 | <0.0001 |
| **FBG** (mg/dL) | 99.67 ± 25.69 | 97.75 ± 21.29 | <0.0001 | 93.41 ± 20.04 | 91.24 ± 16.06 | <0.0001 |
| **Creatinine** (mg/dL) | 0.98 ± 0.22 | 1.00 ± 0.19 | <0.0001 | 0.75 ± 0.18 | 0.75 ± 0.12 | 0.08 |
| **eGFR** (ml/min per 1.73 m$^2$) | 82.59 ± 14.70 | 80.91 ± 13.32 | <0.0001 | 84.19 ± 16.03 | 84.52 ± 14.90 | <0.05 |
| **Diabetes mellitus**, n (%) | 6,210 (13.11) | 1,025 (11.49) | <0.0001 | 7,263 (7.97) | 798 (5.45) | <0.0001 |
| **Hypertension**, n (%) | 17,203 (36.32) | 3,215 (36.05) | 0.63 | 25,389 (27.85) | 3,116 (21.27) | <0.0001 |

RT, resistance training; PA time, total time of regular participation in any sport or exercise to the point of sweating; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; T-Chol, total cholesterol; HDL-C, high-density lipoprotein cholesterol; TG, triglyceride; FBG, fasting blood glucose; eGFR, estimated glomerular filtration rate.

performing RT was associated with an 8% reduction in hypertension risk in women ($p$ < 0.001) but not in men. We further investigated the presence of an inverse dose–response association between RT levels and the risk of hypertension. As shown in Table 3, no inverse dose–response relationship was observed between RT frequency and the risk of hypertension in either sex. In women, compared with those who did not engage in RT, performing RT for 3–4 days/week decreased the risk of hypertension by 11% after adjusting for covariates ($p$ < 0.05). However, in men, no significant association was observed between training frequency and the risk of hypertension.

Figure 2 presents results on analysis the risk of hypertension evaluated by simultaneously considering both the training frequency and period of RT after adjustment for covariates. Among individuals who performed RT for less than 6 months, no significant associations were observed between training frequency and the risk of hypertension, regardless of sex. Among female participants who performed RT for 6 or more months, performing RT for 3–4 days/week and ≥5 days/week were related to a risk reduction of 14% ($p$ < 0.0001) and 1% ($p$ < 0.01), respectively, compared with their counterparts who did not perform RT. In men, however, no significant associations between training frequency and the risk of hypertension was observed, regardless of whether RT was performed for 6 or more months.

Subgroup analyses were performed for each sex to investigate whether the association between hypertension risk reduction and the performance of long-term RT (≥6 months) for 3 or more days/week was consistent in the various subgroups, including age, educational level, current drinking habits, smoking status, BMI, and diabetes mellitus status. In men, no significant relationship between long-term RT and a reduced risk of hypertension was observed in any subgroup (Supplementary Table 2). In women, the significance of the association between long-term RT and hypertension risk reduction was different in some of the subgroups (Supplementary Table 3). Particularly, the protective benefit of long-term RT against

TABLE 2 Odds ratios for hypertension prevalence according to RT regularity and sex.

| | *N* | RT levels | | | | Crude model OR (95% CI) | Adjusted model OR (95% CI) |
|---|---|---|---|---|---|---|---|
| | | Frequency | Time | Training period | | | |
| | | (days/week) | (min/week) | (month) | ≥6 month (%) | | |
| **Men** | | | | | | | |
| non-RT | 47,365 | – | – | – | – | 1 (reference) | 1 (reference) |
| RT | 8,917 | 3.99 ± 1.87[b] | 230.20 ± 186.76[a] | 19.94 ± 39.57[b] | 87.45[b] | 0.99 (0.94–1.04) | 1.01 (0.96–1.07) |
| **Women** | | | | | | | |
| non-RT | 91,172 | – | – | – | – | 1 (reference) | 1 (reference) |
| RT | 14,648 | 3.59 ± 1.67[b] | 223.58 ± 163.94[a] | 14.17 ± 21.04[b] | 80.80[b] | 0.70 (0.67–0.73)**** | 0.92 (0.88–0.96)*** |

RT, resistance training; OR, odds ratio; CI, confidence interval; BMI, body mass index; T-Chol, total cholesterol; eGFR, estimated glomerular filtration rate; PA, physical activity; [a]$p < 0.01$ compared women with men in RT group; [b]$p < 0.0001$ compared women with men in RT group; ***$p < 0.001$; ****$p < 0.0001$; Adjusted for age, drinking, smoking, educational level, BMI, T-Chol, eGFR, PA time, and diabetes mellitus.

TABLE 3 Odds ratios for hypertension prevalence according to RT frequency and sex.

| | *N* | RT levels | | | | Crude model OR (95% CI) | Adjusted model OR (95% CI) |
|---|---|---|---|---|---|---|---|
| | | Frequency | Time | Training period | | | |
| | | (days/week) | (min/week) | (month) | ≥6 month (%) | | |
| **Men** | | | | | | | |
| non-RT | 47,365 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 | 1 (reference) | 1 (reference) |
| 1–2 days/week | 1,990 | 1.54 ± 0.50 | 76.58 ± 60.51 | 17.14 ± 36.35 | 70.60 | 0.87 (0.79–0.96)** | 1.07 (0.96–1.19) |
| 3–4 days/week | 3,599 | 3.44 ± 0.50 | 204.17 ± 118.58 | 20.92 ± 39.82 | 91.03 | 0.92 (0.86–0.99)* | 1.06 (0.96–1.17) |
| ≥5 days/week | 3,328 | 6.05 ± 0.89 | 350.21 ± 216.38 | 20.55 ± 41.06 | 93.66 | 1.15 (1.07–1.23)*** | 1.12 (0.98–1.27) |
| **Women** | | | | | | | |
| non-RT | 91,172 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 | 1 (reference)[a] | 1 (reference) |
| 1–2 days/week | 4,018 | 1.65 ± 0.48 | 96.12 ± 60.47 | 10.85 ± 14.74 | 65.38 | 0.74 (0.68–0.79)**** | 1.01 (0.92–1.10) |
| 3–4 days/week | 6,399 | 3.37 ± 0.48 | 209.06 ± 101.81 | 14.87 ± 20.98 | 85.47 | 0.63 (0.59–0.67)**** | 0.89 (0.80–0.98)* |
| ≥5 days/week | 4,231 | 5.75 ± 0.86 | 366.58 ± 194.19 | 16.26 ± 25.40 | 88.40 | 0.78 (0.72–0.84)**** | 0.93 (0.80–1.07) |

RT, resistance training; OR, odds ratio; CI, confidence interval; BMI, body mass index; T-Chol, total cholesterol; eGFR, estimated glomerular filtration rate; PA, physical activity; [a]$p < 0.0001$ in the test for trend of ORs; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; ****$p < 0.0001$; Adjusted for age, drinking, smoking, educational level, BMI, T-Chol, eGFR, PA time, RT time, RT period, and diabetes mellitus.

hypertension was significant only in those who were < 65 years ($p < 0.0001$), had never smoked ($p < 0.0001$), and with a BMI < 25 kg/m$^2$ ($p < 0.0001$). Although a significant interaction was observed for current drinking habits ($p$ for interaction < 0.001), long-term RT conferred a protective benefit against hypertension in both subgroups (no and yes).

## 4 Discussion

To the best of our knowledge, the present study is the first to examine sex-based differences in the association between the risk of hypertension and specific RT levels (e.g., training frequency and period) in nationwide Korean cohorts. This study indicated no inverse dose–response association between RT levels and the risk of hypertension in either sex. When RT was performed for at least 6 months, an RT frequency of 3–4 days/week and ≥5 days/week in women were markedly related to 14 and 11% hypertension risk reduction, respectively. Taken together, given that no inverse dose–response association was observed between RT frequency and hypertension risk, we recommend that women should perform RT for 3–4 days/week for at least 6 months. Moreover, considering that RT did not increase the risk of hypertension in men, regular RT is also recommended for men to improve their musculoskeletal fitness and health.

Lifestyle modifications, including regular aerobic exercise training, are recommended for preventing and/or managing hypertension. However, the antihypertensive effects of RT are controversial. A recent cohort study revealed that engaging in RT for more than 1 day/week decreased the risk of hypertension by 19% in an Australian cohort (15). However, the study did not consider potential sex-based differences in the antihypertensive effects of RT. Accordingly, we investigated sex-based differences in the association between RT regularity and hypertension risk reduction in Korea. In the present study, although men had significantly higher RT levels including training time, period, and frequency, than women, performing RT was associated with a reduction in hypertension by 8% in women but not in men. This is consistent with the results of a recent meta-analysis that reported that regular RT significantly reduced both SBP and DBP in women but not in men (11). Although the potential mechanism underlying sex-based differences in the antihypertensive effect of RT has not been fully elucidated, RT-related changes in arterial stiffness may be the cause of this effect. According to prospective studies, a higher level of arterial stiffness in normotensive participants is an independent predictor of new-onset hypertension, as well as increased BP (22, 23). In a previous study, neither moderate- nor high-intensity long-term RT programs increased arterial stiffness in women (24). Another RCT reported that moderate-intensity RT for 16 weeks significantly improved arterial stiffness in women (25). In contrast, men who had been performing moderate-to-high-intensity long-term RT programs had higher arterial stiffness and SBP than those had by the control group (26). In another study, although 4 weeks of moderate-intensity RT reduced DBP and did not increase arterial stiffness in women, a significant increase in arterial stiffness was observed in men after they followed the same RT program (27). Therefore, based on previous studies, RT-related changes in arterial stiffness are likely due to sex-based differences in the antihypertensive effects of RT. However, according to recent studies, higher levels of muscular strength, which is a major outcome of long-term RT, are significantly related to a reduction in the risk of hypertension in both sexes (18, 19). Given these contradictory findings, sex-based differences in the antihypertensive effects of RT have not been fully investigated. The possible mechanisms underlying these differences in RT-related changes in arterial stiffness remain unclear. Further prospective studies that simultaneously consider both participation in RT and long-term changes in arterial stiffness are needed to investigate RT-related changes in arterial stiffness, which could explain sex-based differences in the risk of incident hypertension beyond the BP-lowering effect.

Current guidelines recommend engaging in RT for 2–3 days/week to improve BP as well as musculoskeletal fitness (5, 6, 9). However, to our knowledge, few studies have investigated whether there is an inverse-graded dose–response relationship between RT frequency and the risk of hypertension. Although a recent meta-analysis has demonstrated that significant BP-lowering effects were observed with 3 days/week of RT compared with 2 days/week of RT (11), additional effects of RT at frequencies exceeding the current guidelines were not evaluated. Accordingly, we further examined the presence of an inversely graded dose–response relationship between RT frequency and the risk of hypertension. Our findings showed no inverse dose–response relationship between RT frequency and the risk of hypertension in either sex, and no significant association between any of the training frequencies and the risk of hypertension was observed in men. In contrast, the risk of hypertension was reduced by 11% in women who performed RT for 3–4 days per week, even after adjusting for covariates, including the total training volume (e.g., RT time per week and period). Our findings are consistent with those of previous studies. In recent RCTs, no significant reductions in both SBP and DBP were observed in middle-aged women after a long-term RT program (≥12 weeks) for 2 days/week at moderate- (28) and progressive-intensity (from moderate- to high-intensity) levels, regardless of their menopausal status (29, 30). In contrast, previous RCTs have reported significant BP-lowering effects in postmenopausal women following a 12-week RT program for 3 days/week at low- (31), moderate- (32), and progressive- intensity (from low- to moderate-intensity) levels (33). Another RCT also reported a significant BP-lowering effect in an obese population that was mostly women (more than 70% of the total participants) after 24 weeks of progressive (from moderate-to-high-intensity) RT for 4 days/week (34). Similar findings have been reported for the effect of different weekly frequencies of RT on musculoskeletal fitness and body composition. After 12 weeks of a high-intensity RT program, body fat percentage significantly decreased in the group that performed RT for 4 days/week but not in the group that performed RT for 2 days/week (35). After 8 weeks of a high-intensity RT program, even when the total training volume was consistent per week, performing RT for 4 days/week provided a greater increase in muscular strength than that observed with a frequency of 2 days/week (36). Our findings and those of previous studies suggest that performing RT for 3–4 days/week is recommended to prevent hypertension and improve muscular fitness in women. Considering that RT did not increase the risk of hypertension in men, regular RT for at least 3–4 days/week is recommended to improve musculoskeletal fitness and body composition in men.

We also evaluated the risk of hypertension by simultaneously considering both the RT frequency and period. When RT was performed for at least 6 months, RT frequencies of 3–4 days/week and ≥5 days/week were significantly related to 14 and 11% hypertension risk reduction, respectively, in only women. Notably, even when RT was performed for ≥6 months, no inverse dose–response relationship between RT frequency and the risk of hypertension in either sex was observed. A meta-analysis demonstrated that short-term RT (≤6 weeks) had no effect on BP, while long-term RT for more than 24 weeks (6 months) markedly reduced SBP and DBP by 5.1 and 4.9 mmHg, respectively (37). According to another study that recruited older adult women, long-term RT for more than 8 months compared with a sedentary condition was significantly related to lower SBP and circulating levels of proinflammatory cytokines, such as tumor necrosis factor alpha and interleukin 6 (38). Accordingly, these results indicate that long-term RT for at least 6 months is recommended to manage and/or prevent hypertension. The potential mechanisms underlying the reduction in BP after regular RT include increased endothelial function and vascular conductance. According to RCTs, endothelial function, measured as brachial artery flow-mediated dilation, and plasma levels of nitric oxide metabolites significantly improved after 12 weeks of an RT program (39–41). Furthermore, long-term RT for 6 months markedly increased the resting diameter of the brachial artery and decreased its wall-to-lumen ratio, beyond improving endothelial function (42). Therefore, regular RT may be associated with protective benefits against hypertension by improving vasodilatory function, and if RT is performed for longer periods, it may even cause structural adaptations in the conduit arteries. However, the training intensity of long-term RT, which was not considered in our study and the previous study (42), may play an important role in the antihypertensive effects of RT. Since high-intensity RT and the concurrent Valsalva maneuver are likely to increase central arterial stiffness by increasing plasma norepinephrine levels and BP during exercise (43), further RCTs are required to verify the mechanism behind RT-related antihypertensive effects by simultaneously considering training intensity and changes in vascular structure and function.

One of the crucial strengths of our study is the use of large nationwide cohorts representative of the general Korean population aged 40–79 years. However, this study had some limitations. First, because we only included the Korean population, our findings may not be applicable to other populations. Second, we were unable to deduce cause-and-effect associations due to the cross-sectional design of our study. Third, a self-report questionnaire was used to assess RT levels, which may have introduced recall bias. Finally, specific information on RT intensity was not available from the self-reported questionnaire. Further studies are required to verify the optimal frequency, intensity, type, volume, and training period of RT for the management and/or prevention of hypertension.

In conclusion, our findings show that when RT was performed for at least 6 months, training frequencies of 3–4 days/week and ≥5 days/week were significantly associated with 14 and 11% hypertension risk reduction, respectively, in women only. Furthermore, as no inverse dose–response association between RT frequency and hypertension risk was observed, engaging in RT for 3–4 days/week for at least 6 months is recommended for women. Considering that RT did not increase the risk of hypertension in men, regular RT is also recommended for men to improve musculoskeletal fitness and health. However, it is important to note the cross-sectional design of the present study; further longitudinal studies are required to validate our findings.

## Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: the Korean Genome and Epidemiology Study (KoGES; 6635-302), Korea National Institute of Health, Korea Disease Control and Prevention Agency.

## Ethics statement

The studies involving humans were approved by the Institutional Review Board of the Korea National Institute of Health, Korea Disease Control and Prevention Agency (Approval No. KDCA-2024-02-12-P-01). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

JHP: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Investigation, Formal analysis, Conceptualization. H-YP: Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization.

## Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This work was supported by the Korea National Institute of Health, Korea Disease Control and Prevention Agency (Grant No. 2024-NI-003-00).

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1401254/full#supplementary-material

## References

1. Peng X, Jin C, Song Q, Wu S, Cai J. Stage 1 hypertension and the 10-year and lifetime risk of cardiovascular disease: a prospective real-world study. *J Am Heart Assoc*. (2023) 12:e028762. doi: 10.1161/JAHA.122.028762

2. Zhou D, Xi B, Zhao M, Wang L, Veeranki SP. Uncontrolled hypertension increases risk of all-cause and cardiovascular disease mortality in US adults: the NHANES III linked mortality study. *Sci Rep*. (2018) 8:9418. doi: 10.1038/s41598-018-27377-2

3. World Health Organization. *Guideline for the pharmacological treatment of hypertension in adults*. Geneva: World Health Organization (2021). 7 p.

4. Seo E, Jung S, Lee H, Kim HC. Sex-specific trends in the prevalence of hypertension and the number of people with hypertension: analysis of the Korea National Health and Nutrition Examination Survey (KNHANES) 1998–2018. *Korean Circ J*. (2022) 52:382–92. doi: 10.4070/kcj.2021.0347

5. Mancia G, Kreutz R, Brunström M, Burnier M, Grassi G, Januszewicz A, et al. 2023 ESH guidelines for the management of arterial hypertension the task force for the management of arterial hypertension of the European Society of Hypertension: endorsed by the International Society of Hypertension (ISH) and the European Renal Association (ERA). *J Hypertens*. (2023) 41:1874–2071. doi: 10.1097/HJH.0000000000003480

6. Unger T, Borghi C, Charchar F, Khan NA, Poulter NR, Prabhakaran D, et al. 2020 International Society of Hypertension global hypertension practice guidelines. *Hypertension*. (2020) 75:1334–57. doi: 10.1161/HYPERTENSIONAHA.120.15026

7. Fu Y, Feng Q, Wei Y, Fan L, Pan Y, Ji J, et al. Meta-analysis of the effect of aerobic training on blood pressure in hypertensive patients. *Comput Math Methods Med*. (2022) 2022:9281661. doi: 10.1155/2022/9281661

8. Saco-Ledo G, Valenzuela PL, Ruiz-Hurtado G, Ruilope LM, Lucia A. Exercise reduces ambulatory blood pressure in patients with hypertension: a systematic review and meta-analysis of randomized controlled trials. *J Am Heart Assoc*. (2020) 9:e018487. doi: 10.1161/JAHA.120.018487

9. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing

exercise. *Med Sci Sports Exerc*. (2011) 43:1334–59. doi: 10.1249/MSS.0b013e318213fefb

10. Abrahin O, Moraes-Ferreira R, Cortinhas-Alves EA, Guerreiro JF. Is resistance training alone an antihypertensive therapy? A meta-analysis. *J Hum Hypertens*. (2021) 35:769–75. doi: 10.1038/s41371-021-00582-9

11. Oliver-Martínez PA, Ramos-Campo DJ, Martínez-Aranda LM, Martínez-Rodríguez A, Rubio-Arias J. Chronic effects and optimal dosage of strength training on SBP and DBP: a systematic review with meta-analysis. *J Hypertens*. (2020) 38:1909–18. doi: 10.1097/HJH.0000000000002459

12. Park JH, Jae SY. Resistance training does not mitigate cardiovascular reactivity to sympathoexcitation in young adults. *Exerc Sci*. (2019) 28:388–95. doi: 10.15857/ksep.2019.28.4.388

13. Cortez-Cooper MY, Anton MM, Devan AE, Neidre DB, Cook JN, Tanaka H. The effects of strength training on central arterial compliance in middle-aged and older adults. *Eur J Cardiovasc Prev Rehabil*. (2008) 15:149–55. doi: 10.1097/HJR.0b013e3282f02fe2

14. Rossow LM, Fahs CA, Thiebaud RS, Loenneke JP, Kim D, Mouser JG, et al. Arterial stiffness and blood flow adaptations following eight weeks of resistance exercise training in young and older women. *Exp Gerontol*. (2014) 53:48–56. doi: 10.1016/j.exger.2014.02.010

15. Mielke GI, Bailey TG, Burton NW, Brown WJ. Participation in sports/recreational activities and incidence of hypertension, diabetes, and obesity in adults. *Scand J Med Sci Sports*. (2020) 30:2390–8. doi: 10.1111/sms.13795

16. Hyde ET, Whitfield GP, Omura JD, Fulton JE, Carlson SA. Trends in meeting the physical activity guidelines: muscle-strengthening alone and combined with aerobic activity, United States, 1998–2018. *J Phys Act Health*. (2021) 18:S37–44. doi: 10.1123/jpah.2021-0077

17. Park JH, Lim NK, Park HY. Association of leisure-time physical activity and resistance training with risk of incident hypertension: the Ansan and Ansung study of the Korean Genome and Epidemiology Study (KoGES). *Front Cardiovasc Med*. (2023) 10:1068852. doi: 10.3389/fcvm.2023.1068852

18. Feng Q, Jiang C, Wang M, Cai R, Wang H, Wu D, et al. Association between relative handgrip strength and hypertension in Chinese adults: an analysis of four successive national surveys with 712,442 individuals (2000–2014). *PLoS One*. (2021) 16:e0258763. doi: 10.1371/journal.pone.0258763

19. Park JH, Lim NK, Park HY. Relative handgrip strength is inversely associated with hypertension in consideration of visceral adipose dysfunction: a nationwide cross-sectional study in Korea. *Front Physiol*. (2022) 13:930922. doi: 10.3389/fphys.2022.930922

20. Kim Y, Han BG. Cohort profile: the Korean Genome and Epidemiology Study (KoGES) consortium. *Int J Epidemiol*. (2017) 46:e20. doi: 10.1093/ije/dyv316

21. Levey AS, Coresh J, Greene T, Stevens LA, Zhang YL, Hendriksen S, et al. Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. *Ann Intern Med*. (2006) 145:247–54. doi: 10.7326/0003-4819-145-4-200608150-00004

22. Kaess BM, Rong J, Larson MG, Hamburg NM, Vita JA, Levy D, et al. Aortic stiffness, blood pressure progression, and incident hypertension. *JAMA*. (2012) 308:875–81. doi: 10.1001/2012.jama.10503

23. Takase H, Dohi Y, Toriyama T, Okado T, Tanaka S, Sonoda H, et al. Brachial-ankle pulse wave velocity predicts increase in blood pressure and onset of hypertension. *Am J Hypertens*. (2011) 24:667–73. doi: 10.1038/ajh.2011.19

24. Morgan B, Mirza AM, Gimblet CJ, Ortlip AT, Ancalmo J, Kalita D, et al. Effect of an 11-week resistance training program on arterial stiffness in young women. *J Strength Cond Res*. (2023) 37:315–21. doi: 10.1519/JSC.0000000000004280

25. Williams AD, Ahuja KD, Almond JB, Robertson IK, Ball MJ. Progressive resistance training might improve vascular function in older women but not in older men. *J Sci Med Sport*. (2013) 16:76–81. doi: 10.1016/j.jsams.2012.05.001

26. Kawano H, Tanimoto M, Yamamoto K, Sanada K, Gando Y, Tabata I, et al. Resistance training in men is associated with increased arterial stiffness and blood pressure but does not adversely affect endothelial function as measured by arterial reactivity to the cold pressor test. *Exp Physiol*. (2008) 93:296–302. doi: 10.1113/expphysiol.2007.039867

27. Collier SR, Frechette V, Sandberg K, Schafer P, Ji H, Smulyan H, et al. Sex differences in resting hemodynamics and arterial stiffness following 4 weeks of resistance versus aerobic exercise training in individuals with pre-hypertension to stage 1 hypertension. *Biol Sex Differ*. (2011) 2:9. doi: 10.1186/2042-6410-2-9

28. Yoshizawa M, Maeda S, Miyaki A, Misono M, Saito Y, Tanabe K, et al. Effect of 12 weeks of moderate-intensity resistance training on arterial stiffness: a randomised controlled trial in women aged 32–59 years. *Br J Sports Med*. (2009) 43:615–8. doi: 10.1136/bjsm.2008.052126

29. Cardoso GA, Silva AS, de Souza AA, Dos Santos MA, da Silva RS, de Lacerda LM, et al. Influence of resistance training on blood pressure in patients with metabolic syndrome and menopause. *J Hum Kinet*. (2014) 43:87–95. doi: 10.2478/hukin-2014-0093

30. Félix-Soriano E, Martínez-Gayo A, Cobo MJ, Pérez-Chávez A, Ibáñez-Santos J, Samper NP, et al. Effects of DHA-rich n-3 fatty acid supplementation and/or resistance training on body composition and cardiometabolic biomarkers in overweight and obese post-menopausal women. *Nutrients*. (2021) 13:2465. doi: 10.3390/nu13072465

31. Figueroa A, Vicil F, Sanchez-Gonzalez MA, Wong A, Ormsbee MJ, Hooshmand S, et al. Effects of diet and/or low-intensity resistance exercise training on arterial stiffness, adiposity, and lean mass in obese postmenopausal women. *Am J Hypertens*. (2013) 26:416–23. doi: 10.1093/ajh/hps050

32. Gelecek N, Ilçin N, Subaşi SS, Acar S, Demir N, Ormen M. The effects of resistance training on cardiovascular disease risk factors in postmenopausal women: a randomized-controlled trial. *Health Care Women Int*. (2012) 33:1072–85. doi: 10.1080/07399332.2011.645960

33. Son WM, Pekas EJ, Park SY. Twelve weeks of resistance band exercise training improves age-associated hormonal decline, blood pressure, and body composition in postmenopausal women with stage 1 hypertension: a randomized clinical trial. *Menopause*. (2020) 27:199–207. doi: 10.1097/GME.0000000000001444

34. Sigal RJ, Alberga AS, Goldfield GS, Prud'homme D, Hadjiyannakis S, Gougeon R, et al. Effects of aerobic training, resistance training, or both on percentage body fat and cardiometabolic risk markers in obese adolescents: the healthy eating aerobic and resistance training in youth randomized clinical trial. *JAMA Pediatr*. (2014) 168:1006–14. doi: 10.1001/jamapediatrics.2014.1392

35. Serra R, Saavedra F, Jotta B, Novaes J, Cardozo D, Alves H, et al. The influence weekly resistance training frequency on strength and body composition. *Int J Sports Sci*. (2018) 8:19–24. doi: 10.5923/j.sports.20180801.04

36. Arazi H, Asadi A, Gentil P, Ramírez-Campillo R, Jahangiri P, Ghorbani A, et al. Effects of different resistance training frequencies on body composition and muscular performance adaptations in men. *PeerJ*. (2021) 9:e10537. doi: 10.7717/peerj.10537

37. Ashton RE, Tew GA, Aning JJ, Gilbert SE, Lewis L, Saxton JM. Effects of short-term, medium-term and long-term resistance exercise training on cardiometabolic health outcomes in adults: systematic review with meta-analysis. *Br J Sports Med*. (2020) 54:341–8. doi: 10.1136/bjsports-2017-098970

38. Córdova C, Lopes-E-Silva F Jr, Pires AS, Souza VC, Brito CJ, Moraes CF, et al. Long-term resistance training is associated with reduced circulating levels of IL-6, IFN-γ and TNF-α in elderly women. *Neuroimmunomodulation*. (2011) 18:165–70. doi: 10.1159/000323396

39. Boeno FP, Ramis TR, Munhoz SV, Farinha JB, Moritz CEJ, Leal-Menezes R, et al. Effect of aerobic and resistance exercise training on inflammation, endothelial function and ambulatory blood pressure in middle-aged hypertensive patients. *J Hypertens*. (2020) 38:2501–9. doi: 10.1097/HJH.0000000000002581

40. Stensvold D, Tjønna AE, Skaug EA, Aspenes S, Stølen T, Wisløff U, et al. Strength training versus aerobic interval training to modify risk factors of metabolic syndrome. *J Appl Physiol*. (2010) 108:804–10. doi: 10.1152/japplphysiol.00996.2009

41. Tomeleri CM, Marcori AJ, Ribeiro AS, Gerage AM, Padilha CS, Schiavoni D, et al. Chronic blood pressure reductions and increments in plasma nitric oxide bioavailability. *Int J Sports Med*. (2017) 38:290–9. doi: 10.1055/s-0042-121896

42. Spence AL, Carter HH, Naylor LH, Green DJ. A prospective randomized longitudinal study involving 6 months of endurance or resistance exercise. Conduit artery adaptation in humans. *J Physiol*. (2013) 591:1265–75. doi: 10.1113/jphysiol.2012.247387

43. Figueroa A, Okamoto T, Jaime SJ, Fahs CA. Impact of high- and low-intensity resistance training on arterial stiffness and blood pressure in adults across the lifespan: a review. *Pflugers Arch*. (2019) 471:467–78. doi: 10.1007/s00424-018-2235-8

frontiers | Frontiers in Nutrition

TYPE Original Research
PUBLISHED 18 June 2024
DOI 10.3389/fnut.2024.1400726

Check for updates

OPEN ACCESS

EDITED BY
Mora Murri,
University of Malaga, Spain

REVIEWED BY
Siti Wulan,
University of Brawijaya, Indonesia
Amani Alrasheedi,
King Abdulaziz University, Saudi Arabia
Mingjiang Liu,
University of South China, China

*CORRESPONDENCE
Deguang Wang
✉ wangdeguang@ahmu.edu.cn
Bao Zhang
✉ 5962555382@qq.com

RECEIVED 28 March 2024
ACCEPTED 03 June 2024
PUBLISHED 18 June 2024

CITATION
Zu S, Yang ML, Li XD, Wu HH, Li XL, Fan YS, Wang DG and Zhang B (2024) Flavonoids intake and weight-adjusted waist index: insights from a cross-sectional study of NHANES.
*Front. Nutr.* 11:1400726.
doi: 10.3389/fnut.2024.1400726



# Flavonoids intake and weight-adjusted waist index: insights from a cross-sectional study of NHANES

Shuang Zu[1], Meiling Yang[2], Xiude Li[1], Hanhan Wu[1], Xunliang Li[3], Yunshan Fan[1], Deguang Wang[3]* and Bao Zhang[1]*

[1]Department of Clinical Nutrition, The First Affiliated Hospital of Anhui Medical University, Hefei, Anhui, China, [2]Department of Gastroenterology, The First Affiliated Hospital of Anhui Medical University, Hefei, Anhui, China, [3]Department of Nephrology, The Second Affiliated Hospital of Anhui Medical University, Hefei, Anhui, China

This study conducted data on 15,446 adults to explore the impact of flavonoids on weight-adjusted waist index (WWI). This was a nationwide cross-sectional study among US adults aged 20 years or older. Dietary intake of flavonoids was assessed through 24-h recall questionnaire. WWI was calculated by dividing waist circumference (WC) by the square root of weight. We utilized weighted generalized linear regression to evaluate the association between flavonoids intake and WWI, and restricted cubic splines (RCS) to explore potential non-linear relationships. Our findings indicated that individuals with lower WWI experienced a notable increase in their consumption of total flavonoids, flavanones, flavones, flavan-3-ols, and anthocyanidins intake ($\beta$ (95% CI); −0.05(−0.09, −0.01); −0.07(−0.13, 0.00); −0.07(−0.11, −0.02); −0.06(−0.11, 0.00); −0.13(−0.18, −0.08), respectively), with the exception of flavonols and isoflavones. Additionally, consumption of total flavonoids, flavonols, flavanones, isoflavones, and flavan-3-ols had a non-linear relationship with WWI (all *P* for non-linearity $< 0.05$). Furthermore, the effect of total flavonoids on WWI varied in race (*P* for interaction = 0.011), gender (*P* for interaction = 0.038), and poverty status (*P* for interaction = 0.002). These findings suggested that increase the intake of flavonoids might prevent abdominal obesity, but further prospective studies are requested before dietary recommendation.

KEYWORDS

**flavonoids intake, weight-adjusted waist index, NHANES, abdominal obesity, flavonoids dietary recommendation**

## 1 Introduction

Obesity arises from the disproportionate accumulation of body fat, a consequence of energy intake surpassing energy expenditure. The prevalence of obesity has reached epidemic levels globally, impacting a growing population of people (1, 2). Abdominal obesity, a form of obesity characterized by an accumulation of fat specifically in the abdominal region, is associated with an increased risk of metabolic imbalances, diabetes, high blood pressure, and cardiovascular diseases, beyond overall amount of body fat (3). These elements are poised to create a public health concern, necessitating intervention strategies once the contributing factors have been assessed. Research indicated that people with a high volume of abdominal fat and a large waist circumference (WC) not only have more intra-abdominal fat but also larger subcutaneous fat cells, accompanied by adipose tissue that is dysfunctional and inflamed (4). Numerous indicators have been utilized to assess obesity, with a particular focus on the detrimental intra-abdominal fat mass. While Body Mass Index (BMI) remains the most prevalent anthropometric measurement for obesity, it has limitations as it does not differentiate between lean and fat mass. WC has been introduced as an alternative for indirectly assessing the increase in visceral fat, serving as a marker for abdominal obesity and aiding in the diagnosis of metabolic syndrome (5). However, similar to BMI, WC on its own is incapable of differentiating between visceral and subcutaneous fat masses. In fact, the accuracy of WC in estimating abdominal fat mass is enhanced when BMI is included as an explanatory variable (6). Weight-adjusted waist index (WWI), which Park et al. (7), is an innovative measure of abdominal obesity that normalizes WC by body weight, leveraging the advantages of WC while reducing its correlation with BMI. The WWI serves not only to differentiate between adipose and muscular tissues but also to address issues of central obesity that are not directly related to overall body weight (8). As reported by Kim et al. (9), there was a positive correlation between both BMI and WC with measurements of fat and muscle. In contrast, the WWI showed a positive relationship with overall and abdominal fat measurements, while it exhibited a negative correlation with the mass of appendicular skeletal muscle (9). In a 40-month longitudinal study involving 1,946 participants, computed tomography (CT) data revealed a rise in measurements of abdominal fat along with a corresponding decline in muscle mass, concurrent with an escalation in the WWI (10). In addition, previous studies had identified a notable association between elevated WWI values and various health issues, including non-alcoholic fatty liver disease (11), diabetic kidney disease (12), bone mineral density (13), and depression (14).

Flavonoid, derived from the Latin term 'flavus' which signifies the color yellow, is omnipresent in the plant kingdom and represent the most prevalent polyphenolic substances in the human diet (15). A vast array of naturally occurring flavonoids, numbering over 5,000, have been identified in a variety of plant species. These compounds feature a 15-carbon (C6–C3–C6) backbone structure, with two benzene rings linked by a straight 3-carbon chain. The classification of flavonoid into multiple subcategories is based on the substitution patterns of the C ring, with further differentiation within each class achieved through the A and B substitutions (16). The main subgroups of flavonoid include flavonols, flavanones, isoflavones, flavones, flavans-3-ols, and anthocyanins. Over the past two decades, flavonoid compounds have been extensively studied for their potential positive effects on human health. Dietary flavonoid intake has been shown to be significantly and negatively associated with hepatic steatosis and fibrosis (17), metabolic syndrome (18), and obesity (19). The anti-obesity effects of flavonoid is believed to operate through a variety of mechanisms, such as inhibiting enzymes, modulating neuro-hormonal responses related to food consumption and satiety, and promoting the generation of mitochondria (20). So, can flavonoids compounds naturally prevent or reduce abdominal obesity? Currently, there is a lack of research regarding the potential of flavonoids consumption in reducing the risk of developing abdominal obesity. Hence, the importance of this study lies in investigating the effects of dietary flavonoids intake on WWI using data from the National Health and Nutrition Examination Survey (NHANES) database, and uncovering the potential of flavonoids compounds in reducing the risk of abdominal obesity.

# 2 Methods

## 2.1 Study population

NHANES, overseen by the National Center for Health Statistics (NCHS), is a comprehensive, nationwide survey aimed at assessing the health of the American population. The NCHS Ethics Review Board has endorsed the stratified multistage sampling approach employed in the survey. NHANES data collection involved an initial in-home interview, followed by a health examination at mobile examination center (MEC), and concludes with a follow-up telephone interview. For this study, we utilized data from the survey periods of 2007–2010 and 2017–2018. All participants were required to provide written consent after receiving comprehensive information about the study. Our study included 17,032 participants above the age of 20 and collected information on their flavonoids intake and WWI values. After careful consideration, participants with missing 24-h recall data ($n = 1,109$) were removed from the study. Participants who had missing WC and weight data ($n = 175$) were omitted, too. Furthermore, a total of 302 participants were excluded as they had either extremely low or high energy intakes: < 500 kcal or > 5,000 kcal/day for females and < 500 kcal or > 8,000 kcal/day for males. Finally, 15,446 participants were selected for inclusion (Figure 1).

## 2.2 Dietary assessment of flavonoids

The United States Department of Agriculture (USDA) Food Codes' Flavonoid Database for the years 2007–2010 and 2017–2018 offers detailed information on the flavonoid content of a wide array of foods and beverages, as listed in the USDA and Food and Nutrient Database for Dietary Studies (FNDDS) version 5.0. The database contains detailed information on 29 specific flavonoids, which are divided into six categories: Anthocyanidins, Flavan-3-ols, Flavanones, Flavones, Flavonols, and Isoflavones, aligning with the dietary data provided by NHANES for the years 2007–2010 and 2017–2018. To determine the average daily flavonoids intake during these time-frames, a two-day dietary recall approach was utilized, involving in-person interviews with participants to document their food consumption over 2 days, supplemented by a subsequent telephone interview approximately 1 week later. In this study, flavonoids intake was determined solely from dietary sources, including water, without consideration for the consumption of flavonoid supplements or pharmaceuticals.

## 2.3 WWI

WWI (cm/$\sqrt{\text{kg}}$) is calculated by dividing WC (cm) by the square root of the individual's weight (kg). These body measurements were conducted at MEC, with a health technologist responsible for recording and documenting the data. The current anthropometric standards were used to measure weight and WC (21). The participants were asked to wear specific attire for the assessment and then position

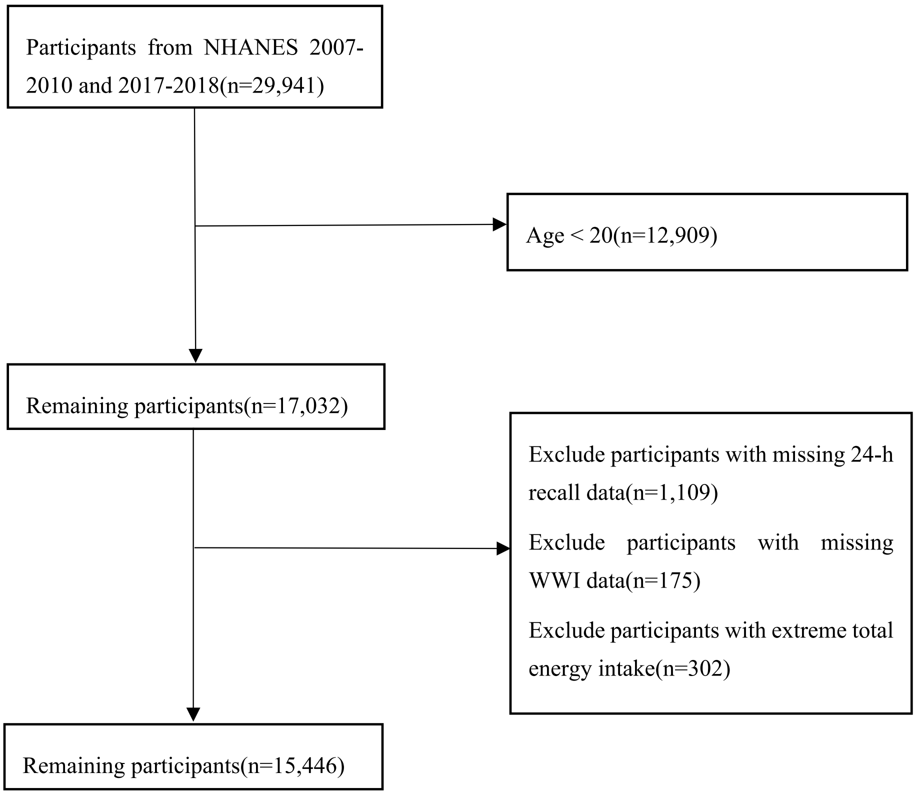



FIGURE 1
Sample inclusion flow.

themselves in the center of a digital scale, barefooted, with arms resting by their sides and their gaze directed straight ahead. WC was determined using a measuring tape, with MEC health technicians marking a horizontal line above the superior lateral edge of the right ilium. A right midaxillary line was then drawn, and the tape was positioned horizontally at the intersection of these two lines. Technicians, standing on the participant's right side, wrapped the tape around the torso in a horizontal plane.

## 2.4 Covariates

The survey's covariates encompassed demographic factors such as age, gender, ethnicity, educational attainment, and the family poverty income ratio (PIR), alongside lifestyle factors including alcohol and tobacco consumption, physical activity levels, and dietary intake of calories, carbohydrates, proteins, fats, and fiber. We categorized education levels as follows: below high school (below 11th grade), high school (graduated from high school or obtained a GED equivalent), and beyond high school (completed college or achieved a higher level of education). Poverty status was categorized into two groups based on income level: PIR <130% referred to low income, while PIR ≥130% designated high income (22). Smoking status was categorized into three groups: never smoked (consuming fewer than 100 cigarettes throughout their life), former smokers (having smoked over 100 cigarettes but are currently abstaining), and current smokers (who have smoked over 100 cigarettes and continue to smoke either occasionally or regularly). Alcohol consumption status was categorized into three groups: lifetime abstainer (who have consumed alcohol less than 12 times in their lifetime), former drinker (who have consumed alcohol more than 12 times in their lifetime but have not consumed it in the past year) and current drinker (who currently consume alcohol more than three times a week). Physical activity was categorized into two levels: low, defined as less than 599 metabolic equivalents (METs) per week, and high, defined as 599 METs or more per week (23).

## 2.5 Statistical analysis

Taking into account the complex sampling strategy of NHANES, we applied appropriate weights to the data in accordance with NHANES guidelines, which involved using a third of the weights from both the 2007–2010 and 2017–2018 periods. In this study, 15,446 individuals were adjusted for accuracy to represent a population of 218,690,615. Continuous data were presented as the mean with the standard deviation, whereas categorical data were represented as unweighted numbers (weighted percentages). The participant characteristics were analyzed according to tertile of total flavonoids intake, using weighted student's t-tests for continuous variables and weighted chi-squared tests for categorical variables. The levels of flavonoids consumption were divided into three groups (T1, T2 and T3) and employed weighted generalized linear regression models with the low-intake group (T1) as the reference group. The crude model did not take into account any of the variables, whereas model 1 adjusted for potential confounding factors such as age, gender, ethnicity, education levels, and PIR. After considering physical activity levels, total carbohydrate intake, total protein intake, total fat intake, and total fiber intake, we made additional adjustments in model 2. We selected the above covariates based on professional knowledge, previously identified risk factors for WWI (7, 9, 10), and the observed incomparability of participant characteristics (Table 1). We decided to exclude the other covariates for the reasons that preliminary analyses indicated potential collinearity between them. Furthermore, to maintain model parsimony and avoid overfitting, we aimed to include only above covariates that had the most substantial and theoretically justified impact on the relationship between flavonoid intake and WWI. Restricted cubic splines (RCS) were utilized in Model 2 to explore the possible non-linear relationships between flavonoids intake and WWI. Furthermore, in order to examine the influence of total flavonoids intake on WWI, subgroup analyses and interaction exploration were performed to assess the effect of covariates that exhibited notable variations across different levels of total flavonoids intake. All subgroup variable analyses performed using a fully adjusted Model 2, and generalized linear regression models were additionally applied to assess the interactive effects between these subgroups and WWI. The missing covariate values were imputed by the "mice" package in R. The nationally representative estimates in NHANES were calculated by utilizing "SDMVPSU"and "SDMVSTRA." The data processing was done in R version 4.3.1. A statistically significant difference was determined by considering a two-sided $p$-value <0.05.

# 3 Results

## 3.1 Characteristics of participants

The study involved 15,446 participants with an average age of 47.35 ± 16.96 years, of whom 7,533 (47.83%) were male and 7,913 (52.17%) were female. The average WWI across all participants was 10.91 ± 0.90 cm/$\sqrt{}$kg. The mean total flavonoids intake for all participants was 227.90 ± 410.82 mg/100 g foods/day, with the values for the different tertiles as follows: T1: 0–36.08 mg; T2: 36.08–160.52 mg; T3: 160.52–8,018.67 mg. Participants in the highest tertile of total flavonoids intake were older, Non-Hispanic White, had a higher level of education, higher PIR, smoked less, and consumed alcohol more frequently. Additionally, higher intakes of total flavonoids were more likely to with higher physical activity, total caloric intake, carbohydrate, protein, fat consumption, as well as fiber intake (Table 1).

## 3.2 Associations between dietary flavonoids intake and WWI

Table 2 displayed the outcomes of weighted linear regression analyses that evaluate the relationships between total flavonoids and flavonoid subclass intake with WWI. In model 2, A statistically significant negative correlations were observed between total flavonoids, flavanones, flavones, flavan-3-ols, and anthocyanidins ($p = 0.025$, $p = 0.041$, $p = 0.006$, $p = 0.0.035$, $p < 0.001$, respectively) with WWI after adjusting demographic variables and lifestyle variables except flavonols and isoflavones. Notably, when using the first tertile as the reference, the third tertile of total flavonoids ($\beta$: -0.05, 95%CI: −0.09, −0.01), flavanones ($\beta$: -0.07, 95%CI: −0.13, 0.00), flavones ($\beta$: -0.07, 95%CI: −0.11, −0.02), anthocyanidins ($\beta$: -0.13, 95%CI: −0.18, −0.08), and the second tertile of flavan-3-ols ($\beta$: -0.06, 95%CI: −0.11, 0.00) had demonstrated the most significant potential for reducing WWI. In all three models, there was a significant negative correlation seen between T3 of total flavonoids (all $p < 0.05$), T2 and T3 of flavones ($p < 0.01$), T2 of flavan-3-ols ($p < 0.05$), T3 of anthocyanidins ($p < 0.01$) and WWI. Forest plot was used to show the relationship between the third tertile of flavonoids and linear trend test was conducted by treating each flavonoid as a continuous variable. In model 2, total flavonoids, flavanones, flavones, and anthocyanidins indicted a linear trend with WWI ($P$-trend = 0.033, $P$-trend = 0.014, $P$-trend = 0.047, $P$-trend = 0.002, respectively) (Figure 2).

## 3.3 The non-linear relationships between flavonoids intake and WWI

We utilized an RCS to examine the non-linear relationships between the intake of flavonoids and WWI, with the median consumption of all flavonoids serving as the baseline for comparison. In Model 2, it was determined that total flavonoids ($P$ for non-linearity < 0.001), flavonols ($P$ for non-linearity = 0.031), flavanones ($P$ for non-linearity < 0.001), isoflavones ($P$ for non-linearity = 0.002), and flavan-3-ols ($P$ for non-linearity = 0.001) exhibited a statistically significant non-linear association with WWI. Association between total flavonoids, flavonols, flavanones, flavan-3-ols and WWI was J-shaped curve. The WWI showed a consistent decline with the increment in total flavonoids intake, up to a point where the intake reached 108.86 mg/100 g foods/day and the consumption rage of total flavonoids in 65.43–217.45 mg/100 g foods/day have the ability to decrease WWI. Beyond this rage, WWI started to rise with further increases in total flavonoids consumption. Within the dietary intake range of <8.39 mg/100 g foods/day and 12.12–57.81 mg/100 g foods/day, flavonols exhibited a capacity to decrease WWI and the optimal reduction occurring at a level of 30.77 mg/100 g foods/day. At 2.80 mg/100 g foods/day (flavanones) and 41.85 mg/100 g foods/day (flavan-3-ols) points, WWI values were the lowest, respectively. Additionally, beyond the rage of flavanones (1.40–40.63 mg/100 g foods/day) and flavan-3-ols (20.92–104.64 mg/100 g foods/day), WWI started to increase. On the contrary, when isoflavones intake increased, WWI values consistently dropped, and the downward trend then slightly increased (Figure 3).

## 3.4 Subgroup and interaction analysis

Figure 4 presented the subgroup and interaction analysis between WWI and total flavonoids intake, revealing significant interactions with respect to races, gender, and poverty status ($P$ for interaction = 0.011, P for interaction = 0.038, P for interaction = 0.002, respectively). When compared to Non-Hispanic White, the intake of total dietary flavonoids appeared to have a more pronounced protective effect against obesity in other populations ($p < 0.001$). Notably, a higher intake of total flavonoids was linked to a lower WWI among males ($p = 0.001$) and individuals in poverty ($p < 0.001$).

# 4 Discussion

Based on a representative sample of 15,446 US adults, the present analyses showed that the average consumption of total flavonoids was

TABLE 1 Basic characteristics of total participants stratified by total flavonoids tertile.

| Characteristics | Total ($n$ = 15,446) | Category of Flavonoid Intake, mg/100 g foods/day | | | $p$-value |
|---|---|---|---|---|---|
| | | T1 ($n$ = 5,380) | T2 ($n$ = 5,384) | T3 ($n$ = 4,682) | |
| Age (year) | 47.35 (16.96) | 45.02 (17.05) | 48.14 (17.22) | 48.88 (16,34) | <0.001 |
| Gender, $n$ (%) | | | | | 0.3 |
| Male | 7,533 (47.83%) | 2,623 (48.59%) | 2,654 (48.31%) | 2,257 (46.61%) | |
| Female | 7,913 (52.17%) | 2,757 (51.41%) | 2,730 (51.69%) | 2,425 (53.39%) | |
| Ethnicity, $n$ (%) | | | | | <0.001 |
| Mexican-American | 2,551 (8.61%) | 979 (10.18%) | 1,035 (10.30%) | 537 (5.34%) | |
| Non-Hispanic White | 6,847 (67.03%) | 2,309 (65.75%) | 2,203 (64.14%) | 2,334 (71.19%) | |
| Non-Hispanic Black | 3,149 (11.22%) | 1,222 (12.99%) | 1,050 (11.30%) | 877 (9.38%) | |
| Others | 2,901 (13.14%) | 870 (11.08%) | 1,096 (14.26%) | 934 (14.09%) | |
| Poverty status, $n$ (%) | | | | | <0.001 |
| No | 9,658 (72.42%) | 3,092 (68.28%) | 3,383 (73.37%) | 3,181 (75.61%) | |
| Yes | 5,790 (27.58%) | 2,288 (31.72%) | 2,001 (26.63%) | 1,501 (24.39%) | |
| Education levels, $n$ (%) | | | | | <0.001 |
| More than high school | 7,726 (58.49%) | 2,184 (48.93%) | 2,831 (62.54%) | 2,709 (63.98%) | |
| High school | 3,684 (25.43%) | 1,458 (30.70%) | 1,184 (21.80%) | 1,042 (23.81%) | |
| Less than high school | 4,038 (16.08%) | 1,738 (20.37%) | 1,369 (15.66%) | 931 (12.21%) | |
| Smoking status, n (%) | | | | | <0.001 |
| Never | 8,436 (55.21%) | 2,597 (48.34%) | 3,128 (59.04%) | 2,709 (58.24%) | |
| Former | 3,829 (24.65%) | 1,311 (23.72%) | 1,360 (25.35%) | 1,158 (24.89%) | |
| Current | 3,180 (20.14%) | 1,472 (27.94%) | 895 (15.61%) | 813 (16.87%) | |
| Drinking status, $n$ (%) | | | | | 0.006 |
| Never | 3,241 (16.23%) | 1,087 (15.29%) | 1,098 (16.29%) | 1,055 (17.12%) | |
| Former | 3,062 (16.84%) | 1,190 (19.20%) | 1,009 (15.30%) | 862 (16.01%) | |
| Current | 9,146 (66.93%) | 3,103 (65.51%) | 3,277 (68.41%) | 2,765 (66.87%) | |
| Physical activity, $n$ (%) | | | | | 0.001 |
| High | 9,137 (65.02%) | 2,963(62.51%) | 3,275 (65.66%) | 2,898 (66.88%) | |
| Low | 6,311 (34.98%) | 2,417 (37.49%) | 2,109 (34.34%) | 1,786 (33.12%) | |
| BMI, $n$ (%) | | | | | <0.001 |
| BMI < 25 | 4,234 (29.18%) | 1,368 (26.33%) | 1,497 (29.48%) | 1,369 (31.75%) | |

*(Continued)*



10.3389/fnut.2024.1400726

TABLE 1 (Continued)

| Characteristics | Total ($n$ = 15,446) | Category of Flavonoid Intake, mg/100 g foods/day | | | $p$-value |
|---|---|---|---|---|---|
| | | T1 ($n$ = 5,380) | T2 ($n$ = 5,384) | T3 ($n$ = 4,682) | |
| BMI ≥ 25 | 1,1214 (70.82%) | 4,012 (73.67%) | 3,887 (70.52%) | 3,313 (68.25%) | |
| Weight (kg) | 82.86 (21.83) | 84.28 (22.44) | 82.46 (21.62) | 81.83 (21.34) | 0.003 |
| WC (cm) | 99.13 (16.67) | 100.31 (16.93) | 98.71 (16.58) | 98.37 (16.44) | <0.001 |
| WWI (cm/$\sqrt{kg}$) | 10.91 (0.90) | 10.95 (0.90) | 10.90 (0.89) | 10.89 (0.90) | 0.034 |
| Total calories (kcal/d) | 2,095.41 (837.56) | 1,930.17 (785.30) | 2,183.91 (870.05) | 2,172.47(830.56) | <0.001 |
| Total carbohydrate (g) | 249.87 (108.69) | 225.19 (102.75) | 259.14 (106.27) | 265.31 (112.51) | <0.001 |
| Total protein (g) | 81.83 (35.18) | 75.82 (33.20) | 85.25 (36.73) | 84.43 (34.75) | <0.001 |
| Total fat (g) | 81.26 (39.58) | 77.42 (38.63) | 83.14 (41.43) | 83.24 (38.32) | <0.001 |
| Total fiber (g) | 16.76 (9.03) | 12.96 (6.46) | 18.61 (8.76) | 18.71 (10.21) | <0.001 |
| Total flavonoids (mg) | 227.90 (410.82) | 17.50 (9.47) | 78.79 (33.90) | 587.41 (556.19) | <0.001 |
| Flavonols (mg) | 18.96 (18.73) | 7.83 (5.30) | 15.38 (10.11) | 33.67 (23.86) | <0.001 |
| Flavanones (mg) | 12.60 (26.63) | 1.35 (3.80) | 18.94 (24.76) | 17.53 (36.19) | <0.001 |
| Isoflavones (mg) | 2.14 (11.40) | 0.54 (2.08) | 2.65 (10.20) | 3.24 (16.67) | <0.001 |
| Flavones (mg) | 0.95 (2.10) | 0.49 (0.74) | 1.00 (1.44) | 1.35 (3.19) | <0.001 |
| Flavan-3-ols (mg) | 178.95 (391.91) | 5.37 (5.21) | 25.32 (27.68) | 506.17 (547.01) | <0.001 |
| Anthocyanidins (mg) | 14.30 (37.50) | 1.92 (3.74) | 15.51 (20.84) | 25.46 (59.10) | <0.001 |

T, Tertile; BMI, body mass index; WC, weight circumference; WWI, Weight-adjusted waist index; continuous data were displayed as weighted means (standard deviation) and categorical variables were exhibited as unweighted numbers (weighted percentages).

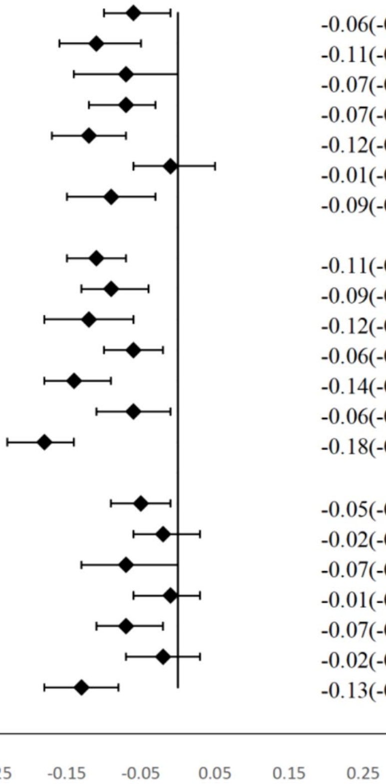
TABLE 2 Associations between flavonoids intake and WWI.

| | Crude Model β (95% CI) | *p*-value | Model 1 β (95% CI) | *p*-value | Model 2 β (95% CI) | *p*-value |
|---|---|---|---|---|---|---|
| Total flavonoids(mg) | | | | | | |
| T1(0–36.08 mg) | Reference | – | Reference | – | Reference | – |
| T2 (> 36.08, ≤ 160.52) | 0.05 (−0.10, 0.00) | 0.064 | −0.10 (−0.14, −0.06) | <0.001 | −0.04 (−0.08, 0.00) | 0.040 |
| T3 (> 160.52, ≤ 8,018.67) | −0.06 (−0.10, −0.01) | 0.020 | −0.11 (−0.15, −0.07) | <0.001 | −0.05 (−0.09, −0.01) | 0.025 |
| Flavonols (mg) | | | | | | |
| T1 (0–9.31) | Reference | – | Reference | – | Reference | – |
| T2 (> 9.31, ≤ 20.01) | −0.03 (−0.08, 0.02) | 0.300 | −0.03 (−0.07, 0.02) | 0.200 | 0.01 (−0.03, 0.06) | 0.500 |
| T3 (> 20.01, ≤ 332.04) | −0.11 (−0.16, −0.05) | <0.001 | −0.09 (−0.13, −0.04) | <0.001 | −0.02 (−0.06, 0.03) | 0.400 |
| Flavanones (mg) | | | | | | |
| T1 (0–0.14) | Reference | – | Reference | – | Reference | – |
| T2 (> 0.14, ≤ 4.17) | −0.07 (−0.14, 0.00) | 0.053 | −0.09 (−0.15, −0.02) | 0.009 | −0.06 (−0.12, 0.00) | 0.054 |
| T3 (> 4.17, ≤ 590.62) | −0.07 (−0.14, 0.00) | 0.067 | −0.12 (−0.18, −0.06) | <0.001 | −0.07 (−0.13, 0.00) | 0.041 |
| Isoflavones (mg) | | | | | | |
| T1 (= 0) | Reference | – | Reference | – | Reference | – |
| T2 (> 0, ≤ 0.01) | 0.01 (−0.06, 0.07) | 0.031 | −0.03 (−0.08, 0.02) | 0.200 | −0.02 (−0.07, 0.03) | 0.700 |
| T3 (> 0.01, ≤ 390.60) | −0.07 (−0.12, −0.03) | 0.008 | −0.06 (−0.10, −0.02) | 0.006 | −0.01 (−0.06, 0.03) | 0.900 |
| Flavones (mg) | | | | | | |
| T1 (0–0.28) | Reference | - | Reference | - | Reference | - |
| T2 (> 0.28, ≤ 0.90) | −0.09 (−0.13, −0.04) | <0.001 | −0.09 (−0.13, −0.06) | <0.001 | −0.06 (−0.10, −0.03) | 0.002 |
| T3 (> 0.90, ≤ 87.25) | −0.12 (−0.17, −0.07) | <0.001 | −0.14 (−0.18, −0.09) | <0.001 | −0.07 (−0.11, −0.02) | 0.006 |
| Flavan-3-ols (mg) | | | | | | |
| T1 (0–8.19) | Reference | – | Reference | – | Reference | – |
| T2 (> 8.19, ≤ 66.11) | −0.08 (−0.14, −0.01) | 0.018 | −0.11 (−0.16, −0.05) | <0.001 | −0.06 (−0.11, 0.00) | 0.035 |
| T3(> 66.11, ≤ 7,727.37) | −0.01 (−0.06, 0.05) | 0.700 | −0.06 (−0.11, −0.01) | 0.015 | −0.02 (−0.07, 0.03) | 0.400 |
| Anthocyanidins (mg) | | | | | | |
| T1 (0–0.405) | Reference | – | Reference | – | Reference | – |
| T2 (> 0.405, ≤ 6.92) | −0.01 (−0.06, 0.05) | 0.700 | −0.08 (−0.13, −0.04) | <0.001 | −0.06 (−0.11, −0.02) | 0.011 |
| T3 (> 6.92, ≤ 1,497.9) | −0.09 (−0.15, −0.03) | 0.005 | −0.18 (−0.23, −0.14) | <0.001 | −0.13 (−0.18, −0.08) | <0.001 |

T, Tertile; WWI, Weight-adjusted waist index; PIR, family income to poverty. Weighted generalized linear regression models for the association between flavonoids intake and WWI. Model 1: no covariates were adjusted. Model 2: adjusted for age, gender, ethnicity, education levels and PIR. Model 3: adjusted for age, gender, ethnicity, education levels, PIR, physical activity levels, total carbohydrate intake, total protein intake, total fat intake and total fiber intake.

227.90 mg/100 g foods/day mostly from flavan-3-ols (178.95 mg/100 g foods/day) and flavonols (18.96 mg/100 g foods/day). Our findings revealed that WWI decreased with increasing levels of dietary intake of total flavonoids, flavanones, flavones, flavan-3-ols, and anthocyanidins after adjusting demographic variables and lifestyle variables. Additionally, the RCS curves demonstrated that the intake of total flavonoids, flavonols, flavanones, and flavan-3-ols within a certain range can exert the greatest effect in reducing WWI levels. Subgroup and interaction analysis further revealed that other ethnic groups (Mexican American and Others), male, and participants living in poverty had a stronger negative correlation between the total amount of flavonoids and WWI.

Flavonoids, a class of polyphenolic compounds unique to the plant kingdom, have recently sparked significant interest due to their potential health benefits for humans. Notable sources of these dietary components encompass a variety of plant-based foods, such as tea, berries, citrus fruits, and soy products (24). In the present study, tea emerged as the predominant source for the total flavonoids, flavonols, and flavan-3-ols categories. Meanwhile, a diverse array of foods significantly contributed to the intake of other flavonoid classes, with orange juice being a key source of flavanones, protein powders for isoflavones, sweet peppers for flavones and blueberries for anthocyanins (25). Kim et al. (26) examined the relationship between the regular consumption of various flavonoids categories and obesity in 23,118 adults in Korea found that a higher total intake of flavonoid was associated with a lower prevalence of obesity in women (OR = 0.82; 95%CI: 0.71–0.94) and the consumption of flavonols (OR = 0.88; 95%CI:0.78–0.99), isoflavones (OR = 0.85; 95%CI:0.75–0.96) and proanthocyanidins (OR = 0.81; 95%CI:0.71–0.92) was found to be inversely associated with the risk of abdominal obesity. However, the intake of flavonols (OR = 1.16; 95%CI:1.02–1.33), flavanones (OR = 1.18; 95%CI:1.04–1.35), and anthocyanidins




| Model Name | β (95%CI) | P-value | P-trend |
|---|---|---|---|
| **Crude Model** | | | |
| Total flavonoids | -0.06(-0.10,-0.01) | 0.02 | 0.039 |
| Flavonols | -0.11(-0.16, -0.05) | <0.001 | 0.076 |
| Flavanones | -0.07(-0.14, 0.00) | 0.067 | 0.047 |
| Isoflavones | -0.07(-0.12, -0.03) | 0.008 | 0.058 |
| Flavones | -0.12(-0.17, -0.07) | <0.001 | 0.085 |
| Flavan-3-ols | -0.01(-0.06, 0.05) | 0.7 | 0.006 |
| Anthocyanidins | -0.09(-0.15, -0.03) | 0.005 | 0.062 |
| **Model 1** | | | |
| Total flavonoids | -0.11(-0.15, -0.07) | <0.001 | 0.074 |
| Flavonols | -0.09(-0.13, -0.04) | <0.001 | 0.13 |
| Flavanones | -0.12(-0.18, -0.06) | <0.001 | 0.042 |
| Isoflavones | -0.06(-0.10, -0.02) | 0.006 | 0.084 |
| Flavones | -0.14(-0.18, -0.09) | <0.001 | 0.097 |
| Flavan-3-ols | -0.06(-0.11, -0.01) | 0.015 | 0.062 |
| Anthocyanidins | -0.18(-0.23, -0.14) | <0.001 | 0.023 |
| **Model 2** | | | |
| Total flavonoids | -0.05(-0.09, -0.01) | 0.025 | 0.033 |
| Flavonols | -0.02(-0.06, 0.03) | 0.4 | 0.092 |
| Flavanones | -0.07(-0.13, 0.00) | 0.041 | 0.014 |
| Isoflavones | -0.01(-0.06, 0.03) | 0.9 | 0.048 |
| Flavones | -0.07(-0.11, -0.02) | 0.006 | 0.047 |
| Flavan-3-ols | -0.02(-0.07, 0.03) | 0.4 | 0.013 |
| Anthocyanidins | -0.13(-0.18, -0.08) | <0.001 | 0.002 |

FIGURE 2
Forest plots were used to show the relationship between the third tertile of flavonoids and WWI in three models and linear trend test was conducted by treating each flavonoid as a continuous variable. T Tertile; WWI Weight-adjusted waist index; PIR family income to poverty. Model 1: no covariates were adjusted. Model 2: adjusted for age, gender, ethnicity, education levels and PIR. Model 3: adjusted for age, gender, ethnicity, education levels, PIR, physical activity levels, total carbohydrate intake, total protein intake, total fat intake and total fiber intake.

(OR = 1.27; 95%CI:1.11–1.46) was positively correlated with obesity as determined by BMI in males (26). In our research, we found that flavanones (β:-0.07; 95%CI: −0.13, 0.00) and flavones (β:-0.07; 95%CI:-0.11, −0.02) were more effective in reducing WWI and male participants had a stronger negative correlation between the total amount of flavonoids and WWI. This disparity could be attributed to the fact that the authors of the referenced study utilized the Korean health and nutrition survey, which may have a predisposition towards abdominal obesity and distinct dietary pattern (kimchi was the main source of flavonoid intake) (27, 28). What is more, abdominal obesity was defined by WC in the research of Kim et al. (28), while in the presented study, the WWI was to describe abdominal obesity. Quercetin is the most commonly found individual flavonols in daily dietary intake. The research conducted by Nishimura et al. (29) indicated that quercetin intake was inversely correlated with fat mass, BMI and WC in central obese participants. However, daily quercetin supplement of 60 mg did not alter the overall abdominal fat content in a healthy population (29). Additional research has indicated that the administration of high doses of quercetin (500 or 1,000 mg) did not influence body mass or composition among healthy individual (30). These findings were different from the outcomes reported in our study that the dietary flavonols within a certain rage (12.12–57.81 mg/100 g foods/day) had the ability to attenuated WWI. This could imply that the effects of quercetin on certain parameters might be predominantly observed in individuals with higher body mass or when combined with other flavonols, as these also showed potential effects on obesity-related measures.

In our subgroup analysis, we identified that certain demographic groups may experience greater benefits from the intake of total flavonoids. Given the multi-ethnic composition of the United States, our study revealed that total flavonoids consumption has a particularly significant impact on populations other than Non-Hispanic Whites, notably among Mexican-Americans ($p = 0.007$) and individuals of Others ($p < 0.001$) ethnic backgrounds. This could be attributed to variations in lifestyle, dietary practices, and genetic predispositions across different racial and ethnic groups (31). It is possible that Non-Hispanic Whites have a reduced sensitivity to the effects of flavonoids, although additional research is necessary to confirm this hypothesis. With an increase in total flavonoids intake, we observed a trend of decreasing WWI among male participants. The potential mechanisms behind these associations might be related to sex differences in body composition influenced by dietary consumption. Body fat distribution varies between genders, with men tending to accumulate a greater amount of fat in the abdominal region compared to women. This makes men more prone to developing abdominal

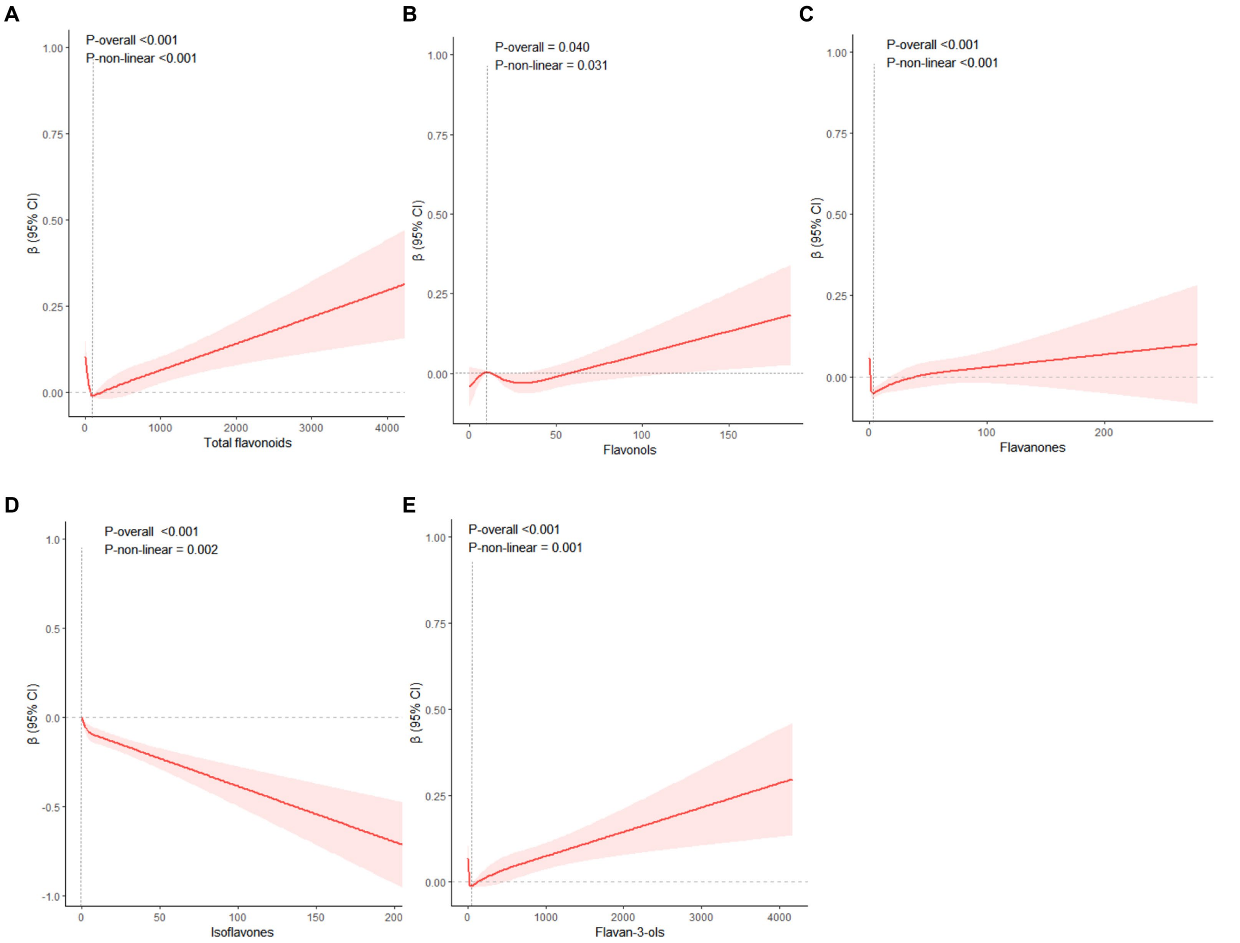



FIGURE 3
The restricted cubic splines were used to display the association between total flavonoids **(A)**, flavonols **(B)**, flavanones **(C)**, isoflavones **(D)**, flavan-3-ols (E) with WWI. Adjusted for age, gender, ethnicity, education levels, PIR, physical activity levels, total carbohydrate intake, total protein intake, total fat intake and total fiber intake. WWI Weight-adjusted Waist index; PIR family poverty income ratio.

obesity (32). Given the consistent rise in the incidence of abdominal obesity among men in the US (33), the inverse relationship between total flavonoids consumption and abdominal obesity in this demographic suggested that dietary recommendations emphasizing flavonoid-rich foods might be less effective in preventing abdominal obesity in women. Furthermore, a stronger correlation between total flavonoids intake and the WWI had been noted in individuals with PIR below 1.3. This could be attributed to disparities in the primary sources of flavonoids between lower and higher socioeconomic groups, with lower-income families potentially engaging more frequently in home-cooked meals, which may influence their dietary flavonoid intake (34, 35).

It is known that the pathogenesis of abdominal obesity was different from generalized obesity (36). Human omental preadipocytes cultured preadipocytes undergo lower adipogenic transcription factor expression and more TNF-a-induced apoptosis than human abdominal subcutaneous. Additionally, there are preadipocytes within visceral fat that have limited ability to proliferate and differentiate compared to subcutaneous fat (37). Omental adipocytes have been observed to display comparable or reduced levels of basal lipolysis and exhibit decreased sensitivity to the insulin-induced antilipolytic effects *in vivo* (38). In fact, there is a higher level of glucose absorption in visceral fat in comparison to subcutaneous fat (39). Furthermore, the omental fat demonstrates a higher capacity to absorb plasma free fatty acids compared to the abdominal subcutaneous fat, which suggests that this specific process might play a role in the selective buildup of visceral fat (40). For our research, we observed a strong inverse relationship between the consumption of total flavonoids, flavanones, flavones, flavan-3-ols, and anthocyanidins with WWI. This finding indicated that a sufficient intake of above flavonoids could potentially be a mildly effective intervention for combating abdominal obesity. Naringenin (4′,5,7-thrihydroxyflavanone) is a flavanone commonly found in a variety of vegetables, fruits, herbs, and nuts that are widely consumed by humans (41, 42). Research conducted by Atsuyoshi et al. had shed light on the anti-diabetic properties of naringenin. Their findings indicated that naringenin can increase the secretion of adiponectin and reduce the size of 3 T3-L1 cells in a concentration-dependent manner during the process of adipocyte differentiation (43). Adiponectin is significant for its role in enhancing glucose uptake without the need for insulin receptor stimulation, improving fatty acid metabolism, and reducing fatty acid levels, which in turn

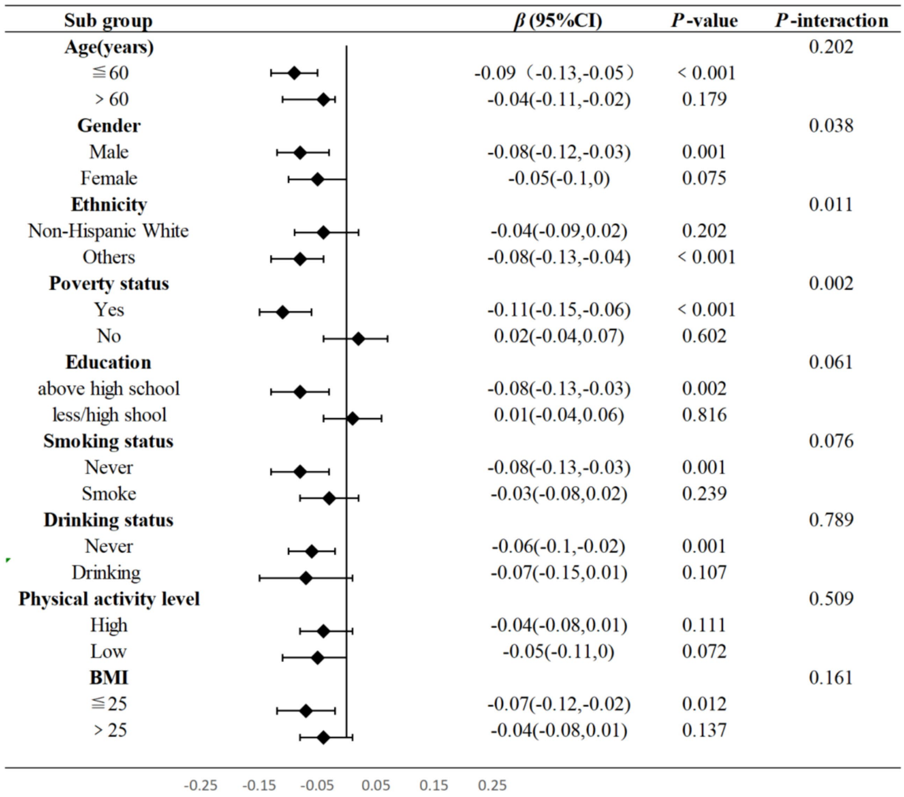



FIGURE 4
Subgroup and interaction analysis between total flavonoids and WWI. Adjusted for age, gender, ethnicity, education levels, PIR, physical activity levels, total carbohydrate intake, total protein intake, total fat intake and total fiber intake. T, Tertile, BMI, Body Mass Index, WWI, Weight-adjusted Waist, PIR, family poverty income ratio.

increases the sensitivity of the insulin receptor. Additionally, it promotes insulin sensitivity through the activation of liver AMP-activated protein kinase (AMPK), prevents arteriosclerosis, exhibits anti-inflammatory effects, and suppresses myocardial hypertrophy (44). Baicalein, which root constitute flavones baicalein (45), has been demonstrated in multiple studies to effectively alleviate insulin resistance and ameliorate complications associated with obesity (46, 47). Additionally, baicalein had been shown to exert protective effects on the functionality of INS382/13 cells and human pancreatic islets, thereby enhancing their secretory capacity (48). Luteolin, a widely available flavone in the diet, had also been identified for its potential anti-obesity characteristics (49). According to research by Lin et al. (50), luteolin was capable of diminishing fat storage in *Caenorhabditis elegans* by stimulating central serotonin signaling, which triggers fat loss. Treatment with luteolin led to an increase in serotonin synthesis within ADF neurons and the subsequent activation of serotonin-linked receptors MOD-1 and SER-6. This activation sequence ultimately results in an upregulation of lipolysis and fatty acid β-oxidation in the nematode model, *Caenorhabditis elegans* (50). Flavan-3-ols, encompassing the catechin group of compounds, are characterized by a 2-phenyl-3,4-dihydro-2H-chromen-3-ol framework. Green tea is particularly abundant in catechins, including epigallocatechin 3-gallate (EGCG) and catechin 3-gallate, which are both classified under flavan-3-ols (51). The impact of catechins and EGCG on abdominal obesity and metabolic syndrome has been a focus of extensive research, particularly in animal models. For instance, a study involving mice on a high-fat diet, which constituted 60% of their caloric intake, demonstrated that a dietary regimen incorporating EGCG at a concentration of 0.32% for 16 weeks led to significant reductions in body weight gain, overall body fat, and visceral fat weight when compared to the control group without EGCG supplementation (52). Zang et al. (53) conducted research on the effects of green tea extract in juvenile and adult zebrafish models of obesity. Their findings indicated that green tea extract not only significantly reduced the accumulation of visceral adipose tissue in juveniles but also improved visceral adiposity and plasma triglyceride levels in adult zebrafish. The proposed molecular mechanism behind the anti-obesity effects of green tea extract involves the activation of the Wnt/β-catenin and AMPK signaling pathways, which may help to ameliorate obesity-related phenotypes (53). Multiple studies indicated that the transition of preadipocytes into adipocytes is governed by a tightly regulated sequence of transcriptional events, with proliferator-activated receptor gamma (PPARγ) and CCAT/enhancer-binding proteinα (C/EBPα) being pivotal mediators in this process (54, 55). PPARγ functions as a regulator in the lipid synthesis pathway, and its overexpression leads to an enlargement and multiplication of lipid molecules within 3T3-L1 preadipocytes undergoing differentiation (56). The black soybean contains various anthocyanins like cyanidin-3-O-glucoside, and delphinidin-3-O-glucoside, which have significant implications. They have been studied to increase preadipocyte differentiation through downregulated the expression of PPARγ and C/EBPα in a concentration-dependent manner (57). Additionally, anthocyanins can stimulate lipolysis in mature adipocytes. Oral administration of cyanidin had been shown to decrease hepatic and plasma triglyceride levels, reduce adiposity, and enhance glucose tolerance in mice on a high-fat diet. Metabolomic analysis of the liver indicated that cyanidin influenced the metabolic profile towards increased fatty acid oxidation and ketogenesis (58).

The robustness and broad applicability of our research findings were bolstered by the large and diverse sample size, enabling us to detect subtle association between dietary flavonoids consumption and abdominal obesity within multiple subgroups. Our study suggested that dietary flavonoids could pave the way for creating functional foods to combat abdominal obesity. However, it is crucial to recognize and address the limitations inherent in our study. Initially, our research was confined to examining the link between flavonoids consumption and the WWI, and further investigation is required to confirm the correlation between flavonoid intake and other metabolic health markers. Additionally, different dietary sources (foods/drinks) affect flavonoids bioavailability, the intake data may overestimated the actual amount of flavonoids intake that exhibit physiological health benefits. Lastly, the exclusion of supplement data may limit the generalizability of our findings, as it does not account for all possible sources of flavonoids that participants may have consumed. Future studies should consider including data on the use of flavonoids supplements to provide a more comprehensive evaluation of total flavonoids intake.

## 5 Conclusion

Our research contributed novel insights into the intricate relationship between flavonoids consumption and abdominal obesity, with our findings indicating a significant inverse correlation between flavonoids intake and the WWI among adults in the US. This underscored the potential significance of flavonoids intake in the management of abdominal obesity and laid a foundation for the development of dietary guidelines for flavonoid consumption. Nonetheless, the observed associations between flavonoids and WWI should not be interpreted as indicative of a causal relationship, and additional prospective cohort studies or randomized controlled trials are necessary to confirm the causal relationship between flavonoids intake and abdominal obesity, as well as to determine the safe and effective dosages of flavonoids for various populations.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by The National Centre for Health Statistics' research ethics review board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

SZ: Writing – original draft. MY: Writing – original draft. XiL: Writing – original draft. HW: Writing – original draft. XuL: Writing – original draft. YF: Writing – original draft. DW: Funding acquisition, Writing – review & editing. BZ: Writing – review & editing.

## Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This work was supported by the Anhui Provincial Natural Science Foundation (2008085MH244) and grants from The National Key Research and Development Program of China (2020YFC2006502). The funding agency had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

## Acknowledgments

This study used data from the NHANES. We thank the NCHS and the US Centers for Disease Control and Prevention for their financial support for data collection and analysis. We also thank the study participants and staff.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## References

1. Yanovski JA. Trends in underweight and obesity — scale of the problem. *Nat Rev Endocrinol*. (2018) 14:5–6. doi: 10.1038/nrendo.2017.157

2. Abarca-Gómez L, Abdeen ZA, Hamid ZA, Abu-Rmeileh NM, Acosta-Cazares B, Acuin C, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. *Lancet*. (2017) 390:2627–42. doi: 10.1016/S0140-6736(17)32129-3

3. Pischon T, Boeing H, Hoffmann K, Bergmann M, Schulze MB, Overvad K, et al. General and abdominal adiposity and risk of death in Europe. *N Engl J Med*. (2008) 359:2105–20. doi: 10.1056/NEJMoa0801891

4. Klöting N, Fasshauer M, Dietrich A, Kovacs P, Schön MR, Kern M, et al. Insulin-sensitive obesity. *Am. J. Physiol. Endocrinol. Metab.* (2010) 299:E506–15. doi: 10.1152/ajpendo.00586.2009

5. Kawada T, Andou T, Fukumitsu M. Waist circumference, visceral abdominal fat thickness and three components of metabolic syndrome. *Diabetes Metab Syndr*. (2016) 10:4–6. doi: 10.1016/j.dsx.2015.08.013

6. Berentzen TL, Ängquist L, Kotronen A, Borra R, Yki-Järvinen H, Iozzo P, et al. Waist circumference adjusted for body mass index and intra-abdominal fat mass. *PLoS One*. (2012) 7:e32213. doi: 10.1371/journal.pone.0032213

7. Park Y, Kim NH, Kwon TY, Kim SG. A novel adiposity index as an integrated predictor of cardiometabolic disease morbidity and mortality. *Sci Rep*. (2018) 8:16753. doi: 10.1038/s41598-018-35073-4

8. Qin Z, Chang K, Yang Q, Yu Q, Liao R, Su B. The association between weight-adjusted-waist index and increased urinary albumin excretion in adults: a population-based study. *Front Nutr*. (2022) 9:941926. doi: 10.3389/fnut.2022.941926

9. Kim NH, Park Y, Kim NH, Kim SG. Weight-adjusted waist index reflects fat and muscle mass in the opposite direction in older adults. *Age Ageing*. (2021) 50:780–6. doi: 10.1093/ageing/afaa208

10. Kim JY, Choi J, Vella CA, Criqui MH, Allison MA, Kim NH. Associations between weight-adjusted waist index and abdominal fat and muscle mass: multi-ethnic study of atherosclerosis. *Diabetes Metab J*. (2022) 46:747–55. doi: 10.4093/dmj.2021.0294

11. Hu Q, Han K, Shen J, Sun W, Gao L, Gao Y. Association of weight-adjusted-waist index with non-alcoholic fatty liver disease and liver fibrosis: a cross-sectional study based on NHANES. *Eur J Med Res*. (2023) 28:263. doi: 10.1186/s40001-023-01205-4

12. Wang Z, Shao X, Xu W, Xue B, Zhong S, Yang Q. The relationship between weight-adjusted-waist index and diabetic kidney disease in patients with type 2 diabetes mellitus. *Front Endocrinol*. (2024) 15:1345411. doi: 10.3389/fendo.2024.1345411

13. Zhang Y, Wu H, Li C, Liu C, Liu M, Liu X, et al. Associations between weight-adjusted waist index and bone mineral density: results of a nationwide survey. *BMC Endocr Disord*. (2023) 23:162. doi: 10.1186/s12902-023-01418-y

14. Li M, Yu X, Zhang W, Yin J, Zhang L, Luo G, et al. The association between weight-adjusted-waist index and depression: results from NHANES 2005-2018. *J Affect Disord*. (2024) 347:299–305. doi: 10.1016/j.jad.2023.11.073

15. Prasad S, Phromnoi K, Yadav VR, Chaturvedi MM, Aggarwal BB. Targeting inflammatory pathways by flavonoids for prevention and treatment of cancer. *Planta Med*. (2010) 76:1044–63. doi: 10.1055/s-0030-1250111

16. Havsteen BH. The biochemistry and medical significance of the flavonoids. *Pharmacol Ther*. (2002) 96:67–202. doi: 10.1016/s0163-7258(02)00298-x

17. Xie R, Zhang Y. Associations between dietary flavonoid intake with hepatic steatosis and fibrosis quantified by VCTE: evidence from NHANES and FNDDS. *Nutr Metab Cardiovasc Dis*. (2023) 33:1179–89. doi: 10.1016/j.numecd.2023.03.005

18. Zhao Z, Gao W, Ding X, Xu X, Xiao C, Mao G, et al. The association between dietary intake of flavonoids and its subclasses and the risk of metabolic syndrome. *Front Nutr*. (2023) 10:1195107. doi: 10.3389/fnut.2023.1195107

19. Vernarelli JA, Lambert JD. Flavonoid intake is inversely associated with obesity and C-reactive protein, a marker for inflammation, in US adults. *Nutr Diabetes*. (2017) 7:e276. doi: 10.1038/nutd.2017.22

20. Aloo S-O, Ofosu FK, Kim N-H, Kilonzi SM, Oh D-H. Insights on dietary polyphenols as agents against metabolic disorders: obesity as a target disease. *Antioxidants*. (2023) 12:416. doi: 10.3390/antiox12020416

21. Ogden CL, Carroll MD, Lawman HG, Fryar CD, Kruszon-Moran D, Kit BK, et al. Trends in obesity prevalence among children and adolescents in the United States, 1988-1994 through 2013-2014. *JAMA*. (2016) 315:2292–9. doi: 10.1001/jama.2016.6361

22. Ali MK, Bullard KM, Beckles GL, Stevens MR, Barker L, Venkat Narayan KM, et al. Household income and cardiovascular disease risks in U.S. children and young adults. *Diabetes Care*. (2011) 34:1998–2004. doi: 10.2337/dc11-0792

23. Castro-Barquero S, Ruiz-León AM, Sierra-Pérez M, Estruch R, Casas R. Dietary strategies for metabolic syndrome: a comprehensive review. *Nutrients*. (2020) 12:2983. doi: 10.3390/nu12102983

24. Beecher GR. Overview of dietary flavonoids: nomenclature, occurrence and intake. *J Nutr*. (2003) 133:3248S–54S. doi: 10.1093/jn/133.10.3248S

25. Sebastian RS, Fanelli Kuczmarski M, Wilkinson Enns C, Goldman JD, Murayi T, Moshfegh AJ, et al. Application of the database of flavonoid values for USDA food codes 2007–2010 in assessing intake differences between the healthy aging in neighborhoods of diversity across the life span (HANDLS) study and what we eat in America (WWEIA), NHANES. *J Food Compost Anal*. (2021) 104:104124. doi: 10.1016/j.jfca.2021.104124

26. Kim S-A, Kim J, Jun S, Wie G-A, Shin S, Joung H. Association between dietary flavonoid intake and obesity among adults in Korea. *Appl Physiol Nutr Metab*. (2020) 45:203–12. doi: 10.1139/apnm-2019-0211

27. Lim U, Ernst T, Buchthal SD, Latch M, Albright CL, Wilkens LR, et al. Asian women have greater abdominal and visceral adiposity than Caucasian women with similar body mass index. *Nutr Diabetes*. (2011) 1:e6. doi: 10.1038/nutd.2011.2

28. Kim YJ, Park MY, Chang N, Kwon O. Intake and major sources of dietary flavonoid in Korean adults: Korean National Health and nutrition examination survey 2010-2012. *Asia Pac J Clin Nutr*. (2015) 24:456–63. doi: 10.6133/apjcn.2015.24.3.04

29. Nishimura M, Muro T, Kobori M, Nishihira J. Effect of daily ingestion of quercetin-rich onion powder for 12 weeks on visceral fat: a randomised, double-blind, placebo-controlled, parallel-group study. *Nutrients*. (2019) 12:91. doi: 10.3390/nu12010091

30. Knab AM, Shanely RA, Jin F, Austin MD, Sha W, Nieman DC. Quercetin with vitamin C and niacin does not affect body mass or composition. *Appl Physiol Nutr Metab*. (2011) 36:331–8. doi: 10.1139/h11-015

31. Byrd AS, Toth AT, Stanford FC. Racial disparities in obesity treatment. *Curr Obes Rep*. (2018) 7:130–8. doi: 10.1007/s13679-018-0301-3

32. Power ML, Schulkin J. Sex differences in fat storage, fat metabolism, and the health risks from obesity: possible evolutionary origins. *Br J Nutr*. (2008) 99:931–40. doi: 10.1017/S0007114507853347

33. Sun J-Y, Huang W-J, Hua Y, Qu Q, Cheng C, Liu H-L, et al. Trends in general and abdominal obesity in US adults: evidence from the National Health and nutrition examination survey (2001–2018). *Front Public Health*. (2022) 10:925293. doi: 10.3389/fpubh.2022.925293

34. Fanelli Kuczmarski M, Sebastian RS, Goldman JD, Murayi T, Steinfeldt LC, Eosso JR, et al. Dietary flavonoid intakes are associated with race but not income in an urban population. *Nutrients*. (2018) 10:1749. doi: 10.3390/nu10111749

35. Monsivais P, Aggarwal A, Drewnowski A. Time spent on home food preparation and indicators of healthy eating. *Am J Prev Med*. (2014) 47:796–802. doi: 10.1016/j.amepre.2014.07.033

36. Breitfeld J, Kehr S, Müller L, Stadler PF, Böttcher Y, Blüher M, et al. Developmentally driven changes in Adipogenesis in different fat depots are related to obesity. *Front Endocrinol*. (2020) 11:138. doi: 10.3389/fendo.2020.00138

37. Tchkonia T, Tchoukalova YD, Giorgadze N, Pirtskhalava T, Karagiannides I, Forse RA, et al. Abundance of two human preadipocyte subtypes with distinct capacities for replication, adipogenesis, and apoptosis varies among fat depots. *Am J Physiol Endocrinol Metab*. (2005) 288:E267–77. doi: 10.1152/ajpendo.00265.2004

38. Boivin A, Brochu G, Marceau S, Marceau P, Hould F-S, Tchernof A. Regional differences in adipose tissue metabolism in obese men. *Metabolism*. (2007) 56:533–40. doi: 10.1016/j.metabol.2006.11.015

39. Veilleux A, Blouin K, Rhéaume C, Daris M, Marette A, Tchernof A. Glucose transporter 4 and insulin receptor substrate-1 messenger RNA expression in omental and subcutaneous adipose tissue in women. *Metabolism*. (2009) 58:624–31. doi: 10.1016/j.metabol.2008.12.007

40. Koutsari C, Ali AH, Mundi MS, Jensen MD. Storage of circulating free fatty acid in adipose tissue of postabsorptive humans: quantitative measures and implications for body fat distribution. *Diabetes*. (2011) 60:2032–40. doi: 10.2337/db11-0154

41. Lin L-Z, Mukhopadhyay S, Robbins RJ, Harnly JM. Identification and quantification of flavonoids of Mexican oregano (*Lippia graveolens*) by LC-DAD-ESI/MS analysis. *J Food Compost Anal*. (2007) 20:361–9. doi: 10.1016/j.jfca.2006.09.005

42. Bugianesi R, Catasta G, Spigno P, D'Uva A, Maiani G. Naringenin from cooked tomato paste is bioavailable in men. *J Nutr*. (2002) 132:3349–52. doi: 10.1093/jn/132.11.3349

43. Nishina A, Sato D, Yamamoto J, Kobayashi-Hattori K, Hirai Y, Kimura H. Antidiabetic-like effects of Naringenin-7- *O* -glucoside from edible *Chrysanthemum* 'Kotobuki' and Naringenin by activation of the PI3K/Akt pathway and PPARγ. *Chem Biodivers*. (2019) 16:e1800434. doi: 10.1002/cbdv.201800434

44. Lazra Y, Falach A, Frenkel L, Rozenberg K, Sampson S, Rosenzweig T. Autocrine/paracrine function of globular adiponectin: inhibition of lipid metabolism and inflammatory response in 3T3-L1 adipocytes. *J Cell Biochem*. (2015) 116:754–66. doi: 10.1002/jcb.25031

45. Gao Y, Snyder SA, Smith JN, Chen YC. Anticancer properties of baicalein: a review. *Med Chem Res*. (2016) 25:1515–23. doi: 10.1007/s00044-016-1607-x

46. Xing Y, Ren X, Li X, Sui L, Shi X, Sun Y, et al. Baicalein enhances the effect of Acarbose on the improvement of nonalcoholic fatty liver disease associated with prediabetes via the inhibition of *De novo* lipogenesis. *J Agric Food Chem*. (2021) 69:9822–36. doi: 10.1021/acs.jafc.1c04194

47. Guo S, Zhang L, Wu S, Liu H. Research progress of typical flavonoids in improving insulin resistance. *Arch Med Sci Atheroscler Dis*. (2020) 5:335–e342. doi: 10.5114/amsad.2020.103472

48. Liu Y, Zhao G, Zhang S. Effects and action mechanism of baicalein on glucolipid metabolism and renal function of the rats with type 2 diabetes mellitus. *Western J Traditional Chin Med*. (2016) 29:23–6.

49. Xu N, Zhang L, Dong J, Zhang X, Chen Y-G, Bao B, et al. Low-dose diet supplement of a natural flavonoid, luteolin, ameliorates diet-induced obesity and insulin resistance in mice. *Mol Nutr Food Res*. (2014) 58:1258–68. doi: 10.1002/mnfr.201300830

50. Lin Y, Yang N, Bao B, Wang L, Chen J, Liu J. Luteolin reduces fat storage in *Caenorhabditis elegans* by promoting the central serotonin pathway. *Food Funct*. (2020) 11:730–40. doi: 10.1039/C9FO02095K

51. Yang YJ, Kim YJ, Yang YK, Kim JY, Kwon O. Dietary flavan-3-ols intake and metabolic syndrome risk in Korean adults. *Nutr Res Pract*. (2012) 6:68–77. doi: 10.4162/nrp.2012.6.1.68

52. Bose M, Lambert JD, Ju J, Reuhl KR, Shapses SA, Yang CS. The major green tea polyphenol, (−)-Epigallocatechin-3-Gallate, inhibits obesity, metabolic syndrome, and fatty liver disease in high-fat–fed mice. *J Nutr*. (2008) 138:1677–83. doi: 10.1093/jn/138.9.1677

53. Zang L, Shimada Y, Nakayama H, Kim Y, Chu D-C, Juneja LR, et al. RNA-seq based transcriptome analysis of the anti-obesity effect of green tea extract using zebrafish obesity models. *Molecules*. (2019) 24:3256. doi: 10.3390/molecules24183256

54. Assi M, Kenawi M, Ropars M, Rébillard A. Interleukin-6, C/EBP-β and PPAR-γ expression correlates with intramuscular liposarcoma growth in mice: the impact of voluntary physical activity levels. *Biochem Biophys Res Commun*. (2017) 490:1026–32. doi: 10.1016/j.bbrc.2017.06.158

55. Kim E-J, Kang M-J, Seo YB, Nam S-W, Kim G-D. Acer okamotoanum Nakai leaf extract inhibits Adipogenesis via suppressing expression of PPAR γ and C/EBP α in 3T3-L1 cells. *J Microbiol Biotechnol*. (2018) 28:1645–53. doi: 10.4014/jmb.1802.01065

56. Guo L, Li X, Tang Q-Q. Transcriptional regulation of adipocyte differentiation: a central role for CCAAT/enhancer-binding protein (C/EBP) β. *J Biol Chem*. (2015) 290:755–61. doi: 10.1074/jbc.R114.619957

57. Park M, Sharma A, Lee H-J. Anti-Adipogenic effects of Delphinidin-3-O-β-glucoside in 3T3-L1 Preadipocytes and primary white adipocytes. *Molecules*. (2019) 24:1848. doi: 10.3390/molecules24101848

58. Jia Y, Wu C, Kim Y-S, Yang SO, Kim Y, Kim J-S, et al. A dietary anthocyanin cyanidin-3-O-glucoside binds to PPARs to regulate glucose metabolism and insulin sensitivity in mice. *Commun Biol*. (2020) 3:514. doi: 10.1038/s42003-020-01231-6

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 08 August 2024
DOI 10.3389/fpubh.2024.1399185

Check for updates

OPEN ACCESS

EDITED BY
Luis Suarez-Arrones,
Universidad Pablo de Olavide, Spain

REVIEWED BY
Olutosin Ademola Otekunrin,
University of Ibadan, Nigeria
Francilene Maria Azevedo,
Universidade Federal de Viçosa, Brazil

*CORRESPONDENCE
Abriham Shiferaw Areba
✉ abriamshiferaw@gmail.com

RECEIVED 11 March 2024
ACCEPTED 29 July 2024
PUBLISHED 08 August 2024

CITATION
Areba AS, Akiso DE, Haile A, Abire BG, Kanno GG, Tirore LL and Abame DE (2024) Factors associated with food insecurity among pregnant women in Gedeo zone public hospitals, Southern Ethiopia. *Front. Public Health* 12:1399185. doi: 10.3389/fpubh.2024.1399185



# Factors associated with food insecurity among pregnant women in Gedeo zone public hospitals, Southern Ethiopia

Abriham Shiferaw Areba[1]*, Denebo Ersulo Akiso[1], Arega Haile[2], Belayneh Genoro Abire[2], Girum Gebremeskel Kanno[3], Lire Lemma Tirore[1] and Desta Erkalo Abame[1]

[1]School of Public Health, College of Medicine and Health Sciences, Wachemo University, Hossana, Ethiopia, [2]Department of Statistics, College of Natural Sciences, Dilla University, Dilla, Ethiopia, [3]School of Public Health, College of Medicine and Health Sciences, Dilla University, Dilla, Ethiopia

**Background:** Food insecurity refers to a lack of consistent access to sufficient food for active, better health. Around two billion people worldwide suffer from food insecurity and hidden hunger. This study focuses on food insecurity and associated factors among pregnant women in Gedeo Zone Public Hospitals, Southern Ethiopia.

**Method:** An institutional-based cross-sectional study was conducted among pregnant women in Gedeo zone public hospitals from May to June 2021. Primary data of 506 pregnant women were collected using interviewer-administered structured questionnaire and a multi-stage sampling technique was used to select study participants. The household food insecurity access scale of the questionnaire was used and a woman was considered as food insecure when it has any of the food insecurity conditions mild, moderate, or severe food insecure, otherwise, it was classified as food secure. Adjusted odds ratio (AOR) and their 95% confidence intervals (CI) determined the association between various factors and outcomes.

**Results:** Of all study participants, 67.39% of the women were food insecure, and the remaining 32.6% had food security. The pregnant women from rural areas [AOR = 0.532, 95% CI: 0.285, 0.994], married [AOR = 0.232, 95% CI: 0.072, 0.750], had a secondary education [AOR = 0.356, 95%CI: 0.154, 0.822], and be employed [AOR = 0.453, 95% CI: 0.236, 0.872], the wealth index middle [AOR = 0.441, 95% CI: 0.246, 0.793] and rich [AOR = 0.24, 95% CI: 0.128, 0.449] were factors associated with food insecurity.

**Conclusion:** The study area had a high prevalence of food insecurity. Food insecurity was reduced in those who lived in rural areas, were married, had a secondary education, were employed, and had a wealth index of middle and rich.

KEYWORDS

**food insecurity, factors, pregnant women, Gedeo zone, public hospitals, Ethiopia**

# Introduction

Food insecurity refers to a lack of sufficient food, as well as restrictions on the quality, quantity, and/or frequency of food consumption (1–4). Goal 2 of the Sustainable Development Goals (SDGs) aims to end hunger, increase food security, and promote sustainable agriculture. Target 2.1 of the SDGs is aimed at achieving the objective of ending hunger and ensuring year-round access to food for all people, including pregnant and lactating mothers, by 2030 (5).

At the worldwide level, gender differences in the incidence of moderate and severe food insecurity have expanded in the year of the COVID-19 pandemic, with women experiencing 10% more moderate or severe food insecurity in 2020 than males, compared to 6% in 2019. Severe food insecurity affects 28.7% of the population in Eastern Africa, while moderate to severe food insecurity affects 65.3 percent of the population (6).

According to the FAO estimate for 2021, over 2 billion people worldwide are afflicted by moderate food insecurity and hunger, with Sub-Saharan Africa having the highest prevalence (21 percent of the population) (6, 7). According to recent studies in Ethiopia, 7% of households experience severe food insecurity, while 11 and 22% of households experience mild and moderate food insecurity, respectively (8). According to various studies, Food insecurity has been linked to poor pregnancy outcomes, including low birth weight, gestational diabetes, and pregnancy problems (9–16). A study conducted in the United States showed that maternal food insecurity was associated with an increased risk of certain birth defects, such as cleft palate, transposition of the great arteries, and Anencephaly (17).

Furthermore, young children from food-insecure families have poorer general health (18–20), are more likely to be hospitalized (19, 21), have lower levels of parent–child attachment, and experience developmental delays (22–24). Food insecurity and food shortages are associated with poor general, mental, and physical health in women. A study in the USA indicated that food insecurity was associated with women's reduced mental health. Mental symptoms including depression, stress, and anxiety were associated with household food insecurity in a dose–response relationship and were increased with worsening the food insecurity status (25).

Food insecurity has a substantial effect on the physical health of both the pregnant woman and her child, directly compromising the nutritional state and serum profile of micronutrients, such as iron. It may also trigger a series of stressful events in the family environment due to the difficulty in obtaining food, provoking deterioration in maternal mental health and consequent development of anxiety and depression, and also leading to negative outcomes concerning childcare (8).

Household food insecurity is expected to vary depending on the household head's gender, age, and level of education; the size of the household; the quantity of livestock held; and financial and human capital-related issues (26). Because food security affects a pregnant woman's nutritional condition, which is a significant environmental risk factor for poor pregnancy outcomes, securing a sufficient food supply for pregnant women has been a top priority for concerned parties.

Abbreviations: AGP, Agricultural growth program; AOR, Adjusted Odds Ratio; FAO, Food and Agricultural Organization; FANTA, Food and Nutrition Technical Assistance; FI, Food insecurity; HFIAS, Household Food Insecurity Access Scale.

However, the risk of food insecurity in pregnant women in this particular study area does not identify at the household level/ pregnant women. This causes difficulty in identifying those women who require targeted intervention, aid, and risk of food insecurity at women to work. Though there is a continually high magnitude of food insecurity in Ethiopia, published research does not give significant evidence on its risk factors in all parts of the country. Most surveys done in Ethiopia had a lesser number of research participants and were not conducted on a large scale, making them ineffective for identifying risk factors. This problem motivates the authors to conduct a study supported by an appropriate statistical model on this current crucial issue. Though there is a continually high magnitude of food insecurity in Ethiopia, published research does not give significant evidence on its risk factors in all parts of the country. Most surveys done in Ethiopia had a lesser number of research participants and were not conducted on a large scale, making them ineffective for identifying risk factors. Therefore, this study aimed to assess the magnitude of food insecurity and its associated factors among pregnant mothers in Gedeo zone public Hospitals, in Southern Ethiopia.

# Methods

## Study design and area description

An institution-based cross-sectional study was conducted in Gedeo Zone Public Hospitals in Southern Ethiopia. Gedeo zone is located 369 km from Addis Ababa to the south on the Addis Ababa-Moyale international road and 90 km from Hawassa (Capital city of the region) in the south Nation Nationality and People regional state. The Zone has 1 referral hospital, 3 primary hospitals (Bule, Gedeb, and Yerga Chefe), 38 health centers, 146 health posts, 4 NGO clinics, and 17 reported private health facilities.

## Source population and study population

All pregnant mothers attending antenatal care in Gedeo Zone Health facilities were the source population, while pregnant mothers attending antenatal care in Gedeo Zone Public Hospitals were the study population.

## Determination of sampling size and sampling procedure

The sample size used for this investigation was estimated and computed using a single population proportions method with the following assumptions: 32.4% FI among nursing moms, 95 percent confidence level of 1.96, margin of error of 0.05, and design effect of 1.5. As a result, the study's ultimate sample size was 506 participants (27). The study subjects were selected using a multi-stage sampling technique. Proportional allocation of the sample was done to each Hospital based on the number of pregnant women available in the Hospital. After consent, one mother was randomly selected from among the pregnant women who matched the eligibility criteria to participate in the study.

 10.3389/fpubh.2024.1399185

TABLE 1 Description of independent variables used in the study.

| Covariates | Description | Categories |
|---|---|---|
| Age | Age of pregnant women | 0 = 15–19, 1 = 20–24, 2 = 25–29, 3 = ≥ 30 |
| Woreda | Woreda of pregnant women | 0 = Dilla, 1 = Gedebe, 2 = Yirga Chafe, 3 = Bule, 4 = Others |
| Residence | Residence of women who live | 0 = Urban 1 = Rural |
| Education | Educational level of women | 0 = No education, 1 = Primary, 2 = Secondary, 3 = Higher |
| Marital status | Marital status of women | 0 = Others (Single, Divorce), 1 = Married |
| Employment | Employment status of women | 0 = Unemployed, 1 = Employed |
| Wealth index | Wealth Index of Women | 1 = Poor, 2 = Middle, 3 = Rich |
| Family size | No. of a family member | 1 = 2, 2 = 3–4, 3 = 5 and above |
| Parity | No. of live birth | 0 = No Birth, 1 = One Birth, 2 = Two Birth, 3 = Three and above birth |
| Gravid | No. of pregnancy | 1 = First pregnancy, 2 = 2–3 Pregnancy, 3 = 4 and above |
| Willingness | Pregnancy willingness | 0 = Unwanted, 1 = Wanted |
| Complication | Pregnancy Complication | 0 = No, 1 = Yes |
| Food extension | Food Extension Service | 0 = No, 1 = Yes |

## Data collection and procedures

The study data collection instruments were developed after searching PubMed, Google Scholar, Hinari, and the Lancet series for various types of literature. The data was collected using a standardized interviewer-administered questionnaire. The questionnaire was written in English, then translated into Amharic, and then returned to English by language experts to ensure consistency and correctness. Six diploma nurses who were proficient in the local language (Gedeo'ufa) as data collectors and two BSc midwives as supervisors were hired based on their past data-collecting experience.

Nine standard Household Food Insecurity Access Scale (HFIAS) questions derived from the Food and Nutrition Technical Assistance (FANTA) project were used to determine the outcome variable, food insecurity. The instrument consists of nine questions that illustrate the frequency of occurrence and quantify the severity of food insecurity in the previous 4 weeks using Likert scale responses [0 = Never, 1 = rarely (1 or 2 times), 2 = occasionally (3–10 times), and 3 = frequently (>10 times)]. The pregnant ladies were required to respond to these questions on behalf of their entire household. At the time of data collection, this technique was used to assess food access for all family members. The nine items ranging from 0 to 27 were used to compute the cumulative score of food insecurity among expectant mothers, with a higher score indicating that the household members experienced more food insecurity. All "Yes" responses were coded as 1 and "No" responses were coded as 0, and the responses were totaled to determine the level of household food insecurity (28).

The household's wealth index was calculated using Principal Component Analysis (PCA) and took into account the latrine, water source, household assets, livestock, and ownership of agricultural land. All non-dummy variables' responses were divided into three groups. The highest score was given a 1 rating. The two lower values, on the other hand, were given code 0. The variables with a commonality value larger than 0.5 were used to generate factor scores in PCA. Finally, the wealth score was calculated using each household's score on the first major component. The wealth score was divided into three quintiles to classify households as low, medium, or wealthy.

## The study's variables

The following are the response and predictor variables considered in the model for parameter estimation.

### Response variable

Food insecurity among pregnant women is the study's outcome variable. If the women are food insecure, this can be dichotomized as 1 and 0 correspondingly.

### Explanatory variables

The Table 1 lists the predictor variables that were investigated in this study to investigate food insecurity among pregnant women.

## Eligibility criteria

### Inclusion criteria

All Pregnant mothers of pregnancy attending ANC services at selected health institutions were included in this study.

### Exclusion criteria

Pregnant mothers' co-morbidities with complications and special requirements were excluded from the study. Diagnosed with chronic diseases like diabetes, hypertension, and twin pregnancy.

## Operational definitions

### Food secure women

Women who have experienced none of the Food Insecurity (access) conditions or have just been worried, although rarely, during the past 4 weeks (28).

### Food insecure women

Women who are unable at all times to access food sufficient to lead an active and healthy life (includes all stages of FI; mild, moderate, and severe) (28).

### Mildly food insecure women

Women who worry about not having enough food sometimes or often and/or are unable to eat preferred foods and/or eat a more monotonous diet than desired and/or some foods considered undesirable, but only rarely (28).

### Moderately food insecure women

Women who sacrifice quality more frequently, by eating a monotonous diet or undesirable foods sometimes or often, and/or have started to cut back on quantity by reducing the size of meals or number of meals, rarely or sometimes. However, they do not experience any of the three most severe conditions (28).

### Severely food insecure women

Women who have been forced to cut back on the meal size or number of meals often and experience any of the three most severe conditions (running out of food, going to bed hungry, or going a whole day and night without eating) (28). A woman was considered as food insecure when it has any of the food insecurity conditions mild, moderate, or severe food insecure, otherwise, it was classified as food secure (28).

### Wealth status

A reliability test was performed using the economic variables involved in measuring wealth. The variables that were employed to compute the principal component analysis, at the end of the principal component analysis, the wealth index was obtained as a continuous scale of relative wealth. Finally, the Percentile group of the wealth index was created to group under three wealth categories, poor, middle, and rich (29).

## Data quality control

Before data collection, the questionnaire was first written in English, then translated into Amharic, and then back to English for consistency. The purpose, methodology of the research on food insecurity, data collecting and interviewing style, and data recording were all covered in two days of training one week previous to the day of data collection. In a health center outside of the study area, the questionnaire was pre-tested on 5% of actual respondents. The supervisors and primary investigators kept a close eye on the overall activities during the data collection period to guarantee that the data was of high quality. Before analysis, all of the obtained data were double-checked, coded, entered into SPSS version 25, and cleaned to eliminate inconsistencies and incompleteness. The STATA/SE statistical software package version 14.0 was used to analyze the data.

## Data analysis

Descriptive statistics was used to report the distribution of the data among variables using frequency and percentage. A bi-variable logistic regression analysis was performed to assess associations between each independent variable and food insecurity. A multivariable model should include all covariates relevant in bi-variable analyses at the $p = 0.20$ to 0.25 level from the start. In a multivariable model, the variables that tend to be relevant from the bi-variable analysis are fitted together. For multivariate analysis, statistical significance was determined using a 95% confidence interval and a $p$-value of less than 0.05. As a consequence, backward exclusion is used to omit non-significant variables from the final model (30).

## Results

A total of 506 pregnant moms were considered in this investigation. Food insecurity and food security were found in 67.4% and 32.6 percent of those moms, respectively. There were 139 (27.47 percent) and 367 (72.53 percent) women from rural and urban areas, respectively, with rural residents experiencing 108 (21.34 percent) less food insecurity than urban residents experiencing 233 (46.05 percent).

When it comes to the age of the mothers, the minimum number of women discovered in the age group of 15–19 years is 26 (5.14%), while the greatest number of women found in the age group of 20–24 years is 224 (44.27 percent). 478 (94.47 percent) of the moms in the research were married, whereas 28 (5.53) were unmarried (single and divorced) (Table 2).

A single covariate binary logistic regression model analysis is an appropriate approach for screening out potentially essential variables before including them directly in a multivariable model. Each covariate's association with food insecurity among pregnant women was discussed. Food insecurity among pregnant mothers was significantly associated with place of residence, marital status, educational status, employment status, wealth index, family size, parity, and gravidity, but age of the mother, pregnancy willingness, pregnancy complications, and food extension service were not significant at a modest level of significance of 0.25 (Table 3).

In the Gedeo zone Public Hospitals, the place of residence, marital status, educational status, employment status, average monthly income, and wealth index all had statistically significant effects on food insecurity, i.e., the confidence interval for the adjusted odds ratio did not include one and the $p$-value was less than 0.05. The estimated odds ratio for pregnant mothers from rural areas were 0.532 when other predictor factors were kept constant in a multivariable regression model. This means that pregnant mothers from rural areas were 0.532 times (AOR = 0.532, 95% CI: 0.285, 0.994) less likely than mothers from urban areas to be food insecure (Figure 1).

Food insecurity was reduced by 76.8% in expectant pregnant mothers who were married compared to those who were not (single, divorced) (AOR = 0.232, 95 percent CI: 0.072, 0.750). When the influence of other factors was held constant in the model, pregnant mothers with a secondary education had a 35 percent lower risk of food insecurity than pregnant mothers without a secondary education (AOR = 0.35, 95 CI: 0.154, 0.822). With the effect of other independent variables constant in the model, pregnant mothers who had employment status were 0.453 times (AOR = 0.453, 95% CI: 0.236 to 0.872) less likely to have food insecurity than those who had unemployment status.

When other predictor variables in the regression model were held constant, pregnant women with middle and high economic status were 0.441 and 0.24 times less likely to have food insecurity than those with low economic status (AOR = 0.441, 95 percent CI 0.246 to 0.793) and (AOR = 0.24, 95 percent CI 0.128 to 0.449) respectively (Table 4).

TABLE 2 Descriptive summaries of food insecurity among pregnant mothers in Gedeo zone public hospitals.

| Covariates | Categories | Food insecurity status | | No. out of 506 (%) |
|---|---|---|---|---|
| | | Food secure (%) | Food insecure (%) | |
| Residence | Rural | 31 (6.13) | 108 (21.34) | 139 (27.47) |
| | Urban | 134 (26.48) | 233 (46.05) | 367 (72.53) |
| Age (year) | 15–19 | 8 (1.58) | 18 (3.56) | 26 (5.14) |
| | 20–24 | 75 (14.82) | 149 (29.45) | 224 (44.27) |
| | 25–29 | 61 (12.06) | 106 (20.95) | 167 (33) |
| | 30 and above | 21 (4.15) | 68 (13.44) | 89 (17.59) |
| Marital status | Unmarried | 4 (0.79) | 24 (4.74) | 28 (5.53) |
| | Married | 161 (31.82) | 317 (62.65) | 478 (94.47) |
| Educational status | No Education | 13 (2.57) | 82 (16.21) | 95 (18.77) |
| | Primary | 54 (10.67) | 141 (27.87) | 195 (38.54) |
| | Secondary | 55 (10.87) | 77 (15.22) | 132 (26.09) |
| | Higher | 43 (8.50) | 41 (8.10) | 84 (16.60) |
| Employment status | Unemployed | 112 (22.13) | 303 (59.88) | 415 (82.02) |
| | Employed | 53 (10.47) | 38 (7.51) | 91 (17.98) |
| Wealth index | Poor | 24 (4.74) | 144 (28.46) | 168 (33.20) |
| | Middle | 58 (11.46) | 111 (21.94) | 169 (33.40) |
| | Rich | 83 (16.40) | 86 (17) | 169 (33.40) |
| Family size | 2 | 37 (7.31) | 86 (17) | 123 (24.31) |
| | 3–4 | 83 (16.40) | 146 (28.85) | 229 (45.26) |
| | 5 and above | 45 (8.89) | 109 (21.54) | 154 (30.43) |
| Parity | No Previous Birth | 50 (9.88) | 112 (22.13) | 162 (32.02) |
| | 1 Previous Birth | 54 (10.67) | 86 (17) | 140 (27.67) |
| | 2 Previous Birth | 29 (5.73) | 59 (11.66) | 88 (17.39) |
| | 3 and above | 32 (6.32) | 84 (16.60) | 116 (22.92) |
| Gravid | 1 Pregnancy | 45 (8.89) | 110 (21.74) | 155 (30.63) |
| | 2–3 Pregnancies | 87 (17.19) | 147 (29.05) | 234 (46.25) |
| | 4 and above | 33 (6.52) | 84 (16.60) | 117 (23.12) |
| Pregnancy willingness | Unwanted | 10 (1.98) | 25 (4.94) | 35 (6.92) |
| | Wanted | 155 (30.63) | 316 (62.45) | 471 (93.08) |
| Complication of pregnancy | No | 152 (30.04) | 304 (60.08) | 456 (90.12) |
| | Yes | 13 (2.57) | 37 (7.31) | 50 (9.88) |
| Food extension service | No | 142 (28.06) | 284 (56.13) | 426 (84.19) |
| | Yes | 23 (4.55) | 57 (11.26) | 80 (15.81) |

Unmarried (single, divorced).

# Discussion

Food security and proper nutrition are essential for human growth and development, which necessitates access to enough, diverse, and high-quality food resources (25). In terms of food insecurity, 67.39% with (95% CI: 63.3, 71.5%) of pregnant women in this survey were food insecure. The findings of this study were similar to those of studies conducted in Hossana (67.5 percent) (31) and Areka (69.6 percent) (32). On the other hand, it is greater than the Atay District (36.8%) (33), Abay District (38.1%) (8), and Sodo town (37.6%) studies completed in Ethiopia (34).

Seasonal variations in family food security status, which are frequently higher in Ethiopia's summarizing season, could explain the increased degree of food insecurity. It could also be explained by households having fewer and smaller meals as a result of a monotonous diet and a lack of variety in food items. These discrepancies could be related to variances in the study participants' socio-demographic variables. Seasonal fluctuation may be another major explanation for the apparent difference, as this study was conducted during the summer season whereas the other experiments were conducted during the pre-harvest season.

TABLE 3 Prevalence of food insecurity, based on individual FIAS among pregnant mothers in Gedeo zone public hospitals.

| Nine FIAS | Yes | Rarely | Sometimes | Often |
|---|---|---|---|---|
| | Freq (%) | Freq (%) | Freq (%) | Freq (%) |
| Worry about food | 215 (42.5) | 56 (11.1) | 125 (24.7) | 34 (6.7) |
| Unable to eat preferred foods | 204 (40.3) | 64 (12.6) | 101 (20) | 39 (7.7) |
| Eat a limited variety of foods | 184 (36.4) | 65 (12.8) | 92 (18.2) | 27 (5.3) |
| Eat foods they really do not want eat | 181 (35.8) | 52 (10.3) | 69 (13.6) | 60 (11.9) |
| Eat a smaller meal | 181 (35.8) | 57 (11.3) | 90 (17.8) | 34 (6.7) |
| Eat fewer meals in a day | 198 (39.1) | 50 (9.9) | 111 (21.9) | 37 (7.3) |
| No food of any kind in the household | 194 (38.3) | 54 (10.7) | 99 (19.6) | 41 (8.1) |
| Go to sleep at night hungry | 194 (38.3) | 56 (11.1) | 101 (20) | 37 (7.3) |
| Go a whole day and night without eating | 206 (40.7) | 57 (11.3) | 74 (14.6) | 75 (14.8) |

FIAS, Food Insecurity Access Scale; Freq, frequency.

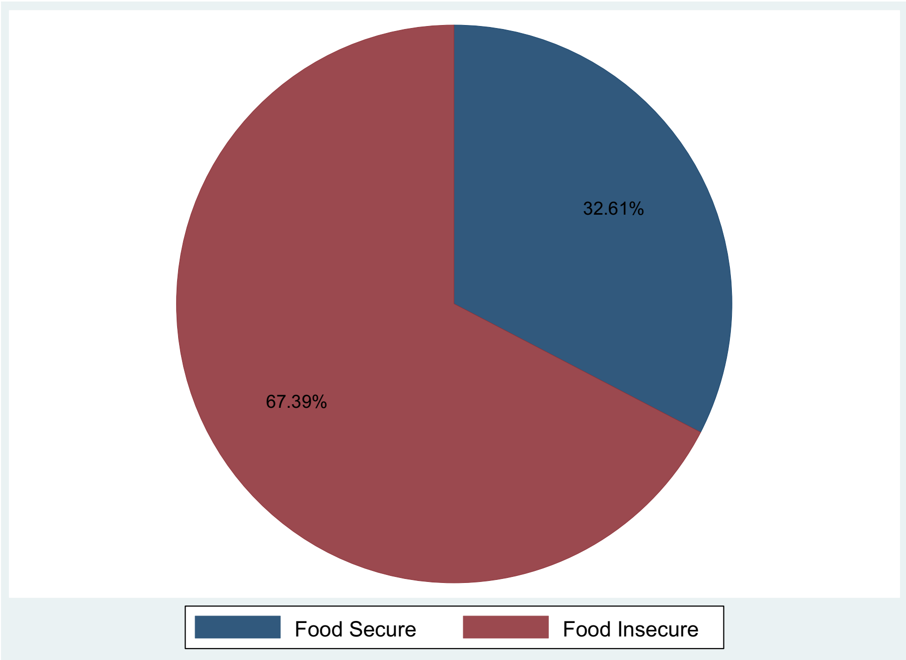



FIGURE 1
Magnitude of food insecurity among pregnant women in Gedeo zone public hospitals, Southern Ethiopia.

According to the findings, rural residency, marriage, secondary education, and wealth index intermediate and rich were all significant predictors of food insecurity among pregnant women. The location of residence was found to be a major differential for food insecurity in this study, and the findings suggest that moms from urban areas are more likely to have food insecurity than mothers from rural areas. Previous research backs up this conclusion (35).

Pregnant mothers who were part of a married pair were less likely to be food insecure than those who were single or divorced. This could be because married households in the study area had better access to farmland and social security than unmarried households. This was supported by research (34, 36). Mothers' educational status is one of the determinants of their food insecurity.

This implies that women with secondary education were less likely to be food insecure than those without. Previous research backs up this research (25, 33, 36–38). This is because educated mothers are more likely to know how to create, improve, manage, and produce enough varieties of farms to ensure their families and their own food security. Employment status is one factor that influences food insecurity among pregnant women. The findings reveal that expectant moms who are employed are less likely to be food insecure than those who are unemployed. The findings of this study were similar to those of others (25, 31, 38, 39).

Pregnant women with medium and upper-class economic positions were less likely to experience food insecurity than mothers with lower-class economic status. i.e., poor pregnant women were

TABLE 4 Multivariable logistic regression analysis for food insecurity among pregnant mothers in Gedeo zone public hospitals.

| Covariates | $\hat{\beta}$ | SE | Z | Sig | AOR | 95% CI for AOR | |
|---|---|---|---|---|---|---|---|
| Place of residence | | | | | | | |
| Urban® | | | | | | | |
| Rural | −0.631 | 0.319 | −1.98 | 0.048 | 0.532 | 0.285 | 0.994 |
| Marital status | | | | | | | |
| Others (single, divorced)® | | | | | | | |
| Married | −1.463 | 0.599 | −2.44 | 0.015 | 0.232 | 0.072 | 0.750 |
| Educational status | | | | | | | |
| No education® | | | | | | | |
| Primary | −0.542 | 0.378 | −1.44 | 0.151 | 0.581 | 0.277 | 1.22 |
| Secondary | −1.033 | 0.427 | −2.42 | 0.016 | 0.356 | 0.154 | 0.822 |
| Higher | −0.583 | 0.509 | −1.15 | 0.252 | 0.558 | 0.206 | 1.513 |
| Employment status | | | | | | | |
| Unemployed® | | | | | | | |
| Employed | −0.791 | 0.333 | −2.37 | 0.018 | 0.453 | 0.236 | 0.872 |
| Wealth index | | | | | | | |
| Poor® | | | | | | | |
| Middle | −0.818 | 0.298 | −2.67 | 0.006 | 0.441 | 0.246 | 0.793 |
| Rich | −1.429 | 0.321 | −4.45 | 0.000 | 0.240 | 0.128 | 0.449 |
| Constant | 1.62 | 0.806 | 1.01 | 0.000 | 5.030 | 3.450 | 6.610 |

$\hat{\beta}$, regression coefficients; SE, standard error; 95% CI for AOR, 95% confidence interval for adjusted odds ratio; ®, reference.

more likely to be food insecure as a result of their low wealth index. This could be explained by the fact that poor pregnant women may have no or only one source of income, making it difficult for them to purchase appropriate foods to meet the demands of their household members owing to extreme poverty. This finding was in line with earlier research (31–33, 40).

## Limitations of the study

Some variables that can affect the food insecurity of women; are knowledge level, dietary practice, and perception of the participants which were not addressed in this study. Since the study depends on self-reporting, there might be social desirability and recall bias from respondents. In addition, the predictors of food insecurity may not necessarily have a cause-and-effect relationship with food insecurity because the study design was cross-sectional. Further research with strong study designs will also need to come through seasonal variations of household food insecurity among pregnant women and also use advanced statistical models like multilevel models using individual level and community level variables to identify variation of each level.

## Conclusion

The present study revealed a high level of food insecurity among pregnant mothers' households. Place of residence, marital status, educational status, employment status, and wealth index were factors significantly associated with food insecurity. Rural residence, marriage, secondary education level, and wealth index intermediate and rich were reduced significant predictors of food insecurity.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by the Dilla University Institutional Research and Ethical Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

AA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing –

original draft, Writing – review & editing. DenA: Funding acquisition, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AH: Writing – review & editing, Conceptualization, Data curation, Investigation, Methodology, Resources, Visualization, Writing – original draft. BA: Funding acquisition, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. GK: Conceptualization, Formal analysis, Funding acquisition, Investigation, Project administration, Resources, Validation, Visualization, Writing – review & editing. LT: Formal analysis, Funding acquisition, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. DesA: Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

## Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

## Acknowledgments

The authors would like to thank Dilla University for their financial support. We would also like to express our gratitude to the data collectors and supervisors.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## References

1. Blumberg SJ, Bialostosky K, Hamilton WL, Briefel RR. The effectiveness of a short form of the household food security scale. *Am J Public Health*. (1999) 89:1231–4. doi: 10.2105/AJPH.89.8.1231

2. Tarasuk VS. Household food insecurity with hunger is associated with women's food intake, health, and household circumstances. *J Nutr*. (2001) 131:2670–6. doi: 10.1093/jn/131.10.2670

3. Bhattacharya J, Currie J, Haider S. Poverty, food insecurity, and nutritional outcomes in children and adults. *J Health Econ*. (2004) 23:839–62. doi: 10.1016/j.jhealeco.2003.12.008

4. Kaiser LL, Melgar-Quinonez H, Townsend MS, Nicholson Y, Fujii ML, Martin AC, et al. Food insecurity and food supplies in Latino households with young children. *J Nutr Educ Behav*. (2003) 35:148–53. doi: 10.1016/S1499-4046(06)60199-1

5. United Nations. Transforming our world: The 2030 agenda for sustainable development. New York: United Nations, Department of Economic and Social Affairs. (2015).

6. FAO, IFAD, UNICEF, WFP and WHO. The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome: FAO (2021).

7. FAO, Ifad, UNICEF, WFP, & WHO. The State of Food Security and Nutrition in the World 2019. Safeguarding against economic slowdowns and downturns. CC, Rome: FAO. Licence (2019).

8. Gebre GG, Rahut DB. Prevalence of household food insecurity in East Africa: linking food access with climate vulnerability. *Clim Risk Manag*. (2021) 33:100333. doi: 10.1016/j.crm.2021.100333

9. Anderson SA. Core indicators of nutritional state for difficult-to-sample populations. *J Nutr*. (1990) 120:1555–98. doi: 10.1093/jn/120.suppl_11.1555

10. FAO. The state of food insecurity in the world: Addressing food insecurity in protracted crises. Rome, Italy: FAO (2010).

11. Broca SS. Food insecurity, poverty and agriculture: a concept paper. Rome, Italy: FAO (2002).

12. Pinstrup-Andersen P. Food security: definition and measurement. *Food Secur*. (2009) 1:5–7. doi: 10.1007/s12571-008-0002-y

13. Campbell CC. Food insecurity: a nutritional outcome or a predictor variable? *J Nutr*. (1991) 121:408–15. doi: 10.1093/jn/121.3.408

14. Borders AE, Grobman WA, Amsden LB, Holl JL. Chronic stress and low birth weight neonates in a low-income population of women. *Obstet Gynecol*. (2007) 109:331–8. doi: 10.1097/01.AOG.0000250535.97920.b5

15. Laraia BA, Siega-Riz AM, Gundersen C. Household food insecurity is associated with self-reported pregravid weight status, gestational weight gain, and pregnancy complications. *J Am Diet Assoc*. (2010) 110:692–701. doi: 10.1016/j.jada.2010.02.014

16. Carmichael SL, Yang W, Herring A, Abrams B, Shaw GM. Maternal food insecurity is associated with increased risk of certain birth defects. *J Nutr*. (2007) 137:2087–92. doi: 10.1093/jn/137.9.2087

17. Cook JT, Black M, Chilton M, Cutts D, Ettinger de Cuba S, Heeren TC, et al. Are food insecurity's health impacts underestimated in the U.S. population? Marginal food security also predicts adverse health outcomes in young U.S. children and mothers. *Adv Nutr*. (2013) 4:51–61. doi: 10.3945/an.112.003228

18. Cook JT, Frank DA, Levenson SM, Neault NB, Heeren TC, Black MM, et al. Child food insecurity increases risks posed by household food insecurity to young children's health. *J Nutr*. (2006) 136:1073–6. doi: 10.1093/jn/136.4.1073

19. Bronte-Tinkew J, Zaslow M, Capps R, Horowitz A, McNamara M. Food insecurity works through depression, parenting, and infant feeding to influence overweight and health in toddlers. *J Nutr*. (2007) 137:2160–5. doi: 10.1093/jn/137.9.2160

20. Cook JT, Frank DA, Meyers AF, Berkowitz C, Black MM, Casey PH, et al. Food insecurity is associated with adverse health outcomes among human infants and toddlers. *J Nutr*. (2004) 134:1432–8. doi: 10.1093/jn/134.6.1432

21. Zaslow M, Bronte-Tinkew J, Capps R, Horowitz A, Moore KA, Weinstein D. Food security during infancy: implications for attachment and mental profciency in toddlerhood. *Matern Child Health J*. (2009) 13:66–80. doi: 10.1007/s10995-008-0329-1

22. Hernandez DC, Jacknowitz A. Transient, but not persistent, adult food insecurity influences toddler development. *J Nutr*. (2009) 139:1517–24. doi: 10.3945/jn.109.105593

23. Rose-Jacobs R, Black MM, Casey PH, Cook JT, Cutts DB, Chilton M, et al. Household food insecurity: associations with at-risk infant and toddler development. *Pediatrics*. (2008) 121:65–72. doi: 10.1542/peds.2006-3717

24. Moafi F, Kazemi F, Samiei Siboni F, Alimoradi Z. The relationship between food security and quality of life among pregnant women. *BMC Pregnancy Childbirth*. (2018) 18:1–9. doi: 10.1186/s12884-018-1947-2

25. Shone M, Demissie T, Yohannes B, Yohannis M. Household food insecurity and associated factors in west Abaya district. *Agric Food Secur*. (2017) 6:1–9. doi: 10.1186/s40066-016-0080-6

26. Nantale G, Mbona Tumwesigye N, Kiwanuka N, Kajjura R. Prevalence and factors associated with food insecurity among women aged 18-49 years in Kampala slums Uganda; a mixed methods study. *J Food Secur*. (2017) 5:120–8. doi: 10.12691/jfs-5-4-2

27. Coates J, Swindale A, Bilinsky P. Household food insecurity access scale (HFIAS) for measurement of food access: indicator guide questionnaire by food and nutrition technical assistance (FANTA) III, Washington, DC: USAID (2007).

28. Ghose B, Tang S, Yaya S, Feng Z. Association between food insecurity and anemia among women of reproductive age. *Peer J*. (2016) 4:e1945. doi: 10.7717/peerj.1945

29. EDHS. Central statistics agency. Ethiopian demographic and health survey. Ethiopia: Addis Ababa (2016).

30. Stevenson M., An introduction to survival analysis, (EpiCentre, IVABS, Massey University) (2009). pp. 1–32.

31. Mekuria A. Food insecurity: prevalence and associated factors among adult individuals receiving highly active antiretroviral therapy (HAART) in ART clinics of hosanna town, Hadiya zone, southern Ethiopia. *Open Access Libr J*. (2015) 2:1–9. doi: 10.4236/oalib.1101800

 10.3389/fpubh.2024.1399185

32. Samuel H, Egata G, Paulos W, Bogale TY, Tadesse M. Food insecurity and associated factors among households in Areka town, southern Ethiopia. *J Health Med Nurs*. (2019) 66:42–50. doi: 10.7176/JHMN

33. Getacher L, Egata G, Aynalem YA, Molla A, Tesfaye A, Abebe H, et al. Food insecurity and its predictors among lactating mothers in north Shoa zone, Central Ethiopia: a community based cross-sectional study. *BMJ Open*. (2020) 10:1–9. doi: 10.1136/bmjopen-2020-040627

34. Tadesse A. Household food insecurity and associated factors among households in Sodo town. *Food Sci Qual Manag*. (2015) 56:10–20. doi: 10.1186/s40066-017-0098-4

35. Ukegbu P, Nwofia B, Ndudiri U, Uwakwe N, Uwaegbute A, et al. Food insecurity and associated factors among university students. *Food Nutr Bull*. (2019) 40:271–81. doi: 10.1177/0379572119826464

36. Goldberg SL, Mawn BE. Predictors of food insecurity among older adults in the United States. *Public Health Nurs*. (2020) 32:397–407. doi: 10.1111/phn.12173

37. Abrahams Z, Lund C, Field S, Honikman S. Factors associated with household food insecurity and depression in pregnant south African women from a low socio-economic setting: a cross-sectional study. *Soc Psychiatry Psychiatr Epidemiol*. (2018) 53:363–72. doi: 10.1007/s00127-018-1497-y

38. Dadras AO, Nakayama T, Kihara M, Ono-Kihara M, Seyedalinaghi S, Dadras F. The prevalence and associated factors of adverse pregnancy outcomes among afghan women in Iran; 2020, the possible impacts of domestic violence, poor mental health, housing issues, and food security. *medRxiv*. (2021) 16:e0245007 doi: 10.1371/journal.pone.0245007

39. Tantu AT, Gamebo TD, Sheno BK. Household food insecurity and associated factors among households in Wolaita Sodo town. *Agric Food Secur*. (2017) 6:1–8.

40. Shakiba M, Salari A. Food insecurity status and associated factors among rural households in the north of Iran. *Nutr Health*. (2022) 27:301–7. doi: 10.1177/0260106021996840

# Frontiers in
# Public Health

**Explores and addresses today's fast-moving healthcare challenges**

One of the most cited journals in its field, which promotes discussion around inter-sectoral public health challenges spanning health promotion to climate change, transportation, environmental change and even species diversity.

---

## Discover the latest Research Topics

See more →


**Frontiers**

Avenue du Tribunal-Fédéral 34
1005 Lausanne, Switzerland
frontiersin.org

**Contact us**

+41 (0)21 510 17 00
frontiersin.org/about/contact