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# Exploring the interaction between health-promoting and health risk behaviours in health

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**Published in**
Frontiers in Public Health
Frontiers in Medicine

ISSN 1664-8714
ISBN 978-2-8325-4968-1
DOI 10.3389/978-2-8325-4968-1

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# Exploring the interaction between health-promoting and health risk behaviours in health

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**Citation**

Zhou, H., Jiang, F., Tang, Y.-l., eds. (2024). *Exploring the interaction between health-promoting and health risk behaviours in health*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-4968-1

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frontiers | Frontiers in Public Health

TYPE Editorial
PUBLISHED 21 May 2024
DOI 10.3389/fpubh.2024.1428819



OPEN ACCESS

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RECEIVED 07 May 2024
ACCEPTED 13 May 2024
PUBLISHED 21 May 2024

CITATION
Jiang F, Zhou H and Tang Y-l (2024) Editorial: Exploring the interaction between health-promoting and health risk behaviours in health. *Front. Public Health* 12:1428819. doi: 10.3389/fpubh.2024.1428819



# Editorial: Exploring the interaction between health-promoting and health risk behaviours in health

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KEYWORDS

**physical activity, health promotion, health-risk behaviors, lifestyle, interaction, health outcome**

Editorial on the Research Topic
Exploring the interaction between health-promoting and health risk behaviours in health

Health behaviors are pivotal determinants of individual wellbeing and are typically classified into health-promoting and health-risk behaviors (1). Understanding the complex interplay between these behaviors is crucial for designing effective health interventions and promoting overall health outcomes (2). In this Research Topic, the authors investigated the dynamic relationship between health promotion and health-risk behaviors in various health contexts.

One key aspect is the role of social and environmental factors in shaping health behaviors (3). Shi and Zhang underscored the influence of cultural beliefs on health attitudes and behaviors. Similarly, Wang et al. investigated the impact of social support on health-promoting behaviors among patients with type 2 diabetes mellitus. They highlighted the significance of interpersonal relationships in fostering positive health practices. Meanwhile, Huang et al. demonstrated that socioecological characteristics also affect health-promoting lifestyles.

Furthermore, health-promoting behaviors (Tao et al.), particularly physical exercise (Mu et al.), can mitigate negative emotions, yet strategies for improvement remain unclear (4). Zhang et al. designed an incentive program for promoting physical activity, revealing the multifaceted nature of behavior determinants. Yang et al. demonstrated that knowledge, attitudes, and practices were associated with health behaviors among middle school students. At the same time, Won and Shin indicated that health literacy was integral to health behaviors. These studies emphasize the importance of tailored approaches to address diverse population needs.

However, it is crucial to acknowledge the potential adverse consequences of certain behaviors on health outcomes (5). For instance, Qiu et al. revealed a positive association between television viewing and musculoskeletal disorders, which supports the known adverse effects of sedentary lifestyles. Similarly, findings from Jaswal et al., which linked alcohol consumption to smoking equivalents, and from Hou et al., which proved that unhealthy lifestyles linked with periodontitis, underscored the need to address multiple health risk behaviors comprehensively.

Moreover, interventions targeting specific populations, such as individuals with cardiovascular disease (Guo et al.), metabolic disorders (Jiang et al.), multiple sclerosis (Du et al.), or both cardiovascular and metabolic diseases (Li et al.), highlight the importance of personalized approaches in promoting health behaviors. These interventions encompass promoting physical activity, education, and socioeconomic factors influencing behavior change.

In conclusion, studies included in this Research Topic underscore the complex relationship between health-promoting and health-risk behaviors in shaping individuals' health trajectories. By shedding light on the intrinsic mechanisms and contextual elements that shape these behaviors, healthcare practitioners and policymakers can craft tailored interventions aimed at encouraging healthier lifestyles and alleviating the burden of preventable illnesses (6). Additionally, the content of this Research Topic could serve as a valuable material for textbooks on health behavior studies.

Future research should increasingly focus on promoting healthy behaviors and motivating individuals to take proactive actions toward their health, thereby effectively taking charge of their own health and wellbeing (7). This Research Topic requires a comprehensive exploration of multifaceted interventions spanning various domains such as education, healthcare, community engagement, and policy development. Utilizing innovative strategies grounded in behavioral science, technology, and social determinants of health, researchers can develop tailored approaches that resonate with diverse populations and address the underlying drivers of unhealthy behaviors. Furthermore, a multidisciplinary approach integrating insights from psychology, sociology, economics, and public health can offer holistic perspectives and novel solutions to encourage sustainable behavior change. Advancing knowledge in this domain is fundamentally important for nurturing a culture centered on health empowerment. Such a culture facilitates the empowerment of individuals to preserve their wellbeing. Consequently, this active engagement significantly contributes to the overall health of society.

## Author contributions

FJ: Conceptualization, Writing – original draft. HZ: Conceptualization, Writing – review & editing. Y-lT: Conceptualization, Writing – review & editing.

## 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 Social Science Foundation (23BGL292 to FJ). The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

## 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



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frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 01 November 2023
DOI 10.3389/fpubh.2023.1281740



OPEN ACCESS

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RECEIVED 23 August 2023
ACCEPTED 16 October 2023
PUBLISHED 01 November 2023

CITATION
Zhang J, Li Q, Zhang J, Zhao X, Jiang M, Huang X, Liu D, Yan Y, Li X, Chen J, Ma ZF, Zhang X, Ming W-K, Wong T-h, Yan G and Wu Y (2023) Chinese university students' preferences for physical activity incentive programs: a discrete choice experiment.
*Front. Public Health* 11:1281740.
doi: 10.3389/fpubh.2023.1281740



# Chinese university students' preferences for physical activity incentive programs: a discrete choice experiment

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**Purpose:** This study aims to explore and compare Chinese university students' preferences for various physical activity motivation programs.

**Patients and methods:** A cross-sectional study was conducted in China from February 25 to March 25, 2022. Participants anonymously completed an online questionnaire based on a DCE. A total of 1,358 university students participated in the survey. The conditional logit model (CLM), willingness to accept (WTA), and propensity score matching (PSM) were used to assess college students' preferences for different attributes and levels of physical activity incentive programs.

**Results:** Respondents identified the number of bonus, exercise time, and academic rewards as the three most significant attributes of the athletic incentive program. The importance of each attribute varied based on individual characteristics such as gender and BMI. In CLM, college students displayed a preference for a "¥4" bonus amount (OR: 2.04, 95% CI 1.95–2.13), "20 min" of exercise time (OR: 1.85, 95% CI 1.79–1.92), and "bonus points for comprehensive test scores" as academic rewards (OR: 1.33, 95% CI 1.28–1.37). According to the WTA results, college students were willing to accept the highest cost to obtain academic rewards tied to composite test scores.

**Conclusion:** The number of bonus, exercise time, and academic rewards emerge as the three most crucial attributes of physical activity incentive programs. Furthermore, college students with different characteristics exhibit heterogeneity in their preferences for such programs. These findings can guide the development of programs and policies aimed at motivating college students to engage in physical activities.

KEYWORDS

health behavior, management and policy, health promotion, willingness to accept, physical activity

# 1. Introduction

Regular physical activity provides numerous health benefits, such as enhancing immunity, preventing non-communicable diseases, and enhancing mental well-being. For optimal health benefits, adults should avoid sedentary behavior and engage in a weekly routine of no less than 150–300 min of moderate-intensity aerobic physical exertion or at least 75–150 min of vigorous-intensity aerobic activity or a balanced combination of both types (1, 2). However, despite these benefits, a lack of physical activity remains a widespread global issue.

In a 2018 Lancet publication, the authors collected data from 358 research endeavors spanning 168 countries, revealing that 27.5% of 1.9 million individuals engaged in inadequate physical exercise (3). Physical inactivity and sedentary lifestyles are associated with conditions such as obesity, cancer, cardiovascular disease, and diabetes (4, 5). Due to the substantial time college students dedicate to classrooms and scholastic pursuits, they are particularly vulnerable to physical inactivity and sedentariness (6–8).

According to the SHoT study (Students' Health and Well-being Study), the vast majority of college students' physical activity levels fail to meet recommended standards. Meanwhile, the trend toward overweight and obesity among colleges students continues to surge (9, 10). As per the guidelines set by the People's Republic of China's Ministry of Education, students in traditional Chinese institutions are expected to meet certain physical education requirements. Specifically, students are expected to complete 144 h of physical education coursework within 4 years (11). Nonetheless, the issue of low physical exercise levels among Chinese university students remains an acute concern. Furthermore, insufficient physical activity among university students may exert a deleterious impact on physical literacy, amplify feelings of anxiety and despondency, and curtail the overall health-related quality of life (12–14).

In light of this, it is essential to devise appropriate policies or interventions to ameliorate college students' physical activity levels. Given the substantial time spent in academia, schools play an indispensable role in promoting physical exercise among college attendees. Research shows a strong link between student physical activity and school policies (15). Moreover, studies have indicated the potential link between academic performance and the motivation to engage in physical activities. Schools can leverage academic achievements as incentives to encourage students to partake in physical endeavors (16); additionally, economic rewards emerge as a potent tool to motivate individuals to engage in physical activities (17).

Identifying individuals' preferences concerning the type and timing of physical activity programs holds paramount importance (18, 19). In response to these preferences, policymakers could devise incentive programs that cater to college students' reward preferences for physical exercise. Conducting a discrete choice experiment can help us understand college students' preferences for physical activity incentive programs. Discrete Choice Experiments (DCE) stand as a prominent quantitative method in health economics and policy research. Built on the foundation of random utility theory, DCE enables the assessment of both individual and group preferences for various behaviors (20). This methodology has previously proven effective in estimating preferences related to physical activity within specific populations. For instance, it has been utilized to gauge preferences for physical activity among patients experiencing non-specific low back pain and preferences regarding financial incentives to encourage physical activity among older adults (21, 22).

However, despite the proven value of DCE in designing incentive programs to promote physical activity, no prior studies have specifically examined the preferences of Chinese college students for such programs. Recognizing the significance of college students as a demographic group whose physical activity habits profoundly impact their immediate health and long-term well-being, this study employed DCE. Our aim was to explore Chinese college students' preferences and willingness to accept (WTA) incentive programs for physical activity. This exploration provides valuable insights into college students' choices and preferences for these programs, contributing to the development of more effective health policies and interventions aimed at increasing physical activity levels among them.

# 2. Materials and methods

## 2.1. Discrete choice experiment

The foundation of Discrete Choice Experiment (DCE) lies in the random utility theory in economics. This method proposes that entities can be defined by a set of important attributes and their corresponding levels (e.g., test procedure, detection rate, test cost). Consequently, individuals mentally compare these qualities and levels in hypothetical scenarios before making choices among different options.

## 2.2. Identification of attributes and levels

Various methodologies are employed in ascertaining attributes and levels for DCE, including literature reviews, expert consultations, existing health outcome metrics, surveys, interviews, and focus groups. Esteemed scholars in the field advocate for the prioritization of qualitative approaches in identifying these attributes and levels (23). Such qualitative methods allow researchers to capture respondents' perspectives, thus reducing the potential for attribute and level misspecification due to over-reliance on the researcher's viewpoints (24, 25).

In this investigation, a comprehensive array of attributes and levels for motivational strategies in physical activity was compiled by drawing insights from pertinent literature and contextualizing them within the milieu of Chinese universities (26–30). An expert panel comprising two sports experts, two medical professionals, and two

methodologists was convened to evaluate and appraise these attributes and levels. The panel received via email the attribute list, along with a concise overview. The experts individually assessed the attributes' relevance, feasibility, and degrees, offering their invaluable insights. The researchers duly considered these valuable suggestions and compiled a refined list of attribute levels, which was subsequently presented to a focus group for further deliberation.

The focus group comprised five physical education teachers and five undergraduate university students, who engaged in detailed interviews about the questionnaire. They deemed the questionnaire to be thoughtfully prepared but requested clarification on some listed attributes and levels. Respondents pointed out minor spelling errors, which were promptly rectified. Importantly, the number of attribute levels and the questionnaire's length were both deemed acceptable during the pretest. The completion of the survey took participants approximately 15–20 min. Aside from the minor spelling issues, the attributes and levels remained unchanged. Table 1 presents the six conclusively determined attributes concerning incentive techniques for physical exercise and their corresponding levels.

## 2.3. Experimental design and development of the questionnaire

Participants are invited to deliberate between diverse gradations of attributes, electing their preferred exercise incentive program. The DCE selection array is curated with six attributes, each featuring 3–4 tiers. An all-encompassing analytical design would entail 1,296 (4^2 × 3^4) potential choices, but this vastness proves excessive for a single survey and laborious for respondents to undertake. In pursuit of proportional inclusion of levels (level balancing) and to eliminate correlations among levels of distinct attributes, we devised a 16-choice set, employing a fractional ordinal orthogonal main effects design from the design compendium. Subsequently, respondents were randomly assigned to an 8-choice subset (orthogonality). To safeguard against any inherent bias in parameter estimation, we fashioned unlabeled choice experiments comprising three distinct choice scenarios, each harboring two discrete scenarios and an exit option.

The following sample size calculation formulas are commonly used in DCE studies. In the formula below, N stands for the minimum sample size advised, t for the number of tasks chosen, a for the number of choices made for each task, and c for the maximum number of attributes (31).

$$N \geq 500c / ta$$

Based on this formula, we determine $n \geq 125$ (t = 8, a = 2, and c = 4). We intend to collect a sample of 1,250. There is a large number of samples, which ensures that the calculation will be accurate and reliable.

The questionnaire is divided into three distinct sections. The initial segment delves into respondents' particulars, encompassing gender, age, household dynamics, academic level, scholastic achievements, living costs, BMI, and whether their parents are affiliated with the sports industry. Furthermore, we inquired about

TABLE 1 Attributes and levels of physical activity incentive programs.

| Attributes | Levels of attributes | Explain |
|---|---|---|
| Amount of bonus | ¥1 | The amount of prize money is set up to incentive university students to participate in the exercise incentive program, which is awarded at regular intervals. |
| | ¥2 | |
| | ¥3 | |
| | ¥4 | |
| Frequency of bonus payments | Paid every 4 weeks | Frequency of awarding prizes to university students participating in the exercise incentive program. |
| | Paid every 3 weeks | |
| | Paid every 2 weeks | |
| | Paid every 1 week | |
| Academic awards | Bonus points for moral education credits | Academic incentives for university students participating in the exercise incentive program. |
| | Bonus points for physical education test scores | |
| | Bonus points for comprehensive test scores | |
| Frequency of exercise | 5 times a week | Frequency of training in an exercise incentive program. |
| | 3 times a week | |
| | 1 time a week | |
| Exercise time | 60 min each time | Minimum time to be achieved in each exercise. |
| | 40 min each time | |
| | 20 min each time | |
| Conditions for receiving the award | Pass the physical fitness test | Conditions for participants to receive prizes and academic awards. |
| | Complete the exercise program on a regular basis and upload it to the online platform | |
| | Register for the exercise incentive program | |

respondents' visual health, mobile phone usage patterns, and habits related to smoking and alcohol consumption.

The second section of the survey employed the International Physical Activity Questionnaire Short Form (IPAQ-SF), a robust and reliable instrument comprising seven items, to gauge the participants' physical health and activity levels (32). This comprehensive questionnaire appraises and computes three distinct intensities of activity: low-intensity activity (3.3 METs)(Metabolic Equivalent of Task, MET), moderate-intensity activity (4.0 METs), and high-intensity activity (8.0 METs). Respondents were requested to disclose the frequency and duration of their engagement in each intensity of activity, provided it persisted for at least 10 min (33). Based on the following formula, each participant's total weekly exercise was calculated:

$$\begin{aligned}\text{Total MET} - \text{minutes / week} = {} & \text{Low PA}\left(\text{METs} \times \text{min} \times \text{days}\right) \\ & + \text{Moderate PA}\left(\text{METs} \times \text{min} \times \text{days}\right) \\ & + \text{Vigorous PA}\left(\text{METs} \times \text{min} \times \text{days}\right).\end{aligned}$$

Based on the derived computations, the respondents were classified into three distinct tiers of physical activity: the low-activity group (<600 MET-minute/week), the moderate-activity group (≥600 MET-minute/week), and the high-activity group (≥3,000 MET-minute/week).

The third segment of the questionnaire probed the respondents to contemplate their favored physical activity incentive program within a thought-provoking three-task choice scenario. Each scenario required the respondents to envision themselves embarking on a physical activity incentive program comprising six attributes, each with a maximum of four levels. Nine task selection scenarios were presented to each respondent, with three alternatives offered for each scenario. The initial among the nine choice sets was designated as a fixed choice set. By including extreme options in this set, the validity of the DCE was rigorously ascertained. An example of a task selection scenario is depicted in Table 2.

## 2.4. Data collection

This investigation employed a multi-stage sampling approach. Initially, 10 university students hailing from distinct schools in China's eastern, central, and western regions were meticulously selected as enumerators, factoring in their geographical location and the economic development of the respective regions (amounting to a total of 30 enumerators). These adept enumerators were entrusted with the task of administering the questionnaires, with each one accountable for collecting 40–60 questionnaires. Prior to the survey, all enumerators underwent comprehensive and standardized training. The inclusion criteria comprised the following: (i) ordinary full-time undergraduates, encompassing both four-year and five-year programs, but excluding specialists; (ii) current residential students, excluding day students; (iii) individuals capable of participating in regular sports activities; and (iv) those proficient in independently completing the Chinese electronic questionnaire. Notably, no personally identifiable information was gathered in the questionnaire. In order to commence answering the questions and complete the questionnaire, respondents were required to select the "agree to participate in the survey" option, thereby signifying their voluntary engagement in the study. They were duly informed of the safeguarding of their privacy by law. Data collection for the survey spanned from 25 February to 25 March 2022.

## 2.5. Statistical analysis

Data analyses were conducted using lighthouse studio version 9.13.2 and SPSS (Statistical Package for the Social Sciences) version 25.0. The results of the descriptive analysis are presented as numbers of percentage stages regarding the participants' general characteristics. In this study's analysis, we employed a conditional logit model (CLM) (34, 35). CLM assist in assessing the influence of various attributes and levels on college students' engagement in physical activity incentive programs and can gauge the relative significance of these attributes to college students. In this model, respondents' choices served as the dependent variable, while the attributes investigated in the study were treated as the independent variables. The numerical representation of this model can be expressed as follows:

$$\begin{aligned}U_{ijs} = {} & \beta_1 \text{bonus}\left(2\right) + \beta_2 \text{bonus}\left(3\right) + \beta_3 \text{bonus}\left(4\right) \\ & + \beta_4 \text{frequency of payments}\left(3\text{weeks}\right) \\ & + \beta_5 \text{frequency of payments}\left(2\text{weeks}\right) \\ & + \beta_6 \text{frequency of payments}\left(1\text{week}\right) \\ & + \beta_7 \text{academic awards}\left(\text{physical education test scores}\right) \\ & + \beta_8 \text{academic awards}\left(\text{comprehensive test scores}\right) \\ & + \beta_9 \text{frequency of exercise}\left(3\text{ times}\right) \\ & + \beta_{10} \text{frequency of exercise}\left(1\text{ time}\right) \\ & + \beta_{11} \text{exercise time}\left(40\text{min}\right) \\ & + \beta_{12} \text{exercise time}\left(20\text{min}\right) \\ & + \beta_{13} \text{Award conditions}\left(\text{Completion of the incentive program}\right) \\ & + \beta_{14} \text{Award conditions}\left(\text{Registered Incentive Program}\right) + \varepsilon_{\text{ijs}}\end{aligned}$$

Where $U_{ijs}$ is the utility for individual I for scenario j ($j = 1, 2$) in the choice set s ($s = 1, 2, 3$). $\beta$ are a fixed vector of parameters for each attribute level.

We determined preference heterogeneity across classes, including $p$-value, Odds ratios (OR), and 95%CI, by digitally encoding features and levels. OR are metrics frequently employed in DCE to enhance comprehension of the CLM. The choice of the reference level for each characteristic serves as the foundation for the calculation of OR and 95% CI. Statistics on the respondents' preference weights for each characteristic and level may be deduced from the CLM. Its sign—whether positive or negative—indicates the respondents' preference.

We also represented the bonus amount as a continuous variable to compute respondents' Willingness to Accept (WTA),as shown in the following formula. Amid the formula, $\beta_X$ stands for nonprice attributes, and $\beta_{\text{Price}}$ stands for price attributes.

$$\text{WTA}(X) = \frac{\beta_X}{\beta_{\text{Price.}}}$$

When assessing a person's WTP, we can determine how much they are willing to give up to choose one attribute level over another. WTA analysis via DCE has been applied to various interventions in different markets, including smoking cessation incentive programs, medication adherence incentive programs, vaccine preferences, and more (36–38). We want to use the WTA as an indicator to understand

TABLE 2 Example discrete choice experiment question.

| | Option A | Option B | Option C |
|---|---|---|---|
| Amount of bonus | ¥2 | ¥3 | Choose nothing |
| Frequency of bonus payments | Paid every 2 weeks | Paid every 4 weeks | |
| Academic awards | Bonus points for physical education test scores | Bonus points for comprehensive test scores | |
| Frequency of exercise | 5 times a week | 1 time a week | |
| Exercise time | 20 min each time | 60 min each time | |
| Conditions for receiving the award | Complete the exercise program on a regular basis and upload it to the online platform | Register for the exercise incentive program | |
| | ☐ | ☐ | ☐ |

better university students' preferences for various attributes and levels of the exercise incentive program.

Finally, we also conducted a subgroup analysis using propensity score matching (PSM) to understand the preferences of university students for various attributes of physical activity motivation strategies across gender, residence status, body mass index, and physical activity level. PSM is a regression method to identify patients in treatment and control groups with similar underlying characteristics. This method is commonly used in studies of impact factors, policy decisions, or case studies (39, 40). PSM is primarily based on the Roy-Robin theory (41–43). We matched each group of respondents according to their demographic characteristics (e.g., age, academic performance, and cost of living).

## 2.6. Ethics

This study was reviewed and approved by the ethics committees of the Shaanxi Health Culture Research Center (JKWH-2022-03). All methods were performed by the relevant guidelines and regulations (Declaration of Helsinki). Informed consent was obtained from all participants.

# 3. Results

## 3.1. Participants' general information

Table 3 shows the general characteristics of each responder. A total of 1,475 respondents filled out the official survey; 1,358 (92.07%) of them passed the validity test, while 117 failed the logical tests' one-choice sets. We thoroughly went over each respondent's response before excluding them. 706 (51.9%) of the respondents who passed the validity test were female, and 55.45% were between the ages of 23 and over. A total of 28.06% of respondents were senior students, and 21.50% of respondents were first-year students. There were 179 (13.18%) respondents whose parents worked in sports-related industries. There are 170 (27.25%) respondents living from ¥1,101 to ¥1,400. 1,068 (78.65%) respondents had myopia problems, and only 211 respondents (15.54%) were without vision problems. A total of 182 (13.40%) respondents were overweight or obese on the Body Mass Index. 1,095 respondents had a high or medium level of physical activity, and 263 respondents had a low level of physical activity. 564 (41.53%) respondents spent more than 4 h a day using their cell phones. There are 605 (44.55%) respondents who never consumed alcohol and 1,187 (87.41%) respondents who never smoked or smoked for less than 6 months.

## 3.2. University students' preferences for the exercise incentive program

Utilizing the CLM, we can ascertain the relative significance assigned by the respondents to each attribute of the exercise incentive program. Among the identified attributes, the "amount of the prize" emerged as the most pivotal, garnering a substantial importance score of 33%. Following closely, the attributes of "time to exercise" and "academic rewards" secured the second and third positions with significance scores of 28 and 13%, respectively. Comparatively, the attribute of "condition of receiving the reward" obtained the least prominence, bearing an importance score of 7% (Figure 1).

The results of the conditional logit model are shown in Table 4. It can be seen from the table that the utility of other attributes is statistically significant, except for "Frequency of bonus payments: paid every 3 weeks," "Frequency of exercise: 3 times a week," and" Conditions for receiving the award: Complete the exercise program regularly and upload it to the online platform. "As we expected, college students have different preferences for each level of attributes. Of all levels, "exercise time = 20 min each time" ($\beta = 0.34$, $p < 0.001$) is the most preferred of the respondents; the second is "amount of bonus = ¥4″ ($\beta = 0.34$, $p < 0.001$). It should not be ignored that the difference in utility between "paid every 1 week" ($\beta = 0.07$, $p = 0.003$) and "paid every 2 weeks" ($\beta = 0.06$, $p = 0.006$) is very little. For attribute academic awards, respondents preferred "bonus points for comprehensive test scores" ($\beta = 0.17$, $p < 0.001$) to other levels. Among attributes, frequency of exercise, and Conditions for receiving the award, respondents preferred "1 time a week" ($\beta = 0.12$, $p < 0.001$) and "Register for the exercise incentive program" ($\beta = 0.06$, $p = 0.001$).

In our calculation, we found that the odds ratio of some attributes' levels is greater than 1, compared with the reference level, and the lower limit of 95% CI is also greater than 1. It means that college students are willing to choose other more advantageous levels than the reference level. Take the example of the attribute frequency of exercise. When using level "5 times a week" as a reference, the odds ratio for levels "3 times a week" and "1 time a week" are 1.14 (95%CI = 1.10 ~ 1.18) and 1.29 (95%CI = 1.24 ~ 1.33). As the attribute' frequency of exercise' decreases, the OR increases, meaning that university students prefer a lower exercise frequency in their choice of exercise incentive program. Therefore, university students prefer exercise incentive schemes that are less frequent and shorter, have more bonuses and payout bonuses more frequently, can increase total test scores and require only registration to receive awards.

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TABLE 3 General characteristics of all respondents ($N = 1,358$).

| Characteristics | *N* | Proportion (%) |
|---|---|---|
| Gender | | |
| Male | 652 | 48.01 |
| Female | 706 | 51.99 |
| Age (years) | | |
| ≤22 | 605 | 44.55 |
| ≥23 | 753 | 55.45 |
| Nature of residence | | |
| Non-agricultural residence | 773 | 56.92 |
| Agricultural residence | 585 | 43.08 |
| Grade Level | | |
| Freshman year | 292 | 21.50 |
| Sophomore year | 348 | 25.63 |
| Third Year | 337 | 24.81 |
| Senior year | 381 | 28.06 |
| Parents in sports-related industries | | |
| Yes | 179 | 13.18 |
| No | 1,179 | 86.82 |
| Living expenses(¥) | | |
| ≤800 | 53 | 3.90 |
| 801–1,100 | 228 | 16.79 |
| 1,101–1,400 | 370 | 27.25 |
| 1,401–1700 | 305 | 22.46 |
| 1701–2000 | 222 | 16.35 |
| >2000 | 180 | 13.25 |
| Vision Health | | |
| No vision problems | 211 | 15.54 |
| Myopia | 1,068 | 78.65 |
| Hyperopia | 37 | 2.72 |
| Amblyopia | 42 | 3.09 |
| Astigmatism | 329 | 24.23 |
| Others | 19 | 1.40 |
| Body mass index (BMI) | | |
| Thin | 222 | 16.35 |
| Normal | 954 | 70.25 |
| Overweight | 157 | 11.56 |
| Obesity | 25 | 1.84 |
| Physical activity level | | |
| High | 168 | 12.37 |
| Medium | 927 | 68.26 |
| low | 263 | 19.37 |
| Hours of mobile phone use per day | | |
| <1 h | 43 | 3.17 |
| 1 ~ 2 h | 94 | 6.92 |
| 2 ~ 3 h | 353 | 25.99 |
| 3 ~ 4 h | 304 | 22.39 |
| >4 h | 564 | 41.53 |
| Frequency of alcohol consumption in the last year | | |
| Never | 605 | 44.55 |
| No more than once a month | 492 | 36.23 |
| 2–4 times per month | 210 | 15.46 |
| 2–3 times per week | 36 | 2.65 |
| More than 4 times per week | 15 | 1.11 |
| Smoked continuously or cumulatively for 6 months | | |
| Yes | 171 | 12.59 |
| No | 1,187 | 87.41 |

## 3.3. Willingness to accept

The findings from the Willingness to Accept (WTA) estimation shed light on the comparison of college students' preferences for the exercise incentive program concerning monetary aspects (Table 5). Based on the WTA results, it was observed that college students display a willingness to accept the highest cost to receive academic awards for total test scores (¥1.16). The second most significant aspects are engaging in each exercise session lasting 20 min (¥1.01) and exercising once a week (¥1.01). Regarding the frequency of bonus payments, there was marginal disparity in WTA between college students receiving a bonus every week (¥0.58) or every 2 weeks (¥0.60). Among the conditions for receiving rewards, their preference is to register for the exercise incentive program (¥0.48).

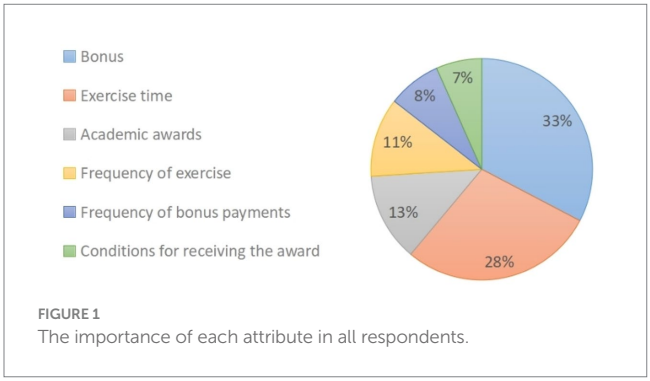


FIGURE 1
The importance of each attribute in all respondents.

## 3.4. Differences in university students' preferences for exercise incentive programs by different characteristics

Utilizing propensity score matching, we conducted an analysis of college students' preferences for each attribute of the physical activity incentive program across gender, household nature, body mass index, and physical activity level. The pre-matching and post-matching comparisons across groups, along with the results from conditional logit models, have been presented in the Supplementary material.

TABLE 4 General results of the conditional logit model.

| Attributes | *β* | SE | *t* | *p* | *OR* | 95%CI | |
|---|---|---|---|---|---|---|---|
| Amount of bonus | | | | | | | |
| ¥1* | −0.38 | 0.02 | −16.16 | <0.001 | REF | REF | REF |
| ¥2 | −0.07 | 0.02 | −3.18 | 0.002 | 1.36 | 1.30 | 1.42 |
| ¥3 | 0.11 | 0.02 | 5.06 | <0.001 | 1.63 | 1.56 | 1.70 |
| ¥4 | 0.34 | 0.02 | 14.98 | <0.001 | 2.04 | 1.95 | 2.13 |
| Frequency of bonus payments | | | | | | | |
| paid every 4 weeks* | −0.10 | 0.02 | −4.61 | <0.001 | REF | REF | REF |
| paid every 3 weeks | −0.02 | 0.02 | −1.05 | 0.292 | 1.08 | 1.03 | 1.13 |
| paid every 2 weeks | 0.06 | 0.02 | 2.76 | 0.006 | 1.18 | 1.13 | 1.23 |
| paid every 1 week | 0.07 | 0.02 | 2.93 | 0.003 | 1.19 | 1.13 | 1.24 |
| Academic awards | | | | | | | |
| bonus points for moral education credits* | −0.11 | 0.02 | −6.09 | <0.001 | REF | REF | REF |
| bonus points for physical education test scores | −0.06 | 0.02 | −3.38 | 0.001 | 1.05 | 1.01 | 1.09 |
| bonus points for comprehensive test scores | 0.17 | 0.02 | 9.53 | <0.001 | 1.33 | 1.28 | 1.37 |
| Frequency of exercise | | | | | | | |
| 5 times a week* | −0.13 | 0.02 | −7.09 | <0.001 | REF | REF | REF |
| 3 times a week | 0.01 | 0.02 | 0.29 | 0.769 | 1.14 | 1.10 | 1.18 |
| 1 time a week | 0.12 | 0.02 | 6.89 | <0.001 | 1.29 | 1.24 | 1.33 |
| Exercise time | | | | | | | |
| 60 min each time* | −0.28 | 0.02 | −15.06 | <0.001 | REF | REF | REF |
| 40 min each time | −0.07 | 0.02 | −3.69 | <0.001 | 1.23 | 1.19 | 1.28 |
| 20 min each time | 0.34 | 0.02 | 19.08 | <0.001 | 1.85 | 1.79 | 1.92 |
| Conditions for receiving the award | | | | | | | |
| Pass the physical fitness test* | −0.09 | 0.02 | −4.78 | <0.001 | REF | REF | REF |
| Complete the exercise program on a regular basis and upload it to the online platform | 0.03 | 0.02 | 1.46 | 0.145 | 1.12 | 1.08 | 1.16 |
| Register for the exercise incentive program | 0.06 | 0.02 | 3.37 | 0.001 | 1.16 | 1.12 | 1.20 |

*REF, reference level.

TABLE 5 Willingness to accept (WTA) for each attribute ($N = 1,358$).

| Attributes and levels | WTA (¥) |
|---|---|
| Frequency of bonus payments | |
| paid every 4 weeks* | REF |
| paid every 3 weeks | 0.28 |
| paid every 2 weeks | 0.60 |
| paid every 1 week | 0.58 |
| Academic awards | |
| bonus points for moral education credits* | REF |
| bonus points for physical education test scores | 0.21 |
| bonus points for comprehensive test scores | 1.16 |
| Frequency of exercise | |
| 5 times a week* | REF |
| 3 times a week | 0.60 |
| 1 time a week | 1.01 |
| Exercise time | |
| 60 min each time* | REF |
| 40 min each time | 0.60 |
| 20 min each time | 1.01 |
| Conditions for receiving the award | |
| Pass the physical fitness test* | REF |
| Complete the exercise program on a regular basis and upload it to the online platform | 0.38 |
| Register for the exercise incentive program | 0.48 |

*REF, reference level.

In terms of attribute importance, both male and female participants considered "Amount of bonus" and "Exercise time" to be the two most crucial attributes. However, males attributed greater significance to "Amount of bonus" (43.38%), whereas females emphasized the importance of "Exercise time" (32.27%). The most preferred level for males was "Amount of bonus = ¥4" ($\beta = 0.43$, $p < 0.001$), while for females, it was "Exercise time = 20 min each time" ($\beta = 0.47$, $p < 0.001$).

Furthermore, for males, the attributes ranked in descending order of importance are "Academic rewards" (16.27%), "Frequency of bonus payments" (7.71%), "Frequency of exercise" (5.74%), and "Conditions for receiving the award" (3.78%). In contrast, for females, the order of importance is "Frequency of exercise" (14.85%), "Academic rewards" (9.70%), "Conditions for receiving the award" (9.35%), and "Frequency of bonus payments" (6.78%).

No significant difference in attribute importance was found between university students from non-agricultural and agricultural households. The ranking of importance for each attribute was as follows: "Amount of bonus," "Exercise time," "Academic rewards," "Frequency of bonus payments," "Frequency of exercise," and "Conditions for receiving the award."

We observed that university students with different body mass indexes displayed differing importance for the attributes of the incentive program. Thin and average university students considered "Amount of bonus" (36.79%) the most critical, followed by "Exercise time" (22.83%), "Academic rewards" (14.15%), "Frequency of exercise" (13.08%), "Frequency of bonus payments" (10.33%), and "Conditions for receiving the award" (2.81%). The most preferred level for them was "Amount of bonus = ¥4" ($\beta = 0.46$, $p < 0.001$).

On the other hand, overweight and obese university students valued "Exercise time" (28.03%) the most, followed by "Amount of bonus" (22.35%), "Academic rewards" (16.69%), "Frequency of bonus payments" (12.93%), "Conditions for receiving the award" (10.63%), and "Frequency of exercise" (9.37%). Their most preferred level was "Exercise time = 20 min each time" ($\beta = 0.36$, $p < 0.001$).

Additionally, we found that the physical activity level of university students influenced the relative importance of "Academic rewards" and "Frequency of exercise." Those with a low level of physical activity considered "Academic rewards" (10.11%) to be more significant, while those with a medium or high level of physical activity valued "Frequency of exercise" (16.00%) more. For the remaining attributes, "Amount of bonus" and "Exercise time" remained the two most important attributes, with "Frequency of bonus payments" being the least important. The most preferred level for them was "Amount of bonus = ¥4." For more detailed information, please refer to the Supplementary material.

## 4. Discussion

Through a comprehensive questionnaire survey and data analysis from 1,358 participants, we find that the attribute "bonus amount" emerges as the most critical and prioritized factor among the incentive measures, emphasizing the financial incentives in influencing college students. Among the six incentive attributes, attributes such as "single exercise duration" and "academic incentives" secure the second and third positions. Furthermore, college students prefer regular financial rewards for their accuracy, effectiveness, and dire financial needs. Additionally, academic rewards hold paramount importance for college students. Our study concludes that college students prefer immediate and tangible rewards.

Considering that college students necessitate stable financial incomes, they display heightened sensitivity to financial rewards, prompting a preference for regular bonuses. As a result, institutions can allocate a portion of their financial resources to incentive college students to participate in physical exercise. Simultaneously, initiating recurring sports competitions with associated rewards can effectively promote physical activities on campus. Furthermore, emphasizing the significance of physical health as the foundation for all activities, particularly for graduates embarking on their professional journey, it can foster the development of exercise habits before entering the workforce.

In tandem with the expansion of higher education, the competition among college students has become increasingly intense. Consequently, they attach great importance to academic performance, viewing all activities in the context of their academic achievements, which profoundly impact their future development. In the survey, respondents show favor the measure of "extra score points in a comprehensive test." As a response, schools can appropriately enhance the proportion of physical education scores in the overall assessment of college students, thereby elevating its importance and motivating students to accord more attention to physical exercise. Moreover,

various studies corroborate that physical exercise not only bears no detrimental effects on academic performance but also enhances cognitive abilities and academic achievements to a certain extent (44).

Moreover, our study indicates college students' preference for short-term physical exercise. While some studies recommend a 90-min minimum for physical exercise to avoid harm to the body (45), particularly for individuals with irregular exercise habits, other studies have discovered that a 10-min set of joint exercises not only enhances physical fitness but also improves students' attention and concentration (46). Additionally, studies involving children indicate that short-term aerobic exercise of varying intensity exerts selective positive effects on executive function (47). Therefore, even if college students engage in shorter and less frequent exercise sessions, it contributes to physical health, fitness, and academic performance. Furthermore, once an exercise habit is firmly established, it can significantly contribute to college students' physical and psychological well-being over an extended period (48–50).

In parallel, we explore the differences in exercise incentive program preferences among university students based on various characteristics. Males exhibit a stronger preference for the attribute "Amount of bonus," while females prioritize "Exercise time." This difference may be attributed to gender disparities in personality and physiology (51). Moreover, the survey indicates a trend that females in our sample placed greater emphasis on the exercise process and duration of exercise, as these factors are often associated with weight management and overall well-being. Simultaneously, women often associate good health with a certain level of physical exercise. Additionally, university students with different body mass indexes display distinct preferences for incentive program attributes. For those with lower and average body mass indexes, the "Amount of bonus" ranks as the most critical attribute. Conversely, overweight and obese university students prioritize "Exercise time." Average-weight students find physical exercise more manageable, allowing them to focus on completing exercise tasks effectively and obtaining rewards. In contrast, overweight or obese students recognize the challenges of exercise and are therefore more concerned about the time devoted to exercise. Consequently, schools should consider flexible adjustments based on students' weight levels when devising strategies to motivate their participation in physical activities.

Finally, the demand for physical activity varies significantly among individuals with different exercise levels (52). Hence, accurately identifying the appropriate type and level of exercise suitable for the target audience is essential. Additionally, incorporating scientific, safe, and popular physical exercise methods that align with students' interests can effectively promote physical exercise among college students (53). For instance, sports, dance, physical exercise, and fitness aerobics programs that align with college students' psychological needs for physical attractiveness can enhance their interest in physical activities.

In this study, we investigated the preferences of college students concerning physical activity incentive programs. Furthermore, we applied propensity score matching to examine the variability in college students' preferences for such programs across several factors like gender, family income level, and body mass index. The results of this analysis helped us to better comprehend the influence of demographic characteristics on their preferences for different features and levels of incentives. To ensure the quality and precision of the DCE, we collaborated with a team of experts specializing in sports, education, and methodology. After conducting an extensive literature review, we held interviews with these experts to identify the most relevant attributes and levels for the DCE.

However, it is essential to acknowledge certain limitations in this study. Firstly, given the vast population of college students in China, our sample data dose not fully encapsulate the entire college student population, thereby potentially leading to selection bias and impacting the generalizability of the findings. Despite the meticulous selection of attribute levels through literary reviews and expert advice, the hypothetical scenarios presented in the questionnaire may not perfectly mirror real-life situations. Moreover, this study focused on only six attributes of physical activity incentive programs, possibly overlooking other influential factors in such programs. Finally, the utilization of self-reported preferences from college students introduces subjectivity, which may affect the study's degree of objectivity.

This study makes a substantial contribution to our comprehension of college students' preferences for physical activity incentive programs. We employed propensity score matching to scrutinize these preferences, enhancing the statistical rigor of our analysis and allowing us to explore variations across factors such as gender and body mass index. To ensure the quality and precision of the Discrete Choice Experiment (DCE), we collaborated with a multidisciplinary team of experts specializing in sports, education, and research methodology. Following an extensive literature review, we conducted interviews with these experts to identify the most pertinent attributes and attribute levels for the DCE.

However, it is imperative to acknowledge several limitations in this study. Firstly, due to the vast population of college students in China, our sample data may not fully represent the entire college student population. This potential sampling bias could impact the generalizability of our findings. And we fail to provide a comprehensive analysis for more individual characteristics. Despite our meticulous selection of attribute levels through literature reviews and expert advice, the hypothetical scenarios presented in the questionnaire may not perfectly reflect real-life situations. Additionally, our study focused exclusively on six attributes of physical activity incentive programs, potentially overlooking other influential factors within these programs. Lastly, the reliance on self-reported preferences from college students introduces a degree of subjectivity, which may influence the objectivity of our study.

## 5. Conclusion

Based on the findings of a discrete choice experiment, this study presents college students' preferences for physical activity incentive programs. The results reveal that prize amounts, exercise time, and academic rewards are the three most crucial attributes of the program. Students tend to prefer higher financial and academic rewards while minimizing their physical activity time. Furthermore, we observed variations in college students' preferences for physical activity incentive programs based on individual characteristics such as gender, BMI, and physical activity level. These characteristics significantly influence students' preferences for incentive programs. Therefore, it is recommended that educational institutions tailor physical activity incentive programs to meet the diverse needs of college students. This customization could involve designing varied reward structures that

encompass financial and academic aspects and creating customized physical activity programs aligned with the unique characteristics of students of different genders and body weight levels. These strategies can enhance college students' adherence to physical activity incentive programs, promoting a healthier and more active lifestyle among them.

## 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.

## Ethics statement

The studies involving humans were approved by the ethics committees of the Shaanxi Institute of International Trade & Commerce. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

## Author contributions

JingbZ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft. QL: Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Conceptualization, Project administration. JingzZ: Formal analysis, Visualization, Writing – review & editing. XiaZ: Investigation, Writing – original draft. MJ: Writing – original draft. XH: Writing – original draft. DL: Investigation, Writing – review & editing. YY: Investigation, Writing – review & editing. XL: Investigation, Writing – review & editing. JC: Writing – review & editing. ZM: Writing – review & editing. XiyZ: Writing – review & editing. W-KM: Software, Writing – review & editing. T-hW: Writing – review & editing. GY: Conceptualization, Funding acquisition, Resources, Supervision, Writing – review & editing. YW: Conceptualization, Funding acquisition, Resources, Supervision, 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 supported by the Shaanxi Provincial Education Science Planning Project (SGH21Y0484) and the Harbin Medical University School of Humanities Research Fund Project (HMURW20210204).

## Acknowledgments

We are extremely grateful to all study participants for the use of their personal data. We would like to express our deepest gratitude to everyone who participated and cooperated in the surveys.

## 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.2023.1281740/full#supplementary-material

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frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 16 November 2023
DOI 10.3389/fpubh.2023.1292712



OPEN ACCESS

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RECEIVED 12 September 2023
ACCEPTED 31 October 2023
PUBLISHED 16 November 2023

CITATION
Li L, Dai F and Zhang D (2023) The effect of exercise intensity types on the self-rated health status of young-old comorbidities patients: a cross-sectional study in Guangdong, China. *Front. Public Health* 11:1292712. doi: 10.3389/fpubh.2023.1292712



# The effect of exercise intensity types on the self-rated health status of young-old comorbidities patients: a cross-sectional study in Guangdong, China

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**Objective:** Explore the effect of different types of exercise intensity on the self-rated health status of young-old comorbid patients with cardiovascular disease and metabolic disease, as well as the differences in effect among different genders. Provide more references and suggestions for chronic disease management in older comorbidities patients based on the results of the study.

**Methods:** A multi-stage stratified cluster random sampling method was used to select older (≥60 years old) comorbidities patients from communities in Guangdong Province as the survey subjects. Using the "Survey Questionnaire on the Current Status and Influencing Factors of older Comorbidities Patients," face-to-face interviews were conducted with 1,300 old patients. Data from 965 young-old patients (aged 60–74) who simultaneously suffered from cardiovascular and metabolic diseases were selected. Unordered multifactor Logistic regression analysis was used to explore the association between the type of exercise intensity and self-rated health. Stratified analysis was performed based on gender.

**Results:** The results of unordered multivariate logistic regression analysis showed that compared with young-old comorbidities patients with poor self-rated of health status, young-old comorbidities patients who underwent vigorous-intensity exercise were more likely to have better self-rated of health status (OR = 4.368, 95% CI: 2.491–7.661, $p < 0.05$). Stratified analysis based on gender showed that for young-old comorbidities male patients, those who engaged in vigorous-intensity exercise were more likely to have better self-rated of health status (OR = 2.924, 95% CI = 1.266–6.751, $p < 0.05$); for young-old comorbidities female patients, those who were encouraged by their family to exercise (OR = 2.460, 95% CI: 1.143–5.291, $p < 0.05$), participate in social activities (OR = 6.173, 95% CI: 2.285–16.678, $p < 0.05$), and engage in vigorous-intensity (OR = 4.232, 95% CI: 1.869–9.583, $p < 0.05$) or moderate-intensity exercise (OR = 4.555, 95% CI: 1.825–11.368, $p < 0.05$) were more likely to have better self-rated of health status.

**Conclusion:** If the physical condition allows, vigorous-intensity exercise has a significant positive effect on the self-rated of health status of young-old comorbidities patients with cardiovascular disease and metabolic disease. Specifically, for young-old comorbidities male patients, those who engage in vigorous-intensity exercise are more likely to self-evaluate their health as good; for young-old comorbidities female patients, both vigorous-intensity and moderate-intensity exercise can improve their self-rated of health status.

KEYWORDS

young-old, older comorbidities, chronic disease, physical activity, exercise intensity, self-rated health

# 1. Introduction

As residents' life expectancy increases, the disease spectrum is changing. According to the recent research by the British Medical Journal (BMJ), aging is currently the main factor causing comorbidities in high-income countries around the world, and the proportion of people with two or more diseases is continuously increasing (1). WHO defined that comorbidities refer to the simultaneous presence of two or more chronic diseases in an individual (2). Older comorbidities refer to people aged 60 and above who suffer from comorbidities and are the main group of chronic comorbidities (3). The probability of comorbidities have exceeded the probability of getting one single chronic disease (4); in the study by Zhang et al., it was found that among the middle-aged and older population aged 50 and above in China, the number of comorbidities patients is 2.4 times that of patients with one single chronic disease (5). Compared to suffering from one single chronic disease, chronic comorbidities can significantly reduce the quality of life of older patients, cause more health losses, increase the economic burden on families, and consume more social medical resources. The issue of older comorbidities patients has become one of the main public health issues in China (and even the world), and it is a major challenge that countries must face in building an aging society (6). If there is a lack of scientific and efficient methods for the prevention and management of chronic comorbidities, it will increase the burden of medical services and affect the normal life of individuals, families, and society (7).

A study analyzed data from the 2018 China Health and Retirement Longitudinal Study (CHARLS) and found that the probability of chronic comorbidities among older people aged 60 and above in Guangdong Province were 43.7% (8); the research of Wang et al. found that the main chronic diseases were hypertension, chronic pain, inflammatory connective tissue disease, diabetes and dyslipidemia in Guangdong Province (9). The harm brought by chronic comorbidities to the older people is continuously accumulating, so the key to managing chronic comorbidities in older patients should be moved forward, and more attention should be paid to prevention and control compared to treatment and relief. Lack of exercise is an independent risk factor for chronic disease (10). In the chronic disease management guidelines of other countries, the importance of sports is emphasized, especially for cardiovascular and cerebrovascular diseases, diabetes and musculoskeletal diseases (11, 12), and different sports methods have different effects on the prevention/rehabilitation of chronic diseases. Therefore, identifying and analyzing the effect of exercise patterns or intensity on the health of older comorbidities patients has positive significance for optimizing clinical diagnosis and treatment guidelines for chronic comorbidities and health management of comorbidities patients (13).

Previous studies have explored the association between exercise and older people' health from multiple perspectives such as the type and frequency of exercise (14, 15), and have shown that the health benefits of exercise vary depending on demographic characteristics (16). There have been studies that have shown gender differences in the association between exercise and health (17) and between health behavior and the onset of chronic diseases (18). Therefore, different guidance measures should be taken for male and female older comorbidities patients in preventing chronic disease or improving the quality of life of chronic disease patients through exercise behavior. However, there are currently few studies focusing on gender differences in the management of chronic diseases in young-old comorbidities patients with different exercise intensity. Therefore, in order to better understand the effect of different types of exercise on the health of older comorbidities patients of different genders, this study intended to use the data from "The current situation and influencing factors of older comorbidities in Guangdong Province" to explore the effect of different types of exercise intensity on the health status of older comorbidities patients. Further this article analyzed the different effects on male and female older comorbidities patients and explore the reasons. Suggestions were also provided for the practice of older chronic comorbidities patients' management, promoting the health of older patients with chronic comorbidities.

# 2. Materials and methods

## 2.1. Data source and data sampling

The data comes from a questionnaire survey of older chronic comorbidities patients in communities in Guangdong Province. Based on the Health Status Survey Scale (SF-36) [Chinese Version (19)], Health Promotion Lifestyle Scale (HPLP-C) (20), and 8-item Morisky Questionnaire (MMAS-8) (21), a survey questionnaire on the current situation and influencing factors of older comorbidities was designed, which included socio-demographic data and disease-related data, including gender, age, marital status, residential status, education level, duration of illness, work status, per capita annual income of families, body mass index (BMI), number and types of comorbidities, exercise style, exercise frequency, self-rated of health status, lifestyle, and self-management ability. The effectiveness and feasibility of this questionnaire survey has been proven through Delphi expert consultation method and pre survey experiments. A questionnaire survey was conducted by interviewing patients with chronic comorbidities by community general practice clinics, centralized discussions among residents, hospital management graduate students, general practice standardized training interns, community general practitioners, and nurses who have undergone unified training as investigators.

This survey used the Guangdong Provincial Community Resident Health Record Information System and adopted a multi-stage stratified cluster random sampling method. In the first stage, three cities were randomly selected in Guangdong Province based on economic level and geographical location. In the second stage, three districts were randomly selected from each city. In the third stage,

three communities were randomly selected from each district for investigation. After signing the informed consent, we investigated the patients aged over 60 and living in the community for more than 1 year, and have been diagnosed with two or more chronic diseases (mainly combined with hypertension, diabetes, hyperlipidemia, coronary heart disease, stroke, diabetes, chronic obstructive pulmonary disease, osteoporosis, osteoarthropathy and other common chronic diseases) by hospitals at the second level or above. A total of 1,300 older comorbidities patients were surveyed based on the proportion of older comorbidities patients in the city to the old population, according to the formula for calculating the sample size of a cross-sectional survey, $N = \mu_{\frac{\alpha/2}{2}}{}^2 P(1-P)/\delta^2$ (22), $\alpha = 0.05$, and taking into account a 20% inefficiency. An effective questionnaire is defined as survey data without missing values and duplicate responses are removed. A total of 1,000 valid datasets were obtained, with a questionnaire effective recovery rate of 76.9%.

Previous studies have classified older people in the age group of 60–74 as young-old people (23). Most of these older people are in good physical condition and have the ability to take care of themselves. In contrast, they have better physical activity and responsiveness among the entire old population, and their acceptance and benefit from exercise are also relatively high. Therefore, this study sets the target user as the older people aged 60–74.According to the follow-up data of CHARLS in 2018 (the latest data released in September 2020), the prevalence of cardiovascular diseases (such as hypertension, dyslipidemia (high/low cholesterol), heart disease, stroke) and metabolic diseases (such as diabetes or elevated blood sugar) among older people with chronic comorbidity were relatively high (24), which indicated that these two types of diseases have a greater effect on the older patients with chronic comorbidity. Therefore, we selected 965 patients with both cardiovascular and metabolic diseases from the 1,000 young-old comorbidities patients effectively surveyed to continue the following study.

## 2.2. Outcome variables

Self-rated of health refers to a comprehensive evaluation of the health status of individuals based on their comprehensive physical, psychological, social, and role functions (25), which is simple and easy to implement. It allows users to understand the overall status of individuals and predict health-related mortality rates (26) by asking "What do you think of your health status." Most researchers believe that self-rated health can reliably measure the health status and quality of life of older people (27), and previous studies have shown that self-rated health indicators have good validity among Chinese older people (28). When self-rated health indicators are used to estimate overall health status, explore factors influencing health, and determine overall health needs in research, biases may not have a substantial effect on the results. In large-scale social surveys, especially for older people, using self-rated health indicators to measure health status has an advantage that other measurement tools cannot match (25). Therefore, this article uses self-rated of health to measure the health level of older people.

In this study, we used the self-rated of health of the respondents as the outcome variable. Specifically, the response was measured using a 5-point Likert scale (29): 1 = very good, 2 = good, 3 = average, 4 = poor, and 5 = very poor. According to previous research (30, 31), we used a score of 3 as the cutoff point, and respondents who answered "1" or "2" were classified as good and assigned a value of 1; the respondents who answered "3" were still average and assigned a value of 2; respondents who answer "4" or "5" were classified as poor and assigned a value of 3.

## 2.3. Independent variables

In CHARLS, the definition of high-intensity exercise is that "vigorous activities make you breathe much harder than normal and may include heavy lifting, digging, plowing, aerobics, fast bicycling, and cycling with a heavy load." The definition of moderate-intensity exercise is that "moderate physical activities make you breathe somewhat harder than normal and may include carrying light loads, bicycling at a regular pace, or mopping the floor." The definition of low intensity exercise is that "low intensity exercise includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure." Based on this, the present study combines the definitions of exercise modes and exercise frequency for older adults from the "Physical Activity Guidelines for the Chinese Population (2021)" (32) and the "Physical Activity Guidelines for Americans" (33), as well as the intensity classification from previous research (34). The classification of exercise intensity into five categories, namely sedentary activity, light-intensity activity, moderate-intensity activity, vigorous-intensity activity, and high-intensity activity, was adopted following the method proposed by Norton et al. (35). However, since the target population of this study is older people, sedentary activity and high-intensity activity are less likely to occur. Therefore, the final classification of exercise types includes light-intensity activity, moderate-intensity activity, and vigorous-intensity activity. The determination of the exercise type was based on the participants' exercise methods and frequency.

The independent variable of this study is the type of exercise intensity. According to the previous literature (36), the control variables we included are gender, age, BMI, comorbidity duration, household registration type, education level, per capita annual income, living conditions, marital status, family members' supervision on exercise, participation in social activities, taking health care products, and sleep quality. After conducting an overall analysis, we divided the respondents into two groups based on gender: male and female, and conducted separate analyses. The specific assignment of variables is shown in Table 1.

## 2.4. Statistical analysis

Since all included variables are categorical variables, the $\chi^2$-test was used to detect the correlation between each variable and self-rated health. Due to the parallel test, the result was $p < 0.05$. Therefore, an unordered multivariate logistic regression model was used to analyze the effect of exercise intensity types on the self-rated health of young-old patients with chronic comorbidities. The control variables

TABLE 1 Variables and assignments of independent variables.

| Self-assessment of health status | Good = 1, Average = 2, Bad = 3 |
|---|---|
| Exercise intensity type | Vigorous-intensity = 1, Moderate-intensity = 2, Light-intensity = 3 |
| Variables | Assignment |
| Gender | Male = 1, Female = 2 |
| Age | 60–64 = 1, 65–69 = 2, 70–74 = 3 |
| BMI | Low weight = 1, Normal weight = 2, Overweight = 3, Obesity = 4 |
| Comorbidity duration | Less than 6 years = 1, 6–10 years = 2, More than 10 years = 3 |
| Household registration type | Urban registration = 1, Rural registration = 2 |
| Education level | Junior high school and below = 1, High school/Polytechnic school = 2, Junior college = 3, College and above = 4 |
| Per capita annual income | Less than 30,000 yuan = 1, 30,000–50,000 yuan = 2, More than 50,000 yuan = 3 |
| Living conditions | Living alone = 1, Living with spouse = 2, Living with children = 3 |
| Marital status | Married = 1, Widowed = 2, Separated/Divorced = 3 |
| Will family members supervise exercise | Will = 1, Will not = 2 |
| Whether respondents participates in social activities | Yes = 1, No = 2 |
| Does respondents take health products | Yes = 1, No = 2 |
| Can respondents have at least 6 h of sleep per day | Yes = 1, No = 2 |

with statistical significance in the $\chi^2$-test were input into the model using the forward stepping method. In the unordered multivariate logistic regression model, the dependent variable was the self-rated poor health as the control, and the independent variable is the one with the highest assigned value as the control. And a stratified and unordered multivariate logistic regression analysis was conducted on men and women based on gender. The data is represented as adjusted ORs (aORs) and their corresponding 95% confidence intervals. SPSS 27.0 software was used for statistical analysis, and $p < 0.05$ was used as the statistically significant difference.

# 3. Results

## 3.1. Characteristics of sampling respondents

Table 2 shows the characteristics of young-old patients with chronic comorbidities related to self-rated health ($n = 965$). Overall, 406 (42.07%) older patients with chronic comorbidities engaged in vigorous-intensity exercise, 175 (18.14%) engaged in moderate-intensity exercise, and 384 (39.79%) engaged in light-intensity exercise; 365 (37.82%) young-old patients with chronic comorbidities reported good self-rated health status, 472 (48.92%) reported average self-rated health status, and 128 (13.26%) reported poor self-rated health status. Specifically, there was a statistically significant difference ($p < 0.05$) in the self-rated health status of different genders, BMI, comorbidity duration, household registration types, per capita annual income, living conditions, marital status, family members' supervision on exercise, participation in social activities, taking health care products, sleep qualities and exercise intensity types.

After grouping the data by gender, Table 3 shows that out of 496 young-old male patients with chronic comorbidities, 172 (34.67%) engaged in vigorous-intensity exercise, 96 (19.36%) engaged in moderate-intensity exercise, and 228 (45.97%) engaged in light-intensity exercise; 152 (30.64%) reported good health status, 284 (57.26%) reported average health status, and 60 (12.10%) reported poor health status. There were statistically significant differences ($p < 0.05$) in the self-rated health status of different ages, BMI, comorbidity duration, household registration types, living conditions, marital status, family members' supervision on exercise, taking health care products, and exercise intensity types. Table 4 shows that out of 469 young-old female patients with chronic comorbidities, 234 (49.89%) engaged in vigorous-intensity exercise, 79 (16.85%) engaged in moderate-intensity exercise, and 156 (33.26%) engaged in light-intensity exercise; 213 (45.41%) reported good health status, 188 (40.09%) reported average health status, and 68 (14.50%) reported poor health status. There were statistically significant differences ($p < 0.05$) in the self-rated health status of different BMI, comorbidity duration, household registration types, per capita annual income, living conditions, family members' supervision on exercise, participation in social activities, taking health care products, sleeping qualities, and exercise intensity types.

## 3.2. Gender, exercise intensity and self-rated of health

Using the self-rated of health among young-old patients with chronic comorbidities as the dependent variable and the statistically significant indicators in Table 2 as the independent variable, the model used the forward step method for an unordered multivariate logistic regression analysis. As shown in Table 5, compared with young-old comorbidities patients with poor self-rated health status, young-old patients who had been suffering from chronic comorbidities duration for less than 6 years (OR = 2.475, 95% CI: 1.292–4.743, $p < 0.05$) and engaged in vigorous-intensity exercise (OR = 4.368, 95% CI: 2.491–7.661, $p < 0.05$) were more likely to have better self-rated health status; Young-old patients who took health supplements were less likely to have a good self-rated health status (OR = 0.215, 95% CI: 0.132–0.351, $p < 0.05$); young-old male (OR = 1.926, 95% CI: 1.250–2.969, $p < 0.05$), with comorbidities duration less than 6 years (OR = 2.660, 95% CI: 1.468–4.818, $p < 0.05$), having family members' supervision on exercise (OR = 2.298, 95% CI: 1.428–3.699, $p < 0.05$) and doing vigorous-intensity exercise (OR = 2.422, 95% CI: 1.406–4.173, $p < 0.05$) were more likely to have average self-rated health status; young-old patients who lived alone (OR = 0.351, 95% CI: 0.149–0.825, $p < 0.05$) and took health supplements (OR = 0.342, 95% CI: 0.220–0.532, $p < 0.05$) were less likely to have an average self-rated of their health status.

Randomized multivariate logistic regression analysis was conducted on male and female patients, and the results are shown in

TABLE 2 Comparison of self-rated health of young-old comorbidities patients with different data.

| Variables | *N* | Good self-rated health [*n*(%)] | Average self-rated health [*n*(%)] | Poor self-rated health [n(%)] | | *p*-value |
|---|---|---|---|---|---|---|
| Exercise intensity type | | | | | 63.384 | <0.001 |
| Vigorous-intensity | 406 | 207(51.0) | 173(42.6) | 26(6.4) | | |
| Moderate-intensity | 175 | 54(30.9) | 90(51.4) | 31(17.7) | | |
| Light-intensity | 384 | 104(27.1) | 209(54.4) | 71(18.5) | | |
| Gender | | | | | 29.488 | <0.001 |
| Male | 496 | 152(30.6) | 284(57.3) | 60(12.1) | | |
| Female | 469 | 213(45.4) | 188(40.1) | 68(14.5) | | |
| Age | | | | | 5.784 | 0.216 |
| 60–64 | 365 | 145(39.7) | 174(47.7) | 46(12.6) | | |
| 65–69 | 513 | 188(36.6) | 261(50.9) | 64(12.5) | | |
| 70–74 | 67 | 29(36.8) | 28(42.5) | 10(20.7) | | |
| BMI | | | | | 28.077 | <0.001 |
| Low weight | 55 | 14(25.5) | 32(58.2) | 9(16.4) | | |
| Normal weight | 610 | 206(33.8) | 321(52.6) | 83(80.9) | | |
| Overweight | 246 | 126(51.2) | 90(36.6) | 30(12.2) | | |
| Obesity | 54 | 19(35.2) | 29(53.7) | 6(11.1) | | |
| Comorbidity duration | | | | | 47.822 | <0.001 |
| Less than 6 years | 372 | 112(30.1) | 224(60.2) | 36(9.7) | | |
| 6–10 years | 438 | 208(47.5) | 166(37.9) | 64(14.6) | | |
| More than 10 years | 155 | 45(37.6) | 82(36.3) | 28(18.1) | | |
| Household registration types | | | | | 8.849 | 0.012 |
| Urban registration | 798 | 318(39.8) | 381(47.7) | 99(12.4) | | |
| Rural registration | 167 | 47(28.1) | 91(54.5) | 29(17.4) | | |
| Education level | | | | | 12.019 | 0.062 |
| Junior high school and below | 211 | 71(33.6) | 103(48.8) | 37(17.5) | | |
| High school/Polytechnic school | 292 | 108(37.0) | 155(53.1) | 29(9.9) | | |
| Junior college | 242 | 89(36.8) | 116(47.9) | 37(15.3) | | |
| College and above | 220 | 97(44.1) | 98(44.5) | 25(11.4) | | |
| Per capita annual income | | | | | 12.938 | 0.012 |
| Less than 30,000 yuan | 164 | 46(28.0) | 91(55.5) | 27(16.5) | | |
| 30,000–50,000 yuan | 341 | 137(40.2) | 171(50.1) | 33(9.7) | | |
| More than 50,000 yuan | 460 | 182(39.6) | 210(45.7) | 68(14.8) | | |
| Living conditions | | | | | 29.049 | <0.001 |
| Living alone | 53 | 12(22.6) | 27(50.9) | 14(26.4) | | |
| Living with spouse | 733 | 308(42.0) | 335(45.7) | 90(12.3) | | |
| Living with children | 179 | 45(25.1) | 110(61.5) | 24(13.4) | | |
| Marital status | | | | | 17.854 | 0.001 |
| Married | 910 | 352(38.7) | 446(49.0) | 112(12.3) | | |
| Widowed | 52 | 11(21.2) | 25(48.1) | 16(30.8) | | |
| Separated/Divorced | 3 | 2(66.7) | 1(33.3) | 0(0.0) | | |

*(Continued)*

TABLE 2 (Continued)

| Variables | *N* | Good self-rated health [*n*(%)] | Average self-rated health [*n*(%)] | Poor self-rated health [n(%)] | | *p*-value |
|---|---|---|---|---|---|---|
| Will family members supervise exercise | | | | | 17.398 | <0.001 |
| Yes | 742 | 286(38.5) | 376(50.7) | 80(10.8) | | |
| No | 223 | 79(35.4) | 96(43.0) | 48(21.5) | | |
| Whether respondents participates in social activities | | | | | 29.696 | <0.001 |
| Yes | 832 | 337(40.5) | 401(48.2) | 94(11.3) | | |
| No | 133 | 28(21.1) | 71(53.4) | 34(25.6) | | |
| Does respondents take health products | | | | | 51.531 | <0.001 |
| Yes | 232 | 54(23.3) | 119(51.3) | 59(25.4) | | |
| No | 733 | 311(42.4) | 353(48.2) | 69(9.4) | | |
| Can respondents have at least 6 h of sleep per day | | | | | 42.552 | <0.001 |
| Yes | 419 | 202(49.3) | 172(42.0) | 36(8.8) | | |
| No | 370 | 163(29.4) | 300(54.1) | 92(16.6) | | |

TABLE 3 Comparison of self-rated health of young-old comorbidities male patients with different data.

| Variables | *N* | Good self-rated health [*n*(%)] | Average self-rated health [*n*(%)] | Poor self-rated health [n(%)] | | *P*-value |
|---|---|---|---|---|---|---|
| Exercise intensity type | | | | | 22.924 | <0.001 |
| Vigorous-intensity | 172 | 75(43.6) | 84(48.8) | 13(7.6) | | |
| Moderate-intensity | 96 | 21(21.9) | 58(60.4) | 17(17.7) | | |
| Light-intensity | 228 | 56(24.6) | 142(62.3) | 30(13.2) | | |
| Age | | | | | 20.403 | <0.001 |
| 60–64 | 169 | 60(35.5) | 95(56.2) | 14(8.3) | | |
| 65–69 | 278 | 83(29.9) | 164(59.0) | 31(11.2) | | |
| 70–74 | 49 | 9(18.4) | 25(51.0) | 15(30.6) | | |
| BMI | | | | | 15.823 | 0.012 |
| Low weight | 28 | 8(28.6) | 14(50.0) | 6(21.4) | | |
| Normal weight | 297 | 81(27.3) | 184(62.0) | 32(10.8) | | |
| Overweight | 138 | 57(41.3) | 63(45.7) | 18(13.0) | | |
| Obesity | 33 | 6(18.2) | 23(69.7) | 4(12.1) | | |
| Comorbidity duration | | | | | 33.742 | <0.001 |
| Less than 6 years | 211 | 59(28.0) | 135(64.0) | 17(8.1) | | |
| 6–10 years | 188 | 78(41.5) | 91(48.4) | 19(10.1) | | |
| More than 10 years | 97 | 15(15.5) | 58(59.8) | 24(24.7) | | |
| Household registration types | | | | | 17.510 | 0.004 |
| Urban registration | 389 | 123(31.6) | 222(57.1) | 44(11.3) | | |
| Rural registration | 107 | 29(27.1) | 62(57.9) | 16(15.0) | | |
| Education level | | | | | 12.019 | 0.062 |

*(Continued)*

TABLE 3 (Continued)

| Variables | *N* | Good self-rated health [*n*(%)] | Average self-rated health [*n*(%)] | Poor self-rated health [n(%)] | | *P*-value |
|---|---|---|---|---|---|---|
| Junior high school and below | 87 | 25(28.7) | 45(51.7) | 17(19.5) | | |
| High school/Polytechnic school | 152 | 34(22.4) | 103(67.8) | 15(9.9) | | |
| Junior college | 151 | 50(33.1) | 81(53.6) | 20(13.2) | | |
| College and above | 106 | 43(40.6) | 55(51.9) | 8(7.5) | | |
| Per capita annual income | | | | | 3.170 | 0.531 |
| Less than 30,000 yuan | 86 | 22(25.6) | 51(59.3) | 13(15.1) | | |
| 30,000–50,000 yuan | 180 | 60(33.3) | 103(57.2) | 17(9.4) | | |
| More than 50,000 yuan | 230 | 70(30.4) | 130(56.5) | 30(13.0) | | |
| Living conditions | | | | | 19.534 | 0.001 |
| Living alone | 40 | 7(17.5) | 21(52.5) | 12(30.0) | | |
| Living with spouse | 360 | 125(34.7) | 196(54.4) | 39(10.8) | | |
| Living with children | 96 | 20(20.8) | 67(69.8) | 9(9.4) | | |
| Marital status | | | | | 11.556 | 0.008 |
| Married | 459 | 144(31.4) | 266(58.0) | 49(10.7) | | |
| Widowed | 35 | 7(20.0) | 17(48.6) | 11(31.4) | | |
| Separated/Divorced | 2 | 1(50.0) | 1(50.0) | 0(0.0) | | |
| Will family members supervise exercise | | | | | 7.009 | 0.031 |
| Yes | 371 | 105(28.3) | 225(60.6) | 41(11.1) | | |
| No | 125 | 47(37.6) | 59(47.2) | 19(15.2) | | |
| Whether respondents participates in social activities | | | | | 3.420 | 0.182 |
| Yes | 412 | 132(32.0) | 234(56.8) | 46(11.2) | | |
| No | 84 | 20(23.8) | 50(59.5) | 14(16.7) | | |
| Does respondents take health products | | | | | 19.671 | <0.001 |
| Yes | 115 | 18(15.7) | 75(65.2) | 22(19.1) | | |
| No | 381 | 134(35.2) | 209(54.9) | 38(10.0) | | |
| Can respondents have at least 6 h of sleep per day | | | | | 3.741 | 0.155 |
| Yes | 182 | 63(34.6) | 94(51.6) | 25(13.7) | | |
| No | 314 | 89(28.3) | 190(60.5) | 35(11.1) | | |

Tables 6, 7. With young-old comorbidities male patients with poor self-rated health status as the control group, young-old male patients who had been suffering from chronic comorbidities for less than 6 years (OR = 6.167, 95% CI: 2.527–15.050, $p < 0.05$), 6–10 years (OR = 5.157, 95% CI: 2.137–12.444, $p < 0.05$), and engaged in vigorous-intensity exercise (OR = 2.924, 95% CI: 1.266–6.751, $p < 0.05$) were more likely to have better self-rated health status; Young-old male patients with chronic comorbidities who took health supplements were less likely to have a good self-rated health status (OR = 0.206, 95% CI: 0.093–0.455, $p < 0.05$); Young-old male patients with chronic comorbidities who had been suffering from chronic comorbidities diagnosed for less than 6 years were more likely to have an average self-rated health status (OR = 3.602, 95% CI: 1.736–7.476, $p < 0.05$); young-old male patients with chronic comorbidities who lived alone (OR = 0.273, 95% CI: 0.093–0.801, $p < 0.05$) and took health supplements (OR = 0.482, 95% CI: 0.251–0.927, $p < 0.05$) were less likely to have an average self-rated of their health status.

With young-old female chronic comorbidities with poor self-rated health status as the control, young-old female patients who were supervised by their family to exercise (OR = 2.460, 95% CI:

TABLE 4 Comparison of self-rated health of young-old comorbidities female patients with different data.

| Variables | *N* | Good self-rated health [*n*(%)] | Average self-rated health [*n*(%)] | Poor self-rated health [n(%)] | | *P*-value |
|---|---|---|---|---|---|---|
| Exercise intensity type | | | | | 44.002 | <0.001 |
| Vigorous-intensity | 234 | 132(56.4) | 89(38.0) | 13(5.6) | | |
| Moderate-intensity | 79 | 33(41.8) | 32(40.5) | 14(17.7) | | |
| Light-intensity | 156 | 48(30.8) | 67(42.9) | 41(26.3) | | |
| Age | | | | | 4.519 | 0.340 |
| 60–64 | 196 | 85(43.4) | 79(40.3) | 32(16.3) | | |
| 65–69 | 235 | 105(44.7) | 97(41.3) | 33(14.0) | | |
| 70–74 | 38 | 23(60.5) | 12(31.6) | 3(7.9) | | |
| BMI | | | | | 29.408 | <0.001 |
| Low weight | 27 | 6(22.2) | 18(66.7) | 3(11.1) | | |
| Normal weight | 313 | 125(39.9) | 137(43.8) | 51(16.3) | | |
| Overweight | 108 | 69(63.9) | 27(25.0) | 12(11.1) | | |
| Obesity | 21 | 13(61.9) | 6(28.6) | 2(9.5) | | |
| Comorbidity duration | | | | | 29.194 | <0.001 |
| Less than 6 years | 161 | 53(32.9) | 89(55.3) | 19(11.8) | | |
| 6–10 years | 250 | 130(52.0) | 75(30.0) | 45(18.0) | | |
| More than 10 years | 58 | 30(51.7) | 24(41.4) | 4(6.9) | | |
| Household registration types | | | | | 7.435 | 0.023 |
| Urban registration | 409 | 195(47.7) | 159(38.9) | 55(13.4) | | |
| Rural registration | 60 | 18(30.0) | 29(48.3) | 13(21.7) | | |
| Education level | | | | | 9.129 | 0.165 |
| Junior high school and below | 124 | 46(37.1) | 58(46.8) | 20(16.1) | | |
| High school/Polytechnic school | 140 | 74(52.9) | 52(37.1) | 14(10.0) | | |
| Junior college | 242 | 39(42.9) | 35(38.5) | 17(18.7) | | |
| College and above | 220 | 54(47.4) | 43(37.7) | 17(14.9) | | |
| Per capita annual income | | | | | 12.715 | 0.012 |
| Less than 30,000 yuan | 78 | 24(30.8) | 40(51.3) | 14(17.9) | | |
| 30,000–50,000 yuan | 161 | 77(47.8) | 68(42.2) | 16(9.9) | | |
| More than 50,000 yuan | 230 | 112(48.7) | 80(34.8) | 38(16.5) | | |
| Living conditions | | | | | 10.602 | 0.025 |
| Living alone | 13 | 5(38.5) | 6(46.2) | 2(15.4) | | |
| Living with spouse | 373 | 183(49.1) | 139(37.3) | 51(13.7) | | |
| Living with children | 83 | 25(30.1) | 43(51.8) | 15(18.1) | | |
| Marital status | | | | | 6.327 | 0.107 |
| Married | 451 | 208(46.1) | 180(39.9) | 63(14.0%) | | |
| Widowed | 17 | 4(23.5) | 8(47.1) | 5(29.4) | | |
| Separated/Divorced | 1 | 1(100.0) | 0(0.0) | 0(0.0) | | |
| Will family members supervise exercise | | | | | 21.379 | <0.001 |
| Yes | 371 | 181(48.8) | 151(40.7) | 39(10.5) | | |
| No | 98 | 32(32.7) | 37(37.8) | 29(29.6) | | |

*(Continued)*

TABLE 4 (Continued)

| Variables | *N* | Good self-rated health [*n*(%)] | Average self-rated health [*n*(%)] | Poor self-rated health [n(%)] | | *P*-value |
|---|---|---|---|---|---|---|
| Whether respondents participates in social activities | | | | | 31.777 | <0.001 |
| Yes | 420 | 205(48.8) | 167(39.8) | 48(11.4) | | |
| No | 49 | 8(16.3) | 21(42.9) | 20(40.8) | | |
| Does respondents take health products | | | | | 35.020 | <0.001 |
| Yes | 117 | 36(30.8) | 44(37.6) | 37(31.6) | | |
| No | 352 | 177(50.3) | 144(40.9) | 31(8.8) | | |
| Can respondents have at least 6 h of sleep per day | | | | | 58.629 | <0.001 |
| Yes | 419 | 139(61.0) | 78(34.2) | 11(4.8) | | |
| No | 370 | 74(30.7) | 110(45.6) | 57(23.7) | | |

TABLE 5 Random multivariate logistic regression analysis of the factors influencing self-rated health status in young-old comorbidities patients.

| Influencing factors | Good self-rated health status | | | Average self-rated health status | | |
|---|---|---|---|---|---|---|
| | OR | (95%CI) | *P* | OR | (95%CI) | *P* |
| Intercept | | | 0.689 | | | 0.259 |
| Exercise intensity type: Light-intensity | | | | | | |
| Vigorous-intensity | 4.368 | (2.491, 7.661) | <0.001 | 2.422 | (1.406, 4.173) | 0.001 |
| Moderate-intensity | 1.594 | (0.887, 2.865) | 0.119 | 0.995 | (0.579, 1.709) | 0.985 |
| Gender: Female | | | | | | |
| Male | 1.021 | (0.649, 1.606) | 0.929 | 1.926 | (1.250, 2.969) | 0.003 |
| BMI: Obesity | | | | | | |
| Low weight | 0.659 | (0.171, 2.545) | 0.545 | 0.702 | (0.204, 2.415) | 0.575 |
| Normal weight | 0.912 | (0.322, 2.582) | 0.862 | 0.889 | (0.333, 2.371) | 0.814 |
| Overweight | 1.220 | (0.412, 3.611) | 0.719 | 0.594 | (0.211, 1.672) | 0.324 |
| Comorbidity duration: More than 10 years | | | | | | |
| Less than 6 years | 2.475 | (1.292, 4.743) | 0.006 | 2.660 | (1.468, 4.818) | 0.001 |
| 6–10 years | 1.552 | (0.849, 2.836) | 0.153 | 0.965 | (0.553, 1.686) | 0.901 |
| Living conditions: Living with children | | | | | | |
| Living alone | 0.456 | (0.169, 1.232) | 0.122 | 0.351 | (0.149, 0.825) | 0.016 |
| Living with spouse | 1.459 | (0.797, 2.671) | 0.221 | 0.644 | (0.372, 1.114) | 0.115 |
| Will family members supervise exercise: No | | | | | | |
| Yes | 1.325 | (0. 802, 2.188) | 0.272 | 2.298 | (1.428, 3.699) | 0.001 |
| Does respondents take health products: No | | | | | | |
| Yes | 0.215 | (0.132, 0.351) | <0.001 | 0.342 | (0.220, 0.532) | <0.001 |
| Can respondents have at least 6 h of sleep per day: No | | | | | | |
| Yes | 1.631 | (0.977, 2.722) | 0.062 | 1.048 | (0.640, 1.714) | 0.853 |

TABLE 6 Random multivariate logistic regression analysis of the factors influencing self-rated health status in young-old comorbidities male patients.

| Influencing factors | Good self-rated health status | | | Average self-rated health status | | |
|---|---|---|---|---|---|---|
| | OR | (95%CI) | *P* | OR | (95%CI) | *P* |
| Intercept | | | 0.531 | | | 0.071 |
| Exercise intensity type: Light-intensity | | | | | | |
| Vigorous-intensity | 2.924 | (1.266, 6.751) | 0.012 | 1.305 | (0.592, 2.875) | 0.509 |
| Moderate-intensity | 0.672 | (0.285, 2.584) | 0.363 | 0.627 | (0.301, 1.306) | 0.212 |
| BMI: Obesity | | | | | | |
| Low weight | 0.924 | (0.148, 5.733) | 0.933 | 0.361 | (0.075, 1.739) | 0.204 |
| Normal weight | 1.623 | (0.367, 7.170) | 0.523 | 0.975 | (0.277, 3.432) | 0.968 |
| Overweight | 1.631 | (0.363, 7.332) | 0.523 | 0.500 | (0.138, 1.805) | 0.290 |
| Comorbidity duration: More than 10 years | | | | | | |
| Less than 6 years | 6.167 | (2.527, 15.050) | <0.001 | 3.602 | (0.169, 2.889) | 0.001 |
| 6–10 years | 5.157 | (2.137, 12.444) | <0.001 | 1.995 | (0.044, 0.697) | 0.065 |
| Living conditions: Living with children | | | | | | |
| Living alone | 0.297 | (0.079, 1.118) | 0.073 | 0.273 | (0.093, 0.801) | 0.018 |
| Living with spouse | 1.129 | (0.437, 2.915) | 0.802 | 0.535 | (0.231, 1.235) | 0.143 |
| Will family members supervise exercise: No | | | | | | |
| Yes | 0.881 | (0.422, 1.841) | 0.736 | 1.862 | (0.945, 3.667) | 0.072 |
| Does respondents take health products: No | | | | | | |
| Yes | 0.881 | (0.093, 0.455) | <0.001 | 0.482 | (0.251, 0.927) | 0.029 |

1.143–5.291, $p < 0.05$), participated in social activities (OR = 6.173, 95% CI: 2.285–16.678, $p < 0.05$), had at least 6 h of sleep per day (OR = 4.314, 95% CI: 1.895–9.819, $p < 0.05$), and engaged in vigorous-intensity (OR = 4.232, 95% CI: 1.869–9.583, $p < 0.05$) and moderate-intensity (OR = 4.555, 95% CI: 1.825–11.368, $p < 0.05$) exercise were more likely to have better self-rated health status; young-old female patients with chronic comorbidities who had been suffering from chronic comorbidities for 6–10 years (OR = 0.211, 95% CI: 0.053–0.844, $p < 0.05$) and had taken health supplements (OR = 0.227, 95% CI: 0.109–0.476, $p < 0.05$) were less likely to have a good self-rated health status; young-old female patients with chronic comorbidities who were supervised by their families to exercise (OR = 2.796, 95% CI: 1.330–5.875, $p < 0.05$), participated in social activities (OR = 2.410, 95% CI: 1.079–5.383, $p < 0.05$), and engaged in vigorous-intensity exercise (OR = 3.077, 95% CI: 1.379–6.870, $p < 0.05$) were more likely to have an average self-rated health status; young-old female patients with chronic comorbidities who had been suffering from chronic comorbidities for 6–10 years (OR = 0.176, 95% CI: 0.044–0.697, $p < 0.05$) and have took health supplements (OR = 0.225, 95% CI: 0.111–0.457, $p < 0.05$) were less likely to have an average self-rated health status.

## 4. Discussion

We found that young-old patients with chronic comorbidities who engaged in vigorous-intensity exercise tended to have better self-rated health. This was similar to the research results of Norton et al. (35) and Marques et al. (36), which indicated the help of exercise in cardiovascular and metabolic diseases in older comorbidities patients. Vigorous-intensity exercise can promote the adaptability and improvement of body. Although older patients with chronic comorbidities may face health problems, moderate-intensity exercise and vigorous-intensity exercise can improve muscle strength, cardiovascular and metabolic function (37), having a positive effect on the health of older patients, helping them prevent the occurrence of chronic diseases, and reducing the harm of these diseases to their body. These improvements may make patients feel more energetic and healthy. Previous studies have shown that moderate exercise has a predictive effect on improving health and quality of life (38). Individuals who actively participate in sports activities are able to maintain or improve their physical abilities and better complete daily tasks in daily life (39), leading respondents to make better health self-rated health status. Meanwhile, vigorous-intensity exercise may have a positive effect on the endocrine system, such as promoting the release of neurotransmitters such as endorphins and dopamine, thereby improving emotional and psychological states (30). Exercise therapy is a treatment method often used to improve the physical and mental health of older people without any side effects (31). Vigorous-intensity exercise can significantly help the treatment results, health, metabolism and exercise ability of some older people with chronic comorbidity (such as hypertension, cardiovascular disease, type 2 diabetes, clinical depression, osteoporosis, muscle weakness, etc.) (40).

TABLE 7 Random multivariate logistic regression analysis of the factors influencing self-rated health status in young-old comorbidities female patients.

| Influencing factors | Good self-rated health status | | | Average self-rated health status | | |
|---|---|---|---|---|---|---|
| | OR | (95%CI) | *P* | OR | (95%CI) | *P* |
| Intercept | | | 0.461 | | | 0.897 |
| Exercise intensity type: Light-intensity | | | | | | |
| Vigorous-intensity | 4.232 | (1.869, 9.853) | 0.001 | 3.077 | (1.379, 6.870) | 0.006 |
| Moderate-intensity | 4.555 | (1.825, 11.368) | 0.001 | 2.179 | (0.905, 5.245) | 0.082 |
| BMI: Obesity | | | | | | |
| Low weight | 0.896 | (0.096, 8.402) | 0.924 | 3.749 | (0.420, 33.449) | 0.237 |
| Normal weight | 0.884 | (0.164, 4.765) | 0.886 | 1.911 | (0.326, 11.202) | 0.473 |
| Overweight | 1.378 | (0.238, 7.978) | 0.721 | 1.307 | (0.205, 8.330) | 0.777 |
| Comorbidity duration: More than 10 years | | | | | | |
| Less than 6 years | 0.441 | (0.104, 1.868) | 0.266 | 0.698 | (0.169, 2.889) | 0.620 |
| 6–10 years | 0.211 | (0.849, 2.836) | 0.028 | 0.176 | (0.044, 0.697) | 0.013 |
| Will family members supervise exercise: No | | | | | | |
| Yes | 2.460 | (1.143, 5.291) | 0.021 | 2.410 | (1.079, 5.383) | 0.032 |
| Whether respondents participates in social activities: No | | | | | | |
| Yes | 6.173 | (2.285, 16.678) | <0.001 | 2.410 | (1.079, 5.383) | <0.001 |
| Does respondents take health products: No | | | | | | |
| Yes | 0.227 | (0.109, 0.476) | <0.001 | 0.225 | (0.111, 0.457) | <0.001 |
| Can respondents have at least 6 h of sleep per day: No | | | | | | |
| Yes | 4.314 | (1.895, 9.819) | <0.001 | 2.222 | (0.980, 5.040) | 0.056 |

By persisting in vigorous-intensity exercise, not only can the risk of depression in older chronic comorbidities patients be reduced (41), but also their confidence in their own abilities (42) can be improved, believing that they can make positive changes in their physical health. These factors can enable respondents to more positively evaluate their health status.

Not all older comorbidities patients are suitable for and can adapt to vigorous-intensity exercise levels. Studies by Endeshaw and Goldstein (43) and Lam et al. (44) have shown that mild and moderate-intensity exercise can help older people maintain health. As long as the exercise intensity is appropriate and sufficient, older patients will be healthier and have a lower risk of cardiovascular disease (45). And studies have shown that exercise have different effects on the health status of older men and women (46), with vigorous-intensity exercise having a stronger adverse effect on women's health than men (31). In this study, we found that young-old male patients with chronic comorbidities needed to engage in vigorous-intensity exercise in order to have a positive effect on their self-rated health; Young-old female patients with chronic comorbidities who engaged in vigorous-intensity and moderate-intensity exercise can have a positive effect on their self-rated of health, which was similar to the research findings of Marques et al. (47). It may be due to physiological differences between men and women, including hormone levels, body composition, and muscle mass. These physiological differences may lead to different responses to exercise. Men typically have more muscle mass and higher metabolic rate (48), therefore requiring higher intensity exercise to produce significant effects. And there are also differences in the types of comorbidities between males and females. For example, female comorbidities patients are more likely to suffer from osteoporosis, rheumatism, etc. (49). Vigorous-intensity exercise is not conducive to the recovery of the condition and may lead to worsening symptoms. The results of this study indicated that compared to men, women only needed to engage in moderate-intensity exercise to positively affect their self-rated health, which could avoid the risk of injury caused by vigorous-intensity exercise (50). Additionally, compared to vigorous-intensity exercise, moderate-intensity exercise is more accepted by older patients and can be persisted for a long time, which contributes to the long-term beneficial effect of exercise on the health of comorbidities patients (51).

Regular exercise is crucial for a healthy aging population (15). At present, many communities have adopted a multidisciplinary and comprehensive approach to the management of older patients' chronic diseases, including nutrition, exercise, cognition, emotions, and so on. For older comorbidities patients, a reasonable exercise method is mixed exercise, which combines aerobic exercise with resistance exercise. This

can strengthen the quality of bones and muscles of older patients, significantly reduce the risk of chronic diseases, promote health, and improve the quality of daily life (52). Although the benefits of exercise on the health of older patients with chronic comorbidities are significant, the frequency of exercise will decrease with age (53). Due to various influencing factors, it is difficult for older people to achieve the recommended exercise intensity. Therefore, integrating comprehensive interventions in community health services such as exercise and chronic disease management can improve the health status of older people with chronic diseases in the community. Managing and controlling symptoms related to chronic diseases can optimize the health management of older comorbidities patients and significantly increase their level of exercise participation. When managing chronic diseases among older people in the community through exercise, it is important to pay attention to their exercise compliance management. The key is to integrate their lifestyle with exercise. Communities can also regularly organize sports that are suitable for older people. The most reasonable and effective way may be to customize personalized exercise plans for older people in the community based on their lifestyle and physical health status (54), Based on the results of this study, different intensities of exercise can be recommended for older people of different genders. For example, men should recommend more vigorous-intensity aerobic exercise, while women should recommend moderate-intensity aerobic and resistance training (55). The specific exercise plan (including the type and frequency of exercise, etc.) needs to be designed by healthcare professionals such as professional physical therapists, exercise physiologists, or fitness coaches based on each individual's physical condition, type and quantity of chronic diseases, and other specific circumstances. At the same time, attention should also be paid to safety protection measures during the exercise process, such as the use of safety facilities or specialized guidance, to avoid other damages to their body during the exercise process.

We observed an interesting result in whether to participate in social activities and self-rated of health. Young-old female patients with chronic comorbidities who were urged by their families to exercise and participate in social activities were more inclined to have better self-rated health, while this result was not significant among males. It is possible that older women have a higher probability of widowhood than men (56), and their own economic and social abilities are weaker than men, making them more dependent on their children and other relatives in the family for care. Moreover, the care of children and other relatives plays an important role in the physical and mental health of older people (57). Previous studies have shown that social participation is associated with positive health behaviors among older people (58), and older people who frequently participate in social activities are more likely to engage in vigorous-intensity exercise; less social participation significantly positively affects older people's lack of physical activity, self-rated health, and low quality of life (59). The supervision, support, and assistance of family members can also encourage older comorbidities patients to actively engage in self-care (60), improve satisfaction with health and subjective well-being, make them feel more capable and confident in overcoming problems encountered, achieve their goals, improve their self-efficacy in exercise, and actively engage in beneficial behaviors (such as exercise), thereby positively affecting their self-rated of health outcomes. Based on this, community support networks can be established to encourage older patients with comorbidities to participate in community activities and maintain contact with family and friends, alleviate loneliness and depression, improve self-efficacy, promote exercise, and thereby reduce the risk of developing more diseases and improve self-rated health (61). However, this study mainly focuses on the relationship between gender, exercise intensity, and self-rated health. The effect of participation in social activities on self-rated health requires more detailed research in the future.

## 4.1. Limitations

Firstly, due to the data source of this study being a structured questionnaire, several items in the questionnaire lacked standardized measurement methods. Only several items were flawed and the effectiveness and feasibility of this questionnaire survey were proven, nevertheless, it might still result in possible differences in measurement results between different time points and respondents. Moreover, the expression of individual questions might not be clear and clear enough, causing misunderstandings or difficulties in selection among respondents. This might guide participants to answer in certain specific directions, resulting in report bias and ultimately inaccurate data collection, affecting the reliability of research results.

Secondly, the outcome variable of this study was the respondents' self-rated health status, which was based on an individual's subjective perspective and was therefore influenced by their culture, social experience, and emotional state. During the evaluation process, subjects were prone to memory bias, and the evaluation results were subjective and relative, leading to distortion in health rated. Individual self-rated of health might also be influenced by social expectations. Individuals might tend to answer that meet social expectations to avoid being perceived as "unhealthy" or different from others. This might lead to distortion in the evaluation results. In addition, the independent variable of this study, the type of exercise intensity, was determined by researchers based on previous studies and the definition in the guidelines. Considering the discrete duration variables of exercise and a large amount of missing data, we were unable to calculate the duration of different activity intensity levels. Moreover, this study did not clearly define which specific exercises should be included in each exercise intensity, which was detrimental to the practical application of the results. There were many influencing factors on the self-rated of health among older comorbidities patients, but due to the limited control variables in this study, detailed analysis was not possible and further research was needed. The above possibilities might lead to a lack of objectivity in the results of this study, limiting the promotion and comparison of different research results. If we consider the above information, we may have a better understanding of the relationship between exercise intensity and the health of older comorbidities patients, and the guidance provided by the research results may be more useful for policies and intervention measures. This indicated that future research required standardized research methods and tools. These studies will guide actions aimed at promoting physical exercise, quality of life, and other health factors in older comorbidities patients.

Finally, as this study was cross-sectional, the results of this study only indicated that older patients with chronic comorbidities who engaged in vigorous-intensity to moderate-intensity exercise have relatively better self-rated of health status. The changes in outcomes was not tracked over time in the study, so the clear evidence of causal relationships could not be provided. This also made it difficult to draw conclusions on the relationship between different exercise intensities and health conditions.

## 5. Conclusion

In summary, representative data from Guangdong Province indicated that vigorous-intensity exercise had a significant positive effect on the self-rated health of young-old patients with chronic comorbidities, provided that their physical condition permits. In terms of gender, young-old male patients with chronic comorbidities who engaged in vigorous-intensity exercise are more likely to considerate their health as good; for female patients, both vigorous-intensity and moderate-intensity exercise could improve their self-rated health status. This finding suggests that exercise should be integrated into the management of older chronic comorbidities patients. The exercise style, intensity type, and frequency of older comorbidities patients should be differentiated and determined according to gender to promote their health. It is recommended to conduct a follow-up study to verify the causal relationship between different exercise intensities and the health of older comorbidities patients, and more research is needed to determine the specific exercise patterns, times, and frequencies corresponding to different intensities of exercise, as well as the specific types of exercise corresponding to which chronic diseases are beneficial.

## Data availability statement

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

## Author contributions

LL: Writing – original draft, Writing – review & editing. FD: Writing – review & editing. DZ: Writing – review & editing.

## 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 Outstanding Youth Science Fund Project of National Natural Science of China (grant no. 72004112) and a research grant from the Center for Social Governance and Innovation at Tsinghua University, a major research center for Shenzhen Humanities & Social Sciences Key Research Bases.

## Acknowledgments

We would like to express our gratitude to all the survey participants, including graduate students majoring in hospital management, interns undergoing standardized training in general medicine, community general practitioners, nurses, and other personnel who contributed to the data collection for 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



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frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 14 December 2023
DOI 10.3389/fpubh.2023.1281065



OPEN ACCESS

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RECEIVED 21 August 2023
ACCEPTED 27 November 2023
PUBLISHED 14 December 2023

CITATION
Wang X, Zhang F, Ge Y, Ding Y and Liu T (2023) The associations between social support, self-regulatory fatigue, and health-promoting behaviors among people with type 2 diabetes mellitus: a cross-sectional survey. *Front. Public Health* 11:1281065. doi: 10.3389/fpubh.2023.1281065



# The associations between social support, self-regulatory fatigue, and health-promoting behaviors among people with type 2 diabetes mellitus: a cross-sectional survey

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**Background:** The prevalence of diabetes in China is increasing annually, posing a serious public health challenge. Health-promoting behaviors are crucial for enhancing the quality of life in individuals with type 2 diabetes. However, the relationship between self-regulatory fatigue in type 2 diabetes, social support, and health-promoting behaviors remains unclear.

**Objective:** This study aimed to explore the interconnections among social support, self-regulatory fatigue, and health-promoting behaviors, as well as to examine the mediating role of self-regulatory fatigue in patients with type 2 diabetes mellitus.

**Methods:** A cross-sectional design was employed using the Self-Regulatory Fatigue Scale (SRF-S), the Social Support Rating Scale (SSRS), and the Health Promotion Scale for People with Diabetes Mellitus (T2DHPS). These scales assessed social support, self-regulatory fatigue, and health-promoting behaviors in 316 patients with type 2 diabetes mellitus, exploring the relationships among these variables. SPSS and AMOS were used for statistical analysis to investigate the mediating effects.

**Results:** Social support in type 2 diabetes mellitus positively predicted health-promoting behaviors ($\beta = 0.401$, $p < 0.001$). The regression coefficients of self-regulatory fatigue in patients with type 2 diabetes mellitus social support ($\beta = -0.502$, $p < 0.001$), and health-promoting behaviors ($\beta = -0.331$, $p < 0.001$), both exhibiting significant differences. Self-regulatory fatigue mediated the relationship between social support and health-promoting behaviors in these patients, with a mediation effect of 0.166, consisting of 29.28% of the total effect.

**Conclusion:** A significant interplay exists among social support, self-regulatory fatigue, and health-promoting behaviors in patients with type 2 diabetes mellitus. The findings suggest that self-regulatory fatigue mediates the relationship between social support and health-promoting behaviors. Healthcare professionals should focus on enhancing patients' social support to mitigate self-regulatory fatigue and improve health behaviors.

KEYWORDS

**self-regulatory fatigue, social support, health-promoting behaviors, type 2 diabetes mellitus, mediating effect**

# 1 Introduction

Diabetes mellitus is a major public health concern in China, ranking third among chronic non-communicable diseases, after cardiovascular and cerebrovascular disorders and cancer, in posing a significant health threat (1, 2). The International Diabetes Federation reports that the global diabetes population reached 537 million in 2021, with projections suggesting an increase to 783 million by 2045 (3). In China, the prevalence rate of diabetes is 11.2% (4), the highest globally, with type 2 diabetes mellitus (T2DM) constituting approximately 90% of cases (5). Notably, there is a geographic variation in the prevalence of diabetes across China (6), with higher incidence rates in the northern regions, possibly due to dietary factors (7). T2DM, one of the world's fastest-growing diseases, is expected to continue straining healthcare systems and causing significant personal and economic burdens (3).

Social support, which includes the aid patients perceive and receive from their social networks, such as interactions with friends, family, neighbors, and coworkers, plays a vital role in reducing psychological stress and enhancing social adaptation (8). Other important factors influencing health-promoting behaviors include psychological resilience, literacy, and interpersonal interactions (9, 10). Cultural differences are significant in diabetes management (11), prompting the Chinese Health Commission to provide tailored food and nutritional guidelines for T2DM patients based on regional dietary and cultural variations (12). T2DM patients often need to adhere to strict, long-term health behaviors, such as consistent exercise, calorie restriction, weight management, and blood glucose monitoring (13, 14). Studies have shown that social support is a critical social determinant for the self-management of diabetes mellitus patients, and is far from sufficient if carried out by patients individually (15, 16). Past research has demonstrated that diabetic patients benefitted from strong social support in both their physical and emotional health (17). However, the level of social support for T2DM patients in China needs improvement (18). Xu et al. indicate that T2DM patients receive a medium degree of social support (18), suggesting the necessity to enhance social support for their mental and physical well-being.

In 1987, Pender introduced the concept of health-promoting behaviors, stating that actions individuals undertake to maintain a positive state across all life aspects (19). The health-promoting behavior model (20) highlights the significant influence of interpersonal ties on such behaviors, with strong interpersonal connections being crucial for acquiring social support. This model suggests that individual traits and experiences can impact health behaviors either directly, through previous behavioral habits, or indirectly, by affecting specific behaviors, mental cognitions, and emotions. Health-promoting behaviors are beneficial for physical and emotional well-being, aiding in disease prevention and health maintenance or improvement (21). However, Xu et al. noted that 80% of T2DM patients have inadequate blood glucose control and related complications (22), resulting in a low level of health promotion and a diminished sense of self-care. Hence, it is imperative for T2DM patients to not only receive therapeutic treatment but also enhance their risk factor management and health-promoting behaviors. Furthermore, the link between social support and health-promoting behaviors has been established in various populations (23, 24), but the specific mechanisms of their roles in the diabetic population remain underexplored.

T2DM necessitates long-term management involving dietary monitoring, oral hypoglycemic medications, and insulin injections, due to the disease's prolonged nature, recurrence risk, comorbidities, complex disease progression, and the challenge of achieving a complete cure. This continuous demand often leads to self-regulatory fatigue in patients (25). Self-regulatory fatigue is defined as a temporary decrease in an individual's capacity or willingness to engage in self-directed activities where self-control is required (26). It manifests as a diminished ability to regulate emotions, thoughts, and behaviors. According to the energy model of self-control, an individual's self-control capacity is finite (26), with the performance of an initial task affecting subsequent tasks in the control cycle, a phenomenon known as ego depletion. Nes et al. (27) described self-regulatory fatigue as a persistent fatigue state caused by long-term resource depletion due to factors like economic stress, anxiety, and depression, and it is more challenging to recover from compared to ego depletion, which is transient. Self-regulatory fatigue impacts individuals with chronic illnesses more significantly and for a longer duration than healthy individuals (28). T2DM patients, being at risk of developing self-regulatory fatigue, often experience ongoing fatigue when engaging in self-controlled activities. Hence, this study hypothesizes that self-regulatory fatigue may act as a mediator between social support and health-promoting behaviors. Moreover, most research on self-regulatory fatigue in China has focused on individuals with chronic pain (29), with limited exploration into self-regulatory fatigue in T2DM.

In summary, this study aims to examine the interplay between self-regulatory fatigue, social support, and health-promoting behaviors in T2DM patients. It specifically focuses on the potential mediating role of self-regulatory fatigue in the relationship between social support and health-promoting behaviors. This investigation intends to contribute to the existing body of knowledge on self-regulatory fatigue, particularly in the context of T2DM. An essential aspect of this research is to determine if the self-regulation of fatigue status serves as a predictor for higher levels of health-promoting behaviors in these patients. The findings are expected to enable medical staff to implement targeted strategies, considering social support and self-regulatory fatigue. These insights aim to provide new directions for managing patient care during clinical interactions or follow-ups and to establish a new benchmark for enhancing health-promoting behaviors among T2DM patients.

# 2 Objects and methods

## 2.1 Participants and procedures

This study employed a cross-sectional survey design. Participants were type 2 diabetes mellitus (T2DM) patients recruited from the endocrinology department of a tertiary hospital in Huai'an City, Jiangsu Province, China, from May to August 2023 through convenient sampling. The inclusion criteria were as follows: Age above 18; Diagnosis of T2DM according to the World

Health Organization's 1999 criteria (5); Disease duration exceeding 3 months; Basic language comprehension and response abilities; Awareness of the diagnosis and consent to participate in the study. Exclusion criteria included: Mental and cognitive impairments and multiple serious illnesses.

## 2.2 Research tools

### 2.2.1 General information questionnaire

The questionnaire, designed by researchers, gathered data on gender, age, education level, occupation, place of residence, marital status, monthly household income per capita, years living with diabetes, presence of diabetic complications, and other chronic conditions.

### 2.2.2 Social support rating scale

Developed by Xiao (30), the Social Support Rating Scale (SSRS) is widely used in China to assess levels of social support. The scale encompasses 10 items across three dimensions: 3 items for objective support, 4 items for subjective support, and 3 items for support utilization. Items 1–4 and 8–10 are assessed using a 4-point Likert scale. Question 5 contains 5 options (A to E), each scored from 1 to 4 points, reflecting a range from "no" to "full support". For questions 6 and 7, answers are scored 1–4 points based on the identified sources of support, while "no source" responses receive 0 points. The total score correlates with the level of social support, categorized as: low ($\leq$22), moderate (23–44), or high ($\geq$45). In this study, the SSRS demonstrated robust reliability and validity, with a Cronbach's alpha of 0.806, a Kaiser-Meyer-Olkin (KMO) measure of 0.848, and an approximate chi-square of 1,415.524 ($p < 0.001$) in Bartlett's test of sphericity.

### 2.2.3 Self-Regulatory Fatigue Scale

The Self-Regulatory Fatigue Scale (SRF-S), initially developed by Nes et al. in 2013, was translated and adapted into Chinese by Wang et al. in 2015 (27, 31). Research has shown that this scale is suitable for Chinese residents and possesses good reliability. The SRF-S comprises 16 items, divided into three dimensions: cognitive control (6 items), emotional control (5 items), and behavioral control (6 items). Responses are scored using a 5-point Likert scale (strongly oppose = 1, disapprove = 2, uncertain = 3, approve = 4, strongly agree = 5), with the total score ranging from 16 to 80. Higher scores indicate increased levels of self-regulatory fatigue. In this study, the SRF-S demonstrated excellent reliability and validity, with a Cronbach's alpha of 0.884, a KMO measure of 0.904, and an approximate chi-square of 2019.408 ($p < 0.001$) in Bartlett's test of sphericity.

### 2.2.4 The health promotion scale for people with diabetes

Developed by Chen et al. in 2013, the T2DHPS assesses health-promoting behaviors in T2DM patients (32). Cao et al. evaluated the scale's reliability and validity, confirming its applicability to Chinese residents (33). The T2DHPS consists of 28 items across six dimensions: physical activity (7 items), risk reduction (7 items), stress management (5 items), enjoying life (3 items), health responsibility (3 items), and a healthy diet (3 items). The scale uses a 5-point Likert scale (never = 1, occasionally = 2, about half = 3, often = 4, always = 5), with the total score ranging from 28 to 140. Higher scores indicate greater levels of health promotion in diabetic patients. In this study, the T2DHPS showed high reliability and validity, with a Cronbach's alpha of 0.884, a KMO measure of 0.904, and an approximate chi-square of 2019.408 ($p < 0.001$) for Bartlett's test of sphericity.

## 2.3 Ethical approval and data collection

The study received ethical approval from the Jinzhou Medical University Ethics Committee (JZMULL2023067). Participants were informed by the research team members about the study's purpose and significance. All participants provided informed consent and voluntarily took part in the study. Trained team members distributed and collected the questionnaires in a one-on-one manner in the wards. To ensure confidentiality, all questionnaires were completed anonymously, and participants were assisted with any omissions during the on-site collection. For individuals with limited literacy, researchers read the questionnaires aloud and recorded the responses. The study's questionnaire comprised 22 variables. According to Kendall's rough estimation method for sample size (34), the sample should be 5–10 times the number of variables, suggesting a range of 110–220 cases. Accounting for a 20% sample attrition rate and the potential error due to convenience sampling, the estimated sample size was adjusted to 132–264 cases. Considering structural equation modeling, a sample size of 200 or more was preferred (35). To ensure result reliability, 350 questionnaires were distributed, resulting in 316 valid responses and a validity rate of 90.28%.

## 2.4 Statistical methods

The data collected in this study were analyzed using two statistical software tools: SPSS 27.0 and AMOS 24.0. These tools are commonly utilized in medical research for their user-friendly interface and capability to perform a wide range of statistical functions without requiring complex programming (36). To evaluate the relationships between social support, self-regulatory fatigue, and health-promoting behaviors, descriptive statistics were employed, including mean, standard deviation, skewness, and kurtosis, using Pearson's correlation analysis under a normal distribution. Harman's single factor test was applied to assess potential common methodological biases (37). A result exceeding 40% in this test indicates a significant discrepancy between the measured outcomes and actual conditions.

Structural equation modeling (AMOS) was utilized for path analysis. The normality of the distribution was first assessed by calculating skewness and kurtosis. In this study, skewness values ranged between −0.50 and 0.48, and kurtosis values were between −0.97 and 1.12. These values, falling within the ± 2 range, are generally considered acceptable for assuming a normal distribution

TABLE 1 The demographics and medical characteristics of participants ($n = 316$).

| Factors | Group | *n* | % |
|---|---|---|---|
| Gender | Male | 157 | 49.7 |
| | Female | 159 | 50.3 |
| Age (years) | 18–44 | 57 | 18.0 |
| | 45–59 | 102 | 32.3 |
| | ≥60 | 157 | 49.7 |
| Education | Elementary school and lower | 97 | 30.7 |
| | Junior middle school | 70 | 22.2 |
| | Secondary technical school or Senior high school | 69 | 21.8 |
| | Junior college | 36 | 11.4 |
| | Bachelor's degree and above | 44 | 13.9 |
| Occupation | Farmer | 70 | 22.2 |
| | Worker | 38 | 12.0 |
| | Staff | 47 | 14.9 |
| | Freelancer | 47 | 14.9 |
| | Resignation/retirement | 59 | 18.7 |
| | Unemployed | 55 | 17.4 |
| Residence | Rural | 131 | 41.5 |
| | City | 185 | 58.5 |
| Marital status | Unmarried | 22 | 7.0 |
| | Married | 210 | 66.5 |
| | Divorce | 47 | 14.9 |
| | Widowed | 37 | 11.7 |
| Per-capita family income | <1,000¥ | 17 | 5.4 |
| | 1,000–1,999¥ | 51 | 16.1 |
| | 2,000–2,999¥ | 89 | 28.2 |
| | 3,000–3,999¥ | 87 | 27.5 |
| | ≥4,000¥ | 72 | 22.8 |
| Number of years of illness | 0–10 | 176 | 55.7 |
| | >10 | 140 | 44.3 |
| Complications | No | 136 | 43.0 |
| | Yes | 180 | 57.0 |
| Other chronic illnesses | No | 172 | 43.7 |
| | Hypertension | 130 | 33.0 |
| | Hyperlipidemia | 43 | 10.9 |
| | Coronary heart disease | 32 | 8.1 |
| | Others | 17 | 4.3 |

(38). This finding indicates the data's suitability for AMOS analysis. To determine the goodness of fit of the structural model, various indices were used, including the Comparative Fit Index (CFI), Goodness of Fit Index (GFI), Incremental Fit Index (IFI), Root Mean Square Error of Approximation (RMSEA), and the chi-square to degrees of freedom ratio ($\chi^2$/df). The significance of the direct and indirect effects of the variables within the AMOS framework was ascertained using a 95% confidence interval.

# 3 Results

## 3.1 Characteristics of participants

The study included 316 participants, with a nearly equal distribution of genders: 49.7% men and 50.3% women. Detailed demographic characteristics are provided in Table 1.

## 3.2 Scores of social support, self-regulatory fatigue, and health-promoting behaviors of T2DM

The overall social support score of T2DM was 33.13 ± 9.62 (skewness = 0.18; kurtosis = −0.24), the overall self-regulatory fatigue score was 47.95 ± 8.30 (skewness = −0.19; kurtosis = −0.23), and the overall health-promoting behavior score was 71.57 ± 13.28 (skewness = 0.26; kurtosis = 0.47). See Table 2 for details.

## 3.3 Relationship between social support, self-regulatory fatigue, and health-promoting behaviors in T2DM

Social support was negatively correlated with self-regulatory fatigue ($r = -0.431$, $p < 0.001$), social support was positively correlated with health-promoting behavior ($r = 0.424$, $p < 0.001$), self-regulatory fatigue was negatively correlated with health-promoting behavior ($r = -0.408$, $p < 0.001$). The results are shown in Table 3.

## 3.4 Common method deviation inspection

Harman's single-factor test was conducted to assess common method bias. The variance explained by the first factor was 17.938%, well below the 40% threshold, indicating no significant common method variance. Additionally, 25 components had eigenvalues greater than 1. As a result, this study does not exhibit any significant common methodological variations.

## 3.5 The mediating role of self-regulatory fatigue in the relationship between social support and health-promoting behaviors in T2DM

The study utilized an Amos bias-corrected nonparametric percentile bootstrap approach to confirm the significance of the mediating effect. To minimize Type I errors impacting statistical inference, a random sample of 2000 was selected from the original

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TABLE 2 Scores of social support, self-regulatory fatigue and health-promoting behaviors of T2DM ($n = 316$).

| Variable | Min | Max | Mean ± SD | Skewness | Kurtosis |
|---|---|---|---|---|---|
| **Total score of social support** | **12.00** | **61.00** | **33.13 ± 9.62** | **0.18** | **−0.24** |
| Objective support | 1.00 | 20.00 | 8.19 ± 3.55 | 0.05 | −0.06 |
| Subjective support | 8.00 | 31.00 | 18.36 ± 5.10 | 0.31 | −0.39 |
| Utilization of support | 3.00 | 12.00 | 6.58 ± 2.60 | 0.33 | −0.97 |
| **Total score of self-regulatory fatigue** | **23.00** | **72.00** | **47.95 ± 8.30** | **−0.19** | **−0.23** |
| Cognitive control | 8.00 | 28.00 | 18.95 ± 3.86 | −0.50 | −0.25 |
| Behavior control | 6.00 | 24.00 | 14.69 ± 3.29 | −0.14 | −0.33 |
| Emotion control | 6.00 | 25.00 | 14.31 ± 3.28 | 0.10 | −0.51 |
| **Total score of health-promoting behaviors** | **35.00** | **126.00** | **71.57 ± 13.28** | **0.26** | **0.47** |
| Physical activity | 7.00 | 34.00 | 16.09 ± 5.08 | 0.48 | 0.18 |
| Risk reduction | 8.00 | 35.00 | 18.67 ± 4.76 | 0.42 | 0.40 |
| Stress management | 5.00 | 24.00 | 13.63 ± 2.95 | 0.32 | 1.12 |
| Enjoy life | 3.00 | 14.00 | 7.83 ± 2.28 | 0.12 | −0.46 |
| Health responsibility | 3.00 | 15.00 | 7.85 ± 2.08 | 0.07 | 0.04 |
| Healthy diet | 3.00 | 14.00 | 7.51 ± 2.13 | 0.35 | 0.04 |

TABLE 3 Correlation analysis results of social support, self-regulatory fatigue and health-promoting behaviors of T2DM ($n = 316$).

| Variable | Social support | Self-regulatory fatigue | Health-promoting behaviors |
|---|---|---|---|
| Social support | 1 | | |
| Self-regulatory fatigue | −0.431** | 1 | |
| Health-promoting behaviors | 0.424** | −0.408** | 1 |

**Significant correlation at 0.01 level (bilateral).

sample size of 316. The structural equation model included social support (comprising 3 latent variables) as the predictor, self-regulatory fatigue (3 latent variables) as the mediator, and health-promoting behaviors (6 latent variables) as the outcome, illustrated in Figure 1.

Each fitting index of the structural equation model: CFI = 0.918, GFI = 0.932, IFI = 0.919, RMSEA = 0.073, $\chi^2/df = 2.688$, all of which were in line with the ideal criteria, good model adaptability. These results are detailed in Table 4.

## 3.6 Estimation of parameters related to social support, self-regulatory fatigue, and health-promoting behaviors in T2DM

The regression analysis indicated that social support in T2DM positively predicted health-promoting behaviors ($\beta = 0.401$, $p < 0.001$). Additionally, the regression coefficients of self-regulatory fatigue significantly influenced both the paths from T2DM social support ($\beta = -0.502$, $p < 0.001$) and health-promoting behaviors ($\beta = -0.331$, $p < 0.001$). These results are presented in Table 5 and Figure 1.

The analysis revealed that self-regulatory fatigue indirectly predicted the effect of social support on health-promoting behaviors in T2DM, with a standardized path coefficient of $(-0.502) * (-0.331) = 0.166$. The total effect of social support on health-promoting behaviors was calculated as $(0.166 + 0.401) = 0.567$. This finding suggests that self-regulatory fatigue plays a partially mediating role between social support and health-promoting behaviors, accounting for 29.28% of the total effect. Detailed results are shown in Table 6.

# 4 Discussion

## 4.1 Levels of social support, self-regulatory fatigue, and health-promoting behaviors in T2DM

The study's findings highlighted that individuals with type 2 diabetes mellitus (T2DM) exhibit moderate levels of self-regulatory fatigue, with an average score of 47.95 ± 8.03 and a scoring rate of 59.94%. This level of self-regulatory fatigue suggests that T2DM patients are experiencing fatigue associated with self-management of their condition. These results align with those from Rod et al.'s study (39). Notably, the cognitive aspect of self-regulatory fatigue received the highest scores, indicating that managing diabetes requires significant mental effort and physical stamina.

In terms of social support, the average score for T2DM patients was 33.13 ± 9.62, classified as moderate according to the scale's criteria. This finding is similar to Yang et al.'s research (40). However, the scores for the utilization of support were relatively low, suggesting that T2DM patients might have difficulties effectively utilizing available social support resources.

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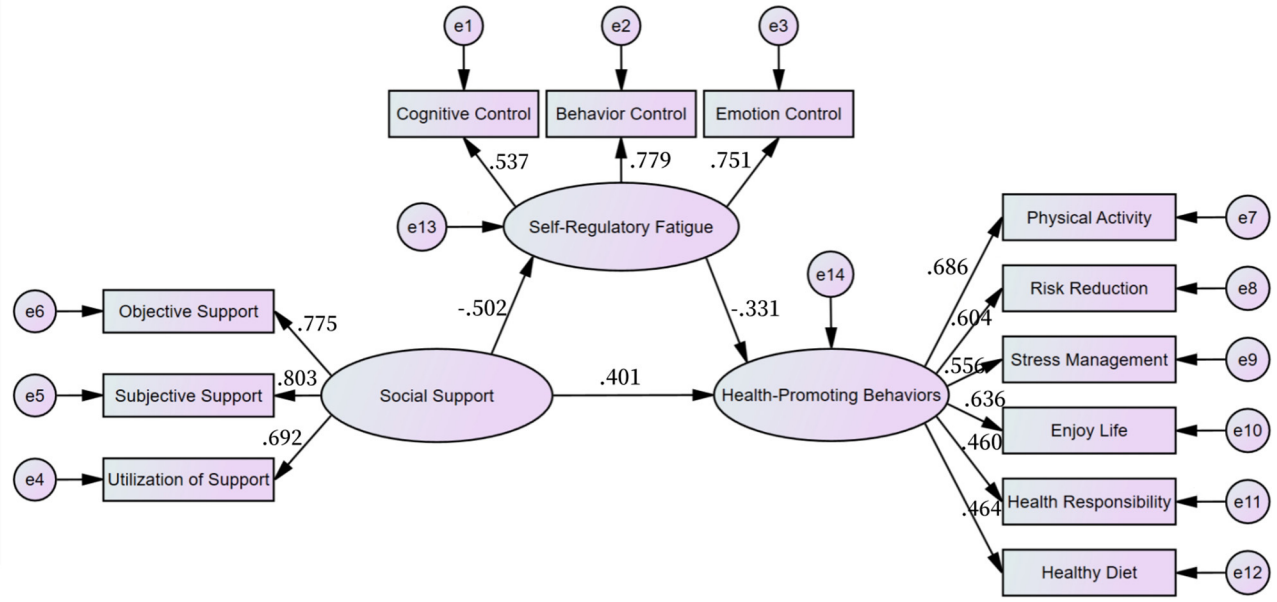


FIGURE 1
A mediated model of social support, self-regulatory fatigue and health-promoting behaviors of T2DM.

TABLE 4 Structural equation model fitting index ($n = 316$).

| Project | $\chi^2$ | $\chi^2$/df | RMSEA | GFI | CFI | IFI |
|---|---|---|---|---|---|---|
| Fitting index | 137.093 | 2.688 | 0.073 | 0.932 | 0.918 | 0.919 |
| Acceptable standards | - | <3 | <0.08 | >0.9 | >0.9 | >0.9 |

$\chi^2$/df Maximum likelihood ratio $\chi$2 values/degrees of freedom, GFI Goodness of fit index, CFI Comparative fit index, IFI Value added index, RMSEA Mean square sum square root of progressive residuals.

TABLE 5 Estimated parameters and 95% CI between social support, self-regulatory fatigue and health-promoting behaviors of T2DM ($n = 316$).

| Project | Unstandardized coefficients | Standardized coefficients | SE | Z(sig.) | confidence interval | |
|---|---|---|---|---|---|---|
| | | | | | Boot CI Upper | Boot CI Lower |
| Social support→ self-regulatory fatigue | −0.289 | −0.502 | 0.051 | $p < 0.001$ | −0.424 | −0.166 |
| Self-regulatory fatigue→ health-promoting behaviors | −0.476 | −0.331 | 0.127 | $p < 0.001$ | −0.805 | −0.184 |
| Social support→ health-promoting behaviors | 0.333 | 0.401 | 0.070 | $p < 0.001$ | 0.152 | 0.531 |

TABLE 6 Decomposition table of total effect, direct effect, and mediating effect.

| | Effect value | Boot CI upper | Boot CI lower | Relative effect value |
|---|---|---|---|---|
| Total effect | 0.567 | 0.312 | 0.643 | 100% |
| Direct effect | 0.401 | 0.152 | 0.531 | 70.70% |
| Mediating effect | 0.166 | 0.060 | 0.249 | 29.30% |

The bootstrap method estimates the standard error of indirect effects and the lower and upper limits of 95% confidence intervals.

The total score for health-promoting behaviors in T2DM patients was 71.57 ± 13.28, with a scoring rate of 51.12%, also indicating a moderate level. This suggests there is room for improvement in T2DM patients' health-promoting behaviors, corroborating the findings of Xu and Baumeister (41, 42). Particularly low scores were observed in the dimensions of exercise and healthy eating. Given that lack of exercise and sedentary lifestyle are high-risk factors for diabetes, and healthy behaviors like maintaining a low-fat diet and regular exercise are essential for its prevention, these areas warrant particular attention (43).

## 4.2 Correlation analysis of social support, self-regulatory fatigue, and health-promoting behaviors of T2DM

This study found a negative correlation between social support and self-regulatory fatigue in T2DM patients, aligning with Zhang et al.'s findings (44). This suggests that higher levels of social support can reduce self-regulatory fatigue in T2DM individuals. Effective management of T2DM involves self-control in diet and regular blood sugar monitoring. When patients perceive strong support from others, they are more inclined to adhere to treatment plans, experience positive emotions, and maintain a constructive attitude toward their illness. They feel valued, supported, and cared for, which reduces self-regulatory fatigue. Conversely, patients with low social support may experience increased depressive symptoms and self-regulatory fatigue, for instance, heightened fear during hypoglycemic episodes. Lack of family and friends' support can hinder positive emotional mobilization, delaying necessary medical interventions.

Furthermore, the study identified a negative correlation between self-regulatory fatigue and health-promoting behaviors. This implies that higher self-regulatory fatigue leads to poorer engagement in health-promoting behaviors. Chronic illness patients, including those with T2DM, often suffer from self-exhaustion (29), which can significantly impair their quality of life and adherence to medical advice. T2DM patients often struggle with depression (45), which can exacerbate their fatigue and reduce active participation in health-promoting behaviors, such as neglecting medical recommendations, skipping blood pressure and glucose checks, adopting unhealthy eating habits, and engaging in minimal physical activity.

Additionally, the study revealed a positive correlation between social support and health-promoting behaviors in T2DM, consistent with Finch et al.'s results (46). Social support, particularly from family and friends is vital in chronic disease management, enhancing self-care in patients (47). Adequate social support can encourage T2DM patients to more diligently follow treatment regimens, access health information more easily (48), improve health-related behaviors, significantly reduce glycated hemoglobin levels (49, 50), and delay the onset of diabetic complications (5, 51). Family members, friends, and romantic partners serve as crucial allies and support managers, bolstering T2DM patients' resolve to engage in health-promoting behaviors.

## 4.3 The mediating role of self-regulatory fatigue

The findings of this study demonstrate the significant mediating role of self-regulatory fatigue in the relationship between social support and health-promoting behaviors in T2DM. The mediation effect was quantified at 0.166, accounting for 29.28% of the total effect. This indicates that social support can influence the level of health-promoting behaviors in T2DM patients through the intermediary of self-regulatory fatigue. Self-regulatory fatigue is a prevalent negative emotion in chronic disease management, intricately linked to cognitive, emotional, and behavioral aspects (52). It can lead to feelings of isolation and reluctance to seek help among patients receiving inadequate social support. Prolonged negative states like anxiety, depression, distress, and loneliness can deplete a patient's limited energy resources (53), significantly impacting their self-control behaviors and leading to a failure in self-regulation, physical exhaustion, and emotional fatigue (54, 55). The consequences of failures in self-regulation can result in reduced self-control and an inability to adopt positive coping styles, adversely affecting the patient's capacity to improve health-promoting behaviors.

Mitigating or avoiding self-regulatory fatigue is possible (56), reducing self-regulatory fatigue through emotional support from others can encourage patients to adopt health-beneficial behaviors. Social support can be categorized into emotional, practical, and behavioral support (57, 58). To help patients feel supported, family members such as partners or children, can accompany them to medical appointments to provide emotional and material support, and assist in understanding diabetes-related biochemical indices, therapeutics, self-care, management and prevention of complications (59). Healthcare professionals should engage more with patients about their conditions, assist in developing personalized diet and exercise plans, and encourage patients to express their support needs (60).

Addressing self-regulatory fatigue involves paying attention to its presence in patients, enhancing thought and behavioral control through goal setting and improved self-efficacy (61), and alleviating the psychological burden it imposes. Maintaining motivation in disease management, changing unhealthy lifestyle habits, and rigorously adhering to health-promoting behaviors such as smoking cessation, alcohol moderation, medication adherence, regular physical exercise, foot care, and blood glucose monitoring are crucial steps in managing diabetes more effectively.

# 5 Strengths and limitations

This study's primary strength lies in its exploration of the relationship between social support, self-regulatory fatigue, and health-promoting behaviors in T2DM, a subject that has not been jointly examined in previous research. The study's identification of moderate levels of self-regulatory fatigue in T2DM is noteworthy, as this aspect has received limited attention in prior studies. The findings underscore the importance of emotional, informational, or tangible support from family, friends, or society in reducing self-regulatory fatigue and promoting physical and psychological adjustments that encourage healthy behaviors in T2DM patients. This research could serve as a foundation for future data collection and cohort studies in broader areas to investigate causal hypotheses.

The study has several limitations inherent to cross-sectional research, including recall bias and challenges in drawing causal conclusions. The sampling population, limited to a tertiary hospital in Jiangsu Province, may affect the generalizability of the findings to the broader T2DM population. Expansion of the sampling scope and level is required for more comprehensive insights. Additionally, the use of a convenience sampling method for the questionnaire may impact the representativeness of the sample.

## 6 Conclusion

This study concludes that T2DM patients experience a state of self-regulatory fatigue and identifies a significant interplay between social support, self-regulatory fatigue, and health-promoting behaviors. Self-regulatory fatigue was found to mediate the relationship between social support and health-promoting behaviors. This finding is crucial for deepening the understanding of the relationship between social support and health-promoting behaviors in T2DM. It suggests that healthcare professionals should facilitate increased social support for T2DM patients through various channels, including wards, outpatient clinics, and community settings. By doing so, they can help reduce self-regulatory fatigue and improve health-promoting behavior levels, thereby enhancing patient 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 the Jinzhou Medical University Ethics Committee (JZMULL2023067). 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

XW conducted the research design, statistical analyses, and manuscript writing and revision. FZ, HG, and QD helped with data collection. TL proposed important revisions to the paper. All authors contributed to the article and approved the submitted version.

## Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research was supported by the Social Science Planning Foundation of Liaoning Province (L21CSH005).

## Acknowledgments

The cooperation of all the participants and community workers who volunteered to participate in this study is appreciated. The authors are also grateful to the hard-working editors and reviewers for their valuable comments and suggestions.

## 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.

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## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1281065/full#supplementary-material

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frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 08 January 2024
DOI 10.3389/fpubh.2023.1309824



OPEN ACCESS

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RECEIVED 08 October 2023
ACCEPTED 28 November 2023
PUBLISHED 08 January 2024

CITATION
Huang L, Li H, Liu H, Tian H, Luo H, Wu J, Luo Y, Peng L and Guo L (2024) Socioecological influencers of health-promoting lifestyles in Chinese: a preliminary survey using convenient samples. *Front. Public Health* 11:1309824. doi: 10.3389/fpubh.2023.1309824



# Socioecological influencers of health-promoting lifestyles in Chinese: a preliminary survey using convenient samples

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**Background:** Healthy lifestyles are considered important means to reduce the burden of diseases. This cross-sectional study was conducted based on the Ecological Model of Health Behavior (EMHB) to analyze the factors associated with the health-promoting lifestyles of Chinese residents.

**Methods:** We carried out a cross-sectional investigation in July 2023. Our investigated factors included social-demographic characteristics (including sex, age, education level, employment status, marital status, personal monthly income, and daily behavioral habits [which were measured by a questionnaire)], health literacy [which was measured by the Chinese version of the Health Literacy Scale Short-Form scale (HLS-SF12)], and family health [which was measured by the Chinese version of the Short-Form of the Family Health Scale (FHS-SF)]. Our outcome was health promoting lifestyle, which was measured by a revised version of Health Promoting Lifestyle Profile-II (HPLP-IIR). Data were analyzed using stepwise regression.

**Results:** A total of 1,402 participants were enrolled. Higher scores of HLS-SF12 ($\beta = 0.467$), having regular exercise ($\beta = 0.212$), and regular physical examination ($\beta = 0.088$) were associated with better health-prompting lifestyles. However, older age (≥60 years) ($\beta = -0.046$), drinking ($\beta = -0.066$), and sleeping time (5–6 h/day) ($\beta = -0.048$) were associated lower levels of health-prompting lifestyles. Living with family ($\beta = 0.077$), FHS-SF ($\beta = 0.104$), and married ($\beta = -0.077$) were significant influencers. Unemployed ($\beta = -0.048$), receiving retirement pay ($\beta = -0.053$), and economic support provided by parents ($\beta = 0.094$) were associated with better health-prompting lifestyles. There were multiple influencing factors of the six dimensions of the HPLP-IIR. Our findings indicate that community residents with higher health literacy, better family health, and health-related behaviors tend to have better health-promoting lifestyles.

**Conclusion:** Our findings have confirmed the complex impacts of social-ecological factors on health-promoting lifestyles, which may help policy makers with health-promotion strategies making and also help researchers to control for confounding in study design.

KEYWORDS

**health-promoting lifestyles, health behavior, ecological model of health behavior, a crosssectional study, health-related behaviors**

# 1 Introduction

Lifestyle has been defined as all those behaviors over which an individual has control, including actions that affect a person's health risks, and as discretionary activities with significant impact on health status that are a regular part of one's daily pattern of living (1). A health-promoting lifestyle is one in which self-initiated, continuous, daily activity is undertaken with the deliberate aim of increasing or promoting an individual's health and well-being (2). According to the World Health Organization (WHO), approximately 60% of factors related to individual health and quality of life are correlated with lifestyle choices (3). Specifically, studies have suggested that many lifestyle factors, such as not smoking, not using alcohol, and engaging in physical exercise, are contributing to the promotion of overall health, such as lowering the risks of cardiovascular disease, mental disorders, and all-case fatality (4, 5). For these reasons, considerable efforts have been made to explore factors that are likely to enhance health-promoting lifestyles. For instance, Mei et al. (6) found that various demographic variables such as sex, age, personal characteristics, smoking, drinking alcohol, and marital status can influence the eating behavior of adults (6). Likewise, Silvanus et al. (7) found that age, family history of diabetes, non-smoking status, and low family income are potential influencers of regular seeking behavior (7). Moreover, Jusoh et al. (8) found that marital status, parents' practice, peer practice and education significantly influenced women inmates to smoke (8). However, little attention has been paid to the overall lifestyles that contain multiple dimensions (e.g., interpersonal relationships, nutrition intake, and, physical activity engagement). Moreover, while some studies have examined the associations between sociodemographic factors (e.g., age, sex, and education) and health promoting-lifestyles (e.g., taking a balanced diet, participating in physical activity, and improving interpersonal relationships), other factors that come from a lager range of social and physical background, namely social ecological factors (e.g., family and neighborhood/community variables), are rarely considered in such a research context. Most importantly, the existing evidences are primarily concentrated in European and American countries, whereas the influencing factors in the general Chinese populations have been insufficiently studied. The "Report on Nutrition and Chronic Disease Status of Chinese Residents (2020)" indicates that Chinese residents generally exhibit unhealthy lifestyles, which have contributed to a continuous increase in the prevalence of chronic diseases in China (9). This fact further highlights the necessity of relevant explorations among Chinese populations.

In recent years, the importance of healthy lifestyles in reducing the burden of diseases has gained significant attention. To understand the complex interplay of factors influencing health-promoting lifestyles, the application of ecological models of behavior has been widely recognized. The Ecological Model of Health Behavior (EMHB) provide is a framework that helps understand the complex interactions between individuals and their environment in relation to health behaviors. In China, the EMHB has primarily been utilized to explore factors related to chronic diseases (10–12), comorbidities (13, 14), physical inactivity (15), and quality of life among individuals with chronic conditions (16). However, there is a significant gap in the exploration of social ecological factors influencing lifestyle behaviors. Specifically, limited research has focused on the comprehensive examination of factors associated with health-promoting lifestyles among the general population, encompassing a range of social and physical dimensions. Therefore, this study is presented to address these gaps by conducting a preliminary investigation using the ecological model of behavior to identify the potential socioecological influencers on health-promoting lifestyles among a subset of Chinese residents.

# 2 Theoretical basis

EMHB is widely recognized as an effective framework for identifying the factors that influence health behavior at various levels and establishing connections among individual, social behaviors and environmental determinants (17). There are several variants of the EMHB, but in general, the levels consist of individual, interpersonal, organizational, community, and policy (18).

In relevant studies, the EMHB was usually employed to guide the selection of factors prior to the investigation (6, 19–21). In practice, there are five levels to be considered. The first level is individual characteristics, such as sex, age, body mass index (BMI), education level, and more. The second level contains individual behaviors, such as smoking, drinking, exercise, and more. The third level is interpersonal networks, including marital status, family health, living status, and more. The fourth level is community, which usually contains variables such as occupation and income. The fifth level refers to the policy environment, which can include economic, social, cultural, and policy-related factors at the community, government, national, and even global levels (22).

In this study, we considered four levels (Figure 1), which were: individual characteristics, individual behaviors, interpersonal networks, and community levels. The first level, namely individual characteristics, included sex, age, BMI, education level, chronic condition, and health literacy. Most of these factors have been demonstrated to be associated with health-promoting lifestyles. It is noteworthy that, health literacy, which usually refers to cognitive and social skills determining individuals' motivation and ability to access, understand, and use the information to maintain and promote their health, has been rarely studied in Chinese communities (23). In the second and individual behaviors level, we considered smoking, drinking, regular exercise, sleep duration, sitting/sedentary duration, and regular physical examination. The third level (interpersonal networks level) included marital status, family health, and living status (e.g., living alone or not). These factors may reflect family members' interactions as well as their emotional and economic status. In this way, they may indicate family health (24). In the fourth level (community level), the length of residence, residential locations (e.g., rural or urban), career status, personal income, and source of income were considered. These factors are common community-level determinants that can affect individuals' health and behaviors.

Our study was conducted with the aim of exploring the association between these socioecological factors and health-promoting behaviors among Chinese residents, based on the theoretical framework described above.

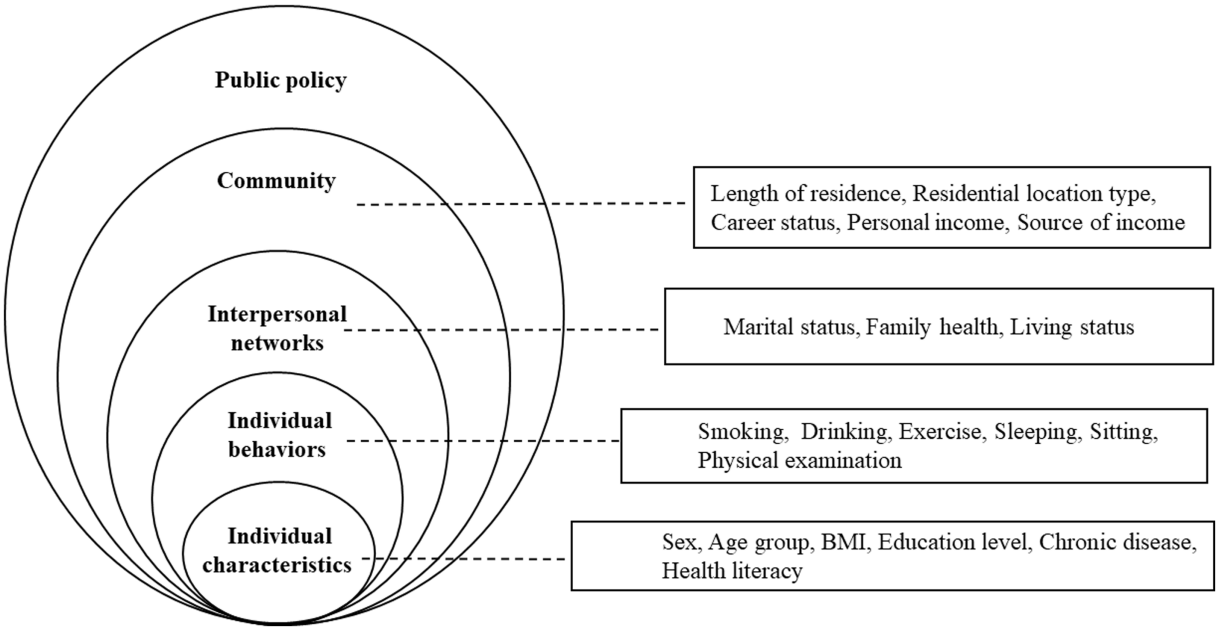


FIGURE 1
Factors associated with lifestyle based on the ecological model of health behavior [Source: Adapted from Mei et al. (6), with modifications].

# 3 Materials and methods

## 3.1 Study design

Our survey was conducted from July to September 2023. We used online convenience sampling for our survey. During the recruitment, we collaborated with faculty members from several universities in China to recruit participants among their communities and used a snowball strategy to attract more participants through the social circles of the initially recruited participants. Convenience sampling was chosen for its practicality and ease of implementation, allowing us to efficiently gather data and complete the survey. Our study utilized the popular survey software in China[1]. The questionnaire was distributed based on the seven major geographical regions of China: Northeast China, North, Central, South, East, Northwest, and Southwest. To ensure data integrity, we monitored participants' devices and IP addresses, allowing each user to complete the survey only once. All collected data were treated with strict confidentiality measures. Prior to providing genuine responses, participants were required to sign an informed consent form to proceed with the survey. We strictly maintained the confidentiality of all data.

## 3.2 Participants

Our inclusion criteria were: (1) Age 18 and above (the legally defined adults in Chinese law), (2) Voluntary participation in this study and confirmation of informed consent, and (3) Residing in communities (defined by the Chinese government) in China. Our exclusion criteria were (1) completion times of less than 270 s (this is the basic time needed for completing the questionnaire according to our pre-testing) and (2) questionnaires displaying patterns of consistent or automated responses (monitored by the questionnaire platform). We initially included residents from 290 cities in 21 provinces, 5 autonomous regions, and 4 municipalities, resulting in a total of 1,538 community residents. After removing those subjects based on our exclusion criteria, a total of 1,402 residents were included in the final analysis.

## 3.3 Variables and measurement

### 3.3.1 Predictor/independent variables

(1) Individual characteristics: sex, age group, BMI, education level, whether having been diagnosed chronic condition, and health literacy were self-reported in the survey. Personal age group was categorized into five types (1 = 18–29 years, 2 = 30–39 years; 3 = 40–49 years;4 = 50–59 years;5 ≥ 60 years). BMI is calculated by taking a person's weight, in kilograms, divided by their height, BMI = weight (in kg)/ height^2 (in m^2). According to Chinese adult standards, BMI was grouped as underweight (BMI of <18.5), normal weight (18.5 ≤ BMI < 24), overweight (24 ≤ BMI ≤ 28), and obesity (BMI > 28) (6). Education level was self-reported and categorized into six types (1 = elementary school or lower, 2 = junior high school; 3 = high school /technical secondary school; 4 = junior college; 5 = undergraduate; 6 = postgraduate). Health literacy was measured by the Chinese version of HLS-SF12 translated by Sun et al. (24). The scale consists of three dimensions: health care, disease prevention, and health promotion, comprising a total of 12 items. Each item is scored on a 4-point scale, with response options ranging from 1 (very

1 https://www.wjx.cn/

difficult) to 4 (very easy), using a formula to calculate a standardized health literacy index ranging from 0 to 50, with a higher scores representing higher level of health literacy. The formula is, index = (mean − 1) * (50/3), where the mean is the average of all items involved for each individual (25). The HLS-SF12 was developed by Duong et al., which is an abbreviated and refined measurement tool designed to assess health literacy in a fast, comprehensive, and effective manner (25). The Chinese version of HLS-SF12 serves as a valuable tool for assessing the current status of health literacy in China and identifying influential factors. In this study, the questionnaire showed acceptable internal consistency (Cronbach's $\alpha = 0.931$).

(2) Individual behaviors: smoking or not (1 = yes, 2 = no), drinking or not (1 = yes, 2 = no), taking regular exercise or not (1 = yes, 2 = no), and taking physical examination regularly or not (1 = yes, 2 = no) were captured by binary choices. Sleeping duration was categorized into four types (1 = less than 5 h/day; 2 = 5–6 h/day; 3 = 6–7 h/day; 4 = more than 7 h/day). Siting duration was categorized into four types (1 = less than 4 h/day; 2 = 4–6 h/day; 3 = 6–8 h/day; 4 = more than 8 h/day).

(3) Interpersonal networks: Marital status was captured by a categorical response scale (1 = unmarried; 2 = married; 3 = divorced; 4 = widowed); living status was categorized into three types (1 = living alone; 2 = living with family; 3 = living in work/school dormitories). Family health was measured using the Short-Form of the Family Health Scale in the Chinese Version (FHS-SF). The Chinese version of FHS-SF was cross-culturally validated by Wang et al. (26). It comprises four dimensions, encompassing a total of 10 items. These dimensions are: (1) Family/Social/Emotional Health Processes (item 1, 2, and 5), (2) Family Health Lifestyle (item 3 and 4), (3) Family Health Resources (item 6, 9, and 10), and (4) External Social Support for the Family (item 7 and 8). The items are rated on a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree." Notably, items 6, 9, and 10 employ reverse scoring, with higher scores indicating a better family health status (6). The Chinese version of FHS-SF demonstrates good reliability and validity, making it suitable for assessing the level of family health among Chinese residents. In this study, the scale showed acceptable internal consistency (Cronbach's $\alpha = 0.737$).

(4) Community: the length of residence was categorized into five types (1 = 0–5 years; 2 = 6–10 years; 3 = 11–15 years; 4 = 16–20 years; 5 = More than 20 years). Residential location was categorized into two types (1 = urban; 2 = rural). Career status was categorized into two types (1 = student; 2 = full time; 3 = part time; 4 = unemployed; 5 = retired; 6 = famer). Monthly personal income was categorized into five types (1 = ≤3,000 RMB; 2 = 3,001–5,000 RMB;3 = 5,001 ~ 8,000 RMB; 4 = 8,001 ~ 12,000 RMB; 5 = >12,000 RMB). According to the data from the National Bureau of Statistics, the wage *income per capita* of residents in China in the first three quarters was 16,747 RMB (Monthly income ≈ 16,747 RMB / 3 = 5,582.33 RMB). One RMB is approximately 0.14 USD or 0.12 EUR (September 2023). Source of income was divided into six categories: 1 = salary; 2 = parental support; 3 = pension/retirement benefits; 4 = support from children or relatives; 5 = government subsidies; 6 = other sources of income.

### 3.3.2 Outcome/dependent variables

The revised version of Health Promoting Lifestyle Profile-II (HPLP-II R) was used for the assessment of health-promoting lifestyles. This questionnaire is a well-validated instrument that evaluates individuals' health-promoting behaviors across multiple dimensions (27). It is an adapted version of the 52-item HPLP-II, specifically tailored for the Chinese population by Cao et al. (28). This questionnaire consists of six dimensions: Interpersonal Relationships (5 items), Nutrition (6 items), Health Responsibility (11 items), Physical Activity (8 items), Stress Management (5 items), and Self-actualization (5 items). Each item is rated on a 4-point Likert-type scale, where 1 indicates "never" and 4 indicates "always." The total score ranges from 40 to 160. Scores ranging from 40 to 80, 81–120, and 121–160 correspond to low, moderate, and high levels of health-promoting lifestyle, respectively (29). In this study, the scale showed excellent internal consistency (Cronbach's $\alpha = 0.96$). Meanwhile, the sub-scales for the six dimensions, including Interpersonal Relationships (Cronbach's $\alpha = 0.822$), Stress Management (Cronbach's $\alpha = 0.791$), Health Responsibility (Cronbach's $\alpha = 0.902$), Nutrition (Cronbach's $\alpha = 0.788$), Physical Activity (Cronbach's $\alpha = 0.888$), and Self-actualization (Cronbach's $\alpha = 0.850$) also showed acceptable internal consistency.

## 3.4 Quality control

Several measures have been implemented for quality control. Firstly, a pilot survey was conducted to validate and refine the questionnaire. Feedback was gathered from a random sample of 30 participants, assessing the clarity and relevance of the survey content. Necessary adjustments and improvements were made based on their feedback. Secondly, as demonstrated in our exclusion criteria, a time limit was established through a pre-test involving multiple participants from different age groups. Surveys completed within 270 s were excluded as this timeframe was deemed inadequate for thoughtful and considered responses. This time restriction aims to prevent hasty answers that might increase common method bias.

## 3.5 Statistical methods

Descriptive statistics were utilized to calculate the number and percentage of categorical variables, while continuous variables were represented by means and standard deviations. Multiple linear regression was selected for analysis, which is particularly useful for identifying the associations between variables. Linear regression exhibits considerable robustness to non-normal data, especially when the sample size for parameter estimation is relatively large (where the number of observations per variable is > 10) (30). Therefore, we did not transform the data before testing.

Prior to the regression, we tested multicollinearity according to the variance inflation factor (VIF), where a VIF value smaller than 5.0 was considered as the absence of multicollinearity issue (31). Based on this rule, we found no risk of multicollinearity (our VIFs were smaller than 2.0). Unordered categorical variables were processed into dummy variables before the analysis.

Based on the method of others (32, 33), we adopted a forward stepwise regression approach. In this approach, the model starts with no independent variables, and at each step, the variable that provides the best improvement in the model's fit (e.g., reduces the residual sum of squares) is added. This process continues until adding more variables no longer significantly improves the model.

### 3.6 Ethics statement

This study obtained approval from the Ethics Committee of Southwest University Hospital, Chongqing, China (SWU-ETF-2023-07-17-011). The methods involved in our research were conducted in accordance with the guidelines and regulations outlined in the Helsinki Declaration.

## 4 Results

### 4.1 Participants' characteristics

Table 1 presents the characteristics of the participants. A total of 1,402 individuals were included in our study. 64.1% of participants were male, 89.3% were undergraduate or higher education level, and 85.3% lived in urban areas. The mean score for the participants' HLS-SF12 was 37.9, FHS-SF was 37.53, and the HPLP-IIR was 111.19. Interpersonal relations showed the highest score, and health responsibility showed the lowest score, with physical activity ranking the second lowest.

### 4.2 The factors relevant to the HPLP-II R scores

Based on the EMHB, our study found 12 significant factors of the health-promoting lifestyles (Table 2). In the first level, People of older age (≥60 years) ($\beta = -0.046$) tended to have an unhealthy lifestyle. Participants who had higher scores of HLS-SF12 ($\beta = 0.467$) were more likely to have better lifestyles. In the second level, participants who exercised regularly ($\beta = 0.212$) and had physical examination regularly ($\beta = 0.088$) tended to have better lifestyles. Participants with shorter sleeping time (5–6 h/day) ($\beta = -0.048$), or drinking ($\beta = -0.066$) tended to have worse lifestyles. In the third level, participants who lived with family ($\beta = 0.077$), and had higher scores of FHS-SF ($\beta = 0.104$) had better lifestyles. Participants who were married ($\beta = -0.077$) showed lower HPLP-II R scores. At the fourth level, participants who were unemployed ($\beta = -0.048$), and receiving retirement pay ($\beta = -0.053$) showed lower HPLP-II R scores. However, the participants who had higher economic support provided by parents ($\beta = 0.094$) showed higher scores of the HPLP-II R.

### 4.3 The factors relevant to the dimensions of HPLP-II R scores

Based on the EMHB, our study found factors of the dimensions of health-promoting lifestyles (Table 3). In the interpersonal relationships, we found 10 significant factors. In the first level, being female ($\beta = 0.050$) and had higher scores of HLS-SF12 ($\beta = 0.459$) were associctated better lifestyles. Participants who had older age (≥60 years) ($\beta = -0.061$) and had a junior high school educational level ($\beta = -0.051$) tended to have an unhealthy lifestyle. In the second level, Participants who exercised regularly ($\beta = 0.069$) had better interpersonal relationships. In the third level, participants who had higher scores of FHS-SF ($\beta = 0.242$) tended to have better interpersonal relationships. At the fourth level, participants who were unemployed ($\beta = -0.043$), relied on retirement income ($\beta = -0.071$), and had a monthly income of 5,001 ~ 8,000 RMB ($\beta = -0.053$) showed lower scores in interpersonal relationships. Participants who received economic support from their parents ($\beta = 0.094$) showed higher scores on the interpersonal relationships.

In the dimension of health responsibility, we found 13 factors. In the first level, participants who were older (≥60 years) ($\beta = -0.060$) and had a junior high school education level ($\beta = -0.049$) tended to have worse health responsibility. Participants who had higher scores of HLS-SF12 ($\beta = 0.384$) showed better health responsibilities. In the second level. Participants who exercised regularly ($\beta = 0.162$) and had physical examination regularly ($\beta = 0.146$) showed better health responsibility. However, participants who had been smoking ($\beta = -0.050$), drinking ($\beta = -0.079$), sitting for more than 8 h ($\beta = -0.063$), and sleeping for 5–6 h ($\beta = -0.047$) had worse health responsibility. In the third level, the participants who were widowed ($\beta = -0.053$) and had lower scores of FHS-SF ($\beta = -0.056$) tended to have worse health responsibilities. At the fourth level, participants who received economic support from their parents ($\beta = 0.097$) showed higher scores on health responsibility. Conversely, the participants who relied on retirement income ($\beta = -0.085$) showed worse health responsibility.

In the dimension of stress management, we found 10 factors. In the first level, the participants who had higher scores of HLS-SF12 ($\beta = 0.421$) tended to have better stress management. However, those who were underweight (<18.5) ($\beta = -0.045$) and had a junior college education level ($\beta = -0.057$) showed lower scores on stress management. In the second level, participants who exercised regularly ($\beta = 0.132$) had better stress management. Conversely, sleeping 5 ~ 6 h ($\beta = -0.054$) was negatively associated with stress management. In the third level, participants who were married ($\beta = -0.122$) showed lower scores of stress management. However, Living with family ($\beta = 0.077$) and having higher scores of FHS-SF ($\beta = 0.127$) tended to have better stress management. At the fourth level, participants who received economic support from their parents ($\beta = 0.116$) showed higher scores of stress management. Conversely, participants with monthly income above 12,000 yuan ($\beta = -0.050$) showed lower scores on stress management.

In the dimension of nutrition, we found 11 factors. In the first level, participants who be female ($\beta = 0.067$) and were overweight (24–28) ($\beta = 0.050$), and had higher scores of HLS-SF12 ($\beta = 0.412$) showed higher scores of nutrition. In the second level, participants who exercised regularly ($\beta = 0.086$), and had physical examination regularly ($\beta = 0.055$) showed higher scores on the nutrition, while who had been smoking ($\beta = -0.076$), drinking ($\beta = -0.087$), and sleeping 5–6 h ($\beta = -0.049$) showed lower scores on nutrition. In the third level, participants who lived with family ($\beta = 0.069$) and had higher scores of FHS-SF ($\beta = 0.224$) had better nutrition. At the fourth level, participants who received economic support from their parents ($\beta = 0.064$) showed higher scores on nutrition.

In the dimension of physical activity, we found 10 factors. In the first level, participants who had higher scores of HLS-SF12 ($\beta = 0.338$) showed higher scores on physical activity. Moreover, females ($\beta = -0.061$), individuals diagnosed with chronic condition ($\beta = -0.061$) and those with a junior college education level ($\beta = -0.052$) exhibited lower scores of physical activity. In the second level, participants who exercised regularly ($\beta = 0.342$) and had physical examination regularly ($\beta = 0.083$) tended to have better physical activity. Conversely, those who had been smoking ($\beta = -0.047$), sitting

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TABLE 1 Participants' characteristics.

| Categorical variables | Category | *N* | Percentage |
|---|---|---|---|
| **Sex** | Male | 898 | 64.1% |
| | Female | 504 | 35.9% |
| **BMI** | | | |
| | Underweight (<18.5) | 75 | 5.3% |
| | Normal weight (18.5–24) | 799 | 57.0% |
| | Overweight (24–28) | 425 | 30.3% |
| | Obese (≥28) | 103 | 7.3% |
| **Education level** | | | |
| | ≤Elementary school | 8 | 0.6% |
| | Junior high school | 24 | 1.7% |
| | High school/technical secondary school | 39 | 2.8% |
| | Junior college | 80 | 5.7% |
| | Undergraduate | 789 | 56.3% |
| | Postgraduate | 462 | 33.0% |
| **Age group (year)** | | | |
| | 18–29 | 621 | 44.3% |
| | 30–39 | 273 | 19.5% |
| | 40–49 | 247 | 17.6% |
| | 50–59 | 172 | 12.3% |
| | ≥60 | 89 | 6.3% |
| **Marital status** | | | |
| | Unmarried | 567 | 40.4% |
| | Married | 788 | 56.2% |
| | Divorced | 37 | 2.6% |
| | Widowed | 10 | 0.7% |
| **Type of residence** | | | |
| | Urban | 1,196 | 85.3% |
| | Rural | 206 | 14.7% |
| **Living situation** | | | |
| | Living alone | 147 | 10.5% |
| | Live with family | 1,123 | 80.1% |
| | Living in work/school dormitories | 132 | 9.4% |
| **Length of residence** | | | |
| | 0–5 years | 256 | 18.3% |
| | 6–10 years | 217 | 15.5% |
| | 11–15 years | 164 | 11.7% |
| | 16–20 years | 240 | 17.1% |
| | More than 20 years | 525 | 37.4% |
| **Working status** | | | |
| | Student | 330 | 23.5% |
| | Full time | 897 | 64.0% |
| | Part time | 23 | 1.6% |
| | Unemployed | 40 | 2.9% |
| | Retired | 99 | 7.1% |

*(Continued)*

TABLE 1 (Continued)

| Categorical variables | Category | *N* | Percentage |
|---|---|---|---|
| | Famer | 13 | 0.9% |
| **Monthly personal income (RMB)** | | | |
| | ≤3,000 | 357 | 25.5% |
| | 3,001–5,000 | 195 | 13.9% |
| | 5,001–8,000 | 332 | 23.7% |
| | 8,001–12,000 | 285 | 20.3% |
| | >12,000 | 233 | 16.6% |
| **Economic sources** | Salary | 949 | 67.7% |
| | Parental support | 313 | 22.3% |
| | Pension/Retirement benefits | 76 | 5.4% |
| | Support from children or relatives | 3 | 0.2% |
| | Government subsidies | 11 | 0.8% |
| | Other sources of income | 50 | 3.6% |
| **Smoking** | | | |
| | Yes | 347 | 24.8% |
| | No | 1,055 | 75.2% |
| **Drinking** | | | |
| | Yes | 612 | 43.7% |
| | No | 790 | 56.3% |
| **Exercise regularly** | | | |
| | Yes | 777 | 55.4% |
| | No | 625 | 44.6% |
| **Regular physical examination** | | | |
| | Yes | 822 | 58.6% |
| | No | 580 | 41.4% |
| **Sitting time** | | | |
| | Less than 4 h/day | 378 | 27.0% |
| | 4–6 h/day | 576 | 41.1% |
| | 6–8 h/day | 304 | 21.7% |
| | More than 8 h/day | 144 | 10.3% |
| **Sleeping time** | | | |
| | Less than 5 h/day | 14 | 1.0% |
| | 5–6 h/day | 173 | 12.3% |
| | 6–7 h/day | 593 | 42.3% |
| | More than 7 h/day | 622 | 44.4% |
| **Chronic condition** | | | |
| | Yes | 216 | 15.4% |
| | No | 1,186 | 84.6% |
| **Continuous variables** | **M (SD)** | **Median(IQR)** | **Range** |
| HLS-SF12(index) | 36.02 (7.92) | 33.33 (8.33) | 0–50 |
| FHS-SF(score) | 37.53 (6.35) | 37(8) | 20–50 |
| **Dimensions** | **M (SD)** | **SS score** | **Rank** |
| Interpersonal relations | 15.28 (2.55) | 76.42 | 1 |
| Health responsibility | 27.79 (6.19) | 63.16 | 6 |

*(Continued)*

TABLE 1 (Continued)

| Categorical variables | Category | *N* | Percentage |
|---|---|---|---|
| Stress management | 14.17 (2.67) | 70.83 | 4 |
| Nutrition | 18.22 (2.94) | 75.92 | 2 |
| Physical activity | 20.80 (5.00) | 65.00 | 5 |
| Self-actualization | 14.93 (2.80) | 74.65 | 3 |
| HPLP-II R total score | 111.19 (18.84) | 69.50 | – |

TABLE 2 The stepwise regression analysis of factors associated with HPLP-II R total score.

| Variables | Coef. | *β* | *t* | *p* |
|---|---|---|---|---|
| Individual characteristics | | | | |
| Age (Ref: 18–29, year) | | | | |
| ≥60 | −2.658 | −0.046 | −2.116 | 0.035 |
| HLS-SF12 | 1.112 | 0.467 | 20.812 | <0.001 |
| Individual behaviors | | | | |
| Whether exercise regularly (Ref: No) | | | | |
| Yes | 8.040 | 0.212 | 9.726 | <0.001 |
| Whether regular physical examination (Ref: No) | | | | |
| Yes | 3.350 | 0.088 | 3.665 | <0.001 |
| Whether drinking(Ref: No) | | | | |
| Yes | −2.495 | −0.066 | −3.117 | 0.002 |
| Sleeping time (Ref: Less than 5 h/day) | | | | |
| 5–6 h/day | −2.761 | −0.048 | −2.295 | 0.022 |
| Interpersonal networks | | | | |
| Marital status (Ref: Unmarried) | | | | |
| Married | −2.919 | −0.077 | −2.448 | 0.014 |
| Living situation (Ref: Living alone) | | | | |
| Living with family | 3.618 | 0.077 | 3.133 | 0.002 |
| FHS-SF | 0.307 | 0.104 | 4.454 | <0.001 |
| Community | | | | |
| Career status (Ref: Student) | | | | |
| Unemployed | −5.455 | −0.048 | −2.309 | 0.021 |
| Economic sources (Ref: Salary) | | | | |
| Provided by parents | 4.266 | 0.094 | 3.387 | 0.001 |
| Retirement pay | −4.429 | −0.053 | −2.505 | 0.012 |

about 6–8 h/day ($\beta = -0.071$), and more than 8 h/day ($\beta = -0.080$) showed lower scores physical activity. At the fourth level, participants who received economic support from their parents ($\beta = 0.134$) showed higher scores on physical activity.

In the dimension of self-actualization, we found 7 factors. Females ($\beta = 0.047$) and individuals with higher scores of HLS-SF12 ($\beta = 0.421$) showed higher scores of self-actualization. The participants who were diagnosed with chronic condition ($\beta = -0.043$) and those had a junior college educational level ($\beta = -0.047$) showed lower scores of self-actualization. In the second, third, and fourth levels, just one influencing factor was identified for each. The participants who exercised regularly ($\beta = 0.145$), had higher scores of FHS-SF ($\beta = 0.236$), and had economic sources of support from their parents ($\beta = 0.103$) showed higher scores of self-actualization.

## 5 Discussion

We found that the health-promoting lifestyles of community-dwelling adults in China was at a moderate level (80–120 point), which is consistent with the results of other research (34, 35), indicating that the health lifestyle of Chinese adults is unsatisfactory. Meanwhile, in our study, interpersonal relationships received the highest score, followed by nutrition. In contrast, health responsibility received the lowest score, with physical activity ranking the second lowest. Our findings align with the research by Zhang et al. (36), where interpersonal relationships also received the highest score while health responsibility received the lowest score. Generally, our findings on health-related lifestyle reinforce some previous studies and underline some commonalities among Chinese populations. Based on the EMHB framework, our study explores the

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TABLE 3 The factors relevant to the dimensions of HPLP -II R scores.

| Variables | Coef. | *β* | *t* | *p* |
|---|---|---|---|---|
| **Interpersonal relationships** | | | | |
| Individual characteristics | | | | |
| Sex (Ref: Male) | | | | |
| Female | 0.265 | 0.050 | 2.369 | 0.018 |
| Age (Ref: 18-29, year) | | | | |
| ≥60 | −0.472 | −0.061 | −2.799 | 0.005 |
| Education level (Ref: ≤Elementary school) | | | | |
| Junior high school | −1.007 | −0.051 | −2.381 | 0.017 |
| HLS-SF12 | 0.148 | 0.459 | 20.139 | <0.001 |
| Individual behaviors | | | | |
| Whether exercise regularly (Ref: No) | | | | |
| Yes | 0.356 | 0.069 | 3.183 | 0.001 |
| Interpersonal networks | | | | |
| FHS-SF | 0.097 | 0.242 | 10.247 | <0.001 |
| Community | | | | |
| Career status (Ref: Student) | | | | |
| Unemployed | −0.656 | −0.043 | −2.001 | 0.046 |
| Economic sources (Ref: Salary) | | | | |
| Provided by parents | 0.576 | 0.094 | 4.018 | <0.001 |
| Retirement pay | −0. 801 | −0.071 | −3.317 | 0.001 |
| monthly income (Ref:≤3000yuan) | | | | |
| 5,001 ~ 8000yuan | −0. 316 | −0.053 | −2.381 | 0.017 |
| **Health responsibility** | **Coef.** | **β** | **t** | **p** |
| Individual characteristics | | | | |
| Age (Ref: 18–29, year) | | | | |
| ≥60 | −1.133 | −0. 060 | −2.510 | 0.012 |
| Education level (Ref: ≤Elementary school) | | | | |
| Junior high school | −2.344 | −0.049 | −2.134 | 0.033 |
| HLS-SF12 | 0.300 | 0.384 | 15.404 | <0.001 |
| Individual behaviors | | | | |
| Whether exercise regularly (Ref: No) | | | | |
| Yes | 2.020 | 0.162 | 6.687 | <0.001 |
| Whether regular physical examination (Ref: No) | | | | |
| Yes | 1.836 | 0. 146 | 5.666 | <0.001 |
| Whether drinking(Ref: No) | | | | |
| Yes | −0.981 | −0.079 | −3.083 | 0.002 |
| Whether smoking (Ref: No) | | | | |
| Yes | −0.721 | −0.050 | −1.994 | 0.046 |
| Sitting time (Ref: Less than 5 h/day) | | | | |
| More than 8 h/day | −1.286 | −0.063 | −2.729 | 0.006 |
| Sleeping time (Ref: Less than 5 h/day) | | | | |
| 5–6 h/day | −0.877 | −0.047 | −1.999 | 0.046 |
| Interpersonal networks | | | | |
| Marital status (Ref: Unmarried) | | | | |

*(Continued)*

TABLE 3 (Continued)

| Variables | Coef. | *β* | *t* | *p* |
|---|---|---|---|---|
| Widowed | −3.883 | −0.053 | −2.292 | 0.022 |
| FHS-SF | −0.054 | −0.056 | −2.167 | 0.030 |
| Community | | | | |
| Economic sources (Ref: Salary) | | | | |
| Provided by parents | 1.445 | 0.097 | 3.747 | <0.001 |
| Retirement pay | −2.329 | −0.085 | −3.625 | <0.001 |
| **Stress Management** | **Coef.** | **β** | **t** | **p** |
| Individual characteristics | | | | |
| Education level (Ref: ≤ Elementary school) | | | | |
| Junior college | −0.651 | −0.057 | −2.572 | 0.010 |
| BMI (Ref: Normal weight (18.5–24)) | | | | |
| Underweight (<18.5) | −0.536 | −0.045 | −1.999 | 0.046 |
| HLS-SF12 | 0.142 | 0.421 | 17. 557 | <0.001 |
| Individual behaviors | | | | |
| Whether exercise regularly(Ref: No) | | | | |
| Yes | 0. 706 | 0.132 | 5.781 | <0.001 |
| Sleeping time (Ref: Less than 5 h/day) | | | | |
| 5 ~ 6 h/day | −0. 441 | −0.054 | −2.446 | 0.015 |
| Interpersonal networks | | | | |
| Marital status (Ref: Unmarried) | | | | |
| Married | −0. 657 | −0.122 | −3.724 | <0.001 |
| Living situation (Ref: Living alone) | | | | |
| Live with family | 0.517 | 0. 077 | 2.958 | 0.003 |
| FHS-SF | 0.053 | 0.127 | 5.120 | <0.001 |
| Community | | | | |
| Economic sources (Ref: Salary) | | | | |
| Provided by parents | 0.746 | 0.116 | 3.914 | <0.001 |
| Monthly income (Ref: ≤3000 yuan) | | | | |
| >12,000 yuan | −0.357 | −0.050 | −2.169 | 0.030 |
| **Nutrition** | **Coef.** | **β** | **t** | **p** |
| Individual characteristics | | | | |
| Sex (Ref: Male) | | | | |
| Female | 0.411 | 0.067 | 2.685 | 0.007 |
| BMI (Ref: Normal weight (18.5–24)) | | | | |
| Overweight (24 ~ 28) | 0.317 | 0.050 | 2.170 | 0.030 |
| HLS-SF12 | 0.153 | 0.412 | 17.748 | <0.001 |
| Individual behaviors | | | | |
| Whether exercise regularly (Ref: No) | | | | |
| Yes | 0.438 | 0.074 | 3.286 | <0.001 |
| Whether regular physical examination (Ref: No) | | | | |
| Yes | 0.330 | 0.055 | 2.279 | 0.023 |
| Whether drinking (Ref: No) | | | | |
| Yes | −0.516 | −0.087 | −3.466 | 0.001 |
| Whether smoking (Ref: No) | | | | |

*(Continued)*

TABLE 3 (Continued)

| Variables | Coef. | *β* | *t* | *p* |
|---|---|---|---|---|
| Yes | −0.520 | −0.076 | −3.144 | 0.002 |
| Sleeping time (Ref: Less than 5 h/day) | | | | |
| 5–6 h/day | −0.441 | −0.049 | −2.283 | 0.023 |
| Interpersonal networks | | | | |
| Living situation (Ref: Living alone) | | | | |
| Live with family | 0. 511 | 0.069 | 3.181 | 0.001 |
| FHS-SF | 0.104 | 0.224 | 9.407 | <0.001 |
| Community | | | | |
| Economic sources (Ref: Salary) | | | | |
| Provided by parents | 0.455 | 0.064 | 2.671 | 0.008 |
| **Physical activity** | **Coef.** | **β** | **t** | **p** |
| Individual characteristics | | | | |
| Sex (Ref: Male) | | | | |
| Female | −0.639 | −0.061 | −2.646 | 0.008 |
| Education level (Ref: ≤Elementary school) | | | | |
| Junior high school | −2.005 | −0. 052 | −2.403 | 0. 016 |
| Whether diagnosed Chronic condition (Ref: No) | | | | |
| Yes | −0. 850 | −0.061 | −2.816 | 0. 005 |
| HLS-SF12 | 0. 213 | 0. 338 | 15.293 | <0.001 |
| Individual behaviors | | | | |
| Whether exercise regularly (Ref: No) | | | | |
| Yes | 3.436 | 0. 342 | 14.988 | <0.001 |
| Whether regular physical examination (Ref: No) | | | | |
| Yes | 0. 839 | 0.083 | 3.442 | 0. 001 |
| Whether smoking (Ref: No) | | | | |
| Yes | 0.549 | −0.047 | 2.040 | 0.042 |
| Sitting time (Ref: Less than 5 h/day) | | | | |
| 6–8 h/day | −0.895 | −0.071 | −3.241 | 0.001 |
| More than 8 h/day | −1.324 | −0.080 | −3.625 | <0.001 |
| Community | | | | |
| Economic sources (Ref: Salary) | | | | |
| Provided by parents | 1.614 | 0.134 | 5.736 | <0.001 |
| **Self-actualization** | **Coef.** | **β** | **t** | **p** |
| Individual characteristics | | | | |
| Sex (Ref: Male) | | | | |
| Female | 0.274 | 0.047 | 2.189 | 0.029 |
| Education level (Ref: ≤Elementary school) | | | | |
| Junior college | −0.573 | −0.047 | −2.196 | 0.028 |
| Whether diagnosed Chronic condition (Ref: No) | | | | |
| Yes | −0.333 | −0.043 | −1.982 | 0.048 |
| HLS-SF12 | 0.149 | 0.421 | 18.238 | <0.001 |
| Individual behaviors | | | | |
| Whether exercise regularly (Ref: No) | | | | |
| Yes | 0.818 | 0.145 | 6.613 | <0.001 |

*(Continued)*

TABLE 3 (Continued)

| Variables | Coef. | $\beta$ | $t$ | $p$ |
|---|---|---|---|---|
| Interpersonal networks | | | | |
| FHS-SF | 0.104 | 0.236 | 9.939 | <0.001 |
| Community | | | | |
| Economic sources (Ref: Salary) | | | | |
| Provided by parents | 0.693 | 0.103 | 4.553 | <0.001 |

factors associated with health-promoting lifestyles across four levels: individual characteristics, individual behaviors, interpersonal networks, and community.

Our research has demonstrated that health-promoting lifestyles were associated with a range of factors. By employing the EMHB model in our study, we identified that these factors are multidimensional and encompass various aspects. It is crucial for future research to consider these holistic perspectives in order to enhance community residents' lifestyles and devise appropriate intervention strategies. Importantly, it should be noted that different dimensions exhibit slight variations in their influencing factors, underscoring the significance of targeted interventions that account for specific factors pertinent to improving specific health lifestyles among community residents. A potential approach to foster the adoption of healthy lifestyles among community residents is to consider the practice pathway involving the community, family, and individual levels. By implementing interventions and strategies targeting these interconnected levels, there exists the possibility of cultivating positive health behaviors and facilitating the development of sustainable healthy lifestyles within the community.

At the individual characteristic level, sex was found a significant influencing factor of health-promoting lifestyles, with females demonstrating advantages in interpersonal relationships, nutrition, and self-actualization. A study conducted in Japan has revealed that females had higher scores for the six dimensions of HPLP-II and also the total score (37). Consistent findings have also been reported in some other studies on Chinese populations (38, 39). This phenomenon may be attributed to females shouldering more obligations to their families and managing family relationships, which allows them to prioritize dietary choices and interpersonal relationship management (38). Additionally, due to increased independence and autonomy among modern women, they tended to prioritize self-care and self-actualization (39). Education level was also associated with interpersonal relationships, health responsibility, and stress management. This finding may be explained by higher levels of education leading to better acceptance and the ability to effectively access health advice. While research on the relationship between BMI and health-promoting lifestyles is still limited, existing studies have emphasized the importance of addressing obesity and overweight issues in health promotion (40). We found that underweight participants tended to have challenges in effectively managing stress. According to previous studies, underweight and obese individuals showed higher rates of emotional problems compared with normal and overweight participants (41). Additionally, underweight individuals face many other physical health-related risks, such as the higher likelihood of stroke (42), eating slowly (43), and engaging in unhealthy behaviors (44). This may result in individuals with underweight obtaining lower scores in stress management. Age was another contributing factor. Individuals aged 60 and above tended to score lower scores on the HPLP-IIR, interpersonal relationships, and health responsibility compared to their younger counterparts. This finding is consistent with another study (45). Furthermore, patients with chronic diseases exhibited lower scores in the physical exercise and spiritual growth subscales, which is similar to the findings of Aygar's research (46), where physical activity subscale scores were low among patients with chronic diseases. Additionally, individuals with chronic diseases are more vulnerable to symptoms such as depression and anxiety, which may negatively impact their mental well-being and, consequently, lead to lower scores in the spiritual growth dimension. Furthermore, health literacy is a key factor that impacts the overall score of the HPLP-IIR and its dimensions (47). Individuals with higher health literacy scores tend to have healthier lifestyles. This aligns with previous research that health literacy has demonstrated an association with healthy lifestyles or health-related behaviors (48) In the individual characteristics, we found that factors such as sex, age, education level, BMI, chronic diseases, and health literacy play distinctive roles in the variations of health-promoting lifestyles. Among these factors, health literacy and sex emerge as significant influencers. According to research findings, health literacy is directly associated with disease mortality, overall health status, disease prevention, and health behaviors (49). In future research, it is worth considering various approaches to enhance the health literacy of community residents in order to promote the healthy lifestyles.

At the individual behavioral level, several factors are significantly associated with the health lifestyles of residents, including regular physical examination, smoking, drinking, sleeping, and sedentary behavior. Among them, regular physical exercise showed an impact on the six dimensions of HPLP-IIR and also its total score. Residents who exercised regularly tended to have higher scores, both in total and across each dimension, and those who participated in physical examination regularly showed higher scores of health responsibility, nutrition, and physical activity. Meanwhile, smoking, drinking, sleep patterns, and sedentary behavior were also significantly associated with various dimensions of a health-promoting lifestyle. Numerous studies have demonstrated that adopting healthy behaviors can prolong lifespan (5) and maintain overall health (50). In contrast, unhealthy behaviors, such as smoking, drinking, insufficient exercise, and inadequate sleep are significantly correlated with metabolic syndrome and can therefore impact health (50).

At the interpersonal network level, family health was a crucial factor, which was positively associated with the overall score and the scores in various dimensions of HPLP-IIR. Theoretically, positive family health promotes belonging, caring, and the capacity to perform family responsibilities, which in turn, promotes the health of

individual members (51). Furthermore, the effect of participants' living situation was also significant. Specifically, participants who live with their family tended to have a higher total score, as well as higher scores in nutrition and stress management dimensions compared to those who live alone, live in school/workplace dormitories, or share accommodations with others. This finding is expected because living with family members allows for mutual care and is more conducive to developing healthy lifestyle habits (52). Marital status was also associated with the total score and the scores in health responsibility and stress management dimensions. Specifically, married participants tended to show lower scores in overall and stress management, while widowed participants had lower scores in health responsibility. Similar to our finding, other scholars have also found that widowed individuals scored lower than married or unmarried/divorced individuals across all scales (35).

At the community level, participants who relied on economic support from their parents exhibited higher scores in the total score and six dimensions. Studies have suggested that ideal socioeconomic status was beneficial to healthy behavior (6) and the source of income was a influencing factor of people's social activity (53). In our study, participants who received financial support from their parents were predominantly college students, and they tended to have a better awareness of health compared to others. This may be a contributing factor to their higher scores in adopting a healthy lifestyle. Additionally, sufficient economic support enables them to fulfill many of their needs in daily life. However, participants relying on retirement pensions tended to have lower scores in interpersonal relationships, health responsibility dimensions, and the total score. This group mainly consists of older adult individuals who had worse health-promoting lifestyles. This finding aligns with several studies conducted in China (34, 45). Moreover, monthly income was associated with interpersonal relationships and stress management. In other words, individuals with higher monthly incomes tended to show worse stress management. This result may come from the fact that higher income levels often coincide with increased work demands and intensity, leading to elevated stress levels and relatively less attention on health-promoting lifestyles (39). Participants with monthly incomes in the range of 5,001–8000 RMB had lower scores in interpersonal relationships, which could result from specific occupational types (54, 55). For example, participants within this salary range may have busy work schedules, more life stress, and fewer financial resources available for social expenses. These may result in weaker interpersonal relationships in their daily lives.

## 6 Limitations

In our study, there are several limitations that warrant consideration. Firstly, due to practical constraints, we were unable to conduct a nationwide random sampling with a large sample size. Consequently, a convenience sample was employed. The gender was not balanced in our sample, which has limited the generalizability of our findings. Caution should therefore be exercised when extrapolating the results to broader contexts. Future research should aim to incorporate more diverse and representative samples to enhance the external validity of the findings.

Secondly, although we used "influencers" as following previous studies to underline the potential roles of these factors in changing residents' health-promoting behaviors, it should be noted that our findings are solely captured from cross-sectional data with only one observational timepoint, and the nature of such data forbid further causal evaluations. Therefore, all the "effects/influences" we found should be explained as associations. To address this limitation, future investigations could employ longitudinal designs, experimental approaches, or instrumental variables to explore causal relationships and further elucidate the impact of these factors on health behavior.

Additionally, it is noteworthy that we only consider personal or individual factors, while some factors at neighborhood or regional levels, such as regional socioeconomic, have not been included. Since individuals residing in poverty or with low socioeconomic statuses generally exhibit poorer performances in terms of health behavior, these should be taken into consideration in future research.

## 7 Conclusions

This study utilized a cross-sectional design and regression analyses to identify factors likely to influence health-promoting lifestyles. Employing the EMHB model, we identified several factors at individual, interpersonal networks and community levels potentially associated with the six sub-dimensions and overall levels of health-promoting lifestyles among Chinese populations. Our findings may contribute to the development of personalized interventions and controlling confounding effects in research on health-promoting lifestyles. Given our study's limitations, we advocate for future research with improved samples and methodologies to confirm causal relationships between these factors and health-promoting lifestyles.

## 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 author.

## Ethics statement

The studies involving humans were approved by Ethics Committee of Southwest University Hospital. 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

LH: Conceptualization, Data curation, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. HLi: Writing – review & editing, Formal analysis. HLiu: Investigation, Methodology, Writing – review & editing, Formal Analysis. HT: Formal analysis, Investigation, Methodology, Writing – review & editing. HLu: Formal analysis, Data curation, Investigation,

Writing – review & editing. JW: Investigation, Writing – review & editing. YL: Investigation, Writing – review & editing. LP: Funding acquisition, Project administration, Supervision, Writing – review & editing. LG: Data curation, Investigation, Project administration, Supervision, 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 supported by National Social Science Fund Project (No. 21BTY092); Chongqing Municipal Doctoral Research and Innovation Project (No. CTY22100); and General Project of Chongqing Sports Bureau (No. B202206).

## 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



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frontiers | Frontiers in Public Health

TYPE Study Protocol
PUBLISHED 11 January 2024
DOI 10.3389/fpubh.2024.1327442



OPEN ACCESS

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RECEIVED 25 October 2023
ACCEPTED 02 January 2024
PUBLISHED 11 January 2024

CITATION
Jiang Y, Sun X, Jiang M, Min H, Wang J, Fu X, Qi J, Yu Z, Zhu X and Wu Y (2024) Impact of a mobile health intervention based on multi-theory model of health behavior change on self-management in patients with differentiated thyroid cancer: protocol for a randomized controlled trial.
*Front. Public Health* 12:1327442.
doi: 10.3389/fpubh.2024.1327442



# Impact of a mobile health intervention based on multi-theory model of health behavior change on self-management in patients with differentiated thyroid cancer: protocol for a randomized controlled trial

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**Introduction:** Theoretical models of health behavior are important guides for disease prevention and detection, treatment and rehabilitation, and promotion and maintenance of physical and mental health, but there are no intervention studies related to differentiated thyroid cancer (DTC) that use theoretical models of health as a guide. In this study, we used a microblogging platform as an intervention vehicle and mobile patient-doctor interactive health education as a means of intervention, with the aim of improving the health behaviors of DTC patients as well as the corresponding clinical outcomes.

**Methods:** This research project is a quantitative methodological study, and the trial will be a single-blind, single-center randomized controlled trial conducted at the Fourth Hospital of Harbin Medical University in Harbin, Heilongjiang Province. The study subjects are patients over 18 years of age with differentiated thyroid cancer who were given radioactive iodine-131 therapy as well as endocrine therapy after radical surgery for thyroid cancer. The intervention group will receive MTM-mhealth, and the realization of health education will rely on the smart terminal WeChat platform. Routine discharge education will be given to the control group at discharge. The primary outcome will be change in thyroid-stimulating hormone (TSH) from baseline and at 3 and 6 months of follow-up, and secondary outcomes will include change in self-management behavior, social cognitive and psychological, and metabolic control.

**Discussion:** This study will explore a feasible mHealth intervention program applied to a population of DTC patients using the Multi-theory model of health behavior change (MTM) as a guide, with the aim of evaluating the MTM-based intervention program for clinical outcome improvement in DTC patients, as well as determining the effectiveness of the MTM-based intervention program

in improving self-management skills in DTC patients. The results of this study will indicate the feasibility as well as the effectiveness of the application of health theoretical modeling combined with mHealth applications in disease prognostic health management models, and provide policy recommendations and technological translations for the development of mobility-based health management applications in the field of health management.

KEYWORDS

**differentiated thyroid cancer, mHealth, MTM, health education, self-management**

## 1 Introduction

Thyroid cancer can be divided into differentiated thyroid cancer and undifferentiated thyroid cancer according to tissue classification, in which differentiated thyroid cancer (DTC) develops in more than 90% of patients (1, 2), and the global incidence of thyroid cancer increased by about 20% from 1990 to 2013 (3). According to the Annual Report of China Tumor Registry, the incidence of thyroid cancer in China has continued to increase from 2008 to 2018, and the incidence is likely to continue to rise in the foreseeable future (4). Wiltshire et al. conducted a systematic review of studies in Europe, North America, Asia, Oceania, and South America, confirming that the overall incidence of thyroid cancer has continued to increase globally (5).

Surgical resection is the standard of care for most patients with DTC. In particular, low-risk patients with highly differentiated thyroid cancer can be treated with surgical resection only, without the need for excessive radiation therapy (6–8), whereas patients with high-risk features require thyroid-stimulating hormone (TSH) suppression and radioactive iodine therapy (RAI) in conjunction with each other (9, 10).DTC is a TSH-dependent tumor, and TSH is able to stimulate the expression of TSH receptors in normal thyroid cells and DTC cells, leading to abnormal proliferation of normal thyroid tissue and cancerous tissue that may remain, increasing the likelihood of recurrence (11–13). Therefore, TSH suppression therapy plays a crucial role in postoperative DTC, particularly for patients undergoing total or near-total resection. These patients require thyroid hormone supplementation to lower TSH levels after surgery, not only to compensate for hormone deficiencies but also to impede the growth of DTC cells and prevent recurrence (14–17). Consequently, the continuous self-management of DTC patients, guided by medical professionals, becomes pivotal for effective TSH suppression therapy. Unfortunately, the existing postoperative care measures are insufficient, leading to various disease-specific health issues following initial treatment (18–20). Thus, it is imperative to adopt more innovative and effective approaches to enhance the prevention and treatment of differentiated thyroid cancer, ultimately improving prognosis and reducing the risk of recurrence.

With the advancement of medical technology, there is an increasing demand for personalized and precise disease management in patients with thyroid tumors. Studies have shown that fatigue and insomnia are two of the most common symptoms in DTC patients, for whom self-monitoring of serum TSH levels should be proactive in order to achieve a favorable prognosis (21, 22). The definition of self-management is for patients to take on the task of managing their own health (9, 23). This self-management by patients by rationalizing their exercise, diet, routine and taking medication in a self-disciplined manner is one way to address this need and may have a crucial role in improving the cure rate of patients with differentiated thyroid cancer.

The development of mobile technology has led to the gradual popularization of social software such as WeChat, where communication between patients and physicians can be shifted from offline to online, in addition, the World Health Organization has called for the expansion of the use of digital technology to improve health support for patients, which have effectively contributed to the development of mobile health (mHealth) (24–28). As a result, mHealth is widely used by a large number of healthcare entities and plays an important role in the prevention and treatment of chronic diseases such as hypertension, diabetes, asthma, and postoperative rehabilitation of the heart and lungs and can save up to seven billion dollars in budgets annually (29, 30). The use of cell phones and mHealth apps continues to proliferate, with an increasing number of healthcare professionals, young and highly educated patients, and the general public using health apps (31–34). Evidence suggests that the use of mHealth apps can play an important role in patient education, disease self-management, remote monitoring of patients, and improvement of quality of life (35–37). For example, LianHong Wang et al. demonstrated that the Transtheoretical Model (TTM)-based mHealth apps can reduce body mass index and other physiological indicators in patients with polycystic syndrome, and improve the exercise and dietary adherence of polycystic syndrome patients in the long term (31–34). syndrome patients' exercise and diet adherence (38). Basch et al. found that a convenient electronic system for cancer patients to query symptom outcomes could lead to early detection of symptoms and prompt clinicians to intervene (39). Therefore, we believe that mHealth intervention models can be well suited to the postoperative self-management environment for patients with differentiated thyroid cancer, which effectively reduces the stress on healthcare providers and improves patient recovery (40), and reduces patients' fear of recurrence (41). In public health research, many interventions have helped to improve patients' self-management level, but there is no study that uses the health theory behavior model as a guide to intervene in the self-health management level of differentiated thyroid cancer patients after surgery. In this study, we will use the WeChat platform as an intervention vehicle for mobile health interventions for DTC patients, with the aim of improving the health behaviors of DTC patients and the corresponding clinical outcomes.

Health behaviors are positive actions taken by individuals to prevent disease and maintain their own health, which include changing health-hazardous lifestyles, reducing or stopping health-risk behaviors

(e.g., smoking, alcohol abuse, poor diet, and unprotected sexual behavior, etc.), adopting positive health behaviors (e.g., regular exercise, regular medical checkups, etc.), and complying with medical advice (42, 43). Theoretical models of health behaviors are important for disease prevention and detection, treatment and rehabilitation, and the promotion and maintenance of physical and mental health, but no intervention studies related to DTC have used theoretical models of health as a guide. Therefore, we aimed to evaluate a mHealth intervention study based on the Multi-theory model of health behavior change (MTM) (44–46) in anticipation of improving self-management in postoperative patients with differentiated thyroid cancer. The MTM divides behavioral change into two components: (1) initiation of behavior change (2) maintenance of behavior change. The initiation of behavior change is influenced by three factors: Participatory Dialog (PD), Behavioral Confidence (BC), and Changes in Physical Environment (CPE). The maintenance of behavioral change is influenced by three factors: Emotional Transformation (ET), Practice for Change (PC) and Changes in Social Environment (CSE) (Figure 1). Its role as a fourth-generation theoretical model used for health education (47–49) has been demonstrated to play an important role in health behavior change, such as smoking cessation (50), promotion of human papilloma virus (HPV) vaccination behaviors (51), and promotion of physical activity practice (47, 52). However, the application of MTM in the field of differentiated thyroid cancer is still in the exploratory stage, with fewer theoretical studies and applications.

In summary, given the great potential of health intervention models guided by the health behavior theory model for prognostic improvement in health care for a wide range of diseases, this study aims to MTM model to construct a health education intervention model for patients with DTC, and to provide a clinical rationale for mobile health intervention to assist in treatment plans related to prognostic rehabilitation of oncology patients by means of mobile patient-doctor interactive health education as a means of intervention.

Specific objectives are

1 To evaluate the impact of the Multi-theory model of health behavior change (MTM) interventions on clinical outcomes in patients with DTC.
2 To determine the effectiveness of the MTM-based intervention program in improving self-management skills of DTC patients.

# 2 Methods

## 2.1 Study design

The study will be conducted from March 2023 to March 2024 using a quantitative methodology study with a measurement protocol that utilizes clinical reagent tests as well as internationally accepted scales to

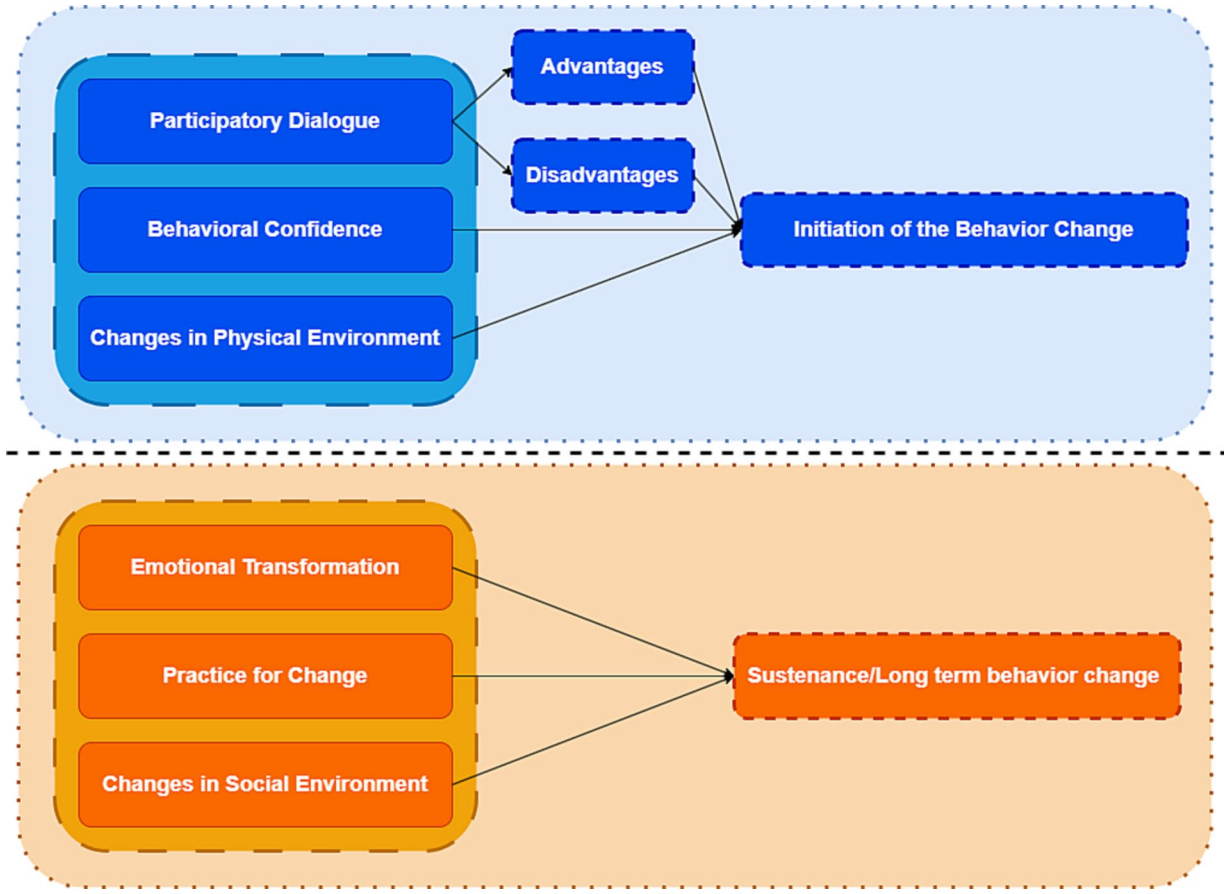


FIGURE 1
Schematic diagram of a multi-theoretical model of health behavior change.

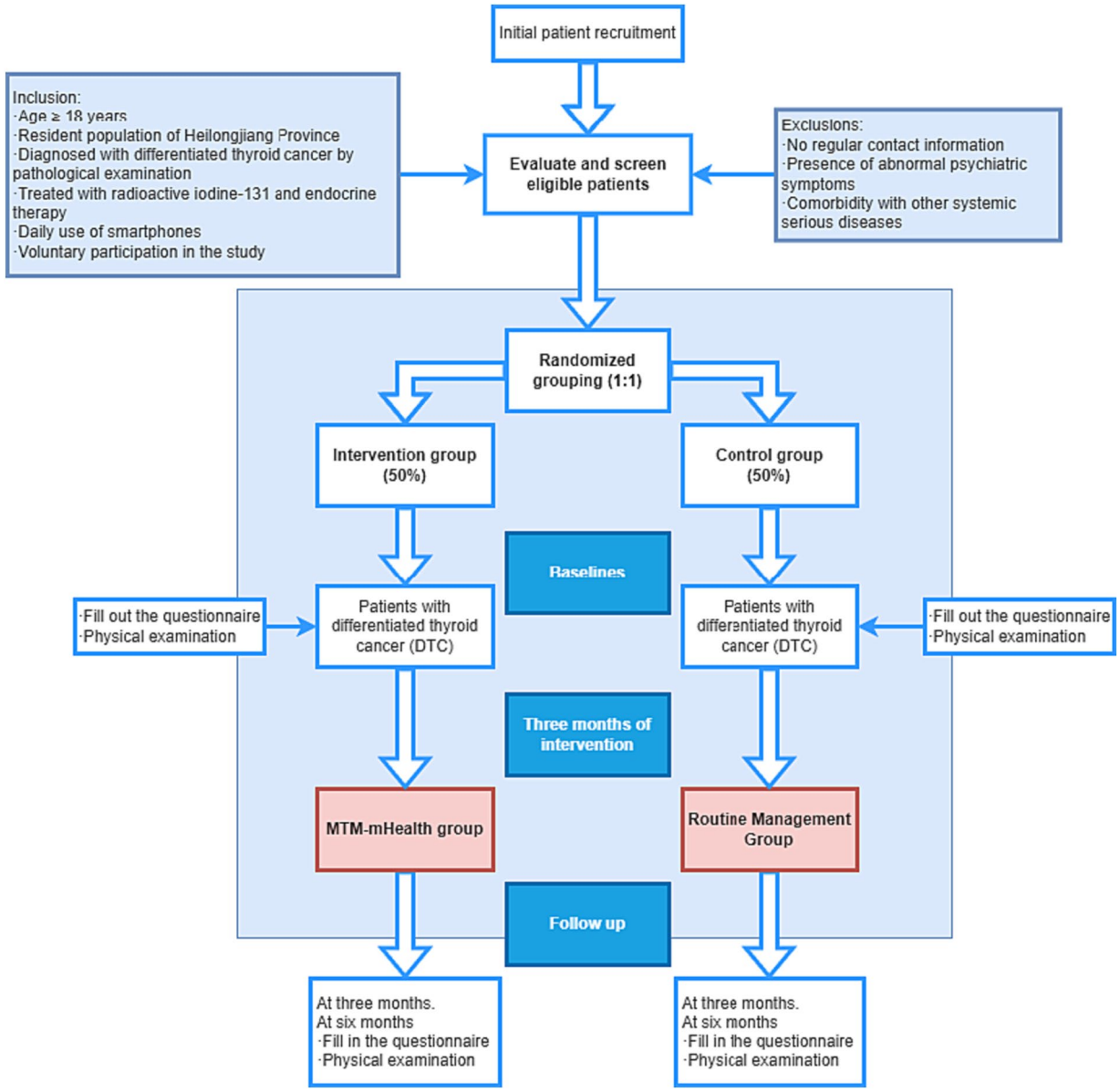


FIGURE 2
Flow chart of patient recruitment and study implementation.

effectively ensure the objectivity of the trial. The quantitative investigation will be conducted as a randomized controlled trial in a hospital-based patient population compared to a routine education control group to compare the effectiveness of the MTM-based intervention program in patients' TSH control and self-management behaviors (e.g., medication use, diet). The intervention group will receive the MTM-mHealth model intervention and the control group will receive usual care. The intervention will last for 3 months. Questionnaires and physical examinations will be conducted at baseline and at 3 and 6 months of follow-up to check for changes in self-management behaviors and TSH control. The flow chart of the study is shown in Figure 2 and Table 1.

### 2.1.1 Study setting and randomization

This research project is a single-blind, single-center randomized controlled trial to be conducted at the Fourth Hospital of Harbin Medical University in Harbin, Heilongjiang Province, China. The study population is patients with differentiated thyroid cancer. Convenience sampling of patients with differentiated thyroid cancer was performed. Given that the proposed patient population is socially dispersed cancer patients, the patients coming to the hospital are far from meeting the trial needs of the minimum study sample size at one time, so the patients will be recruited in the form of consecutive enrollment, and the researcher will recruit the patients who have high adherence to the treatment when they come to the hospital on the same day. A random integer will be generated by the EXCEL function RANDBETWEEN for each patient registered on that day.

Given that the total number of patients registered at the hospital on the daily visit may be odd or even, in order to ensure the complete realization of randomized allocation, if the total number of registered

10.3389/fpubh.2024.1327442

TABLE 1 Timeline for study enrollment, intervention, and evaluation.

| Study Period | Recruitment | Allocation | Intervention | | Follow-up |
|---|---|---|---|---|---|
| TIMEPOINT | -T1 | 0 | 0 M | 3 M | 6 M |
| ENROLMENT: eligbility screen | √ | | | | |
| Informed consent | √ | | | | |
| Allocation | | √ | | | |
| INTERVENTIONS: MTM-mHealth | | | | | |
| Control | | | | | |
| ASSESSMENTS: sociodemographic variables | | | √ | | |
| Anthropometric variables | | | √ | √ | √ |
| The MTM theory scale | | | √ | √ | √ |
| The frequency of iodine-containing diets | | | √ | √ | √ |
| Medication adherence | | | √ | √ | √ |
| Social cognition and psychology | | | √ | √ | √ |

patients on the day is even, we will use the random integer of two patients as a combination of numbers, and the groups will be compared, and divided into different groups according to the size of the corresponding random number (large, intervention group, small, control group); if the total number of registered patients on the day is odd, after removing the even pairs of patients, the remaining individual patients are judged by the parity attribute of their random numbers (odd, intervention group, even, control group), thus achieving randomized allocation.

## 2.2 Study participants

Participants in this study are consecutive patients admitted to the Fourth Hospital of Harbin Medical University in Harbin, Heilongjiang Province, China from March 2023 to March 2024 with differentiated thyroid cancer. We have begun recruiting study participants from March 2023, and each participant will begin the formal trial intervention after enrollment in the trial through face-to-face interactions at the hospital as well as signing the study informed consent form. Therefore, all patients are not recruited or starting the intervention at the same time, but will all complete the 3-month intervention cycle.

Inclusion criteria:

1 Patients are ≥18 years old.
2 The patients are permanent residents of Heilongjiang Province (annual out-of-home time less than 1 month).
3 The patients all met the relevant diagnostic criteria for thyroid cancer in the Guidelines for Diagnosis and Treatment of Thyroid Nodules and Differentiated Thyroid Cancer, and were diagnosed with differentiated thyroid cancer by pathological examination.
4 Radiation iodine-131 therapy and endocrine therapy were given after radical surgery for thyroid cancer.
5 The patient uses a smartphone on a daily basis and is familiar with the general function of WeChat.
6 The patient voluntarily participates in the study and signs an informed consent form.

Exclusion criteria:

1 The patient has no fixed contact information, no family member is responsible for contacting the patient, and it is not convenient to contact the patient by phone or WeChat.
2 The patient is taking any psychotropic drugs.
3 The patient has mental symptoms such as delirium, slurred speech, uncooperative, etc.
4 The patient has a combination of other serious systemic diseases, serious physical impairment and participation in other clinical trials.
5 Pregnant or lactating women.
6 Other reasons are not suitable to participate in the trial.

## 2.3 Sample size

This study is a randomized controlled trial, the intervention group is the mHealth intervention group and the control group is the usual care group, the achievement rate of TSH in the study population is the main outcome indicator observed, and the patients' TSH level control <0.1 mU/L will be completed to achieve the standard. Based on the review of the literature, it is expected that the achievement rate of the mHealth intervention group is 90%, and the achievement rate of the control group is 60%. Setting bilateral $\alpha = 0.05$, the degree of certainty was 90%. Using the PASS15 software, we obtained a sample size of N1 = 39 cases for the treatment group and N2 = 39 cases for the control group, and taking into account the loss of visits and refusal of visits by 20%, the final minimum number of subjects needed for the intervention group and the control group was 49 cases each, for a total of at least 98 subjects to be included in the study.

## 2.4 Treatment programs

Patients in both groups will receive administration of iodine 131 therapy combined with thyroid hormone replacement therapy (53, 54). Prior to receiving iodine 131 therapy, patients will be required to

undergo a thyroid uptake scan to determine if there is any residual or recurrent thyroid cancer (55). Depending on individual circumstances, patients are administered iodine 131 between 50 and 200 meters Curie (mCi) in a separate isolation room within the hospital. After administration, patients are hospitalized in an isolation room for 3 days to minimize radiation hazards, and are kept away from pregnant women and small children, avoiding close contact with other people, etc., to ensure safety. After iodine 131 treatment, start to take oral levothyroxine sodium tablets on the second natural day, generally the initial dose is 50 μg per day, the maximum amount does not exceed 100 μg, and the maintenance dose is 50–200 μg per day. Four weeks later, review the thyroid function index, and according to the results of the test, the dose will be maintained or adjusted. Therapeutic target: TSH 0.3 ~ 0.5 mU/L, free thyroxine (FT4) 10.3 ~ 25.8 pmol/L, free triiodothyronine (FT3) 2.16 ~ 6.78 pmol/L.

## 2.5 Interventions

The research team formed a multidisciplinary team consisting of a thyroid cancer pharmacist, a nursing specialist, a thyroid cancer physician, and a public health specialist to discuss and develop the intervention program. The control group received routine medical and nursing care, and the intervention group received the MTM-based mHealth intervention in addition to routine medical care.

### 2.5.1 Intervention group: online MTM-based health education

The intervention group receives MTM-mHealth, and the realization of health education will rely on the smart terminal WeChat platform. Combined with the chat communication function of WeChat, timely communication between physicians and patients will be realized, and patients' concerns will be answered by physicians or professional nurses in a timely manner. At the same time, through the WeChat platform, physicians or professional nurses can realize timely interventions for patients, including daily reminders of medication taking, popularization of thyroid cancer-related science, and interpretation of cutting-edge research on thyroid cancer.

The intervention group had WeChat group health education, online health education lectures, received routine medical care such as health education program and medication supervision on the day of hospitalization, then received treatment in the outpatient clinic, and received intervention in mobile health education after discharge for 3 months, and the content of the intervention was designed based on the theory of MTM, and the flowchart is shown in Figure 2.

#### 2.5.1.1 Participatory dialog (when strengths outweigh weaknesses)

Purpose: to motivate patients to start behavioral change, so that patients produce initial action self-efficacy.

Measures: Give each patient a copy of the booklet "Health Education for Thyroid Cancer Patients." While distributing the education booklet, the physician explains and emphasizes the common problems of the patients, encourages the patients to face the disease positively, and guides the patients to consciously improve their own health behaviors. During the first visit, patients and physicians ask each other questions as much as possible, encouraging patients to actively participate in the initial patient-physician communication. At the same time, the physician added the patient's WeChat contact information, in order to further provide timely health education to the patient.

After the patient is discharged from the hospital, the physician and the patient regularly communicate with each other through the online doctor-patient salon at 9:00 a.m. on Saturdays, the content of the communication includes disease cognition, prognosis and development, etc., and the link includes the physician's explanation, the physician-patient Q&A, and the patient–patient communication, etc., and the physician needs to guide the patient to explore the advantages and disadvantages of improving the self-health behaviors on the recovery of the disease, and the physician needs to emphasize that the advantages of the self-health behaviors outweigh the disadvantages so that the patient The physician should emphasize that the advantages of self-health behaviors outweigh the disadvantages, so that the patient can actively participate in the joint decision-making process.

#### 2.5.1.2 Behavioral confidence (belief in one's ability to achieve desired behaviors)

Purpose: to enhance patients' confidence in changing health behaviors in the future.

Measures: Physicians and relevant nursing staff set up a doctor-patient exchange group on WeChat, grouping patients according to the initial treatment ward and electing a group leader, who organizes regular exchanges between patients, with the group leader deciding the time of exchanges himself/herself. Physicians and related nursing staff encouraged and instructed all patients to fill out a "health behavior diary" to record the daily maintenance of health behaviors and problems and experiences encountered during the process, and to share and exchange them in the WeChat group every day. At the same time, patients were encouraged to communicate with their physicians in a timely manner, and the physicians evaluated the progress of the patients' health behaviors in a timely manner. With half a month as a cycle, physicians or relevant nursing staff after evaluation and comparison, the merit of inviting patients who maintain good health behavior to present themselves, in the form of WeChat group to open a patients' club, the patients through the group learning and communication, sharing daily experience, discussion, interaction and mutual learning.

#### 2.5.1.3 Changes In The physical environment (environments that enable behavior)

Purpose: Provide patients with educational resources in an online format to make resources that support patient health behavior change more accessible.

Measures: Physicians as well as relevant nursing staff need to emphasize with patients and their families at the time of patient discharge and during online communication that common salt should be used to replace iodized salt as much as possible in daily life, educate patients to control the intake of iodine-containing foods, avoid high iodine diets, such as seaweeds like kelp, seaweed and sea fish, and refrain from drinking stimulating beverages such as coffee, strong tea, and cola, and that they should be given diets that are high in calories and contain sugar, proteins, and B-vitamins.

Based on the "Health Education for Thyroid Cancer Patients" manual, physicians and related nursing staff will independently design a delivery program for educational materials, which will

be based on an independently constructed multimedia database, and the health education materials in the multimedia database will be evaluated and screened by several related experts before inclusion. The push program will take every 3 days as a push cycle, and push three or more pieces of thyroid cancer related educational materials to patients, which will include video, graphics, voice explanations, etc. The content will include popularized articles about the disease process, interspersed with relevant information about the past cases, the danger of thyroid cancer, and the adverse outcomes of the later stages of the development of thyroid cancer, etc. Physicians can cooperate with the related materials to explain the health behavior. Physicians can explain the necessity and effect of healthy behaviors to improve the adverse outcomes, and guide patients to establish risk awareness. Nursing staff will encourage patients to punch cards in the WeChat group every day, so that they can effectively read the relevant popular science articles.

#### 2.5.1.4 Emotional transformation (intention to overcome self-doubt)

Purpose: To guide the patient's feelings and emotions to focus on changes in health behaviors, and to guide thoughts to maintain such changes.

Measures: Physicians or relevant nursing staff will remind patients of the health behaviors they need to pay attention to in their lives on the WeChat platform at 9:00 p.m. every day. Relevant texts will be edited in advance and archived in the missionary material push plan, and reminders will be given according to the relevant plan. Physicians encourage and help patients to develop long-term health behavior improvement plans. For those with low adherence: focus on behavioral reinforcement and supervision, repeatedly emphasizing to patients the dangers of thyroid cancer and the benefits of maintaining healthy behaviors, the benefits of taking medication on time, etc.; for those with intermediate levels: focus on praise and encouragement to help them maintain confidence; for those with high levels: focus on monitoring. Physicians need to take the initiative to solicit the recovery effect of all patients, guide patients to take levothyroxine sodium tablets accurately, inform patients of the precautions to be taken after radioactive iodine-131 treatment in a timely manner, and in response to the adverse reactions of the patients after radioactive iodine-131 treatment, patients should be pacified in a timely manner and encouraged to cooperate with the treatment positively.

If patients have negative emotions, resist or discontinue health behaviors during treatment, physicians should promptly analyze the reasons for the discontinuation of their behaviors, take corresponding measures, and guide patients to carry out self-regulation, so that they can quickly resume healthy behaviors despite the discontinuation of their behaviors in a timely manner.

#### 2.5.1.5 Practice change (assessing and adjusting efforts to achieve desired behaviors)

Purpose: To guide the patient in reflective action and make the patient think about the impact of his or her health behavior change.

Measures: The physician regularly organizes a patient exchange salon on Saturday mornings at 9:00 a.m. every week, where patients share their "health behavior diaries" with each other, the daily maintenance of health behaviors and the problems encountered during the process, experiences, etc. For those with low compliance: focusing on the reinforcement of behaviors and urging, the physician needs to discuss the reasons with the patient and help him or her to find a specific solution. For those with low adherence: focus on behavior reinforcement and supervision, the physician needs to discuss the reasons with the patient and help him/her find specific solutions, and emphasize to the patient the disadvantages of abandoning the maintenance of healthy behaviors; for those with medium level of adherence: focus on praise and encouragement, and help him/her maintain confidence; for those with high level of adherence: focus on monitoring.

#### 2.5.1.6 Social environment change (using positive relationships to achieve desired behaviors)

Purpose: construct timely incentives for patients to change health behaviors.

Measures: Physicians and patients communicate with each other in a timely manner on the WeChat platform to understand their psychological state, and combine psychological massage method, verbal appeasement method, and distraction method to motivate patients to make changes and alleviate their poor psychological state through good cases. For those who maintain good health behaviors, timely encouragement is provided in the WeChat group; for those who maintain poor health behaviors, physicians need to communicate with them on a one-to-one basis in a timely manner, take appropriate measures, and guide the patients to self-regulation, so that they can quickly restore healthy behaviors even in the event of behavioral interruptions in a timely manner.

### 2.5.2 Control group: routine care

Routine discharge education will be given to the control group at the time of discharge, and patients will be given a booklet entitled "Health Education for Patients with Thyroid Cancer," which includes basic knowledge of thyroid cancer and lifestyle guidance, such as rational diet, medication guidance and adverse reactions. Regular telephone follow-up will be given to the patients, the first telephone follow-up will be given at the end of the first month after discharge and monthly thereafter.

## 2.6 Collection and screening of health education materials

### 2.6.1 Sources of health education materials

The educational materials used for health education come from the Internet, including videos and illustrations. The illustrations come from WeChat, Wikipedia, doctor's Q&A, or domestic and international databases such as CNKI, and the videos come from WeChat, Wikipedia, doctor's Q&A, etc. The cases come from Baidu documents or literature. The case information was obtained from Baidu documents or literature, and the educational materials used should be scientific and have corresponding references.

### 2.6.2 Screening of health education materials

After centralizing all the health education materials, they will be sent for external review to the experts in thyroid cancer related fields, who will evaluate the materials according to the thyroid cancer

expert evaluation form. After the experts return the evaluation opinions, they will centralize the screening of the quality health education materials, and the selected health education materials will be used as the push database of the health education materials. The push database will contain article titles, related links, corresponding sources, corresponding material types, etc. The materials will be categorized according to their corresponding contents. The materials will be categorized into disease awareness, postoperative care, diet, exercise, and other sections according to their corresponding content, so as to facilitate the formulation of a corresponding delivery plan for patients.

## 2.7 Outcomes

Primary Outcome: Change in TSH from Baseline and at 3 and 6 Months Follow-Up.

Secondary outcomes:

1 changes in self-management behaviors: changes measured by the MTM Theory Scale, changes in frequency of iodine-containing diets, medication adherence.
2 Social cognitive and psychological: quality of life, satisfaction, depression, anxiety and fear of cancer recurrence.
3 Metabolic control: thyroxine (T4), triiodothyronine (T3), FT3, FT4.

The corresponding study questionnaires completed by all patients at baseline as well as at follow-up were piggybacked on a web-based platform (Questionnaire Star). Clinical pharmacists distributed the questionnaires via Questionnaire Star, and patients were instructed to fill them out by pharmacists either face-to-face (during hospitalization) or by telephone (after discharge). Patient demographic information was collected through the case system and self-designed questionnaires.

## 2.8 Variables measurement

Socio-demographic variables will be collected: gender, age, education, usual residence, *per capita* monthly income of the family, mode of bearing medical expenses, and clinical information such as duration of DTC, detailed medical history.

Physiological Indicator Variables: TSH will be detected using radioimmunoassay (RIA), the medical staff will clean the patient's blood collection site using a sterilized cotton ball, and then use a needle to take an appropriate amount of fasting venous blood 5 mL, centrifuged at 3000 r/min for 5 min, serum will be separated, and a certain amount of TSH antibody labeled with the radioisotope iodine-125 will be added to the processed serum to bind to the TSH to be detected. TSH. Using biochemical techniques, the antibody-bound TSH and unbound free TSH were separated into solid phase and free phase. The radioisotopes in the solid phase are measured to obtain a corresponding count value, from which the concentration of TSH in the sample can be determined. Based on the stratification of risk factors for recurrence of differentiated thyroid cancer, patients can be categorized into low-risk, intermediate-risk, and high-risk strata, and postoperative serum TSH target values are set accordingly (56). In general, the division is based on factors such as age, gender, tumor stage, presence of lymph node metastasis, and type of thyroid cancer variant. All patients included in this trial were high-risk patients treated with iodine 131, and according to treatment guidelines, for high-risk patients, postoperative serum TSH should be suppressed to very low levels (<0.1 mIU/L) or completely suppress thyroid function to minimize the risk of recurrence. Therefore, the TSH compliance rate was defined as postoperative serum TSH < 0.1 mU/L, and this criterion was used to calculate the TSH compliance rate.

T4, T3, FT3, and FT4 will be measured by enzyme-linked immunosorbent assay (ELISA). The medical staff will clean the patient's blood collection site using a sterilized cotton ball, and then use a needle to take a tube of appropriate amount of fasting venous blood of 5 mL, respectively, to prepare the required reagents, including enzyme-labeled antibody, substrate, and washing buffer. At the same time, prepare the sample to be tested. Fix the specific antigen or antibody on a microtiter plate, usually using a multiwell plate, such as a 96-well plate. Add enough antigen or antibody solution to each well and incubate at a constant temperature so that it adsorbs to the well walls. The samples to be tested are pretreated as necessary, e.g., dilution, protein cleavage. The pre-treated samples or standards are added to each well. A series of standard curve samples of varying concentrations are usually set up and used to generate a standard curve to calculate the concentration of the target in the sample to be tested. Enzyme-labeled antibodies conjugated to the target are then added and incubated. The samples and unbound material in the wells are washed away to minimize non-specific binding. An appropriate substrate is added to react with the enzyme-labeled antibody. The choice of substrate depends on the enzyme marker used, commonly horseradish peroxidase (HRP) used in ELISA. After an appropriate period, the reaction is terminated by the addition of a reaction stopping solution and prevented from producing further color changes. The absorbance values of each well are read using an enzyme meter or photometer. Based on the standard curve, the concentration of the target in the sample to be tested is calculated.

Sociodemographic variables will be collected from patients at baseline. Clinical reagent testing and questionnaires will be completed at baseline as well as at 3 and 6 months of follow-up, with data collection times shown in Table 2.

## 2.9 Questionnaires

Changes in self-management behaviors will be assessed by a self-designed MTM scale (57) consisting of 6 dimensions including PD, BC, CPE, ET, PC, and, CSE using a 5-point Likert scale design, the scale will be developed and final validation will be completed by the researcher, and 20 randomly selected participants who did not take part in the final trial will complete a pre-test from the recruited participants to determine the appearance validity and the content validity through pre-testing and expert testing to refine the model scale.

Changes in the frequency of iodine-containing diets will be assessed by patients through a self-administered the Iodine-containing Food Frequency Questionnaire (I-FFQ) questionnaire after adaptive adaptation and refinement based on the Food Frequency Questionnaire (FFQ) (58, 59). Preparation will be done in consultation with experts and based on food guidelines, several foods likely to

TABLE 2 Data collection components and collection timeline.

| Type of research | Data collection component | | Timepoint | | |
|---|---|---|---|---|---|
| | | | 0 M | 3 M | 6 M |
| Quantitative research | Sociodemographic variables | Sex, age, social insurance status, place of residence, average monthly household income, educational level, area of domicile, clinical information | √ | | |
| | Anthropometric variables | Thyroid stimulating hormone (TSH), thyroxine (T4), triiodothyronine (T3), Free T3, Free T4 | √ | √ | √ |
| | The MTM theory scale | Questionnaire: Changes measured by the MTM Theory Scale | √ | √ | √ |
| | Tthe frequency of iodine-containing diets | Questionnaire: Changes in the frequency of iodine-containing diets | √ | √ | √ |
| | Medication adherence | Questionnaire: Medication Refill or Medication Adherence Scale (ARMS-7) | √ | √ | √ |
| | Quality of life | Questionnaire: EuroQol-5 Dimensions 5 Levels(EQ-5D-5 L7) | √ | √ | √ |
| | Satisfaction | Questionnaire: Customer Satisfaction Questionnaire (CSQ-3) | √ | √ | √ |
| | Depression and anxiety | Questionnaire: Simplified version of the Anxiety Depression Scale (PHQ-4) | √ | √ | √ |
| | Fear of cancer recurrence | Questionnaire: Fear of Cancer Recurrence Scale (FCR-4) | √ | √ | √ |

be consumed on a daily basis with an iodine value greater than 400 mg/kg (60, 61), including iodized salt, will be selected as the target for measurement, and the time scale will be measured as the basis for frequency (62).

Medication adherence will be measured using the Renewal or Medication Adherence Scale (ARMS-7), which has seven entries and two dimensions: medication adherence (entries 1–4) and refills (entries 5–7), which is a 4-point Likert scale ranging from 1 (none) to 4 (all), notably one entry in the scale (the seventh) is reverse scored (1 = all to 4 = none). It measures self-reported medication adherence with respect to both taking medication as prescribed and taking medication as scheduled. The total score was derived by summing the responses to all items. The total score ranges between 7 and 28, with higher scores being associated with lower medication adherence. The scale has high validity and reliability in measuring medication adherence, with total scale item correlation coefficients ranging from 0.35 ~ 0.58 and a Cronbach's alpha of 0.75 (63).

Quality of life will be assessed using the EuroQol-5 Dimensions 5 Levels (EQ-5D-5L), which is an improved version of the EQ-5D that introduces five tiers (64, 65) on top of the original five dimensions, (eg. no difficulty, minor difficulty, moderate difficulty, major difficulty, total difficulty) thus providing a more refined health status Assessment. Its health utility values ranged from 0.62 to 0.90 in seven studies reporting cancer patients with high validity and reliability (66–72). Compared to the traditional EQ-5D (EQ-5D-3L), the dimensional and hierarchical structure of the EQ-5D-5L remains unchanged, but the number of ratings for each dimension has been increased to five. The five dimensions of the EQ-5D-5L include Mobility (Mobility), Self-care (Self-care), Usual activities (Usual activities), Pain/Discomfort, and Anxiety/Depression. For each dimension, the individual selects the appropriate level according to his or her situation, thus constituting a five-dimensional description. In addition to the five-dimensional descriptors, the EQ-5D includes a Visual Analog Scale, which allows individuals to give a subjective rating of their current state of well-being based on their feelings on a scale of 0 to 100. This score provides a continuous variable to measure an individual's overall quality of life.

Satisfaction will be adapted using the Customer Satisfaction Questionnaire (CSQ-3), which is a commonly used customer satisfaction questionnaire for assessing customer satisfaction with a product, service, or experience, with a Cronbach's alpha of 0.84, and good reliability and validity (73, 74). The CSQ-3 is a revised version of the CSQ which was developed by Roger, D et al. in 1993 and has been widely used in the fields of market research, customer relationship management, and business decision making (75, 76). This question is designed to assess the customer's level of satisfaction with the overall product, service, or experience. Response options are usually on a five-point scale from very dissatisfied to very satisfied. The CSQ-3 is designed to be simple and straightforward and is suitable for quickly gathering information on customer satisfaction.

Depression and anxiety will be assessed using a simplified version of the Anxiety Depression Scale (PHQ-4), which is a short, self-report scale used to assess an individual's symptoms of depression and anxiety over the past 2 weeks, and consists of two dimensions of depression as well as anxiety, with a total of four entries, the first two of which relate to depressed mood and the last two to anxiety (77). Each entry was rated on a 4-point scale, with "not at all, ""a few days," "more than half the days," and "almost every day," corresponding to 0, 0, and 0, respectively. Each entry is rated on a 4-point scale, with "not at all," "a few days," "more than half the days," and "almost every day" corresponding to a score of 0, 1, 2, and 3, respectively, and the total score ranges from 0 to 12. The Cronbach's alpha of the PHQ-4 was 0.833, which is of high validity and reliability, in a study conducted in China (78). The PHQ-4 scale is very concise, and it is easy to use and comprehend. It can help healthcare professionals to quickly screen individuals with symptoms of anxiety and depression and provide an initial assessment.

Fear of cancer recurrence will be assessed using the Fear of Cancer Recurrence Scale (FCR-4) (79). The FCR-4 scale is a simplified version based on the "FCR-7" scale, developed by Simard and Savard in 2018, with a measured Cronbach's alpha of 0.86 (80). The FCR-4 consists of four questions to assess the level of fear of cancer recurrence among cancer patients. Recurrence and is usually rated on a five-point Likert scale from completely disagree to completely agree. The use of the

FCR-4 scale can help healthcare professionals to understand the level of fear cancer patients have about cancer recurrence and provide them with appropriate support and mental health resources. This information can be used in the development of individualized treatment plans to help patients cope with their fears and improve their quality of life.

# 3 Statistical analysis

Statistical analysis was performed using SPSS Statistics 26.0 software. Count data were expressed as a number of cases and rate (%). The distribution of continuous data will be tested for normality, and information conforming to normal distribution will be expressed as mean ± standard deviation (M ± SD), and non-normal information will be expressed as median (IQR). The Mann–Whitney U test will be used to compare the change in scale scores between baseline and endpoint between the two groups, and the Wilcoxon test will be used to compare the difference in scale scores between baseline and endpoint between the two groups. The chi-square test will be used to compare the demographic characteristics of the two groups. A two-sided test will be used and will be considered statistically significant if $p < 0.05$.

Assuming a reasonable amount of missing data, the data summary will indicate that data are missing at random. In this case, all analyses will be performed with the baseline variable as the auxiliary variable, the missing data will be supplemented by multiple interpolation procedures, linear regression and logistic regression will be selected for the analyses, and the final combined analyses will be performed to complete the process of interpolation and analysis.

## 3.1 Study management

### 3.1.1 Data collection

Prior to the commencement of the study, the investigator will be fully trained and assessed. The investigator will need to ensure that all study results, including clinical and laboratory data, will be recorded in a pre-made subject registration form so that study subjects can be enrolled and coded to minimize the incidence of missed visits during follow-up. To maintain consistency between the intervention and control groups, survey times and questionnaires will remain essentially the same. The investigator will need to ensure that all sections of the registration form are entered correctly and that each completed patient's data must be dated and signed to ensure that the trial can be validated retrospectively based on the data once completed. During subsequent data analysis, a double-checking procedure will be implemented to improve the quality of data entry, and experts will be consulted to select appropriate statistical methods.

### 3.1.2 Storage and archiving of data

Investigators are required to archive all trial data (list of subject identification codes, source data, and investigator files) and related correspondence in study-specific database files. All source data for the database and all related documentation for the study will be archived in accordance with laws and regulations after the trial is finalized.

### 3.1.3 Ethics and regulations

The procedures set out in this trial protocol relating to the conduct, evaluation and documentation of this trial are designed to ensure that all participants in the trial adhere to the ethical principles described in GCP and the current revision of the Declaration of Helsinki. The trial will be conducted in accordance with the requirements of local laws and regulations, and approval for this trial protocol was obtained from the Ethics Committee of the Fourth Hospital of Harbin Medical University (2022-WZYSLLSC-20).

### 3.1.4 Ethics committee

For quality assurance, this trial will comply with ethical and legal requirements and the trial will have to inform the Ethics Committee of all subsequent protocol revisions that require formal approval in accordance with local legal requirements. The Ethics Committee will have to be informed in advance of the trial procedures, if not specified more in the documentation. The Ethics Committee will have to be informed of the end of the trial at the end of this trial.

### 3.1.5 Informed consent

Prior to undergoing the trial, patients will have to voluntarily agree to participate after an explanation of the nature, scope and possible consequences of this trial. Informed consent must be obtained from each individual patient or their legally authorized representative prior to the start of the trial. Patients who are unable to sign but are able to understand the significance of participation in the study may give verbally witnessed informed consent. These patients must clearly demonstrate that they are willing to participate voluntarily and must be able to understand an explanation of the contents of the informed consent form.

### 3.1.6 Confidentiality

Authorized consent to use their trial data must be obtained from the patient prior to enrollment. To protect patient privacy, the patient's age will be recorded on the registration form without recording the patient's year of birth, and the name will be replaced by a cell phone number. During the trial, trial results stored on computers will be stored in accordance with local data protection laws and will be handled in strict confidentiality. The investigator will implement organizational procedures that set access rights to the files to prevent data from being sent to unauthorized persons. Appropriate provisions of local data regulations will be fully complied with. Authorized personnel may inspect subject-related data collected during the trial to ensure that the data are legally protected.

### 3.1.7 Investigator responsibilities

Prior to the start of the trial, the trial protocol, informed consent document and any other appropriate documentation will be presented to the independent study team members. The study leader and principal investigator will regularly supervise the study implementers to ensure that all study procedures are being carried out correctly and that the data collected are accurate. Each investigator should ensure that all personnel assisting with the trial are fully informed about the protocol, any modifications to the protocol, the trial treatment, and their duties and functions related to the trial.

### 3.1.8 Approval of trial protocol and amendments

If the investigator fails to comply with the pre-established survey and follow-up criteria, the study leader will retain the authority to terminate the trial, revise the randomization protocol, and re-collect the data after the revisions have been completed. In the event of fundamental or widespread design errors or inaccuracies in the study questionnaire during the course of the investigation, the investigator will discontinue the trial and revise and redesign the questionnaire. After the necessary revisions have been completed, the revised questionnaire will be redistributed to patients.

### 3.1.9 Data monitoring

The Data Monitoring Committee (DMC) will consist of at least two members from the Medical Ethics Committee of the Fourth Affiliated Hospital of Harbin Medical University, who must not have a conflict of interest with the investigators of the project. The DMC will monitor and review the study on a regular basis and report the results to the Ethics Committee. This process will be independent of the principal investigator. The DMC will have the right to suspend or terminate the study if they find any deviation from the approved study protocol or any unauthorized changes in the study procedures during the course of the study.

### 3.1.10 Safety

All adverse events (SAEs) or adverse events (AEs) reported by the patient or detected by the investigator will be collected during the trial and must be recorded on the appropriate page of the registration form. All SAEs and AEs that occur after the patient has signed the informed consent document will be recorded on the page of the registration form. All patients with SAEs and AEs, whether or not considered relevant to the trial, must be monitored to determine outcomes. This trial will have to be reported to the primary study leader within 24 h of the SAE and AE occurring. The initial report must be as complete as possible, including details of the (serious) SAE and AE in the current trial and an assessment of the causal relationship between the event and the trial and the occurrence of the event. The Principal Study Leader will notify the Trial Supervisor of serious SAEs on request and also has a responsibility to report any serious SAEs or AEs to the Ethics Committee in a timely manner.

## 4 Discussion

The great leap forward in the information age has broken the information gap between "medical" and "personal" for centuries. Obtaining personalized medical knowledge and information through the mobile Internet is an essential skill in this era, and therefore mHealth is rapidly developing. mHealth can be thought of as a healthcare that uses mobile communication devices as a carrier, and supports the long-term sustainability of healthcare by improving effective communication between doctors and patients and the patient's understanding of the disease based on online communication channels, such as video, telephone, and discussion forums. Both at present and in the foreseeable future, mHealth has shown great potential for development in all kinds of medical scenarios, whether it is in the prognosis and management of chronic diseases, or the construction of rapid treatment solutions for sudden illnesses, which can efficiently realize the deployment of medical resources. In addition, mHealth is more affordable than traditional doctor-patient scenarios, with time and geographic costs close to zero for patients, as evidenced by studies of primary care self-management behaviors related to chronic diseases. However, more authoritative health theories have not been widely applied as theoretical guides for health interventions in common mHealth research, especially in the cancer patient population, which is in greater need of postoperative health care. This study will explore the application of MTM theoretical modeling as a guide for health intervention research in the DTC patient population, with the aim of evaluating MTM-based intervention programs for clinical outcome improvement in DTC patients, as well as determining the effectiveness of MTM-based intervention programs in improving self-management skills in DTC patients. This study is conducive to filling the research gap of postoperative health management of Chinese DTC patients after being guided by health-based theories.

For patients with DTC, especially those who are at high risk of recurrence as determined by the postoperative risk factor stratification, it is especially crucial for them to actively cooperate with the doctor's prescription for continuous TSH-suppressing endocrine therapy and self-health management after postoperative iodine 131 treatment. However, given that the mortality rate of differentiated thyroid cancer is very low compared with other types of cancer, patients may become lax in the prognosis process, especially the insufficient control of iodine-containing foods in their daily diets, or the erroneous consumption of other foods or beverages that may have an impact on the TSH-inhibiting drugs, which may have a great negative impact on the therapeutic effect. Therefore, it is important to explore more effective ways to improve patients' self-management in the context of the current information age. In public health research, most mHealth interventions have been helpful in improving patients' self-management, but there is no research on self-management of DTC patients in the context of mHealth. After combining mHealth, we selected the fourth-generation MTM model, which is a guiding significance for health intervention research in the international frontiers, to improve our intervention pathway and transform the theory into practice. Meanwhile, the application of MTM model in China is in the preliminary stage of exploration, and this study will fill the gap in this direction and provide new ideas for health management programs related to cancer prognosis and rehabilitation. The results of this study will show whether the application of health theory modeling based on health theory combined with mHealth application for disease prognosis health management model is feasible as well as effective, and provide policy recommendations and technical translation for the development of the application of mobility health management in the field of health management.

## Ethics statement

The study has been approved by the Ethics Committee of the Fourth Affiliated Hospital of Harbin Medical University, Harbin, Heilongjiang Province (2022-WZYSLLSC-20), and the registration

of the study protocol with the China Clinical Trial Registry (ChiCTR2200064321) has also been completed. The participants provided their written informed consent to participate in this study.

## Author contributions

YJ: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. XS: Conceptualization, Investigation, Project administration, Resources, Writing – original draft, Writing – review & editing. MJ: Funding acquisition, Resources, Writing – review & editing. HM: Supervision, Writing – review & editing. JW: Writing – review & editing. XF: Writing – review & editing. JQ: Writing – review & editing. ZY: Writing – review & editing. XZ: Project administration, Supervision, Writing – review & editing. YW: Project administration, Supervision, Writing – review & editing.

## 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 General Project of National Natural Science Foundation of China (No. 72274023).

## Acknowledgments

We are grateful to the professionals and students who provided enormous support in the recruitment and data collection of this study, and the participants who took the time to cooperate with the survey.

## 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.2024.1327442/full#supplementary-material

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# 5 Glossary

| | |
|---|---|
| DTC | Differentiated thyroid cancer |
| MTM | Multi-theory model of health behavior change |
| PD | Participatory Dialog |
| BC | Behavioral Confidence |
| CPE | Changes in Physical Environment |
| ET | Emotional Transformation |
| PC | Practice for Change |
| CSE | Changes in Social Environment |
| mHealth | Mobile health |
| T4 | Thyroxine |
| T3 | Triiodothyronine |
| TTM | Transtheoretical model |
| DMC | The Data Monitoring Committee |
| SAEs | All adverse events |
| AEs | Adverse events |
| CSQ-3 | The Customer Satisfaction Questionnaire |
| EQ-5D-5L | The EuroQol-5 Dimensions 5 Levels |
| ARMS-7 | The Renewal or Medication Adherence Scale |
| FFQ | The Food Frequency Questionnaire |
| I-FFQ | The Iodine-containing Food Frequency Questionnaire |
| HRP | Horseradish peroxidase |
| ELISA | Enzyme-linked immunosorbent assay |
| HPV | Human papilloma virus |
| mCi | Meters Curie |
| FT4 | Free thyroxine |
| FT3 | Free triiodothyronine |
| RIA | Radioimmunoassay |
| PHQ-4 | A simplified version of the Anxiety Depression Scale |
| FCR-4 | The Fear of Cancer Recurrence Scale |

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 23 January 2024
DOI 10.3389/fpubh.2024.1284594



OPEN ACCESS

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RECEIVED 28 August 2023
ACCEPTED 08 January 2024
PUBLISHED 23 January 2024

CITATION
Qiu Y, Wei X, Tao Y, Song B, Wang M, Yin Z, Xie M, Duan A, Chen Z and Wang Z (2024) Causal association of leisure sedentary behavior and cervical spondylosis, sciatica, intervertebral disk disorders, and low back pain: a Mendelian randomization study. *Front. Public Health* 12:1284594. doi: 10.3389/fpubh.2024.1284594



# Causal association of leisure sedentary behavior and cervical spondylosis, sciatica, intervertebral disk disorders, and low back pain: a Mendelian randomization study

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**Background:** Some studies suggest sedentary behavior is a risk factor for musculoskeletal disorders. This study aimed to investigate the potential causal association between leisure sedentary behavior (LSB) (including television (TV) viewing, computer use, and driving) and the incidence of sciatica, intervertebral disk degeneration (IVDD), low back pain (LBP), and cervical spondylosis (CS).

**Methods:** We obtained the data of LSB, CS, IVDD, LBP, sciatica and proposed mediators from the gene-wide association studies (GWAS). The causal effects were examined by Inverse Variance Weighted (IVW) test, MR-Egger, weighted median, weighted mode and simple mode. And sensitivity analysis was performed using MR-Pleiotropy Residual Sum and Outlier (MR-PRESSO) and MR-Egger intercept test. Multivariable MR (MVMR) was conducted to investigate the independent factor of other LSB; while two-step MR analysis was used to explore the potential mediators including Body mass index (BMI), smoking initiation, type 2 diabetes mellitus (T2DM), major depressive disorder (MDD), schizophrenia, bipolar disorder between the causal association of LSB and these diseases based on previous studies.

**Results:** Genetically associated TV viewing was positively associated with the risk of CS (OR = 1.61, 95%CI = 1.25 to 2.07, $p = 0.002$), IVDD (OR = 2.10, 95%CI = 1.77 to 2.48, $p = 3.79 \times 10^{-18}$), LBP (OR = 1.84, 95%CI = 1.53 to 2.21, $p = 1.04 \times 10^{-10}$) and sciatica (OR = 1.82, 95% CI = 1.45 to 2.27, $p = 1.42 \times 10^{-7}$). While computer use was associated with a reduced risk of IVDD (OR = 0.66, 95%CI = 0.55 to 0.79, $p = 8.06 \times 10^{-6}$), LBP (OR = 0.49, 95%CI = 0.40 to 0.59, $p = 2.68 \times 10^{-13}$) and sciatica (OR = 0.58, 95%CI = 0.46 to 0.75, $p = 1.98 \times 10^{-5}$). Sensitivity analysis validated the robustness of MR outcomes. MVMR analysis showed that the causal effect of TV viewing on IVDD (OR = 1.59, 95%CI = 1.13 to 2.25, $p = 0.008$), LBP (OR = 2.15, 95%CI = 1.50 to 3.08, $p = 3.38 \times 10^{-5}$), and sciatica (OR = 1.61, 95%CI = 1.03 to 2.52, $p = 0.037$) was independent of other LSB. Furthermore, two-step MR analysis indicated that BMI, smoking initiation, T2DM may mediate the causal effect of TV viewing on these diseases.

**Conclusion:** This study provides empirical evidence supporting a positive causal association between TV viewing and sciatica, IVDD and LBP, which were potentially mediated by BMI, smoking initiation and T2DM.

KEYWORDS

leisure sedentary behavior, sciatica, cervical spondylosis, intervertebral disk disorders, low back pain, Mendelian randomization

# 1 Introduction

Cervical spondylosis (CS) is a degenerative condition characterized by the compression of the cervical spinal cord and/or surrounding blood vessels and has been shown to be associated with musculoskeletal neck disorders (1, 2). More than one third of the global population experiences mechanical neck pain for a duration of at least 3 months (3). In addition, prolonged neck flexion is a significant contributing factor in the development of myofascial neck pain (4). Intervertebral disk disorders (IVDD) is a common musculoskeletal condition and age-related degenerative disorder in which the amounts of proteoglycans and water in the nucleus pulposus within the disk gradually decreases (5–7). With increasing age, intervertebral disks gradually lose flexibility, elasticity and shock absorbency due to the degeneration, and the fibrosis surrounding the disks can become fragile and prone to rupture (8). The primary clinical manifestation of IVDD is usually low back pain (LBP) and can lead to radiculopathy and myelopathy (9, 10). Sciatica is considered a symptom, rather than a specific disease diagnosis, resulting from the inflammation or compression of the lumbosacral nerve roots L4-S1 by IVDD (11, 12). Research has shown a substantial range in the occurrence of sciatica symptoms, with prevalence rates ranging from 1.6 to 43% (13). In addition, several systematic reviews have suggested that smoking, obesity, and engaging in physically demanding work are potential risk factors for the initial onset of sciatica (14). LBP is not a distinct disease but rather a symptom characterized by pain in the dorsal region between the lower ribs and the gluteal fold (15). A systematic review found that the prevalence ranged from 1.4 to 20.0% in North America, Northern Europe, and Israel (16).

Leisure sedentary behavior (LSB) encompasses activities that involve maintaining a reclined or seated position, leading to limited physical exertion and low metabolic activity (energy expenditure $\leq$1.5 metabolic equivalents) (17). Such activities include watching television (TV), using a computer, and driving (18). Studies have demonstrated a link between LSB and an increased risk of cardiovascular disease, all-cause mortality, metabolic syndrome, and obesity (19, 20). Additionally, a large cohort study suggests an association between prolonged sedentary leisure time exceeding 6 h and an increased likelihood of neurological, sensory, and musculoskeletal disorders (21). Furthermore, a meta-analysis showed that there may be association between full-day sedentary or sitting time and the risk of cervical, and shoulder pain and LBP (22). However, due to the deficits in potential confounding factors and reverse causality, the precise understanding of the relationship between LSB and sciatica, CS, IVDD, and LBP remains incomplete (21, 23).

Mendelian Randomization (MR) analysis is an analytical method to evaluate the causal effect of specific exposures on outcomes using genetic variants available on genome-wide association study (GWAS) (24). GWAS is a systematic analysis of genes which examines and identify DNA sequence variations regulate a complex trait or affect the risk of the disease (25, 26). Previous observational studies of disk disease are subject to unavoidable potential confounding factors such as heterogeneity of the included studies, individual factors in the study population, investigator subjectivity and measurement error, as well as reverse causation due to the effect of disease phenotypes on exposures during disease progression (27–30). As single nucleotide polymorphisms (SNPs) are randomly assigned at conception, they are unlikely to be influenced by lifestyle and environmental factors (31). This feature of MR reduces the risk of confounding factors and reverse causal association, which is common in observational studies (32). Therefore, using a two-sample MR design to analyze summary statistics from GWAS could increase the statistical efficacy of causal association (33). Multivariable Mendelian Randomization (MVMR) analysis is a further developed exploration of traditional MR, which could evaluate more than two exposures simultaneously, and assess the causal association after adjusting other exposures (34). This study aimed to assess the causal associations between LSB (TV viewing, computer use, and driving) and CS, IVDD, LBP, and sciatica with MR approach. Then we further investigated the potential factor independent of other LSB. Several previous studies suggested there may exist an association between LSB and body mass index (BMI), type 2 diabetes mellitus (T2DM) and smoking (35, 36). In addition, LSB may be risk factors for neuropsychiatric disorders (37) and a recent MR study confirmed that LSB (TV viewing) is a high risk factor for major depressive disorder (MDD) (38). In addition, previous epidemiological studies on risk factors of these musculoskeletal disease indicated that several lifestyle related factors may also associated with these diseases, such as depression, education, smoking, obesity, and physical activities (39–41). These modifiable risk factors may also play a role between the LSB and CS, IVDD, LBP, and sciatica. Mediation analyses using two-step MR method could identify the causal pathways through which exposure affects outcomes and their relative importance, which can help identify which factors mediate the relationship between exposure and outcome, which in turn can be intervened or prevented to reduce the impact of exposure on outcomes (42). Therefore, we also evaluated the potential mediator between the causal association of LSB and these skeletomuscular diseases, which will help to optimize disease prevention at both clinical and health levels.

# 2 Methods

## 2.1 Ethical statement

Our study is a re-analysis of data already included in GWAS; all ethical approvals have been obtained by the original GWAS authors. Thus, no additional ethical approval is required.

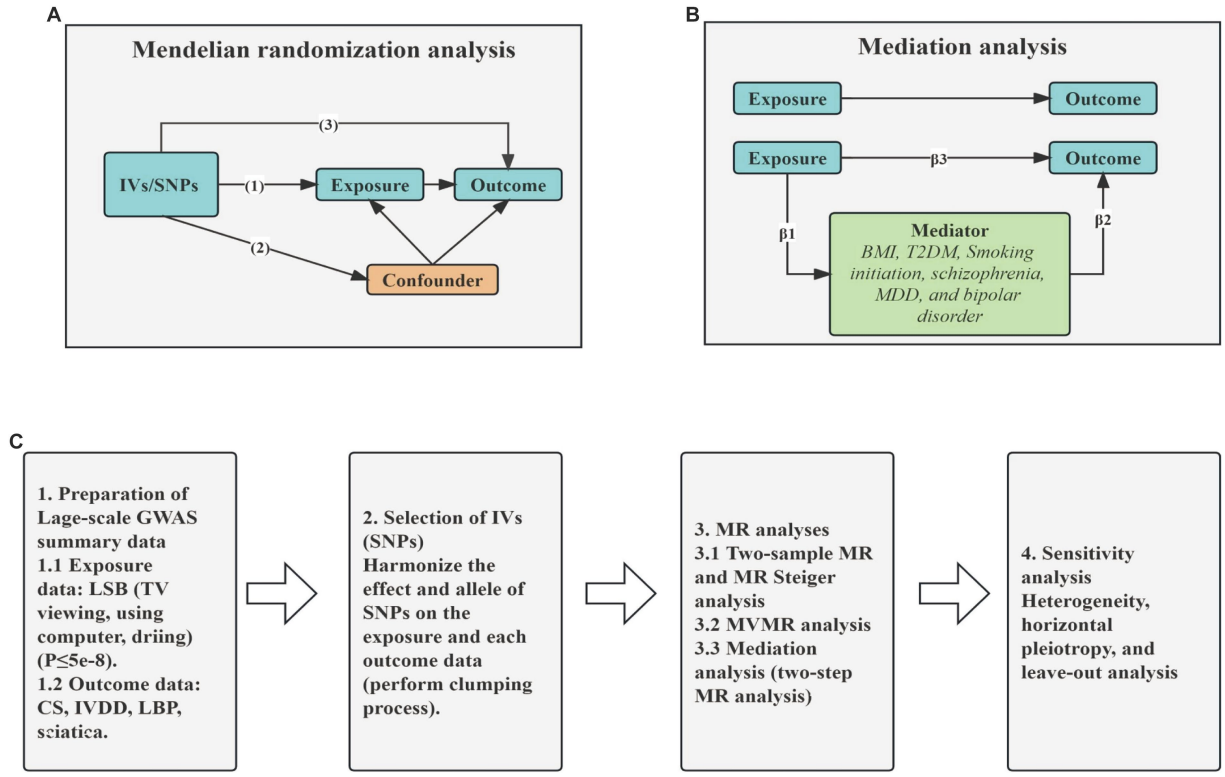


FIGURE 1
Graphical overview of the MR process. **(A)** The principles for two-sample MR analysis. **(B)** The principles for two-step MR analysis. **(C)** The whole workflow of MR analysis. IVs, instrumental variables; SNPs, single nucleotide polymorphisms; BMI, Body mass index; T2DM, type 2 diabetes mellitus; MDD, major depressive disorder; TV, television; CS, cervical spondylosis; IVDD, intervertebral disk disorders; LBP, low back pain; MR, Mendelian Randomization; MVMR, Multivariable Mendelian Randomization.

## 2.2 Study design

In this study, we used MR analysis to detect the association between LSB (TV viewing, computer use and driving) and CS, IVDD, LBP and sciatica using publicly available datasets from large GWAS. We used strict selection criteria to identify SNPs associated with specific LSB (including prolonged TV viewing, computer use, and driving), which were subsequently used as instrumental variables (IVs). The MR design was based on the following assumptions: (1) the genetic variants were directly and robustly associated with LSB and met the GWAS significance threshold; (2) the genetic variants used were not linked to any confounders; (3) the selected genetic variants influenced the development of CS and sciatica only through LSB. We used MR Steiger analysis to determine the precision of the direction. In addition, we also investigated the independent causal role of an exposure after adjusting for other exposures using MVMR. Furthermore, we sought to further explore the potential mechanisms by which genetic proxies for LSB influence susceptibility to CS, IVDD, sciatica and LBP through assessing the effects of potential mediating risk factors (including BMI, T2DM smoking initiation, MDD, schizophrenia, bipolar disorder) using two-step MR analysis (Figure 1). Confounding factors including alcohol use, smoking, low density lipoprotein, triglyceride, etc. are unrelated to genetic variation (43).

## 2.3 Data source

The GWAS summary data of LSB was obtained from a previous publication of the UK Biobank Repository ($N = 422{,}218$; European ancestry) (43). The study conducted a GWAS of sedentary behavior in 422,218 individuals of European origin. We selected IVs significantly associated ($p < 5 \times 10^{-8}$) with LSB on the UK Biobank website,[1] including TV viewing, computer use, and driving. The amount of time respondents spent on these three behaviors was measured by their responses to the following questions: "In a typical day, how many hours do you spend watching television?," "In a typical day, how many hours do you spend using a computer (excluding using a computer at work)?" and "In a typical day, how many hours do you spend driving?." The mean age of the cohort at first assessment was 57.4 years (SD 8.0), and 45.7% of the study population was male. The average daily TV viewing was 2.8 h, computer use was 1.0 h and driving was 0.9 h, with standard deviations (SD) of 1.5 h, 1.2 h and 1.0 h, respectively. A strict threshold ($R^2 < 0.001$, kb = 10,000) clustering procedure was used to ensure the independence of the selected SNPs. SNPs with a significant association with outcomes ($p < 5 \times 10^{-8}$) were also diskarded, and the mean F-statistic of all included exposures was greater than 10 (24).

1 https://www.ukbiobank.ac.uk/

TABLE 1 Data source of the exposures and outcomes.

| Traits | Consortium | Sample size | Ancestry | Author | Year of publication |
|---|---|---|---|---|---|
| Time spent watching TV | UK Biobank | 437,877 | European | Ben Elsworth | 2018 |
| Time spent using computer | UK Biobank | 360,895 | European | Ben Elsworth | 2018 |
| Time spent driving | UK Biobank | 310,555 | European | Ben Elsworth | 2018 |
| CS | FinnGen | 284,358 | European | NA | NA |
| IVDD | FinnGen | 308,600 | European | NA | NA |
| LBP | FinnGen | 300,293 | European | NA | NA |
| Sciatica | FinnGen | 289,533 | European | NA | NA |
| BMI | UK Biobank | 461,460 | European | Ben Elsworth | 2018 |
| Smoking initiation | GSCAN | 607,291 | European | Liu M | 2019 |
| Type 2 diabetes | NA | 655,666 | European | Xue A | 2018 |
| Major depressive disorder | PGC | 173,005 | European | Wray | 2018 |
| Schizophrenia | PGC | 127,906 | European | Trubetskoy V | 2022 |
| Bipolar disorder | PGC | 413,466 | European | Niamh Mullins | 2021 |

TV, television; CS, cervical spondylosis; IVDD, interverbal disk disorder; LBP, low back pain; BMI, Body mass index; GSCAN, Sequencing Consortium of Alcohol and Nicotine use; ICBP, International Consortium of Blood Pressure; PGC, Psychiatric Genomics Consortium.

Summary level GWAS results for CS ($N = 284,358$), IVDD ($N = 308,600$), sciatica ($N = 377,277$), and LBP ($N = 300,293$) were obtained from the Finn-Gen, and participant details, statistical protocols, and genetic information are available on the website.[2] The trait of CS was labeled as "Cervical disk disorders" (44).

We also obtained genetic association for potential mediator (such as BMI, smoking initiation and T2DM) from different database in the IEU open GWAS,[3] and the detailed information of the source of mediators is shown in Table 1. We selected phenotypes of potential mediators with a non-overlapped population to minimize the bias of weak instruments caused by sample overlap.

## 2.4 Statistical analysis

Inverse variance method (IVW) was used as the primary method for MR analysis. Random-effects IVW was used when significant heterogeneity ($I^2 > 50\%$) was detected, otherwise fixed-effects IVW was used. MR-Egger, weighted median, MR Pleiotropy Residuals and Outliers (MR-PRESSO) were also applied for additional statistical analysis. MR-Egger can detect and correct for potential horizontal pleiotropy, but results may be affected by the presence of outlying genetic variables (45–47). Moreover, MR-Egger slopes are relatively effective as estimates of MR in the presence of horizontal pleiotropy. The weighted median method ensures the stability of causality estimates by eliminating errors in the presence of 50% invalid IVs, and may provide better causality detection than the MR-egger under certain conditions (48, 49). MR Steiger directionality test was performed to rule out possibilities of reverse causal association. The estimates are provided for each increase of one standard deviation (SD), and the impact magnitude was reported as the odds ratio (OR) along with a 95% confidence interval (95%CI). Finally, various diagnostic plots were used to detect the robustness of MR estimates. The scatter plots showcase the association of SNPs with exposure and outcome, while the forest plots illustrate the influence of individual instrumental variable on the overall estimation of causality (50). Leave-one-out plots were utilized to visually present the findings of leave-one-out analysis, which involved recalculating the causal estimates obtained from IVW by excluding one SNP at a time. This approach was carried out to assess whether the estimates were affected by biases or driven by outliers (45).

The MR-PRESSO method identifies and corrects outliers by detecting the presence of horizontal multi-effects through global tests, outlier tests and bias tests (51). It is identified horizontal pleiotropy that genetic variants associated with the exposure (LSB) of interest have a direct effect on the outcome (CS, IVDD, sciatica and LBP) through multiple pathways other than the hypothesized exposure, and if horizontal pleiotropy occurs in MR analyses, the results of MR analyses will become unreliable (52). Cochran's Q test and $I^2$ statistics were carried out to evaluate the heterogeneity of the instrumental genetic variable, and a $p$-value <0.05 indicated significant heterogeneity. MR-Egger intercept, ME-PRESSO global test were performed to assess pleiotropy between IVs. Directional pleiotropy was assessed using the intercept term in MR Egger regressions, while in the MR-PRESSO method, heterogeneity is minimized by finding and removing outliers, then reassessing causal estimates. When horizontal pleiotropy still existed, we used the Radial MR method to filter variants identified as outliers (53). In addition, Bonferroni test was used for multiple comparisons, and a $p$-value of 0.016 (0.05/3 exposures) was considered significant, $p$-value ranged from 0.016 to 0.05 was considered suggested significant. In addition, $p$-value <0.05 was considered statistically significant in MVMR, which did not involve errors in multiple comparison.

We used MVMR to further assess the independent effects of these three LSB on these outcomes. MVMR can be used to assess which characteristics maintain causal relationships with outcomes, reflecting the direct effects of exposure on the outcome (54, 55). MR responds

2 https://www.finngen.fi/en

3 https://gwas.mrcieu.ac.uk/

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to the total effect of exposure and outcome and is composed of both direct (MVMR) and indirect effects (mediation effects) (42, 56). In addition, we further explored the effect of potential mediators that may mediate the causality between LSB and these outcomes using two-step MR analysis. The effect of LSB on these outcomes after adjusting for potential mediators is referred to as the direct effect, whereas the effect mediated by potential mediators is referred to as the indirect effect. In two-step MR, the first step is to test the influence of LSB on potential mediators; the second step is to test the influence of potential mediators on CS, IVDD, LBP, and sciatica. All statistical analyses were two-sided. The following packages were all used in R software (version 4.3.0) for analyses: MendelR (version 7.6.2), RadialMR, MR-PRESSO (1.0), and Forestploter (1.1.0) packages.

# 3 Result

## 3.1 Two-sample MR

All instrumental variables used to genetically proxy LSB are shown in Supplementary Table S1, with a total of 113 SNPs for TV viewing, 83 SNPs for computer use, and 7 SNPs for driving. Meanwhile, Steiger filter test showed no reverse causality between the exposure and outcome (Supplementary Table S2). The results of MR estimates are shown in Supplementary Table S3. However, MR-PRESSO and radial MR test detected some of outliers, we therefore preformed MR analysis after remove these outliers (Supplementary Tables S4, S5). The number of eventually enrolled SNPs are shown in Supplementary Table S6.

In the IVW test, no significant causal relationship was found between computer use and CS (OR = 0.80, 95%CI = 0.61 to 1.05, $p = 0.11$). There were also no significant causal associations between driving and CS (OR = 0.40, 95%CI = 0.11 to 1.55, $p = 0.19$), IVDD (OR = 1.67, 95%CI = 0.66 to 4.22, $p = 0.28$), sciatica (OR = 1.73, 95%CI = 0.44 to 6.71, $p = 0.43$) and LBP (OR = 1.38, 95%CI = 0.67 to 2.83, $p = 0.38$) (Figure 2). However, genetically predicted computer use was associated with a reduced risk of IVDD (OR = 0.66, 95%CI = 0.55 to 0.79, $p = 8.06 \times 10^{-6}$), sciatica (OR = 0.58, 95%CI = 0.46 to 0.75, $p = 1.98 \times 10^{-5}$) and LBP (OR = 0.49, 95%CI = 0.40 to 0.59, $p = 2.68 \times 10^{-13}$) (Figure 3); while genetically predicted TV viewing was positively associated with the risk of CS (OR = 1.61, 95%CI = 1.25 to 2.07, $p = 0.002$), IVDD (OR = 2.10, 95%CI = 1.77 to 2.48, $p = 3.79 \times 10^{-18}$), sciatica (OR = 1.82, 95%CI = 1.45 to 2.27, $p = 1.42 \times 10^{-7}$) and LBP (OR = 1.84, 95%CI = 1.53 to 2.21, $p = 1.04 \times 10^{-10}$) (Figure 4). In addition, weight median and other methods (weight mode and MR-Egger) also provided consistent results with IVW, showing the same directions, indicating the robustness of the identified SNP.

Heterogeneity test results were consistent with a value of $p > 0.05$ except for driving and CS ($p < 0.05$) (Supplementary Table S7). The leave-one-out test suggested no SNP derived the causal association between exposure and outcome (Supplementary Figures S1–S12). Furthermore, scatter plot showed the same direction of different methods (Supplementary Figures S13–S24), and the funnel plot displayed a mostly symmetrical distribution (Supplementary Figures S25–S36), indicating the robustness of MR results. Funnel plot showed no specific outlier among SNPs. The results of the MR-PRESSO test after removing outliers showed no potential pleiotropy in MR analysis (Supplementary Table S8). The results of forest plot are shown in Supplementary Figures S37–S48.

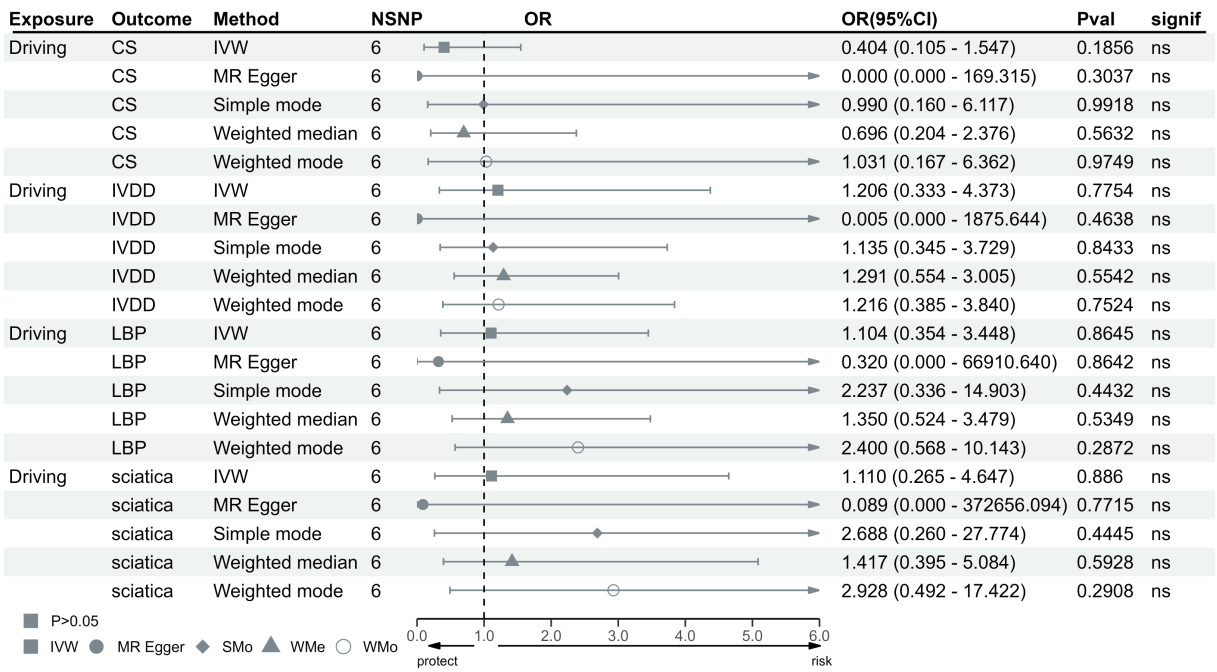


FIGURE 2
MR analysis for time spent driving on outcomes. MR, Mendelian Randomization; IVW, invers variance weighted; CS, cervical spondylosis; IVDD, intervertebral disk disorders; LBP, low back pain; OR, odds ratio; CI, confidence interval.

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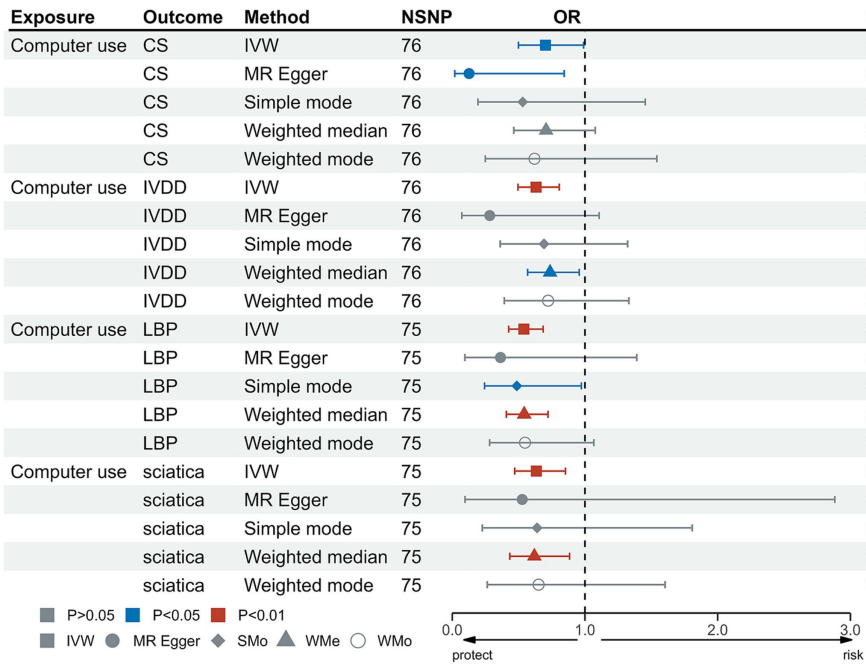


FIGURE 3
MR analysis for time spent using computer on outcomes. MR, Mendelian Randomization; IVW, inverse variance weighted; CS, cervical spondylosis; IVDD, intervertebral disk disorders; LBP, low back pain; OR, odds ratio; CI, confidence interval.

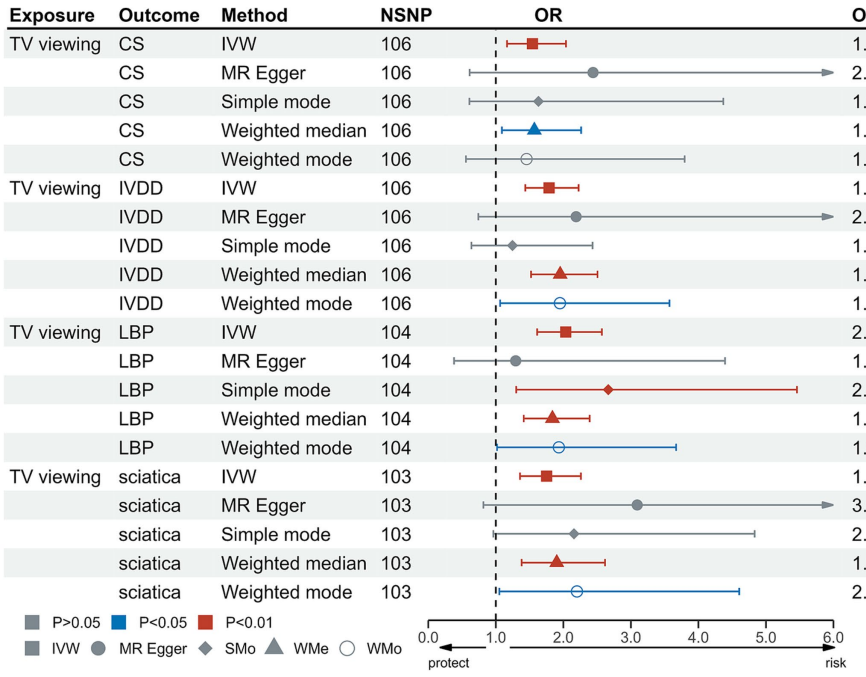


FIGURE 4
MR analysis for TV viewing on outcomes. MR, Mendelian Randomization; IVW, inverse variance weighted; TV, television; CS, cervical spondylosis; IVDD, intervertebral disk disorders; LBP, low back pain; OR, odds ratio; CI, confidence interval.

## 3.2 Multivariable Mendelian randomization and mediation analysis

MVMR was used to evaluate the independent effects of these three LSB on these outcomes. The results of the MVMR analysis showed that TV viewing remained independently causally associated with IVDD (OR = 1.59, 95%CI = 1.13 to 2.25, $p = 0.008$), LBP (OR = 2.15, 95%CI = 1.50 to 3.08, $p = 3.38 \times 10^{-5}$) and sciatica (OR = 1.61, 95%CI = 1.03 to 2.52, $p = 0.037$). However, MVMR analysis demonstrated that TV viewing was not significantly causally related

10.3389/fpubh.2024.1284594

TABLE 2 Result of MVMR analysis between LSB and outcome.

| Exposure | Outcome | SNPs | IVW method | | MR Egger method | | MR Egger intercept | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | OR | *p*-value | OR | *p*-value | Intercept | SE | *p*-value |
| Time spent driving | CS | 96 | 1.44 (0.37 to 0.6) | 0.6 | 1.41 (0.19 to 10.52) | 0.74 | 0.00008 | 0.003 | 0.98 |
| Time spent using computer | CS | 96 | 0.97 (0.6 to 1.57) | 0.91 | 0.97 (0.6 to 1.58) | 0.91 | | | |
| Time spent watching TV | CS | 96 | 1.38 (0.88 to 2.18) | 0.16 | 1.38 (0.87 to 2.19) | 0.17 | | | |
| Time spent driving | IVDD | 96 | 0.78 (0.28 to 2.21) | 0.65 | 0.57 (0.13 to 2.62) | 0.47 | 0.001 | 0.002 | 0.58 |
| Time spent using computer | IVDD | 96 | 0.89 (0.62 to 1.29) | 0.55 | 0.9 (0.62 to 1.29) | 0.55 | | | |
| Time spent watching TV | IVDD | 96 | 1.59 (1.13 to 2.25) | 0.008 | 1.59 (1.13 to 2.25) | 0.01 | | | |
| Time spent driving | LBP | 96 | 0.43 (0.14 to 1.26) | 0.12 | 0.46 (0.09 to 2.29) | 0.35 | −0.0003 | 0.002 | 0.88 |
| Time spent using computer | LBP | 96 | 0.85 (0.58 to 1.24) | 0.39 | 0.85 (0.58 to 1.24) | 0.39 | | | |
| Time spent watching TV | LBP | 96 | 2.15 (1.05 to 2.08) | 0.00003 | 2.15 (1.49 to 3.09) | 0.00004 | | | |
| Time spent driving | sciatica | 96 | 0.88 (0.23 to 3.37) | 0.85 | 0.96 (0.13 to 6.94) | 0.97 | −0.0003 | 0.003 | 0.9 |
| Time spent using computer | sciatica | 96 | 0.73 (0.46 to 1.18) | 0.2 | 0.73 (0.45 to 1.18) | 0.2 | | | |
| Time spent watching TV | sciatica | 96 | 1.61 (1.03 to 2.52) | 0.04 | 1.61 (1.03 to 2.53) | 0.04 | | | |

MVMR, Multivariable Mendelian Randomization; TV, television; CS, cervical spondylosis; IVDD, interverbal disk disorder; LBP, low back pain.

to CS (OR = 1.38, 95%CI = 0.88 to 2.18, $p = 0.16$) and computer use was not significantly causally related to CS (OR = 0.97, 95%CI = 0.60 to 1.57, $p = 0.91$), IVDD (OR = 0.89, 95%CI = 0.62 to 1.29, $p = 0.55$), LBP (OR = 0.85, 95%CI = 0.58 to 1.24, $p = 0.39$) and sciatica (OR = 0.73, 95%CI = 0.46 to 1.18, $p = 0.20$) (Table 2 and Figure 5).

The proportion of mediation is shown in Table 3 and Figure 6. MDD ($p > 0.05$), schizophrenia ($p > 0.05$), bipolar disorder ($p > 0.05$) did not exhibit mediating effects between the relationship of LSB and these outcomes. In the relationship between TV viewing and CS, BMI (0.174), smoking initiation (0.118) and T2DM (0.088) were identified as potential intermediary factors. And in the relationship between TV viewing and IVDD, BMI (0.176), smoking initiation (0.107) and T2DM (0.062) were identified as factors. Meanwhile, BMI (0.14), smoking initiation (0.104) and T2DM (0.01) were found to mediate the effect of TV viewing on sciatica. In particular, BMI (0.187), smoking initiation (0.126) and T2DM (0.034) were also found to mediate the effect of TV viewing on LBP (Supplementary Table S9).

## 4 Discussion

Our MR analysis suggested that LSB (TV viewing) may serve as a significant risk factor that is causally related to the development of IVDD, sciatica, and LBP. Additionally, factors such as BMI, T2DM, and smoking initiation may act as potential mediators in the relationship between TV viewing and IVDD, sciatica, and LBP.

IVDD is a common musculoskeletal disease caused by degenerative changes in the nucleus pulposus of the intervertebral disk (7, 11, 57). And the main cause of LBP is IVDD and results from a variety of known or unknown pathologies or diseases (58, 59). While the etiology of sciatica is attributed to the involvement of the L4-S1 nerve roots by the IVDD (11). Additionally, patients with IVDD may experience LBP and sciatica as a result of inflammation caused by IVDD (7). One study showed that LSB was associated with an increased risk of IVDD and LBP (60) and Euro et al. found a significant association between sitting and the incidence of sciatica (61), which are consistent with our findings.

LSB (TV viewing) may promote the onset and progression of IVDD, sciatica, and LBP by altering disk biomechanical relationships and causing chronic disk inflammation, due to body weight gain. One of the main causes of disk degeneration is damage to the intervertebral disks caused by disturbed biomechanical relationships between the vertebrae (62), and vertebral endplate defects have been shown to be the primary cause of disk degeneration (63, 64). Several studies have demonstrated that LSB plays a role in the development of high BMI and obesity, as evidenced by research conducted by various authors (65–71). TV viewing is considered a 'mentally passive' behavior, whereas using a computer is considered a 'mentally active' behavior (38). Furthermore, as a 'mentally passive' behavior, TV viewing is often perceived as an immersive and less reflective form of leisure and entertainment (52) and unhealthy eating, alcohol consumption and snacking are also associated with TV viewing (72), which may lead to obesity by having more involuntary intake and less consumption compared to non-sedentary population. And obesity can lead to severe postural changes that affect joint loading, while prolonged TV viewing can lead to prolonged periods of poor posture due to 'mentally passivity', which increases spinal strain and muscle fatigue leading disturbed biomechanical relationships and vertebral endplate defects (73–75). In addition, an increase in BMI increases the lumbosacral angle, causing greater flexion of the sacroiliac joints, increased lumbar disk and joint torque, which in turn increases joint loading and causes LBP (76, 77). At the same time, high BMI and obesity lead to metabolic dysregulation and chronic low-grade inflammatory response causing abnormal cytokine production, increased acute phase reactants and activation of inflammatory signaling pathways (78, 79). Moreover, fatty tissue has been shown to promote an inflammatory response through the release of leptin and resistin (80–82). Vertebral endplate defects may allow pro-inflammatory mediators which may be caused by obesity to be transported from the disk to the vertebral body, which in turn cause degenerative disk changes (63).

It has been shown that smoking is associated with LSB using MR analysis (52), and several studies have shown that smoking is an adverse risk factor for LBP and sciatica (83–85), which are consistent

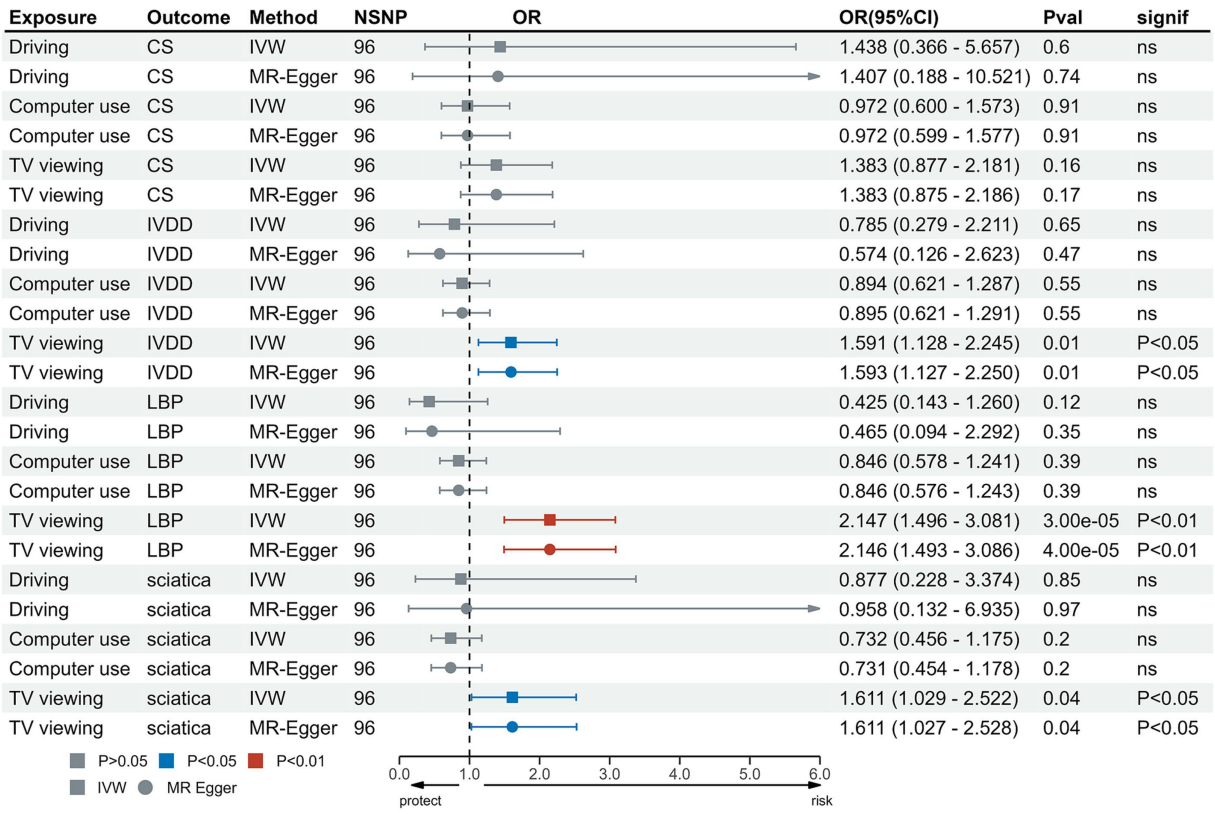


FIGURE 5
MVMR analysis for TV viewing on outcomes. MVMR, Multivariable Mendelian Randomization; IVW, inverse variance weighted; TV, television; CS, cervical spondylosis; IVDD, intervertebral disk disorders; LBP, low back pain; OR, odds ratio; CI, confidence interval.

with the results of our mediation analysis. By reducing the blood supply to the intervertebral disks, smoking can cause intervertebral disk dystrophy (84), and tobacco smoke has been shown to contribute to degenerative changes in intervertebral disks in animal models (86). In addition, tobacco smoke inhalation promotes the production and release of cytokines from inflammatory cells in the intervertebral disk, which causes disk fibrosis and interferes with disk healing and repair (87, 88). Smoking may cause elevated serum levels of advanced glycation end-products (AGEs) and elevated AGEs promote degenerative disk changes by promoting nucleus pulposus apoptosis, facilitating collagen degradation of the annulus fibrosus, and inducing endplate sclerosis (89). In addition, T2DM has also been shown to be causally associated with an increased risk of IVDD (90, 91). In patients with T2DM mellitus, hyperglycemia causes the irreversible formation and accumulation of glycosylation end products, leading to pathophysiological changes in the cartilaginous endplates of the intervertebral disks, while at the same time hyperglycemia affects disk nutrition, cell viability and matrix homeostasis, resulting in changes in disk biomechanics and ultimately leading to IVDD (90). Diabetes accelerates hyperglycemia-induced accumulation of AGEs (92) and the continued accumulation of AGEs associated with hyperglycemia in T2DM was responsible for disk stiffening and the subsequent destructive chain of events (93). Moreover, LSB is considered a potential risk factor for neuropsychiatric disorders (37), and TV viewing was regard as a 'mentally passive' behavior which was considered that associated with an increased MDD risk (38). However, through mediation analyses, we did not find a mediating role for these psychiatric disorders (schizophrenia, MDD and bipolar disorder) between TV viewing and CS, IVDD, LBP, and sciatica. This may be due to the fact that we used mediation analyses (two-step MR analysis) to examine the potential relationship and role of neuropsychiatric disorders in the relationship between LSB (TV viewing) and those outcomes.

In addition, the mechanisms underlying neck pain and CS have been identified as increased intramuscular pressure in the neck, abnormal fascial tension on peripheral nerves, and altered muscle tissue mechanics (2, 4, 94). This condition is primarily caused by increased stress on the intervertebral disks in the neck and a decrease in flexion strength, resulting in the splitting of the annulus and subsequent herniation of the nucleus pulposus (cervical disk herniation), which in turn compresses the spinal cord and blood vessels (95). And studies have shown that inactivity and occasional sitting are associated with more perceived neck pain (96, 97). Although the results of two-sample MR analysis showed a significant association between TV viewing and CS, the results of our MVMR analysis showed no significant association between LSB and CS, which is inconsistent with the expected result. This suggests that the LSB of TV viewing does not have an effect on CS independently of other sedentary behaviors.

As mentioned above, although several observational studies have suggested an association between LSB and CS, IVDD, LBP, and sciatica, they have not provided clear evidence of a causal relationship. In addition, strong evidence of an association may not be available due to confounding variables, reverse causality and survival bias. We therefore performed MR analysis of sedentary behavior and CS, IVDD, LBP, and sciatica to resolve this uncertainty. Our study

TABLE 3 Results of intermediary analyses for TV viewing and outcome.

| Outcome | Intermediary factors | Beta | OR | 95%CI | *p*-value | Proportion (%) |
|---|---|---|---|---|---|---|
| CS | BMI | 0.08 | 1.08 | 1.04, 1.12 | <0.001 | 17.4 |
| CS | Smoking initiation | 0.05 | 1.05 | 1.001, 1.11 | 0.04 | 11.8 |
| CS | Type 2 diabetes | 0.04 | 1.04 | 1.01, 1.07 | 0.006 | 8.8 |
| CS | Major depressive disorder | 0.002 | 1.002 | 0.93, 1.08 | 0.94 | 0.4 |
| CS | Schizophrenia | −0.003 | 1.00 | 0.98, 1.009 | 0.52 | −0.8 |
| CS | Bipolar disorder | 0.003 | 1.003 | 0.98, 1.03 | 0.74 | 0.8 |
| IVDD | BMI | 0.10 | 1.11 | 1.07, 1.14 | <0.001 | 17.6 |
| IVDD | Smoking initiation | 0.06 | 1.06 | 1.02, 1.11 | 0.004 | 10.7 |
| IVDD | Type 2 diabetes | 0.02 | 1.02 | 0.999, 1.04 | 0.05 | 3.2 |
| IVDD | Major depressive disorder | 0.004 | 1.004 | 0.95, 1.06 | 0.83 | 0.6 |
| IVDD | Schizophrenia | −0.0002 | 1.00 | 0.99, 1.006 | 0.91 | −0.03 |
| IVDD | Bipolar disorder | −0.001 | 1.00 | 0.98, 1.01 | 0.88 | −0.2 |
| LBP | BMI | 0.10 | 1.10 | 1.07, 1.14 | <0.001 | 14.0 |
| LBP | Smoking initiation | 0.07 | 1.08 | 1.03, 1.13 | 0.002 | 10.4 |
| LBP | Type 2 diabetes | 0.01 | 1.01 | 0.99, 1.02 | 0.41 | 1.0 |
| LBP | Major depressive disorder | −0.0001 | 1.00 | 0.97, 1.03 | 0.91 | −0.1 |
| LBP | Schizophrenia | −0.003 | 1.00 | 0.99, 1.008 | 0.5 | −0.5 |
| LBP | Bipolar disorder | 0.005 | 1.005 | 0.99, 1.02 | 0.53 | 0.7 |
| Sciatica | BMI | 0.10 | 1.11 | 1.07, 1.15 | <0.001 | 18.7 |
| Sciatica | Smoking initiation | 0.07 | 1.07 | 1.02, 1.13 | 0.005 | 12.6 |
| Sciatica | Type 2 diabetes | 0.02 | 1.02 | 1.0002, 1.04 | 0.04 | 3.4 |
| Sciatica | Major depressive disorder | 0.003 | 1.00 | 0.94, 1.07 | 0.89 | 0.5 |
| Sciatica | Schizophrenia | 2.47 | 1.00 | 0.99, 1.007 | 0.99 | 0.004 |
| Sciatica | Bipolar disorder | 0.002 | 1.002 | 0.98, 1.02 | 0.78 | 0.4 |

TV, television; CS, cervical spondylosis; IVDD, interverbal disk disorder; LBP, low back pain; BMI, Body mass index.

demonstrated that using computer and TV viewing are causally related to the aforementioned musculoskeletal disease, which should be emphasized in the preventive strategies. At the same time, avoiding smoking, maintaining a healthy BMI and preventing the onset of T2DM are also associated with avoiding these musculoskeletal diseases.

Our study has several strengths. First, the causal effect of LSB on IVDD, sciatica, and LBP was investigated using a large, publicly available GWAS database, the results were less likely to be influenced by confounding factors and reverse causality. Second, the population we selected was restricted to European origin to reduce the bias introduced by population stratification. Third, we further assessed the existence possible mediators in the relationship between LSB (TV viewing) and these outcomes, which may play a role in the prevention of these diseases. Fourth, the data sources for the mediators we analyzed were different from the exposures and outcomes, which effectively avoided the problem of overlapping sample sizes. However, there are some limitations to this study. Firstly, we only enrolled European ancestry because there is no GWAS of other origins with large sample size. Therefore, this result may not apply to other ancestries. Second, we did not conduct subgroup analysis on different sex due to the application of summary statistics instead of individual-level data. Additionally, although mediation analysis was conducted and mediators were identified, some other potential mediators, such as poor regions and chances of medical care, need to be heritable and available in GWAS.

## 5 Conclusion

In a summary, our two-sample MR study provides evidence that LSB is associated with the risk of CS, IVDD, sciatica, and LBP, and the causal effect of TV viewing on these diseases was independent of other LSB factors. In addition, mediation analysis indicated that BMI, smoking initiation, and T2DM may mediate the causal associations of TV viewing with IVDD, sciatica and LBP. These modifiable risk factors were the promising interventions for reducing the risk of these diseases.

## 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.

## Ethics statement

The studies involving humans were approved by original GWAS authors. Thus, no additional ethical approval is required. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation

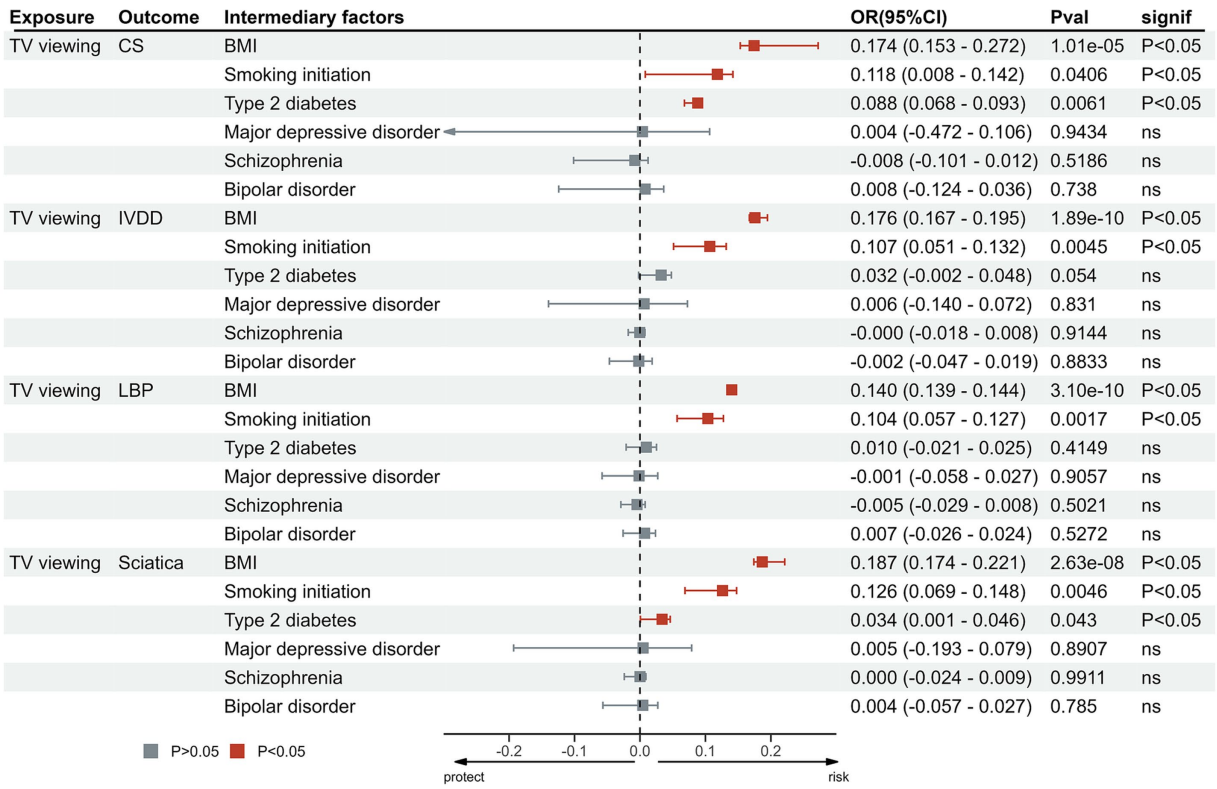


FIGURE 6
Proportion of the effect of TV viewing on outcomes mediated by potential mediators. MR, Mendelian Randomization; IVW, inverse variance weighted; TV, television; CS, cervical spondylosis; IVDD, intervertebral disk disorders; LBP, low back pain.

was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

## Author contributions

YQ: Conceptualization, Investigation, Validation, Writing – original draft, Writing – review & editing. XW: Conceptualization, Investigation, Validation, Writing – original draft, Writing – review & editing. YT: Conceptualization, Investigation, Validation, Writing – original draft. BS: Formal analysis, Methodology, Resources, Software, Writing – original draft. MW: Formal analysis, Methodology, Resources, Software, Writing – original draft. ZY: Data curation, Formal analysis, Methodology, Software, Writing – original draft. MX: Data curation, Methodology, Software, Writing – review & editing. AD: Data curation, Methodology, Supervision, Writing – original draft. ZC: Funding acquisition, Supervision, Writing – review & editing. ZW: Conceptualization, Supervision, Writing – review & editing.

## 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 Suzhou Health Talents Training Project (Grants No GSWS2019002) and the National Natural Science Foundation of China (No 82201445).

## Acknowledgments

The authors acknowledge the investigators of the original studies for sharing the GWAS data used in this project.

## 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.2024.1284594/full#supplementary-material

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frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 26 January 2024
DOI 10.3389/fpubh.2024.1301829



OPEN ACCESS

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RECEIVED 25 September 2023
ACCEPTED 08 January 2024
PUBLISHED 26 January 2024

CITATION
Yang X, Qin Q, Wang Y, Ma Z, Li Q, Zhang F, Han Y and Wang H (2024) Knowledge, attitudes, and practices regarding cardiovascular disease prevention among middle school students in China: a cross-sectional study.
*Front. Public Health* 12:1301829.
doi: 10.3389/fpubh.2024.1301829



# Knowledge, attitudes, and practices regarding cardiovascular disease prevention among middle school students in China: a cross-sectional study

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**Background:** The prevalence of cardiovascular disease (CVD) is rapidly increasing globally. With a concerning increase among adolescents due to unhealthy habits, obesity, and hypertension, understanding the current status of knowledge, attitudes, and practices (KAP) related to CVD prevention among middle school students is crucial for developing effective school-based health programs to prevent CVD.

**Methods:** The analytic cross-sectional survey is used in questionnaires to assess KAP related to CVD prevention among middle school students ($N = 17{,}731$) from 50 schools across 16 provinces in China in June–July 2023. The pass rate of KAP scores is categorized as good and poor. Independent predictors of good KAP of CVD prevention are ascertained using a binary logistic regression model.

**Results:** The study surveyed 8,118 (45.78%) junior high school students and 9,613 (54.22%) high school students. The overall mean [standard deviation (SD)] for the knowledge, attitude, and practice scores were 26.88 (8.12), 53.53 (7.22), and 39.80 (5.96), respectively. The knowledge scores had the lowest pass rate at 56.89%. Only 6.83% of the students know "the definition of blood pressure in adolescents." Attitudes toward health were positive, though the attitude regarding "the danger of prolonged sedentary to cardiovascular health" scored lowest at 73.55%. The practice section had a pass rate of 89.30%; 40.27% of students reported that they spend more than an hour a day on screens. Only one-third of the students would go to bed before 12 o'clock. In univariate analysis, junior high school and high school students differed significantly in knowledge and practice ($p < 0.001$), but attitude did not differ significantly ($p = 0.103$).

**Conclusion:** The majority of students lack sufficient knowledge about CVD. It is also found that socioeconomic background, family environment, and educational levels have an impact on cardiovascular health behaviors among students. Strengthening health education involving students, parents, teachers, and communities is essential to promote health knowledge and practices among adolescents.

KEYWORDS

**cardiovascular disease, adolescents, knowledge, attitude, preventive practice**

# 1 Introduction

Cardiovascular disease (CVD) is one of the major non-communicable diseases with a significant increase in morbidity and mortality globally (1). The prevalence of childhood obesity and other CVD risk factors has been increasing over the past few decades in both developing and developed countries (2, 3). Globally, 39 million children under 5 years old and 340 million children and adolescents are reported to be overweight and obese (4). The main causes of these increases include physical inactivity, unhealthy diet, smoking, and sedentary behavior (5, 6). The synergistic effects of demographic change, globalization, and economic growth have resulted in more children and adolescents being exposed to these behaviors than ever before (7). CVD is now increasing steadily worldwide and has become a major public health problem of the 21st century.

CVD and underlying atherosclerosis begin in childhood. Their presence and intensity are associated with known cardiovascular risk factors (8). Middle school students are in their teenage stage, which is an important life stage. Lifestyle behaviors during this stage have the potential to carry over into higher life stages, and risk factors are more prevalent among adolescents (9, 10). A recent longitudinal study has clarified the direct link between cardiovascular risk factors in childhood and CVD in young adulthood (9), calling for early identification of risk factors. Surveys show that approximately 61% of individuals show some type of atherosclerotic lesion in the coronary arteries by the end of adolescence (11). However, CVD risk factors (such as age, gender, and genetics) are non-modifiable factors for the development of CVD. However, modifiable factors include unhealthy diet, physical inactivity, smoking, obesity, dyslipidemia, and hypertension (12). By making improvements in health approaches and behaviors in relation to identified CVD risk factors, we have the opportunity to reduce the impacts of these modifiable factors on our health, thereby reducing the risk of CVD (13). This study found that physical activity (PA) plays an important role in reducing the risk of chronic diseases, including obesity (14). Knowledge, attitudes, and practices (KAP) associated with CVD risk factors are found to be influenced by socioeconomic factors, social practices, and behavioral patterns (15). Therefore, to understand the KAP of adolescents is necessary. In addition, KAP studies are essential when evaluating interventions related to education and specifying effective measures aimed at improving the population.

This descriptive cross-sectional study was conducted on 17,731 junior high school and high school students from 50 schools in 16 provinces of China. This is the first national study in China to examine knowledge, attitudes, and practices related to CVD risk factors among middle school students. Focusing on the middle school students population in China, this study attempts to provide a framework of information to better understand the extent of our knowledge of cardiovascular health issues and to take positive health actions to increase awareness of CVD and risk factors.

Abbreviations: CVD, Cardiovascular disease; BP, Blood pressure; PA, Physical activity; KAP, Knowledge, attitude, and practice.

# 2 Methods

## 2.1 Sampling method

A stratified cluster random sampling method was used in this study. The seven geographic subregions of China (North China, Northeast China, East China, Central China, South China, Southwest China, and Northwest China) were used as the basis for sampling stratification. Within each geographic subregion, we selected 1–3 provinces; and 1–2 junior high schools and 1–2 high schools were selected from each province. From each school, two classes were randomly selected for each grade level. In the end, our survey encompassed 16 provinces and 50 schools (see the Figure 1).

## 2.2 The sample size calculation

Based on previous research studies on adolescents' knowledge of chronic disease prevention, the adolescents' knowledge rate of chronic disease prevention was 50.8% (16). With a specified tolerance error of 3% and a confidence level of $1-\alpha=0.95$, the sample size to be surveyed was calculated using the PASS 2021 software, resulting in $N=1{,}098$. Considering the presence of seven stratification factors in the survey area, the sample size was adjusted to $1{,}098\times7=7{,}686$. Accounting for potential invalid questionnaires, the sample size was increased by 10%, resulting in a final sample size of at least 8,540.

## 2.3 Participants

We surveyed 17,731 middle school students in China using a questionnaire in June–July 2023. Of these, 8,145 (45.94%) boys and 9,586 (54.06%) girls; 7,473 (42.15%) in cities, 4,493 (25.34%) in townships, and 5,765 (32.51%) in rural areas; 13,273 (74.86%) Han Chinese and 4,458 (25.14%) ethnic minorities; 8,118 (45.78%) junior high school students; and 9,613 (54.22%) in high schools.

Before completing the questionnaire, the researcher explained the background of the study, the purpose, the principle of anonymity and confidentiality, and the precautions and obtained signed informed consent from the participants. Inclusion criteria included middle school students who were willing to participate in the study. Exclusion criteria were failure to complete the questionnaire.

## 2.4 Questionnaire design and data collection

The self-designed questionnaire "Chinese Middle School Students' Cardiovascular Disease Prevention Questionnaire" was used, which was validated and modified by experts, with Cronbach's $\alpha=0.829$, KMO = 0.887 for the knowledge part, KMO = 0.933 for the attitude part, and KMO = 0.647 for the behavior part ($p<0.001$), with good reliability and validity. The final survey includes the following: (1) basic information about middle school students; (2) knowledge of CVD prevention: a total of 22 entries, mainly investigating middle school students knowledge of CVD prevention. Correct answers are scored as 2

points, errors or ignorance is scored as 0 points, and the full score is 44 points; (3) attitude of CVD prevention: a total of 22 entries, using the Likert 5-level scale, the options are divided into five levels, such as very little need, no need, general, need, very much need; in order to assign a score of 1, 2, 3, 4, 5, full score of 60 points; (4) behavior of CVD prevention: a total of 19 entries, in addition to the 8 sub-items in the 1st question item does not count, the remaining 11 entries have 3 or 5 options ranging from 3 or 5, accordingly divided into 3 or 5 grades, options 3 grades are assigned 1, 3, 5 points, options 5 grades are assigned 1, 2, 3, 4, 5 points, out of a total of 55 points. The 2nd, 4th–5th, 7th, 9th–10th entries are assigned points in reverse.

Questionnaires are self-filled in a centralized classroom setting, with the investigator supervising the whole process to ensure that students answer the questionnaires independently and without interference. The questionnaires are collected on-site. The data were double-entered for comparison and error checking.

## 2.5 Statistical analysis

EpiData 3.1 software is used for data entry, and IBM SPSS version 26.0 is used for statistical analysis. Measured data are described using mean scores (SD). Count data are presented as numerical values and percentages. To assess the influence of demographic characteristics on knowledge, attitude, and practice scores, we utilize the chi-square test. Logistic regression analysis is used to explore the factors impacting knowledge, attitude, and practice scores. Statistically significant is defined as a $p$-value of $<0.05$.

## 2.6 Ethical issues

We obtained ethical approval for this research from our Ethics Committee on 27 June 2023 (approval number 20230627001). All participants provided written informed consent. Participant names and potentially identifying information were removed to the greatest extent possible to protect anonymity.

# 3 Results

## 3.1 Demographic characteristics

In this survey of middle school students, a total of 18,500 questionnaires were distributed. Of these, 18,169 were returned, excluding 438 invalid questionnaires, and 17,731 valid questionnaires from middle school students were collected, representing an effective response rate of 95.84%.

A total of 8,145 (45.94%) boys and 9,586 (54.06%) girls were surveyed; 7,473 (42.15%) in cities, 4,493 (25.34%) in townships, and 5,765 (32.51%) in rural areas; 13,273 (74.86%) Han Chinese and 4,458 (25.14%) ethnic minorities; 8,118 (45.78%) junior high school students and 9,613 (54.22%) in high schools; 7,631 (43.04%) students living in schools and 10,100 (56.96%) not living in schools; 14,452 (81.51%) without a history of family chronic diseases and 3,279 (18.49%) with a history of family chronic diseases as detailed in Table 1.

## 3.2 CVD prevention survey KAP score for middle school students

According to the actual content of the survey, (1) the knowledge section consists of 22 questions, 2 points each, totaling 44 points. (2) The attitude section consisted of 12 questions, 5 points each, with a total score of 60 points. (3) The practice section consists of 11 questions; each question is worth 5 points, and the total score is 55.

The pass line is set at 60% of the total score. The pass rate shows that the knowledge section has the lowest pass rate of 56.98%, and the behavior section has a pass rate of 89.30% as detailed in Table 2.

## 3.3 Knowledge

Definitional questions are answered correctly as known and incorrectly answered or omitted as not known. In terms of cardiovascular prevention knowledge, the items with a correct rate of less than 60% are "the concept of CVD (58.12%)," "factors affecting CVD (52.17%)," "the dangers of a high-salt diet (57.79%)," "the definition of sedentary behavior (43.96%)," "the recommended daily activity time for adolescents (34.66%)," "risk factors for CVD (23.77%)," "behaviors that cause to diabetes (33.33%)," and "behaviors that cause to hyperlipidemia (35.59%)." The lowest number of students knowing about "the dangers of being sedentary (22.92%)" and "the definition of blood pressure (BP) in adolescents (6.83%)" and the highest number of students knowing about "behaviors cause overweight and obesity (90.62%)" are detailed in Table 3.

## 3.4 Attitude

The options for middle school students' attitudes toward CVD prevention are set up as five levels of options (e.g., very little need, no need, average, need, very much need), and the choice of need/important/severe and very much need/very important/very severe are selected as positive attitudes. The results show that middle school students have good attitudes toward CVD prevention in general. The aspects below 90% are as follows: the danger of sleep deprivation and staying up late for cardiovascular health (89.24%), the danger of anxiety and depression to cardiovascular health (83.49%), the danger of prolonged sedentary to cardiovascular health (73.55%), and the danger of overweight and obese to cardiovascular health (88.16%), attitude toward adopting a healthy lifestyle (82.14%), and receiving health education on CVD prevention (86.67%) as detailed in Table 4.

## 3.5 Practice

The statistical results show that 19.15% of middle school students ate sweets and sugary drinks 0 times, and 5.58% more than 7 times per week; 32.76% ate high-fat and oily food 0 times, and 3.18% more than 7 times per week; 42.91% ate salty food 0 times, and 3.20% more than 7 times per week; 13.42% ate whole grains and miscellaneous grains 0 times, and 17.61% more than 7 times per week; eating vegetables and fruits 0 times accounted for 3.47%, more than 7 times accounted for 42.80% per week; drinking dairy products 0 times accounted for 9.23%, more than 7 times accounted for 27.20% per week; eating


FIGURE 1
Map of the survey areas (prepared by Adobe Illustrator Artwork 23.0).

aquatic products 0 times accounted for 34.08%, more than 7 times accounted for 5.08% per week; eating nuts 0 times accounted for 30.30%, more than 7 times accounted for 7.66% per week. Middle school students ate various types of food more centered on 1-3 times per week as detailed in Table 5.

The percentage of students who are not picky eaters is 54.51%. The percentages of non-smokers and non-drinkers both are over 85%. In total, 64.07% of students pay attention to their BP, blood glucose, and blood lipids. In total, 43.59% of students eat breakfast less than 7 times a week. In total, 40.27% of students have an average of more than 1 h of screen time a day. In total, 48.64% of students have a daily sleep time of less than 8 h. In total, 33.99% of students go to sleep before 12 o'clock every week. In total, 30.91% of students experience anxiety and depression 1–2 times a week. In total, 15.39% of students do not get up and move their bodies after sitting for a long time. In total, 17.61% of students do not control their diets and exercise regularly in order to maintain a healthy weight as detailed in Table 6.

## 3.6 Univariate analysis of KAP for CVD prevention among middle school students

Statistically significant differences are observed in terms of residence, gender, grade, co-residence with parents, parental occupation, parental education, ethnicity, monthly family income, and family history of chronic diseases about middle school students with good knowledge scores on CVD prevention. Knowledge is better among middle school students residing in urban (62.80%, $n = 4,693$) than in township (53.31%, $n = 2,395$) and rural (52.30%, $n = 3,015$). Girls (60.38%, $n = 5,788$) have better knowledge than boys (52.98%,

10.3389/fpubh.2024.1301829

TABLE 1 Socio-demographic characteristics of participants ($N = 17,731$).

| Characteristics | Frequency |
|---|---|
| **Residence** | |
| City | 7,473 (42.15%) |
| Village | 4,493 (25.34%) |
| Countryside | 5,765 (32.51%) |
| **Gender** | |
| Boys | 8,145 (45.94%) |
| Girls | 9,586 (54.06%) |
| **Monthly family income** | |
| <2000 CNY | 2,432 (13.72%) |
| 2000–3,999 CNY | 5,800 (32.71%) |
| 4,000–5,999 CNY | 4,000 (22.56%) |
| 6,000–7,999 CNY | 2,442 (13.77%) |
| ≥8,000 CNY | 3,057 (17.24%) |
| **Nation** | |
| Han Chinese | 13,273 (74.86%) |
| Ethnic minority | 4,458 (25.14%) |
| **Grade** | |
| Junior high school | 8,118 (45.78%) |
| High school | 9,613 (54.22%) |
| **Father's profession** | |
| Farmer | 5,520 (31.13%) |
| Worker | 4,608 (25.99%) |
| Service worker | 916 (5.17%) |
| Private entrepreneur | 3,201 (18.05%) |
| Civil service | 734 (4.14%) |
| Doctor | 162 (0.91%) |
| Teacher | 354 (2.00%) |
| Staff | 683 (3.85%) |
| Unemployed | 595 (3.36%) |
| Other | 958 (5.40%) |
| **Mother's profession** | |
| Farmer | 5,791 (32.66%) |
| Worker | 2,564 (14.46%) |
| Service worker | 1,678 (9.46%) |
| Private entrepreneur | 2,850 (16.07%) |
| Civil service | 417 (2.35%) |
| Doctor | 288 (1.62%) |
| Teacher | 635 (3.58%) |
| Staff | 618 (3.49%) |
| Unemployed | 2,129 (12.01%) |
| Other | 761 (4.29%) |
| **Father's education** | |
| Secondary | 4,318 (24.35%) |
| Junior | 7,548 (42.57%) |
| Senior | 3,327 (18.76%) |
| University | 2,538 (14.31%) |
| **Mother's education** | |
| Secondary | 5,701 (32.15%) |
| Junior | 6,926 (39.06%) |
| Senior | 2,808 (15.84%) |
| University | 2,296 (12.95%) |
| **Whether living with parents** | |
| Living with parents | 13,235 (74.64%) |
| Not living with parents | 4,496 (25.36%) |
| **Whether living at the school** | |
| Not living at the school | 10,100 (56.96%) |
| Living at the school | 7,631 (43.04%) |
| **Family history of chronic diseases** | |
| Have | 14,452 (81.51%) |
| None | 3,279 (18.49%) |

*(Continued)*

TABLE 1 (Continued)

$n = 4,315$). High school students (64.91%, $n = 6,240$) have better rates of good knowledge than junior high school students (47.59%, $n = 3,863$). The rate of good knowledge of middle school students increased with the higher level of parental education as detailed in Table 7 and Supplementary Table S1.

Good attitude scores on CVD prevention among middle school students are statistically significant, which is observed in terms of residence, whether lives in school, co-residence with parents, parental occupation, parental education, monthly family income, and family history of chronic diseases. Middle school students living in cities (62.02%, $n = 4,635$) have better attitudes than those living in towns (55.46%, $n = 2,492$) and rural areas (53.32%, $n = 3,074$). Middle school students living with parents (58.59%, $n = 7,755$) have better attitudes than those living with other relatives (54.40%, $n = 2,446$) as detailed in Table 7 and Supplementary Table S1.

Good practices in CVD prevention among middle school students are statistically significant, which is observed in terms of residence, gender, grade, whether lives in school, co-residence with parents, parental occupation, parental education, ethnicity, and family history of chronic diseases. Middle school students living in townships (54.13%, $n = 2,432$) and rural areas (53.86%, $n = 3,105$) have better good behavior than those living in urban (49.54%, $n = 3,702$). Boys (54.67%, $n = 4,453$) have better behavior than girls (49.93%, $n = 4,786$). Junior high school students (66.31%, $n = 5,383$) have better behavior than high school students (40.11%, $n = 3,856$) as detailed in Table 7 and Supplementary Table S1.

## 3.7 Logistic regression of factors influencing KAP for CVD prevention in middle school students

Levels of CVD prevention knowledge, attitudes, and practices are used as the dependent variable. The statistically significant factors identified through Chi-square test are used as the independent variables.

TABLE 2 Scoring of knowledge, attitude, and practice on CVD prevention for middle school students.

| Features | Total scores | Mean scores (SD) | Passing rate |
|---|---|---|---|
| Knowledge | 44 | 26.88 (8.12) | 56.98% |
| Attitude | 60 | 53.53 (7.22) | 97.35% |
| Practice | 55 | 39.80 (5.96) | 89.30% |

TABLE 3 Knowledge of cardiovascular disease prevention among middle school students (*N* = 17,731).

| Content of knowledge | Frequency | Content of knowledge | Frequency |
|---|---|---|---|
| Concept of CVD | 10,305 (58.12%) | Influencing factors of CVD | 9,250 (52.17%) |
| Diseases caused by smoking | 14,632 (82.52%) | The dangers of a high-fat diet | 15,083 (85.07%) |
| Benefits of whole grain medley | 13,296 (74.99%) | The dangers of a high-salt diet | 10,246 (57.79%) |
| The dangers of staying up late | 14,991 (84.55%) | Definition of sedentary | 7,794 (43.96%) |
| Diseases caused by excessive alcohol consumption | 14,910 (84.09%) | Behaviors that predispose to overweight and obesity | 16,067 (90.62%) |
| The dangers of snacks and milk tea | 15,860 (89.45%) | The dangers of overweight and obesity | 11,962 (67.46%) |
| Indicators for determining overweight and obesity | 11,619 (65.53%) | The dangers of chronic anxiety and depression | 14,745 (83.16%) |
| Risk factors for CVD | 4,214 (23.77%) | Definition of blood pressure in adolescents | 1,211 (6.83%) |
| The dangers of prolonged sedentary behavior | 4,064 (22.92%) | Preventive measures for high blood pressure | 13,885 (78.31%) |
| Behaviors that tend to cause hyperlipidemia | 6,311 (35.59%) | Behaviors that predispose to diabetes | 5,910 (33.33%) |
| Recommended daily sleeping time for middle school students | 14,061 (79.30%) | Daily recommended activity times for middle school students | 6,146 (34.66%) |

TABLE 4 Positive attitudes toward CVD prevention among middle school students (*N* = 17,731).

| Content of attitude | Frequency | Percentage |
|---|---|---|
| CVD needs to be prevented in adolescence | 16,209 | 91.42% |
| A sensible diet is important for cardiovascular health | 16,508 | 93.10% |
| Physical activity is important in preventing CVD | 16,281 | 91.82% |
| Smoking is dangerous for cardiovascular health | 16,478 | 92.93% |
| Excessive alcohol consumption is dangerous for cardiovascular health | 16,465 | 92.86% |
| Lack of sleep and late nights are dangerous for cardiovascular health | 15,823 | 89.24% |
| Anxiety and depression are dangerous for cardiovascular health | 14,803 | 83.49% |
| Being sedentary is dangerous for cardiovascular health | 13,041 | 73.55% |
| Hypertension, hyperglycemia, and hyperlipidemia are dangerous for cardiovascular health | 16,280 | 91.82% |
| Overweight and obesity are dangerous for cardiovascular health | 15,632 | 88.16% |
| Attitude to adopt a healthy lifestyle | 14,564 | 82.14% |
| Receive health education on cardiovascular prevention | 15,368 | 86.67% |

TABLE 5 Frequency of daily meals per week among middle school students (*N* = 17,731).

| Features | 0 times a week | 1–3 times a week | 4–6 times a week | 7 times a week |
|---|---|---|---|---|
| Sweets and sugary drinks | 3,396 (19.15%) | 11,567 (65.24%) | 1779 (10.03%) | 989 (5.58%) |
| High fat and oil food | 5,808 (32.76%) | 9,976 (56.26%) | 1,383 (7.80%) | 564 (3.18%) |
| Salty food | 7,608 (42.91%) | 8,312 (46.88%) | 1,243 (7.01%) | 568 (3.20%) |
| Whole grains and mixed grains | 2,379 (13.42%) | 8,256 (46.56%) | 3,973 (22.41%) | 3,123 (17.61%) |
| Vegetables and fruits | 616 (3.47%) | 4,359 (24.58%) | 5,168 (29.15%) | 7,588 (42.80%) |
| Dairy product | 1,636 (9.23%) | 6,784 (38.26%) | 4,489 (25.32%) | 4,822 (27.20%) |
| Aquatic product | 6,042 (34.08%) | 9,026 (50.91%) | 1763 (9.94%) | 900 (5.08%) |
| Nuts | 5,372 (30.30%) | 8,609 (48.55%) | 2,392 (13.49%) | 1,358 (7.66%) |

TABLE 6 Daily life behaviors for CVD prevention among middle school students ($N = 17,731$).

| Content of practice | Frequency |
|---|---|
| **Frequency of late bedtime (after 12 o'clock) in the last 7 days** | |
| 0 day | 6,027 (33.99%) |
| 1–2 days | 5,736 (32.35%) |
| 3–4 days | 2,624 (14.80%) |
| 5–6 days | 1,228 (6.93%) |
| 7 days | 2,116 (11.93%) |
| **Frequency of anxiety and depression in the past 7 days** | |
| None | 7,309 (41.22%) |
| 1–2 times | 5,480 (30.91%) |
| 3–4 times | 2,775 (15.65%) |
| 5–6 times | 924 (5.21%) |
| 7 times | 1,243 (7.01%) |
| **Do you concern your blood pressure, blood sugar, and lipids** | |
| No concern | 6,371 (35.93%) |
| Concern | 8,176 (46.11%) |
| Very much concern | 3,184 (17.96%) |
| **Do you get up and move your body after being sedentary?** | |
| No | 2,728 (15.39%) |
| Sometimes | 9,135 (51.52%) |
| Always | 5,868 (33.09%) |
| **Frequency of smoking** | |
| Non-smoking | 16,849 (95.02%) |
| Sometimes | 512 (2.89%) |
| Always | 370 (2.09%) |
| **Frequency of drinking** | |
| Not drinking | 15,602 (87.99%) |
| Sometimes | 1814 (10.23%) |
| Always | 315 (1.78%) |
| **Average screen time per day over the past 7 days** | |
| <30 min | 5,557 (31.34%) |
| 30–60 min | 5,033 (28.39%) |
| ≥1 h | 7,141 (40.27%) |
| **Daily controlled diet and regular exercise to maintain a healthy weight** | |
| No | 3,123 (17.61%) |
| Sometimes | 9,650 (54.42%) |
| Always | 4,958 (27.96%) |
| **Daily sleep duration in the last 7 days** | |
| <8 h | 8,624 (48.64%) |
| 8–10 h | 7,866 (44.36%) |
| ≥10 h | 1,241 (7.00%) |
| **Frequency of breakfast in the last 7 days** | |
| 0 day | 1,362 (7.68%) |
| 1–2 days | 1,493 (8.42%) |
| 3–4 days | 2,198 (12.40%) |
| 5–6 days | 2,676 (15.09%) |
| 7 days | 10,002 (56.41%) |
| **Are you a picky (not vegetables) eater?** | |
| Not picky | 9,666 (54.51%) |
| Not eating one or two vegetables | 5,766 (32.52%) |
| Not eating more than three vegetables | 2,299 (12.97%) |

Logistic regression results show that residence, grade, gender, whether living with parents, mother's occupation, parental education, monthly family income, ethnicity, and family history of chronic disease are influencing factors of middle school students CVD prevention knowledge scores. Middle school students living in townships (95% CI: 0.757, 0.893; $p < 0.001$) are more likely to have poorer knowledge than those living in cities. High school students (95% CI: 1.920, 2.175; $p < 0.001$) are more likely to have better knowledge than junior high school students. Girls (95% CI: 1.314, 1.487; $p < 0.001$) are more likely to have good knowledge than boys. Middle school students living with other relatives (95% CI: 0.811, 0.936; $p < 0.001$) are more likely to have poor knowledge than those living with both parents. Students whose father's education is junior high school (95% CI: 1.171, 1.388; $p < 0.001$), senior high school (95% CI: 1.296, 1.623; $p < 0.001$), and university (95% CI: 1.302, 1.757; $p < 0.001$) are more likely to have better knowledge than students whose fathers are primary school students. Middle school students whose mothers' education is high school (95% CI: 1.085, 1.370; $p < 0.05$) and university (95% CI: 1.082, 1.466; $p < 0.05$) are more likely to have better knowledge than students whose mothers are in primary school. The higher the monthly family income, the more likely students are to have better knowledge. Students from ethnic minorities (95% CI: 0.693, 0.803; $p < 0.001$) are more likely to have poorer knowledge than Han Chinese. Students without a family history of chronic disease (95% CI: 0.852, 0.987; $p < 0.001$) are more likely to have poorer knowledge than students with a family history of chronic disease.

Living in an urban area, not living in school, living with parents, father's occupation as a teacher, father's higher education level, and having a family history of chronic diseases are the influencing factors of better attitude among middle school students. Living in towns and villages, boys, junior high school, living with parents, higher educational level of parents, and no family history of chronic diseases are the influencing factors of better behaviors as detailed in Supplementary Table S2.

## 4 Discussion

As the prevalence of CVD and risk factors is rapidly increasing globally, primary prevention, early diagnosis, and educational preventive measures are now prioritized (17). The aim of this study is to understand the current status of knowledge, attitudes, and practices related to CVD prevention among middle school students. This survey shows that low awareness of CVD prevention among Chinese middle school students is a major health problem. Understanding CVD can

TABLE 7 Chi-square test of KAP for CVD prevention middle school students.

| Features | Knowledge | | Attitude | | Practice | |
|---|---|---|---|---|---|---|
| | $\chi^2$ | *p*-value | $\chi^2$ | *p*-value | $\chi^2$ | *p*-value |
| Residence | 179.542 | <0.001 | 111.386 | <0.001 | 34.211 | <0.001 |
| Gender | 98.435 | <0.001 | 1.341 | 0.247 | 39.722 | <0.001 |
| Grade | 539.015 | <0.001 | 2.657 | 0.103 | 1210.354 | <0.001 |
| Whether living at the school | 1.495 | 0.221 | 29.588 | <0.001 | 11.929 | 0.001 |
| Whether living with parents | 27.274 | <0.001 | 24.123 | <0.001 | 59.755 | <0.001 |
| Father's profession | 195.520 | <0.001 | 124.773 | <0.001 | 24.718 | 0.003 |
| Mother's profession | 176.581 | <0.001 | 105.606 | <0.001 | 19.507 | 0.021 |
| Father's education | 303.558 | <0.001 | 176.211 | <0.001 | 21.424 | <0.001 |
| Mother's education | 227.071 | <0.001 | 97.204 | <0.001 | 30.748 | <0.001 |
| Nation | 85.935 | <0.001 | 1.238 | 0.266 | 14.242 | <0.001 |
| Monthly family income | 178.057 | <0.001 | 23.515 | <0.001 | 4.111 | 0.391 |
| Family history of chronic diseases | 14.996 | <0.001 | 5.537 | 0.018 | 70.161 | <0.001 |

improve middle school students' awareness of the early dangers of CVD, which can ultimately reduce the life-threatening consequences associated with the disease.

Our results showed that awareness rate of knowledge of the Chinese middle school students' CVD prevention survey was 56.98%. The result was higher than Sitaula D et al. survey on diabetes and hypertension among school students in Nepal (18). Because there had hardly been any regular school-based awareness campaigns or health intervention programs focusing on NCDs such as diabetes and hypertension.

It was found that students' knowledge of "concept of CVD (58.12%)" and "factors affecting CVD" (52.17%) was inadequate, which may be due to the fact that students did not receive adequate education on the importance and risk factors of CVD (19). In addition, the knowledge of "behaviors causing overweight and obesity (90.62%)" and "hazards of snacks and milk tea (89.45%)" was better, but there was insufficient knowledge of "hazards of prolonged sedentary behavior (22.92%)" and "definition of BP in adolescents (6.83%)" probably because of the imbalance in the transmission of health information. The hazards of overweight and obesity and snacks and milk tea were more prominent in health education and publicity. The definition of prolonged sedentary behavior and BP in adolescents might not have received enough attention (16).

In our study, 91.82% of students had a positive attitude toward PA being important in the prevention of CVD, but 73.55% had a positive attitude toward sedentary behavior being harmful to cardiovascular health, which was the lowest. The concepts of sedentary behavior and lack of PA are not the same, and meeting PA recommendations does not guarantee that one will not be sedentary (20). Thus, they are independent modifiable risk factors for CVD (21). Promoting PA and reducing sedentary behavior are strategies to prevent CVD. Light or moderate PA as a substitute for sedentary behavior has been found to reduce type 2 diabetes, cardiovascular mortality, and all-cause mortality (22, 23). In total, 82.14% of students indicated that they were willing to adopt a healthy lifestyle and 86.67% were willing to receive health education on CVD prevention. It shows that these students are aware of health issues and the importance of cardiovascular health. Students are willing to take positive actions to improve their lifestyles and improve their health. Therefore, schools and the community can take measures to improve students' awareness of health issues and encourage them to adopt healthy behaviors. However, there are still some students who are reluctant to adopt a healthy lifestyle and unwilling to receive health education on CVD prevention. We should fully understand the possible reasons, change their attitudes, and improve their awareness of the dangers of CVD.

In total, 7.68% of students did not eat breakfast every day, which is similar to the findings by Bassi et al. (24). In total, 56.41% of students eat breakfast every day. A cross-sectional survey showed urban students prioritized having a healthy diet and ate daily breakfast compared to rural (25). It is possible that the economy in rural areas is not as stable as that of students in urban areas, which makes it difficult for families of rural students to provide an adequate breakfast. A study confirmed that eating breakfast away from home is 1.7 times more likely to lead to obesity than eating breakfast at home (26). This may be due to the rapid development of the food service industry, which has led to an increase in the number of students eating out. Other dietary factors included vegetables and fruits, which were not eaten daily by only 3.47% of students and 1–3 times a week by 24.58% of students. The study of Indian adolescents reported that 11.3% of the students did not eat fruits daily (24). In a comparison of 49 low- and middle-income countries, Indian adolescents had the highest proportion of fruit and vegetable consumption in line with WHO recommendations (27). A survey on type II diabetes in American adolescents revealed that participants consumed an average of 1.5 snacks per day. Specifically, 23.0% reported consuming two snacks, 5.1% consuming three snacks. Moreover, the survey observed that these adolescents spend 1.9 times per week on fast food, with 49.3% of them reporting twice-weekly fast-food consumption, and 24.3% three times per week (28). These findings highlighted the prevalence of snacks and fast-food consumption among the adolescent population. In addition, we found that 64.07% of students are concerned about their BP, blood glucose, and blood lipids, which is higher than Asante et al. (29). Regular BP, blood glucose, and lipid testing are essential for early prevention and detection of hypertension and diabetes. Studies have found that the risk of CVD, including hypertension and

diabetes, increases with age (30). Our study showed that 84.61% of students would get up and move their bodies after being sedentary. With the development of electronic technology, the sedentary time of students watching TV, reading mobile phones, and surfing the Internet has been increasing, and outdoor activities have been decreasing. This lifestyle will increase the risk of obesity and CVD in teenagers (31). Our study found that 82.39% of students would maintain a healthy weight by controlling their diet and exercising regularly, which is in line with other survey results (32, 33).

Our study found that students living in urban areas had higher knowledge scores than those living in towns and rural areas because probably urban areas usually have richer educational resources and higher quality of education, which would improve the learning performance of urban students and broaden their knowledge domains. However, the proportion of students living in towns and villages with good behavior, was higher than for those living in cities because possibly towns and villages often have healthier lifestyles, such as healthier diets and increased PA, which can help to reduce the risk of CVD. This was confirmed by a study in Bangladesh (34). Girls scored higher knowledge scores than boys. It is possible that there is a difference in the importance attached to health by students of different genders. However, the percentage of girls scoring good behaviors was lower than that of boys, probably because girls were more physically inactive and consumed more snacks. Gender is an important social determinant of health behaviors from childhood to adolescence to adulthood, and boys will have significantly higher levels of PA than girls during their formative years (35, 36). This inter-gender gap increases during the adolescent transition. The study showed that the percentage of high school students with good knowledge scores was higher than that of junior high school students. However, the percentage of high school students with good practice scores was lower than that of junior high school students, probably due to the pressure of high school, lack of PA, and reduced sleep. A survey from Poland on obesity and nutritional knowledge among adolescents showed that nutritional knowledge among adolescents was positively associated with adhering to a healthy lifestyle (37). Furthermore, adolescents with higher nutritional knowledge exhibited lower trends for fast-food consumption and sedentary behavior. This result emphasized the significant influence of knowledge levels on individual lifestyle choices, particularly in the adolescent population. Understanding of health knowledge may make adolescents more inclined to make healthful lifestyle choices.

Students living with both parents with good knowledge scores and good behaviors were higher than those living with other relatives, probably due to the fact that students living with both parents had easier access to family support and a more favorable educational environment, which helped to improve students' motivation and learning standards (38). The knowledge scores of students whose parents' occupations were teachers and doctors were significantly higher than those of the other groups, which may be due to the fact that parents with higher socioeconomic status were more likely to pass on knowledge about CVD prevention to their children. Thus, their children may have acquired more relevant knowledge. In addition, more educated parents were more likely to provide educational support and resources to facilitate their children's health education, which is consistent with the findings of Ishikawa et al. (39). This suggests that parental occupation and educational level have a significant impact on students' knowledge of CVD prevention, formation of awareness, and development of behaviors. A cross-sectional survey in Germany found a relationship between parental health literacy and certain health behaviors in children. Children whose parents had higher health literacy were found to have higher rates of consumption of vegetables and salads and engaged in more physical activity than their counterparts (40). This finding highlighted the positive impact of parental health literacy on children's dietary and exercise habits. Our survey found students in Han Chinese have higher knowledge scores than students in ethnic minority may be due to the fact that in some areas, educational resources are more concentrated in areas inhabited by Han Chinese, which contributes to higher knowledge scores for Han Chinese students. Moreover, there may be cultural and social differences among different ethnicities, which may affect students' attitudes and behaviors (41). There are differences in the knowledge, attitudes and practices scores of middle school students with different monthly family incomes. The results of the study are consistent with the results of Akter et al. (15). This may be due to the fact that families of different economic levels have different importance on health knowledge, which leads to differences in the students' acceptance of health education and mass communication.

KAP related to CVD prevention was found to be influenced by socioeconomic factors and social behavior patterns (15). Our study found that girls were more likely to have good levels of CVD knowledge, with the opposite result being that girls were more likely to have poorer behaviors, while boys were more likely to have better behaviors. Similar studies have also shown better behavioral scores for boys compared to better attitude scores for girls (42). Previous studies have shown that educational level is associated with awareness of hypertension and diabetes. Educational level may influence health in terms of health knowledge, healthcare competencies, behaviors, and psychosocial aspects (43). This also supports some of the research (44). In addition, a family history of chronic disease affected the knowledge, which is consistent with the findings of Niermann et al. (45). This may be due to the fact that people with a family history of chronic disease are more likely to pay attention to knowledge and their own health status than the general population (46). Students living with both parents showed better knowledge, attitudes, and behaviors on CVD prevention. A study showed that students living with both parents had higher self-rated health scores and were less likely to experience mental health issues (47). This may imply that the home environment and family education play an important role in educating students about cardiovascular health.

This study is the first study of CVD prevention on knowledge, attitudes, and practices among middle school students in China at present. It mainly focuses on junior high school and high school students. Effectively representing all geographic subregions of China (central, northern, eastern, southern, northwestern, southwestern, and northeastern). It also encompasses urban, township, and rural areas, with an inclusive approach that extends to ethnic minority regions.

However, there are some limitations to this study. Despite the comprehensive coverage of seven major geographical subregions in China and participants from diverse socioeconomic backgrounds, certain areas may not have been included in the investigation due to resource constraints. Additionally, due to the lack of a standardized questionnaire on KAP related to CVD, we utilized a self-administered questionnaire that has undergone rigorous reliability and validity

testing. The data collection relies on students' self-reports, so the data collected may have been influenced by recall bias.

## 5 Conclusion

This study revealed poorer levels of CVD prevention knowledge among Chinese middle school students, most of whom lacked knowledge of CVD concepts and associated risk factors, but displayed better attitudes and practices. Moreover, influenced by socio-demographic, socioeconomic, and socio-behavioral patterns, we observed that those living in urban areas, high school students, girls, those living with parents, those whose parents had a higher education level, those who came from higher family income, Han Chinese, and those having a family history of chronic disease were more likely to have a good level of CVD knowledge. We should take effective measures to strengthen cardiovascular health education for students, improve their health knowledge, and help them develop correct health attitudes and adopt positive health practices.

## 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 Human Ethics Committee of Guangxi Normal University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

## Author contributions

XY: Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. QQ: Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. YW: Data curation, Investigation, Supervision, Writing – review & editing. ZM: Investigation, Writing – review & editing. QL: Investigation, Writing – review & editing. FZ: Investigation, Writing – review & editing. YH: Investigation, Writing – review & editing. HW: Funding acquisition, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing, Investigation.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This study was supported by the National Social Science Foundation of China (Grant 19XTY011).

## Acknowledgments

The authors gratefully acknowledge the ethical approval from the Guangxi Normal University Committee. Additionally, the authors thank all the people who took part in the study and the field assistants who helped them collect data.

## 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.

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## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1301829/full#supplementary-material

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frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 13 February 2024
DOI 10.3389/fpubh.2024.1349891



OPEN ACCESS

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RECEIVED 05 December 2023
ACCEPTED 15 January 2024
PUBLISHED 13 February 2024

CITATION
Won MH and Shin S-H (2024) Mediating effects of patient safety perception and willingness to participate in patient safety on the relationship between health literacy and patient participation behavior among inpatients.
*Front. Public Health* 12:1349891.
doi: 10.3389/fpubh.2024.1349891



# Mediating effects of patient safety perception and willingness to participate in patient safety on the relationship between health literacy and patient participation behavior among inpatients

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**Introduction:** In recent years, patient safety activities have shifted from being centered on healthcare providers to involving patients themselves. Health literacy of inpatients has a direct impact on patient participation behavior. Patient safety perception was also associated with willingness to participate in patient safety and patient participation behavior. Therefore, this study aimed to investigate the mediating effects of patient safety perception and willingness to participate in patient safety on the relationship between health literacy and patient participation behavior among inpatients.

**Methods:** This cross-sectional study was conducted to confirm the relationship between study variables. A total of 262 inpatients were recruited from patients admitted to the ward of a tertiary general hospital between October and November 2023. Participants were invited to complete self-reported questionnaires that measured health literacy, patient safety perception, willingness to participate in patient safety, patient participation behavior, and demographic information. Data were analyzed using a dual mediation model applying the PROCESS macro (Model 6) with 95% bias-corrected bootstrap confidence intervals.

**Results:** This study analyzed the direct effects of health literacy on patient safety perceptions and patient participation behavior. Health literacy indirectly affected patient participation behavior through patient safety perceptions and willingness to participate in patient safety. Regarding the relationship between health literacy and patient participation behavior, patient safety perceptions and willingness to participate in patient safety showed a significant dual mediating effect.

**Conclusions:** This study identified the factors that promote patient participation behavior among inpatients. The mediating effect of patient safety perception on the relationship between health literacy and patient participation behavior was found to be strong. Building health literacy among inpatients ensures patient safety by increasing patient safety perceptions.

KEYWORDS

**inpatients, patient safety, perception, patient participation, health literacy**

# 1 Introduction

Patient safety refers to minimizing the risk of harm or error to patients during the delivery of healthcare services (1). One in 10 hospitalized patients suffers harm while receiving medical services, and it is reported that more than 3 million people experience fatal harm due to unsafe medical services every year (2). More than 50% of the harm is reportedly preventable (3, 4), and medication errors, unsafe surgical procedures, healthcare-associated infections, diagnostic errors, falls, pressure ulcers, and patient identification errors can be prevented through patient safety activities (1). Much of the research on patient safety has focused on preventing errors and mistakes in the delivery of healthcare, with particular emphasis on healthcare providers. Recently, however, it has been suggested that actively involving the parties directly affected by patient safety incidents in patient safety activities is the best way to prevent medical errors (5). In other words, patient safety has shifted from a healthcare provider-centered activity to a patient-directed one (6, 7). So active patient participation behavior is critical to reducing the risk of medical errors.

Health literacy is the ability to use information to make decisions and effectively care for one's health, and a patient's health literacy is an important determinant of health (8, 9). Patients with higher health literacy are more likely to understand healthcare providers' explanations and engage in disease-related preventive behaviors (10, 11). In contrast, patients with low health literacy did not adequately manage their health, such as failing to understand treatment prescriptions, not asking questions about medical issues, and not attempting to seek new health information (10). In addition, patients with low health literacy may have problems with communication critical to patient safety, such as taking medications at doses different from those prescribed (12). Inpatient health literacy directly influences patient safety engagement perceptions and acts as a mediator in the relationship between the patient safety environment and patient safety engagement perceptions (13). In this way, health literacy, a patient's personal characteristic, is a major factor affecting patient participation behavior.

Patient safety perception is the level at which patients perceive that their safety is not threatened in the medical field (14). Therefore, patient safety perception refers to the degree to which patients are aware of situations that pose a risk to their safety during the process of receiving medical services and how to prevent them (15, 16). Previous studies have shown that a higher patient safety perception among inpatients is associated with a higher willingness to engage in patient safety (15) and that patient safety perception is positively correlated with the performance of patient safety activities (17). To increase inpatient engagement in patient safety, it is necessary to enhance the perception that patients play a key role in ensuring their safety (17, 18).

Willingness to participate in patient safety is a patient's willingness to take a more active role in patient safety activities, which means taking an interest in their care and taking the initiative to participate in the care process (19). This can improve patient safety through the identification of possible side effects and increased effectiveness of treatment by monitoring patient progress (20). Factors that affect willingness to participate in patient safety include patient-related factors (age, gender, and health status), disease-related factors (underlying disease, severity, and patient safety accident experience), medical staff-related factors (knowledge and beliefs), and medical institution-related factors (type of medical institution and patient safety work type) (19). Inpatients' patient safety perception was a factor that affects willingness to participate in patient safety (15).

Patient participation behavior refers to a patient's participation in the decision-making processes related to health issues. Furthermore, it is the act of taking the initiative to engage patients in various aspects of healthcare, such as self-medication, self-monitoring, patient education, goal setting, and physical care (21). It has been reported that inpatients have limited participation in the care process and low levels of perception of what patient safety activities (7). In addition, the higher the patient safety perception of inpatients, the higher the patient participation behavior level (16). Factors that hinder patient participation include acceptance of new patient roles, low levels of health literacy, lack of confidence in competency, and the presence of diseases and comorbidities (22). In the past, it was assumed that deferring to medical decision-making was the best option for treatment. It is now recommended to listen to patients and involve them in the decision-making process by involving them in all aspects of their care (19). Therefore, interaction between medical staff and patients is an important factor in promoting patient safety (19, 21), and patients themselves need to practice taking an interest in their health and actively participating in decisions related to their care (11).

Previous studies have shown that the health literacy of inpatients has a direct impact on patient participation behavior (13, 23). Additionally, patient safety perception is related to willingness to participate in patient safety (15), and patient safety perception is related to patient participation behavior (16, 17). Health literacy is an individual's ability to make decisions about health, and it was judged to be related to patient safety perception and willingness to participate in patient safety; therefore, the following hypothesis was set: The health literacy of inpatients influences patient participation through patient safety perception and willingness to participate in patient safety.

The specific purposes of this study were as follows: First, the correlations between health literacy, patient safety perceptions, willingness to participate in patient safety, and patient participation behavior will be identified. Second, the mediating path that influences the patient participation behavior will be identified.

# 2 Methods

## 2.1 Study design and participants

This descriptive study examined the correlations between health literacy, patient safety perception, willingness to participate in patient safety, and patient participation behavior among inpatients. Participants were patients admitted to the general ward of a tertiary general hospital with more than 700 beds in South Korea. The criteria for selecting participants were: those who had previously been hospitalized, adults over 20 years of age, those with a clear state of consciousness and the ability to communicate,

and those who understood the purpose of the study and agreed to voluntarily participate. Exclusion criteria were those who had never been hospitalized; those with a history of stroke or vascular dementia, memory impairment, or mental illness; those taking psychiatric drugs such as antidepressants; and those diagnosed with chronic renal failure or terminal cancer. From the data of 295 people who met the selection criteria, 33 who had no previous hospitalization were removed, and the final data of 262 people were used for the analysis.

A *post-hoc* test for multiple regression analysis was performed using G*Power (version 3.1.9.2) to examine the adequacy of the sample size. Since there were no prior studies suggesting the effect size, a medium effect size ($f^2 = 0.15$) was set, the significance level ($\alpha$) was 0.05, and the power of the data was 98.9% when analyzing data from 262 people based on 16 predictive factors. The sample size for the analysis was judged to be appropriate.

## 2.2 Measures

### 2.2.1 Health literacy

Health literacy was measured using the Korean version of the Brief Health Literacy Screener developed by Chew et al. (24) and the Brief Health Literacy Screener (25) to assess individuals' ability to access and utilize health-related information. The instrument has three questions, each rated on a 5-point Likert scale from 0 to 4, with scores ranging from 0 to 12. Higher score indicates a higher level of health literacy. In the study by Son and Song (25), the internal consistency coefficient (Cronbach's α) of the instrument was 0.82, while in the present study it was 0.75.

### 2.2.2 Patient safety perception

The patient safety perception of Korean inpatients was measured using the Patient Safety Perception Scale developed by Kim et al. (14). The instrument was developed based on previous research and qualitative interviews, and its content, criteria and construct validity were verified. The instrument has 24 questions, each rated on a 5-point Likert scale from 1 to 5, with scores ranging from 24 to 120. A higher score indicates a higher level of patient safety perception. In the study by Kim et al. (14), the internal consistency coefficient (Cronbach's α) of the instrument was 0.93, while in the present study it was 0.95.

### 2.2.3 Willingness to participate in patient safety

Patients' willingness to participate in patient safety was measured using the Willingness toward Participation in Patient Safety instrument developed by Lee (26). The instrument was developed based on a literature review of 20 guidelines for preventing medical errors published by the Agency for Healthcare Research and Quality (AHRQ), and its content validity was verified by experts. The instrument has 18 questions, each rated on a 4-point Likert scale from 1 to 4, with scores ranging from 18 to 72. A higher score indicates a higher level of willingness to participate in patient safety. In the study by Lee (26), the internal consistency coefficient (Cronbach's α) of the instrument was 0.88, while in the present study it was 0.94.

### 2.2.4 Patient participation behavior

Patient participation behavior was measured using the Patient Participation Scale developed by Song and Kim (27) for outpatients and inpatients. The instrument was developed based on prior research and was validated for content validity, construct validity, and reliability. The instrument has 21 questions, each rated on a 5-point Likert scale from 1 to 5, with scores ranging from 21 to 105. A higher score indicates a higher level of patient participation. In the study by Song and Kim (27), the internal consistency coefficient (Cronbach's α) of the instrument was 0.92, while in the present study it was 0.93.

## 2.3 Data collection and ethical considerations

This study was approved by the Institutional Review Board of the investigator's university (IRB no: WKIRB-202310-SB-079). The data were collected from October to November 2023, and a face-to-face survey was conducted among inpatients in the ward of a tertiary general hospital. After obtaining permission from the relevant institution, study participants were recruited through postings. An informed consent document was presented to the participants to explain the purpose, content, and procedures of the study. In addition, it was explained in advance that they could freely choose to stop answering the survey or withdraw their consent, and that there would be no disadvantage. After receiving an explanation of the study, participants signed a consent form for voluntary participation and completed the survey. Details on how to ensure the confidentiality of the collected data were provided. Those who completed the survey were compensated for their participation.

## 2.4 Data analysis

SPSS 25.0 (IBM Institute, NY, USA) was used to analyze the data. The general characteristics of the participants were analyzed using descriptive statistics of frequency and percentage, mean, and standard deviation. Differences in the study variables (health literacy, patient safety perception, willingness to participate in patient safety, and participation behavior) according to general characteristics were analyzed using an independent *t*-test, one-way ANOVA, and *post-hoc* Scheffé's test. The relationships between the study variables were analyzed using Pearson's correlation. The reliability of the instrument was checked with the Cronbach's α value. To test the significance of the indirect effect, the PROCESS procedure for SPSS Version 4.1 (Model 6) was used. The 95% confidence intervals (CIs) were calculated using bootstrapping and the mediating effect was considered significant if the lower and upper bounds of the 95% CIs did not include zero. The significance of the size of the mediation effect and the differences in the path

of the mediation effect were verified. All analyses had a statistical significance level of 0.05 or less.

# 3 Results

## 3.1 Differences in patient participation behavior based on general characteristics

The general characteristics of the study participants are presented in Table 1. There were 149 men (56.9 %) and 113 women (43.1 %). The average age was 62.65 years (±18.03), with 140 (53.4%) aged 65 or older. The most common level of education was middle school or lower (111, 42.4%). In total, 156 (59.5%) patients were unemployed. Regarding residence type, 113 (43.1%) lived with several people as a family or group, and 100 (38.2%) lived alone with their spouse. Most patients were in the internal medicine department (132 patients, 50.4%) and patients with surgical experience accounted for more than half (185 patients, 70.6%). There were 139 (53.1%) patients who received patient safety education upon admission and 123 (46.9%) who did not. A total of 163 patients (62.2%) had underlying diseases (cardiovascular system, diabetes, stroke, etc.) and 155 patients (59.2%) were taking medications (antihypertensive drugs, oral hypoglycemic agents, hyperlipidemic drugs, diuretics, etc.).

Descriptive statistics in the study variables according to the general characteristics are shown in Table 2. Health literacy differed significantly by age ($t = 5.06$, $p < 0.001$), education level ($F = 25.55$, $p = 0.001$), occupation ($t = -2.72$, $p = 0.007$), underlying disease ($t = 3.69$, $p < 0.001$), and use of oral medication ($t = 3.29$, $p = 0.001$). *Post-hoc* tests for education level showed that college and high school graduates had higher health literacy than those with a high school diploma or lower. Patient safety perception was significantly different by patient safety education ($t = -2.75$, $p = 0.006$). The willingness to participate in patient safety differed significantly by gender ($t = -2.29$, $p = 0.023$) and patient safety education ($t = -2.50$, $p = 0.013$). Patient participation behavior was significantly different based on patient safety education ($t = -2.40$, $p = 0.017$).

TABLE 1 Demographic characteristics of participant ($N = 262$).

| Characteristics | Categories | *n* (%) |
|---|---|---|
| Gender | Men | 149 (56.9) |
| | Women | 113 (43.1) |
| Age (year) | ≦64 | 122 (46.6) |
| | ≧65 | 140 (53.4) |
| Education level | Middle school | 111 (42.4) |
| | High school | 87 (33.2) |
| | College or higher | 64 (24.4) |
| Occupation | Don't have | 156 (59.5) |
| | Have | 106 (40.5) |
| Residential status | Living alone | 49 (18.7) |
| | Living with a spouse | 100 (38.2) |
| | Live together | 113 (43.1) |
| Medical department | Internal medicine | 132 (50.4) |
| | Surgical department | 86 (32.8) |
| | Others (urology, plastic, etc.) | 44 (16.8) |
| Surgical experience | No | 77 (29.4) |
| | Yes | 185 (70.6) |
| Patient safety training | No | 123 (46.9) |
| | Yes | 139 (53.1) |
| Illness history | No | 99 (37.8) |
| | Yes | 163 (62.2) |
| Medication | No | 107 (40.8) |
| | Yes | 155 (59.2) |

## 3.2 Description and correlations of study variables

The mean scores of the study variables are presented in Table 3. Health literacy averaged 2.09 (±0.90), patient safety perception 4.20 (±0.60), willingness to participate in patient safety 3.33 (±0.49), and patient participation behavior 3.94 (±0.60). As a result of examining the skewness and kurtosis of the research variables, the skewness was within ±2 and the kurtosis was within ±4, forming a normal distribution.

Table 3 presents the results of correlation analyses of the study variables. Health literacy was significantly positively correlated with patient safety perception ($r = 0.14$, $p = 0.026$) and patient participation behavior ($r = 0.13$, $p = 0.034$). However, health literacy did not correlate with willingness to participate in patient safety in the study ($r = 0.08$, $p = 0.179$). Patient safety perception was significantly positively correlated with willingness to participate in patient safety ($r = 0.62$, $p < 0.001$) and patient participation behavior ($r = 0.70$, $p < 0.001$). Willingness to participate in patient safety was significantly positively correlated with patient participation behavior ($r = 0.70$, $p < 0.001$).

## 3.3 Significance of the mediating effect of patient safety perception and willingness to participate in patient safety and differences in the mediating effect by pathway

The results of the dual mediation effect of patient safety perception and willingness to participate in patient safety in the relationship between health literacy and patient participation behavior are shown in Table 4. A mediation analysis was performed after including gender, age, and patient safety education as control variables, which showed a significant difference in patient participation behavior among the general characteristics. In Model 1, the independent variable, health literacy, had a significant positive effect ($\beta = 0.15$, $p = 0.020$) on the primary parameter, patient safety perception ($R^2 = 0.051$, $F = 3.43$, $p = 0.001$). In Model 2, health literacy had no significant effect on the secondary

TABLE 2 Descriptive statistics in health literacy, patient safety perception, willingness to participation in patient safety, and patient participation behavior by demographic characteristics ($N = 262$).

| Characteristics | Categories | Health literacy | | Patient safety perception | | Willingness to participate in patient safety | | Patient participation behavior | |
|---|---|---|---|---|---|---|---|---|---|
| | | M ± SD | t/F (*p*) | M ± SD | t/F (*p*) | M ± SD | t/F (*p*) | M ± SD | t/F (*p*) |
| Gender | Men | 2.15 ± 0.81 | 1.27 (0.207) | 4.18 ± 0.63 | −0.84 (0.404) | 3.27 ± 0.50 | −2.29 (0.023) | 3.89 ± 0.62 | −1.60 (0.111) |
| | Women | 2.01 ± 1.01 | | 4.24 ± 0.57 | | 3.41 ± 0.46 | | 4.01 ± 0.57 | |
| Age (year) | ≦64 | 2.37 ± 0.71 | 5.06 (<0.001) | 4.22 ± 0.55 | 0.43 (0.671) | 3.36 ± 0.44 | 0.94 (0.348) | 3.93 ± 0.55 | −0.16 (0.874) |
| | ≧65 | 1.84 ± 0.97 | | 4.19 ± 0.64 | | 3.31 ± 0.53 | | 3.95 ± 0.64 | |
| Education level | Middle school[a] | 1.67 ± 0.94 | 25.55 (<0.001) a < b,c | 4.17 ± 0.66 | 0.56 (0.573) | 3.32 ± 0.54 | 0.17 (0.843) | 3.99 ± 0.64 | 0.58 (0.558) |
| | High school[b] | 2.47 ± 0.76 | | 4.26 ± 0.56 | | 3.33 ± 0.43 | | 3.90 ± 0.58 | |
| | College or higher[c] | 2.29 ± 0.67 | | 4.19 ± 0.56 | | 3.36 ± 0.47 | | 3.91 ± 0.55 | |
| Occupation | Don't have | 1.96 ± 0.98 | −2.72 (0.007) | 4.18 ± 0.63 | −0.91 (0.364) | 4.18 ± 0.63 | −0.35 (0.728) | 4.18 ± 0.63 | 0.17 (0.865) |
| | Have | 2.27 ± 0.72 | | 4.25 ± 0.55 | | 4.25 ± 0.55 | | 4.25 ± 0.55 | |
| Residential status | Living alone | 1.87 ± 1.07 | 2.29 (0.104) | 4.04 ± 0.80 | 2.90 (0.057) | 3.38 ± 0.58 | 0.32 (0.723) | 3.84 ± 0.73 | 1.60 (0.204) |
| | Living with a spouse | 2.20 ± 0.77 | | 4.29 ± 0.51 | | 3.31 ± 0.47 | | 4.02 ± 0.54 | |
| | Live together | 2.08 ± 0.91 | | 4.20 ± 0.57 | | 3.34 ± 0.46 | | 3.91 ± 0.58 | |
| Medical department | Internal medicine | 1.95 ± 0.88 | 3.03 (0.051) | 4.19 ± 0.66 | 0.09 (0.917) | 3.31 ± 0.52 | 0.35 (0.703) | 3.92 ± 0.67 | 0.47 (0.624) |
| | Surgical department | 2.22 ± 0.91 | | 4.23 ± 0.53 | | 3.34 ± 0.46 | | 3.94 ± 0.50 | |
| | Others (urology, plastic, etc.) | 2.23 ± 0.87 | | 4.19 ± 0.58 | | 3.38 ± 0.44 | | 4.02 ± 0.57 | |
| Surgical experience | No | 2.10 ± 0.75 | 0.40 (0.919) | 4.26 ± 0.65 | 0.88 (0.378) | 3.34 ± 0.53 | 0.11 (0.915) | 3.93 ± 0.64 | −0.22 (0.823) |
| | Yes | 2.08 ± 0.95 | | 4.18 ± 0.58 | | 3.33 ± 0.47 | | 3.95 ± 0.58 | |
| Patient safety training | No | 2.04 ± 0.93 | −0.78 (0.438) | 4.10 ± 0.64 | −2.75 (0.006) | 3.25 ± 0.50 | −2.50 (0.013) | 3.85 ± 0.59 | −2.40 (0.017) |
| | Yes | 2.13 ± 0.87 | | 4.30 ± 0.55 | | 3.40 ± 0.46 | | 4.02 ± 0.60 | |
| Illness history | No | 2.34 ± 0.74 | 3.69 (<0.001) | 4.19 ± 0.59 | −0.25 (0.805) | 3.37 ± 0.48 | 0.85 (0.398) | 3.92 ± 0.56 | −0.50 (0.617) |
| | Yes | 1.93 ± 0.95 | | 4.21 ± 0.61 | | 3.31 ± 0.49 | | 3.96 ± 0.62 | |
| Medication | No | 2.30 ± 0.76 | 3.29 (0.001) | 4.20 ± 0.58 | −0.02 (0.983) | 3.37 ± 0.49 | 1.01 (0.314) | 3.91 ± 0.59 | −0.75 (0.457) |
| | Yes | 1.94 ± 0.96 | | 4.21 ± 0.62 | | 3.31 ± 0.49 | | 3.96 ± 0.60 | |

[a,b,c] Alphabets refer to *post-hoc* test results using Scheffé's method.





10.3389/fpubh.2024.1349891

TABLE 3 Descriptive statistics and correlation of health literacy, patient safety perception, willingness to participate in patient safety, and patient participation behavior ($N = 262$).

| Variables | PSP | WP | PPB | Mean ± SD | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| | r ($p$) | | | | | |
| HL | 0.14 (0.026) | 0.08 (0.179) | 0.13 (0.034) | 2.09 ± 0.90 | −0.18 | 0.08 |
| PSP | | 0.62 (<0.001) | 0.70 (<0.001) | 4.20 ± 0.60 | −0.97 | 2.62 |
| WP | | | 0.70 (<0.001) | 3.33 ± 0.49 | −0.65 | 1.23 |
| PPB | | | | 3.94 ± 0.60 | −0.53 | 1.47 |

HL, Health literacy; PSP, Patient safety perception; WP, Willingness to participate in patient safety; PPB, Patient participation behavior.

TABLE 4 Results of mediating effect analysis ($N = 262$).

| Model | DV | IV | B | SE | β | t | $p$ | Adj. $R^2$ | F ($p$) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | PSP | HL | 0.10 | 0.04 | 0.15 | 2.33 | 0.020 | 0.051 | 3.43 (0.009) |
| 2 | WP | HL | −0.01 | 0.03 | −0.01 | −0.11 | 0.912 | 0.398 | 33.89 (<0.001) |
| | | PSP | 0.49 | 0.04 | 0.61 | 12.17 | <0.001 | | |
| 3 | PPB | HL | 0.04 | 0.03 | 0.06 | 1.52 | 0.130 | 0.616 | 68.02 (<0.001) |
| | | PSP | 0.42 | 0.05 | 0.42 | 8.34 | <0.001 | | |
| | | WP | 0.54 | 0.06 | 0.44 | 8.76 | <0.001 | | |

DV, Dependent variable; IV, Independent variable; Adjusted for gender, age, and patient safety education; HL, Health literacy; PSP, Patient safety perception; WP, Willingness to participate in patient safety; PPB, Patient participation behavior.

parameter, willingness to participate in patient safety ($\beta = -0.01$, $p = 0.912$), while the primary parameter, patient safety perception, had a significant static effect ($\beta = 61$, $p < 0.001$) on willingness to participate in patient safety ($R^2 = 0.398$, $F = 33.89$, $p < 0.001$). In Model 3, where two parameters were entered simultaneously, the first parameter, patient safety perception, had a significant positive effect ($\beta = 0.42$, $p < 0.001$) and the second parameter, willingness to participate in patient safety, had a significant positive effect ($\beta = 0.44$, $p < 0.001$) on patient participation behavior. However, health literacy did not have a significant effect on patient participation behavior ($\beta = 0.06$, $p = 0.130$). The final model had an explanatory power of 61.6% ($R^2 = 0.616$, $F = 68.02$; $p < 0.001$).

The significance of the mediating effect (indirect effect) of patient safety perception and willingness to participate in patient safety in the relationship between health literacy and patient participation behavior was analyzed and is presented in Table 5. The mediating effect of health literacy on patient participation behavior through patient safety perception (Indirect 1) was statistically significant, as the lower and upper 95% confidence intervals did not include zero [$B = 0.04$, boot 95% CI (0.01, 0.09)]. However, the mediating effect of health literacy on patient participation behavior through willingness to participate in patient safety (Indirect 2) was not statistically significant [$B = -0.01$, boot 95% CI (−0.03, 0.03)]. Finally, the dual mediation of patient safety perception and willingness to participate in patient safety (Indirect 3) was statistically significant [$B = 0.03$, Boot 95% CI (0.01, 0.06)]. As a result of checking for a difference in the mediation effect (indirect effect) by path, no significant difference was found among the three mediation paths.

Two pathways were identified in this study. We found that the mediating effect of health literacy on patient participation behavior by increasing patient safety perception ($B = 0.04$) and the mediating effect of health literacy on patient participation behavior by increasing patient safety perception and willingness to participate in patient safety ($B = 0.03$) were significant. These findings suggest a slightly stronger mediating effect of patient safety perception on the relationship between health literacy and patient participation behavior (Figure 1).

## 4 Discussion

This study conducted a mediating effects analysis to examine the correlations among health literacy, patient safety perception, willingness to participate in patient safety, and patient participation behavior among inpatients.

The health literacy of inpatients had a significant direct effect on their participation behavior. This finding aligns with previous research that validated the role of health literacy in promoting patient participation behavior among inpatients (13, 22). Variables showing significant differences in the health literacy of the inpatients included age and educational level. Similar to results from studies targeting inpatients, lower age and higher educational levels were associated with higher health literacy in this study (13, 28, 29). Furthermore, we found that patients with jobs demonstrated higher health literacy than those without. While a study focusing on stroke patients did not reveal differences in health literacy based on occupational status, it indicated lower health literacy in patients with lower monthly income (29), suggesting that economic factors, such as occupation and income, may influence health literacy. In addition, this study observed that inpatients without underlying diseases and those not taking oral medications exhibited higher levels of health literacy than those with such

TABLE 5 Significance test of mediating effects of patient safety perception and willingness to participate in patient safety ($N = 262$).

| Model | Variables | Direct effect | | | | Indirect effect | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Effect | Boot SE | 95% CI | | Effect | Boot SE | 95% CI | |
| | | | | Boot LLCI | Boot ULCI | | | Boot LLCI | Boot ULCI |
| Direct | HL → PPB | 0.11 | 0.43 | 0.03 | 0.20 | | | | |
| Indirect 1 | HL → PSP → PPB | | | | | 0.04 | 0.02 | 0.01 | 0.09 |
| Indirect 2 | HL → WP → PPB | | | | | −0.01 | 0.02 | −0.03 | 0.03 |
| Indirect 3 | HL → PSP → WP → PPB | | | | | 0.03 | 0.02 | 0.01 | 0.06 |
| Differences (ΔB) | Indirect 1 - Indirect 2 | | | | | 0.04 | 0.02 | −0.01 | 0.09 |
| | Indirect 1 - Indirect 3 | | | | | 0.02 | 0.01 | −0.01 | 0.04 |
| | Indirect 2 - Indirect 3 | | | | | −0.03 | 0.02 | −0.07 | 0.01 |

CI, confidence interval; LLCI, lower-level confidence interval; ULCI, upper-level confidence interval. HL, health literacy; PSP, patient safety perception; WP, willingness to participate in patient safety; PPB, patient participation behavior.

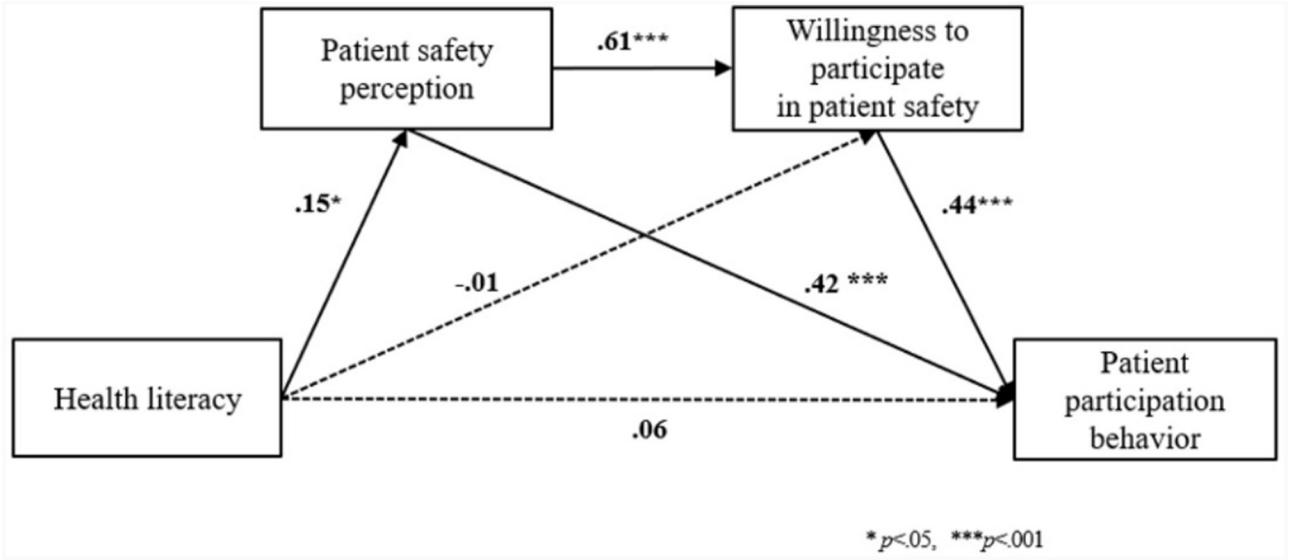


FIGURE 1
The dual mediation effect of patient safety perception and willingness to participate in patient safety in the relationship between health literacy and patient participation behavior. The solid and dashed line indicated significant and non-significant path coefficients.

conditions. Despite the expectation that patients with underlying diseases or on medication should excel in self-management, the lower health literacy observed in these groups emphasizes the need to highlight health information related to diagnosed diseases and prescribed medications, along with conducting periodic education. Glick et al. (23) advocated the development of interventions based on health literacy, integrating strategies for patients, families, and the healthcare system to improve treatment outcomes and enhance patient- and family-centered care. Future research should explore various factors influencing health literacy among inpatients diagnosed with diseases to formulate strategies for tailored education.

The health literacy of inpatients exerted a significant direct impact on patient participation behavior through the dual mediation of patient safety perceptions and willingness to participate in patient safety. Health literacy did not directly influence willingness to participate in patient safety; instead, it affected willingness through patient safety perception. The confirmation that personal factors of health literacy play a crucial role in determining patient safety perceptions among inpatients is meaningful. Jang and Park (13) reported in their study that health literacy among inpatients acts as a mediator between the patient safety environment and participation, suggesting that patient safety participation may vary depending on health literacy. A qualitative study targeting inpatients demonstrated positive outcomes, indicating that active participation in the decision-making process for treatment and sharing health information leads to a desire for active involvement not only in personal treatment, but also in inpatient safety activities (30). Thus, beyond mere knowledge, health literacy represents the ability of patients to

process the information and services necessary to make informed decisions about their healthcare (31), contributing to an increase in patient safety perception among inpatients. Moreover, an increase in patient safety perception, which can play a central role in ensuring patient safety, is expected to enhance the willingness and behavior of inpatients to participate in patient safety efforts (18).

Patient safety perception among inpatients have emerged as a powerful factor that contributes to increased patient willingness and participation behavior. Previous research has demonstrated a positive, static correlation between patient safety perception and the performance of patient safety activities (17). Additionally, patient safety perception was found to enhance willingness to participate in patient safety (15). Patient safety perception has been identified as a contributing factor to increased patient participation behavior in previous studies (16), which aligns with the results of the present study. To enhance patient safety within healthcare institutions, strategies involving the creation of a safe healthcare environment and analysis of the causes of patient safety incidents are imperative (32). The current reporting and learning system for patient safety incidents in South Korea primarily involves reporting by designated patient safety personnel, with patient and caregiver reports constituting a minimal portion (33). Despite patients experiencing temporary or long-term harm and side effects from medical care, voluntary reporting remains relatively low. Although campaigns and activities related to patient safety are conducted within healthcare institutions, there is currently a lack of education and promotion targeting patients and non-medical individuals. This deficiency, coupled with a societal atmosphere in which patients are not inclined to voluntarily report even minor medical errors, poses a challenge. To actively promote inpatient participation, a strategic approach is required to elevate patient safety perceptions by promoting various medical and patient safety activities within healthcare institutions.

Patient safety education has acted as a factor elevating patient participation behavior. Previous studies conducted on inpatients indicated that after implementing patient safety education, there was an increase in patient safety perceptions (34, 35) and behaviors (36). An increase in patient safety knowledge through education has been identified as a factor that enhances health literacy and promotes patient participation behavior (22). However, there is limited research on the effectiveness of patient safety education for inpatients and their caregivers. It is crucial for inpatients to possess an active willingness to participate in ensuring their own safety; therefore, patient safety education targeting inpatients should be prioritized (34). Inpatients often find themselves inundated with various educational materials during their hospital stay, leading to a lack of interest in patient safety education (37). In addition, they tended to focus only on disease education to achieve their hospitalization goals (38). Given the frequent transitions between hospitalization and discharge, education provided by the assigned nurse or patient safety specialist may lack continuity. Therefore, it is necessary to standardize easily understandable educational materials for inpatients and caregivers (37). Furthermore, the development of tailored patient safety education is warranted, considering the characteristics and severity of the patient's illness and differentiating the timing of applying education.

Suggestions based on the limitations of this study were as follows. As the research was conducted with inpatients from a single hospital, caution is needed when generalizing the study results. Therefore, future research should expand the sample to be more diverse, including not only tertiary comprehensive hospitals but also smaller hospitals, to ensure the validity of the research findings. The characteristics of inpatients admitted to tertiary hospitals can vary. This diversity may lead to differences in health information and patient safety-related content, based on factors such as the severity of the patient's condition, pain levels, and surgical history, thereby limiting our understanding of the impact on patient participation behavior. Therefore, in future research, it is essential to acknowledge these limitations and consider the various factors that may influence patient participation behavior to ensure the generalizability of the research results. Finally, considering the relationship between health literacy, patient safety perceptions, and willingness to participate in patient safety, it is recommended that a tailored patient safety education program for inpatients be developed to enhance patient participation behavior. Future research should aim to validate the effectiveness of these programs.

## 5 Conclusion

This study identified the factors that promote patient participation behavior among inpatients. The results revealed that health literacy, patient safety perception, and willingness to participate in patient safety directly influenced patient participation behavior. Additionally, by verifying the dual mediating effects of patient safety perception and patient willingness in the relationship between health literacy and patient participation behavior, this study provides a foundation for understanding the structure of these concepts. There were no differences in the paths of the three mediating effects, and the mediating effect of patient safety perception played a slightly stronger role in the relationship between health literacy and patient participation behavior. Based on the findings of this study, it is necessary to implement effective patient safety education and promote programs to enhance patients' active participation behaviors during hospitalization. This includes establishing high health literacy regarding illnesses and increasing patient safety perception and willingness to participate in patient safety.

## 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 author.

## Ethics statement

The studies involving humans were approved by the Institutional Review Board of Wonkwang University Hospital. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

## Author contributions

MW: Data curation, Formal analysis, Methodology, Project administration, Supervision, Validation, Writing—original draft, Writing—review & editing, Investigation. S-HS: Formal analysis, Funding acquisition, Methodology, Resources, Software, Writing—original draft, Writing—review & editing, Conceptualization.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This research was funded by the National Research Foundation of Korea (No. NRF-2022R1F1A106447).

## 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



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frontiers | Frontiers in Public Health

TYPE Brief Research Report
PUBLISHED 27 February 2024
DOI 10.3389/fpubh.2024.1331190



OPEN ACCESS

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RECEIVED 01 November 2023
ACCEPTED 22 January 2024
PUBLISHED 27 February 2024

CITATION
Jaswal H, Sohi I, Rehm J, Churchill S, Sherk A, Stockwell T, Levesque C, Sanger N, Edalati H, Butt PR, Paradis C and Shield KD (2024) A drink equals how many cigarettes? Equating mortality risks from alcohol and tobacco use in Canada. *Front. Public Health* 12:1331190. doi: 10.3389/fpubh.2024.1331190



# A drink equals how many cigarettes? Equating mortality risks from alcohol and tobacco use in Canada

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**Objective:** To quantify and communicate risk equivalencies for alcohol-and tobacco-attributable mortality by comparing per standard drinks consumed to per number of cigarettes smoked in Canada.

**Methods:** Alcohol-and tobacco-attributable premature deaths (≤75 years of age) and years of life lost (YLL) were estimated using a lifetime risk modeling approach. Alcohol-attributable death statistics were obtained from the 2023 Canadian Guidance on Alcohol and Health data source. Tobacco-attributable death statistics were derived from the Mortality Population Risk Tool (MPoRT) model.

**Results:** The risk of alcohol use on premature death and YLL increased non-linearly with the number of drinks consumed, while the risk for tobacco use on these two measures increased linearly with the number of cigarettes smoked. Males who consumed 5 drinks/day—a standard drink contains 13.45 grams of alcohol in Canada—had an equivalent risk as smoking 4.9 cigarettes/day (when modeling for premature death) and 5.1 cigarettes/day (when modeling for YLL). Females who consumed 5 drinks/day experienced an equivalent risk as smoking 4.2 cigarettes/day for premature deaths and YLL. At all levels of alcohol consumption females and males who consumed <5 drinks/day have less risks from consuming a standard drink than from smoking a cigarette. For males who consumed 5 drinks/day, the increased risks of death from per drink consumed and per cigarette smoked were equal.

**Conclusion:** Risk equivalencies comparing alcohol use to tobacco use could help people who drink improve their knowledge and understanding of the mortality risks associated with increased number of drinks consumed per day.

KEYWORDS

**alcohol use, tobacco use, Canada, mortality metrics, guidance on alcohol and health**

# Introduction

Alcohol use is a causal risk factor for over 230 disease conditions based on the three-digit International Classification of Diseases, Revision 10 (ICD-10) codes (1). These health risks, however, are not always well understood by the public for a multitude of reasons. Studies have shown that people generally have difficulties understanding, evaluating, and communicating mortality risk associated with alcohol use (2). Although the general public tends to be aware of the protective effects of alcohol use on ischemic heart disease, ischemic stroke, and diabetes, especially for people who drink and who drink low amounts or do not engage in heavy episodic drinking (1), they, for the most part, are unaware of the many of the diseases that excessive alcohol consumption can cause (3, 4). For example, alcohol use is a leading cause of many forms of cancer and associated medical complications (1). Gaps in this knowledge is a major reason for why people often underestimate the risks of excessive drinking, and the catastrophic drinking patterns that often result. Providing information on the risk of alcohol use has been found to improve health literacy, decrease peoples' intention to drink, and decrease the harms associated with alcohol consumption (5). Unfortunately, communicating this information about risks has not always been conducted effectively. As a prevention strategy, it is often underutilized by health and public health professionals.

People's understanding of health risks related to alcohol use can be improved by communicating risk equivalencies. A 'risk equivalency' refers to a comparative assessment whereby different risks of health behaviors or related conditions are compared or evaluated so they can be expressed in terms of a common unit or metric — for an example, please see reference 6. Providing risk equivalency information can aid people in improving their understanding of the risks or health impacts they may experience acutely or over time from excessive alcohol use. Such information can also help individuals assess their situation(s) and prioritize their responses to alcohol availability. In contrast to alcohol use, the risk of tobacco use are well known to the general public (7–9). Various studies from different countries have shown that people are generally knowledgeable about diseases related to tobacco use and second-hand smoke exposure (10, 11). Because of this greater awareness about tobacco's risks for harm, risk equivalencies can add value when communicating about risks associated with alcohol use — i.e., equating health loss or harm from standard drinks to health loss or harm from the number of cigarettes smoked. The present study uses Canadian data to address this gap in public health communication, by quantifying the risk equivalencies for alcohol and tobacco use. Premature death and years life lost (YLL) are the two main measures used to generate these equivalencies.

# Methods

The lifetime risks of an alcohol- or tobacco-attributable death were operationalized using the risk of a premature death (i.e., a death which occurred among people 75 years of age and younger) and YLL. YLL were estimated based on the age of death and sex-specific lifetables for 2019, as obtained from Statistics Canada (12). This data source contained lifetables of probabilities on life expectancy and mortality for Canadians by age and sex.

## Defining exposure and reference groups

Exposures to alcohol and tobacco were operationalized using different dimensions. For the present study alcohol use was operationalized as standard drinks consumed per week (in the analyses, this was converted to per day). In Canada, a standard drink comprises 13.45 grams of ethanol (13). Exposure to tobacco was operationalized as the average number of cigarettes smoked per day. To estimate alcohol-and tobacco-attributable deaths, and YLL a theoretical minimum risk exposure level (TMREL) for lifetime abstention was applied. No assumptions were made about the level of exposure for alcohol use that would result in the lowest risk of overall health loss or harm.

## Lifetime risk of an alcohol-attributable death

The lifetime risk estimates of an alcohol-attributable death and YLL were extracted using statistics from the 2023 Canadian Guidance on Alcohol and Health (see (14)). These 2023 statistics were used to generate alcohol use risks for people who consumed 0 to 5 drinks per day using a lifetime risk approach containing multiple steps and data sources (14, 15).

The first step in this approach was to estimate the number of cause-, sex- and age-specific alcohol-attributable deaths in Canada for 2019; this was carried out using a Levin-based population-attributable fraction method that combined data on alcohol exposure, relative risk estimates and mortality estimates (16, 17). The data on alcohol exposure were obtained from the Canadian Alcohol and Drug Use Monitoring Survey (CADUMS); the Canadian Tobacco, Alcohol and Drugs (CTADS) Survey; and Canada's national statistical office, Statistics Canada (18). The data on the relative risk estimates were obtained from meta-analyses found in the literature (14). And the data on mortality estimates were obtained from the Statistics Canada Canadian Vital Statistics database (CVSD) (19).

The second step in the approach was to estimate the number of non-alcohol-attributable deaths in Canada (i.e., the deaths that would occur if no one person consumed alcohol); this was done by subtracting the number of alcohol-attributable deaths (estimated in the first step) from the total number of deaths. The number of non-alcohol-attributable deaths in Canada was subsequently divided by the population of Canada [via Statistics Canada (20)], yielding the risk measure for non-alcohol-attributable deaths - i.e., the risk of death among lifetime abstainers.

The third and final step in the approach was to estimate the lifetime risk of an alcohol-attributable death. To do this, the age- and sex-specific risks of an alcohol-attributable death (estimated in the second step) were summed across the life course (from age 15 years and onward). The age at which an alcohol-attributable death occurred was then used to estimate the alcohol-attributable YLL.

Because the lifetime risk of an alcohol-attributable death was characterized as a measure of public health impact, principally to provide guidance on alcohol use that is considered low risk, the modeling for the lifetime risk approach did not incorporate health loss or harm from causes such as alcohol poisoning, alcohol use disorders, or alcohol cardiomyopathy (14, 15). The latter condition, for instance, disproportionately affects people with alcohol use disorders and/or

those who engage in heavy chronic drinking (21, 22). For additional information about how lifetime risks of premature death and the YLL attributable to alcohol were modeled, please see the Appendix.

## Lifetime risk of a tobacco-attributable death

The lifetime risk of a tobacco-attributable death and YLL in Canada were modeled using data from the Mortality Population Risk Tool (MPoRT) (23). The MPoRT was developed and validated using 2001 to 2008 exposure data from the Canadian Community Health Surveys and mortality data from the Canadian Registered Persons Database (23). The MPoRT estimates the risk of death based on a person's age, sex, neighborhood deprivation, education, immigration status, smoking, alcohol use, physical activity, body mass index, and presence of heart disease, stroke, cancer and/or diabetes. The age- and sex-specific risks of a tobacco-attributable death were estimated by comparing the risk of death for smokers and non-smokers. The age- and sex-specific risks of a tobacco-attributable death (estimated in step 2 of the approach) were summed across the life course to estimate the lifetime risk of this measure. The age at which a tobacco-attributable death occurred was used to estimate the tobacco-attributable YLL. To properly scale the lifetime risk of a tobacco-attributable death and the associated YLL per cigarette smoked, age-specific risks for tobacco use were divided by the average number of cigarettes smoked by Canadians. The average number of cigarettes smoked by Canadians per day among smokers, by sex, was obtained from the 2017 Canadian Tobacco, Alcohol and Drugs Survey (24). This estimate relied on the assumption that the relative risk of death based on the number of cigarettes smoked per day is linear, and that this assumption is consistent with the observations from large cohort studies in the literature (25, 26). Details about the MPoRT model can be found in the Appendix.

## Exposure equivalency ratio

The exposure equivalency ratio for each alcohol use category was determined by dividing the tobacco equivalency, which is the ratio of the number of cigarettes smoked to produce a similar health loss or harm for a person's alcohol use, by that person's number of drinks/day.

## Uncertainty intervals

The 95% uncertainty intervals were based on a set of 1,000 simulations of all lowest level parameters (i.e., parameters sampled from their respective error distributions). These parameters were then utilized to estimate 1,000 simulated estimates. In these simulations, the 2.5th and 97.5th percentiles were the boundaries for the 95% uncertainty intervals (UIs).

# Results

As alcohol consumption increased, the equivalency ratio decreased for both males and females (Table 1; Figures 1, 2). For individuals who consumed 1 drink per day, each drink was equivalent to 0.4 cigarette smoked. For a male who consumes 5 drinks per day, the risk was equivalent to smoking 4.9 cigarettes per day. In other words, each drink was equivalent to one cigarette smoked. Similarly, for a female who consumes 5 drinks per day, the risk was equivalent to smoking 4.2 cigarettes per day (i.e., each drink was equivalent to 0.8 cigarette smoked). In all cases, evaluation of the risks were based on health loss or harm related to the two key study measures: premature death and YLL.

The equivalency ratio for alcohol use and tobacco use varied by sex. For females, consuming a standard drink did not result in as much of a negative impact on health (e.g., loss or harm) as smoking a cigarette; this was true for all alcohol use categories examined. For males who consume fewer than 5 drinks per day, drinking a standard drink also did not result in as much of a negative impact on health as smoking a cigarette. For males who consume 5 drinks per day, the risk associated with alcohol use was equal to that of tobacco use.

# Discussion

Risk equivalencies were explored to characterize the risks associated with alcohol use among Canadians as compared to risks associated with tobacco use, expressed in terms of the number of cigarettes smoked. For both males and females, a negative association was observed between alcohol use and equivalency ratios, such that as the number of standard drinks increased, equivalency ratios decreased. This result implies that for males who consume less than 5 drinks per day, consuming alcohol was less of a risk for health loss than smoking cigarettes, whereas for females, in all alcohol use categories examined, the risks associated with consuming alcohol were lower than the risks associated with smoking cigarettes. The fluctuation in these exposure equivalency ratios is likely related to the daily amount of alcohol consumed, as this amount is directly correlated with the risk of health loss or harm per unit of alcohol used (27). In contrast, the number of cigarettes smoked daily does not necessarily alter this relationship to the risk of health loss or harm per cigarettes smoked (25, 26). In other words, the number of standard drinks consumed per day carries a dose-dependent effect that the number of cigarettes smoked daily do not.

## Public health relevance

Given the magnitude of risks associated with alcohol use, and the generally poor communication of these risks to the target populations alcohol-related health outcomes (they are generally poor) when expressed as a measure of the number of cigarettes smoked, could resonate substantively better with the public than just straight statistics about alcohol consumption's harm. Currently, the general public is not as aware of what constitutes a standard drink, let alone having adequate knowledge about the guidance on what is daily or weekly low-risk drinking; suffice to say, misconceptions about alcohol use are plenty (5, 28, 29). By contrast, tobacco-related risks are very well known to the general public, due in part to the heavy stigma associated with them and the decades of public health counter-advertising levied against the tobacco industry and their sales of tobacco products (30). As such awareness about risks associated with alcohol use could

10.3389/fpubh.2024.1331190

TABLE 1 Equivalency between alcohol consumed and cigarettes smoked based on attributable risks.

| Sex | Drinks per day | (Grams of ethanol per week)* | Alcohol-attributable premature deaths per 1,000 lifetimes** | | Alcohol-attributable YLL per 1,000 lifetimes** | | Cigarette equivalency (per day) | | Equivalence Ratio (cigarettes / standard drinks) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Based on deaths per 1,000 lifetimes | Based on YLL per 1,000 lifetimes | Deaths | YLL |
| Male | | | | | | | | | | |
| | 1 | (98) | 6.0 | (−0.8, 13.7) | 221.1 | (−43, 514.9) | 0.4 | 0.4 | 0.4 | 0.4 |
| | 2 | (196) | 19.4 | (11.7, 30.5) | 728.2 | (429.4, 1142.5) | 1.3 | 1.4 | 0.7 | 0.7 |
| | 3 | (294) | 31.7 | (23.3, 43.5) | 1170.8 | (857, 1604.1) | 2.2 | 2.3 | 0.7 | 0.8 |
| | 4 | (392) | 49.6 | (39.7, 64.4) | 1820.6 | (1457.4, 2342.1) | 3.4 | 3.5 | 0.8 | 0.9 |
| | 5 | (490) | 72.7 | (58.7, 93.4) | 2638.7 | (2,135, 3,354) | 4.9 | 5.1 | 1.0 | 1.0 |
| Female | | | | | | | | | | |
| | 1 | (98) | 5.6 | (2.9, 9.4) | 219.6 | (49.6, 430.7) | 0.4 | 0.4 | 0.4 | 0.4 |
| | 2 | (196) | 15.4 | (11.9, 21.0) | 682.8 | (491.3, 952.2) | 1.2 | 1.2 | 0.6 | 0.6 |
| | 3 | (294) | 25.2 | (20.6, 31.9) | 1102.6 | (884.1, 1404.4) | 2.0 | 2.0 | 0.7 | 0.7 |
| | 4 | (392) | 38.6 | (32.3, 48.6) | 1687.1 | (1410.8, 2092.4) | 3.0 | 3.0 | 0.8 | 0.8 |
| | 5 | (490) | 54.0 | (45.2, 67.4) | 2346.9 | (1972.4, 2889.6) | 4.2 | 4.2 | 0.8 | 0.8 |

*Rounded to the nearest whole number. **95% uncertainty interval. PE, point estimate.

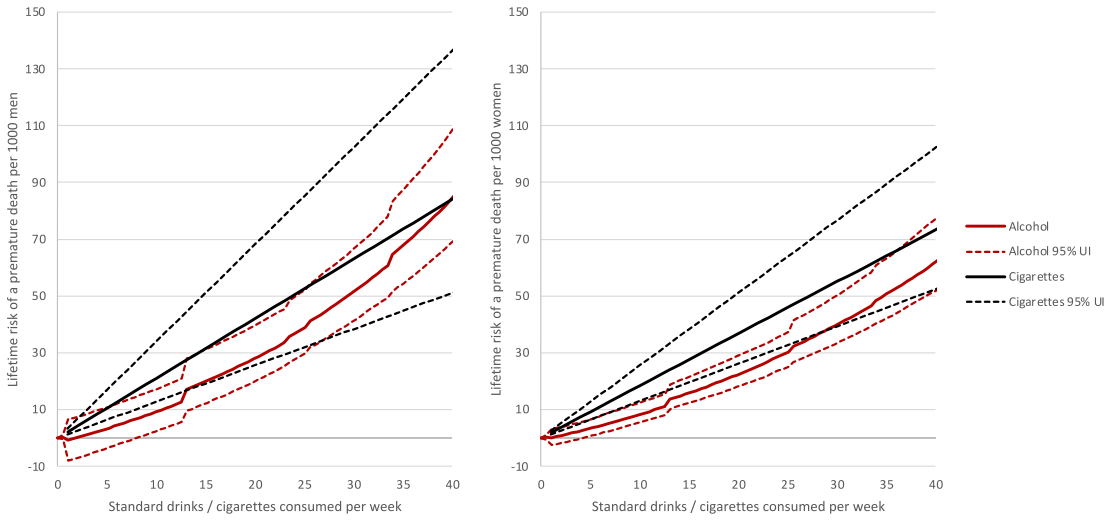


FIGURE 1
Lifetime deaths per 1,000 males and 1,000 females attributable to alcohol and tobacco use.

be enhanced if the public health or medical community uses similar public health messaging tactics and/or field tested strategies proven to work when communicating these risks. In a previous study, researchers showed that consumers of alcohol would decrease their drinking if they were informed about alcohol-attributable risks or harms — e.g., the link between excessive drinking and cancer (5). These consumers

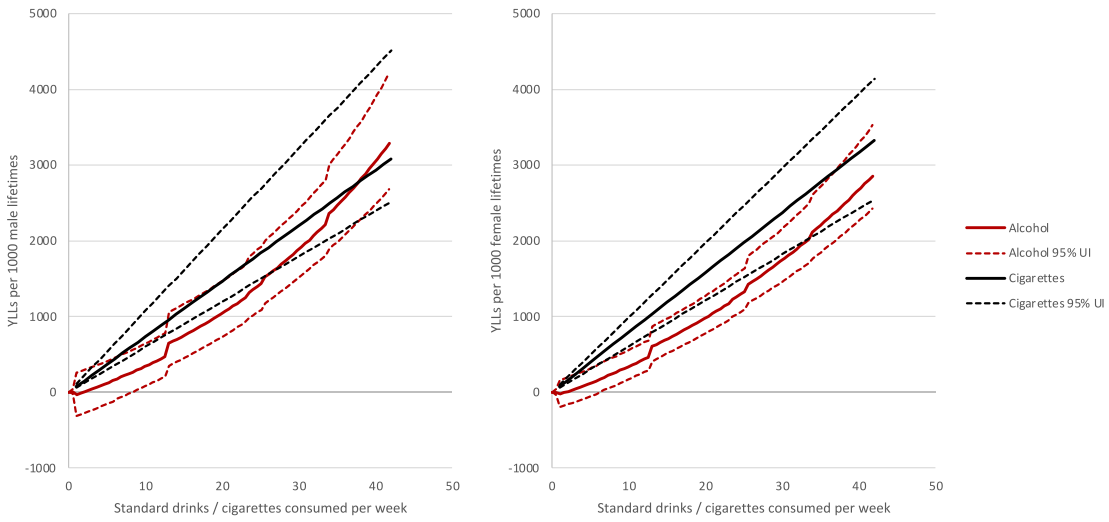


FIGURE 2
Years of life lost per 1,000 male and 1,000 female lifetimes attributable to alcohol and tobacco use.

would take action (decrease drinking) if they were incentivized and understood alcohol-attributable consequences in more familiar terms. Since tobacco use is associated with several diseases that are also related to alcohol consumption (e.g., cancer, cardiovascular diseases, liver disease), it has become an example to emulate for communications purposes (31). However, a one-to-one translation of tobacco control strategies to reducing alcohol use may not be entirely possible since tobacco is highly addictive, the mechanisms of addiction may be different from alcohol, and most mainstream tobacco control interventions typically advocate for complete cessation (32). The approach to alcohol use, on the other hand, often relies on a harm reduction perspective, especially for those with problem drinking but not in full dependency. Furthermore, alcohol and tobacco use often occur concurrently. Thus, when conveying risk equivalencies to alcohol users it may be necessary to exercise caution in how risks are presented so as to avoid normalizing or downplaying the health consequences of tobacco use.

Risk perceptions about alcohol and tobacco use can also be influenced by the following factors: perceived benefit, immediacy of effect, knowledge about the risk to the exposed person, certainty of the scientific information regarding the risk, control over risk, newness of the risk, the severity of the consequences, and the extent to which each of these behaviors are normalized in society (33). These, factors are particularly important to consider when communicating risks about these two different behaviors. For example, the risk perception about alcohol use frequently is complicated by the fact that drinking alcohol has both protective and detrimental effects on health. Previous studies have noted that at low levels of consumption, alcohol use has a protective effect on ischemic heart disease, ischemic stroke, and diabetes; however, at the same level of consumption, there could also be a detrimental effect on other diseases, such as cancer (1). Thus, to tease out these more nuanced health impacts of alcohol use — i.e., protective versus detrimental — more objective measures of burden could be used to communicate accurate facts about alcohol's effects, as has been done in this present study, which used premature death and YLL as primary measures to quantify potential health loss or harm (risks) associated with alcohol use.

Finally, it is also important to take into consideration the levels of alcohol versus tobacco use when communicating public health information. There is a notable difference in the number of people who consume alcohol versus those who use tobacco products. For example, in 2019, 76% of Canadian adults consumed alcohol while only 12% of adults smoked cigarettes in the past year (34, 35). This difference in prevalence between the two behaviors suggests a normalization of alcohol use versus tobacco use, likely the result of alcohol's historical significance, coupled with its role in religious rituals, social gatherings, and cultural traditions. These various factors may have perpetuated the use of alcohol in spite of its known risks or harms, and inhibited public health's progress to reform this behavior (36). In contrast, decades of public health policies and campaigns have rendered tobacco use more unacceptable and represent factors that have lowered smoking prevalence in Canada and elsewhere around the world (37).

## Limitations

The risk equivalency estimates reported here have numerous limitations that should be considered. First, the presented risk equivalencies do not take into account the following factors which may interact with alcohol and tobacco: harms to others, disability, non-health harms, and differences in an person's risk factors. For example, both alcohol and tobacco carry risks for second-hand harms through non-user exposure—i.e., increased risk of alcohol-related injuries (e.g., motor vehicle accidents) or secondhand exposure due to drifting tobacco smoke (1, 38). Second-hand harms from alcohol and tobacco are both prevalent and difficult to avoid. They are dependent upon whether the exposure is acute or chronic. For instance second-hand harms from alcohol use are generally due to the intoxicating effects of the use (i.e., acute alcohol use) (1). Whereas second-hand harms through non-user exposure to tobacco smoke are generally not as acute, imparting a more cumulative effect over time (39). When communicating risks of these two substances, these indirect, second-hand harms, should

be explained carefully, in conjunction with the more immediate, direct effects of their use.

Second, alcohol and tobacco have been noted to interact and share risk factors—e.g., and further interactions through co-use have been shown to exponentially increase the risk of head and neck cancers (1). Alcohol and tobacco use also tend to cluster with other chronic disease risks, such as high body mass index (BMI) (40). This clustering to other risks may be important to consider when formulating individualized treatment plans for patients with alcohol use disorders and tobacco dependence together. While some treatment programs may provide cigarettes as an incentive or reward in drug use treatment (41), this may be counterproductive (42). A systematic review found that in 16 out of 31 studies that examined pharmacological and psychotherapeutic alcohol use disorder treatments, being a non-smoker or having decreased tobacco consumption was significantly associated with reduced alcohol use (42). In stop-smoking studies, however, reduced smoking had no observable effect on drinking behaviors (42). In short, based on these results, treatment of alcohol use disorders may be more effective if tobacco addiction is also being treated concurrently.

Third and lastly, the data analysis and modeling employed in this study have several limitations. For example, the main analysis did not account for heavy drinking or patterns of drinking. Such indirect risks should be publicly communicated in addition to the direct harms experienced by users. Alcohol and tobacco use also contribute greatly to the risk of disability (43). Accordingly, the alcohol lifetime risk estimates are reflective of the patterns of drinking of the participants from the cohort and case–control studies that were used in the meta-analyses which reported cause-specific relative risk functions. There is evidence that drinking patterns affect the risk of infectious diseases (44), the risk of breast cancer (45), the risk of ischemic heart disease and ischemic stroke (46), the risk of diabetes (47), the risk of epilepsy (48), and the risk of injuries (49). Thus, if a person has a higher tendency to engage in heavy episodic drinking than the cohort and case–control participants, they would experience more health loss or harm than reported in the risk curves. If a person has a lower tendency to engage in heavy episodic drinking than the cohort and case–control participants, they will experience less health loss or harm than reported in the risk curves. The tendency to engage in heavy episodic drinking in the underlying cohort and case–control participants was not examined or reported in the meta-analyses.

As previously noted, the lifetime risk curves for alcohol were modeled for people who consume 0 to 5 standard drinks, these health loss or harms related to alcohol use would surpass those associated with tobacco use. It would be pertinent to explore this estimate, as it expands the utility of risk equivalency estimates in knowledge translation products—especially for people who are heavy chronic drinkers and people with alcohol use disorders.

The lifetime risk estimates for alcohol and tobacco use are derived using two different models, thereby limiting their comparability. Ideally, the risks of alcohol and tobacco use would be estimated using identical methods and data sources. The MPoRT model produces risk estimates for alcohol. These risk estimates are based on the reference group of non-drinkers and do not consider "sick quitters," and therefore these risk estimates are biased and should not be used (17).

The data presented in this study are also based on population statistics for Canada. Therefore, the risks presented here apply to Canadians in general, but do not reflect the risks for specific Canadians. For example, for a person who consumes low amounts of alcohol, the risk of developing liver disease and dying from liver cirrhosis is highly dependent upon that person's other risk factors, such as obesity and hepatitis infection (50). Canadians who are obese and/or have a hepatitis infection are at risk for death due to alcohol-attributable liver cirrhosis (i.e., a death that would not occur if the person abstained from alcohol); however, people without these co-occurring risk factors would not be at risk for death due to liver cirrhosis if they consumed small amounts of alcohol. Thus, it is important to note that the risk curves presented are for public health guidance, and are not meant to present health advice that is specific to a person.

The risk curves in this study only apply to people living in Canada. Risk curves for alcohol use were constructed using data from Canada, and are dependent upon the mortality risks of Canadians. Risk curves for tobacco use were based on the MPoRT model which is based on Canadian cohort data (23). Construction of risk curves for alcohol use is feasible for other countries around the world if there are data on alcohol use and mortality [see (14, 15)]. Similarly, tobacco risk curves could be constructed if there is country-specific cohort data or region-specific cohort data. Both of these endeavors may be arduous for low- and middle-income countries where such data are sparse (51, 52).

## Conclusion

The impacts of health risks from alcohol and tobacco use can be directly compared using standardized measurements of lifetime risk for premature death and YLL. While the equivalency estimates for alcohol and tobacco do not incorporate social harms, comparisons of alcohol to tobacco in standard units (number of drinks versus number of cigarettes) could provide alcohol users with a better understanding, in comparative terms, of the risks they partake when they drink.

## Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: 2022 Canadian Guidance on Alcohol and Health: https://www.ccsa.ca/sites/default/files/2022-08/CCSA-LRDG-Update-of-Canada%27s-LRDG-Final-report-for-public-consultation-en.pdf. MPoRT Model data: https://pubmed.ncbi.nlm.nih.gov/27529741/.

## Author contributions

HJ: Formal analysis, Investigation, Writing – original draft, Writing – review & editing. IS: Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. JR: Conceptualization, Investigation, Writing – review & editing. SC: Formal analysis, Methodology, Writing – review & editing. AS: Formal analysis, Investigation, Methodology, Writing – review & editing. TS: Conceptualization, Investigation, Methodology, Writing – review & editing. CL: Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing. NS: Data curation, Investigation, Methodology, Writing – review & editing. HE: Data curation, Investigation, Methodology, Writing – review & editing. PB: Data curation, Formal analysis, Funding acquisition, Investigation,

Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing. CP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. KS: Data curation, Formal analysis, Investigation, Methodology, Project administration, 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. Funding for this study was provided to KS by the Canadian Centre on Substance Use and Addiction.

## Acknowledgments

We extend our gratitude to Rachel Visontay for their contributions in meticulously editing the journal 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



## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1331190/full#supplementary-material

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frontiers | Frontiers in Public Health

TYPE Study Protocol
PUBLISHED 14 March 2024
DOI 10.3389/fpubh.2024.1308745



OPEN ACCESS

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RECEIVED 07 October 2023
ACCEPTED 04 March 2024
PUBLISHED 14 March 2024

CITATION
Guo Z, Wu Q, Wang X, Dai Y, Ma Y, Qiu Y, Zhang Y, Wang X and Jin J (2024) Effects of message framing and risk perception on health communication for optimum cardiovascular disease primary prevention: a protocol for a multicenter randomized controlled study.
*Front. Public Health* 12:1308745.
doi: 10.3389/fpubh.2024.1308745



# Effects of message framing and risk perception on health communication for optimum cardiovascular disease primary prevention: a protocol for a multicenter randomized controlled study

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**Background:** Although several guidelines for cardiovascular disease (CVD) management have highlighted the significance of primary prevention, the execution and adherence to lifestyle modifications and preventive medication interventions are insufficient in everyday clinical practice. The utilization of effective risk communication can assist individuals in shaping their perception of CVD risk, motivating them to make lifestyle changes, and increasing their willingness to engage with preventive medication, ultimately reducing their CVD risks and potential future events. However, there is limited evidence available regarding the optimal format and content of CVD risk communication.

**Objective:** The pilot study aims to elucidate the most effective risk communication strategy, utilizing message framing (gain-framed, loss-framed, or no-framed), for distinct subgroups of risk perception (under-perceived, over-perceived, and correctly-perceived CVD risk) through a multi-center randomized controlled trial design.

**Methods:** A multi-center 3 × 3 factorial, observer-blinded experimental design was conducted. The participants will be assigned into three message-framing arms randomly in a 1:1:1 ratio and will receive an 8-week intervention online. Participants are aged 20–80 years old and have a 10-year risk of absolute CVD risk of at least 5% (moderate risk or above). We plan to enroll 240 participants based on the sample calculation. The primary outcome is the CVD prevention behaviors and CVD absolute risk value. Data collection will occur at baseline, post-intervention, and 3-month follow-up.

**Discussion:** This experimental study will expect to determine the optimal matching strategy between risk perception subgroups and risk information format, and it has the potential to offer health providers in community or clinic

settings a dependable and efficient health communication information template for conducting CVD risk management.

**Clinical trial registration**: https://www.chictr.org.cn/bin/project/edit?pid=207811, ChiCTR2300076337.

KEYWORDS

cardiovascular disease, primary prevention, message framing, health communication, risk perception, randomized controlled trial

## 1 Introduction

Cardiovascular disease (CVD) is the leading cause of death in China, with two out of every five deaths attributed to CVD (1, 2). Over 95% of all CVD deaths are attributable to IHD, stroke, hypertensive heart disease, cardiomyopathy, rheumatic heart disease, and atrial fibrillation (3). Currently, China faces a dual challenge with an aging population and the persisting prevalence of cardiometabolic risk factors, particularly the rates of hypertension, dyslipidemia, and diabetes have reached alarming levels (4), and the burden of CVD is projected to escalate in the future. Therefore, it is imperative to devise effective and robust strategies to raise awareness, improve treatment, and enhance control rates for these conditions.

Lifestyle management and risk factor control form the fundamental to both primary and secondary CVD prevention, as underscored by all major CVD management guidelines (5, 6). Despite this emphasis, implementation and adherence to lifestyle modifications and preventive medication interventions remain inadequate in daily practice (7). CVD risk, which is the likelihood of experiencing a cardiovascular event over a specific time frame (e.g., 10 years), is calculated by mathematically combining multiple predictors (8). Healthcare providers use this information to guide prevention strategies and interventions aimed at reducing CVD risk, such as lifestyle modifications and medication. However, a large number of individuals with risk factors remain unaware of their CVD risk, its implications, and the rationale for medication and lifestyle modification (9). Additionally, lifestyle modification interventions often neglect the individual's preferences, perceptions, and characteristics, which could potentially contribute to suboptimal risk factor management.

Risk perception serves as a cognitive process influencing health behavior and has been regarded as a critical element in various socio-cognitive theories of health behavior, including the Health Belief Model (10), Protection Motivation Theory (11), and Risk Perception Attitude Framework (12) (Supplementary Table S1). Notably, risk perception has also been confirmed to be a motivational determinant that plays a key role in participation and adherence in health-promoting behaviors in empirical researches (13–15). More specify, CVD risk perception, the belief that the individual is vulnerable to develop CVD (16), could affect health behavior change and maintenance (17). However, most people hold inaccurate perception toward their risk to develop CVD when compared with the objective calculated CVD risk (18), our previous research founded that only 30.1% participants accurately perceived their CVD risk (19). These perception bias may lead to diminished motivation, thereby hindering the exertion of requisite effort to mitigate their risk (20). To address this issue, an educational program was designed and proven to effectively improve risk perception for community residents (21) or risk populations (22) in several studies. However, a ceiling effect was revealed for smoker and obesity subgroups. These findings revealed that future campaigns should target risk populations that remarkably hold risk misperceptions.

Prospect theory, developed by Daniel Kahneman and Amos Tversky in 1979, is a psychological theory that describes how people make decisions under uncertainty (23). Prospect theory suggests that individuals weigh potential health outcomes differently depending on whether they perceive them as gains or losses which can affect health-related decision-making (24). Risk communication plays a pivotal role in shared decision-making processes, informing individuals about their CVD risk level and options for risk reduction, thus correcting inappropriate risk perception (25). Previous research has shown that both 'what' is communicated and "how" it is conveyed significantly influence an individual's understanding of CVD risk levels, empowerment, and autonomy (26, 27). Effective risk communication can guide individuals in shaping their perceived CVD risk, motivating them toward lifestyle alterations, and enhancing their willingness to engage with preventive medication, thereby decreasing their CVD risks and potential future events (28). Although current published guidelines suggest discussing the individual CVD risk with patients, there is limited guidance on the appropriate format and optimal presentation strategies (29). Communicating risk is challenging, and the quality of consultation depends on the interpretation and discussion between healthcare practitioners and individuals at risk (30). However, interpretation has consistently been insufficient, and the delivery of information has been inconsistent. Both parties struggle to comprehend CVD risk, and some practitioners lack confidence in explaining risk scores, resulting in inadequate recall of individual CVD risk, confusion, and misunderstandings (31). Given the limited duration of practitioner-patient risk communication, it is of academic and practical value to investigate and elucidate the framework and substance of CVD risk communication, aiming to furnish practitioners and their intended risk populations with a standardized template.

Prospect theory also emphasizes that individuals may exhibit risk aversion or risk seeking behavior depending on the framing of health information (32). Message framing is a health communication strategy supported by theoretical foundations aimed at encouraging behavior change by presenting information in either positive or negative terms (33, 34). The manner in which information is framed can influence decision-making outcomes (35). Gain-framed messages focus on the benefits individuals would gain from adopting recommended behaviors, while loss-framed messages emphasize the negative consequences of not engaging in positive behaviors or continuing with negative behaviors.

Previous reviews (36–38) indicated that framed messages have a modest yet reliable impact on altering health behavior. However, conflicting findings have emerged regarding the comparative benefits of positive/gain- versus negative/loss-framed messages (33). For example, loss-framed messages have been confirmed to persuade people to adopt cancer detection behaviors (39) and diabetes self-care (40), while gained-framed messages have received considerable empirical support for physical activity and dental hygiene behaviors (37). In addition, the literature on message framing consistently demonstrated that when a behavior or characteristic of the individual is not taken into account, there is no discernible advantage for gain- or loss-framed messages (41). Scholars have suggested that the potential moderators may affect the advantage in magnitude and orientation (42), such as risk perception (32, 43) or the nature of behavior (44). Consequently, it is imperative to prioritize the clarification of the potential interaction between message framing and risk perception on health behavior. Regrettably, only a limited number of intervention studies have been conducted to investigate the impact of message framing on behaviors related to CVD prevention, especially targeted populations with risk perception subcategorizes.

# 2 Objective

This pilot study aims to clarify the optimal risk communication strategy by examining the compatibility between message framing (gain-framed, loss-framed, or no-framed) and risk perception subgroups (under-perceived vs. over-perceived vs. correct-perceived CVD risk), using a multi-center randomized controlled trial design in Zhejiang province, China. The specific objectives are as follows:

1 To evaluate the effect of message framing on CVD prevention behaviors among individuals with moderate and high CVD risk.
2 To design a series of CVD risk communication messages based on message framing, then to implement the intervention program among individuals with different risk perception subgroups in the communities.
3 To determine the optimal risk communication message for CVD risk populations with risk perception categories to achieve better CVD prevention behavior change, continuum maintenance, and risk reduction.

# 3 Materials and methods

## 3.1 Study design

A multi-center 3×3 randomized factorial, observer-blinded experimental design was conducted to evaluate the effect of gain-, loss-versus no frame message and under-, over- versus correct risk perception. This trial will be implemented on the basis of National Basic Public Health Service Program (45) and Zhejiang Province Basic Public Service standards (2021 edition). Those includes essential health services for all citizens and chronic health management for hypertensions and diabetes, such as having a free physical examination opportunity once a year, and the electronic physical examination recorded in the community health care system, so that general practitioners (GP) could provide continuous health management services. This study was approved by the Human Research Ethics Committee of the second affiliated Hospital of Zhejiang University school of Medicine (No.2023-0877). It was registered and approved by China Clinical Trials Center (ChiCTR2300076337). We followed the SPIRIT guidelines, and all participants will be followed up for 3 months (Figure 1).

## 3.2 Study setting

This study will be conducted in three communities located in Hangzhou, Zhejiang Province. The health-related cultural norms and values, as well as the availability of local resources for adopting healthier lifestyles and accessing convenient medication consultation, differ between urban and rural communities. Therefore, including urban and rural sites will enhance the generalizability of the findings and facilitate result dissemination across diverse locations. As mentioned before, these risk populations had a free physical examination once a year according to the chronic disease management standard of Zhejiang Province. Thus, biochemical indicators (total cholesterol, high density lipoprotein cholesterol, etc.) were obtained from the health examination recording, eliminating the need for additional blood samples in this study. All study sites will follow the same study procedures.

## 3.3 Blinding

Due to the inherent characteristics of the intervention, both researchers who responsible for intervention and participants will not be blinded to the group allocations. The initial collection of baseline data commenced first, after which participants will be informed of their allocated group. Two other well-trained researchers, who were blinded to group allocation, will be responsible for data collection. The investigators responsible for implementing the intervention will not participate in the data collection process. The statistician conducting the subsequent data analysis will be blinded to the group allocation.

## 3.4 Participants and recruitment

### 3.4.1 Eligibility criteria

1 Inclusion criteria: Aged 20–80 years old; permanent residence; accessible for reliable CVD risk calculation indicators from health examination records (waistline, blood pressure, total cholesterol, high density lipoprotein cholesterol measured in last 6 months); a 10-year risk of absolute CVD risk (based on China-PAR model) of at least 5%; had access to a telephone to receive picture or video message from WeChat; normal visual acuity and hearing (with correction); speaking with Mandarin; be able to adhere to all study procedures.
2 Exclusion criteria: Experienced incident CVD or stroke before; experienced severe anxiety; engagement in concurrent participation in another health research study; current or planned pregnancy during the study period; restricted physical activity due to other medical conditions; and ongoing treatment for severe disease or terminal medical condition.

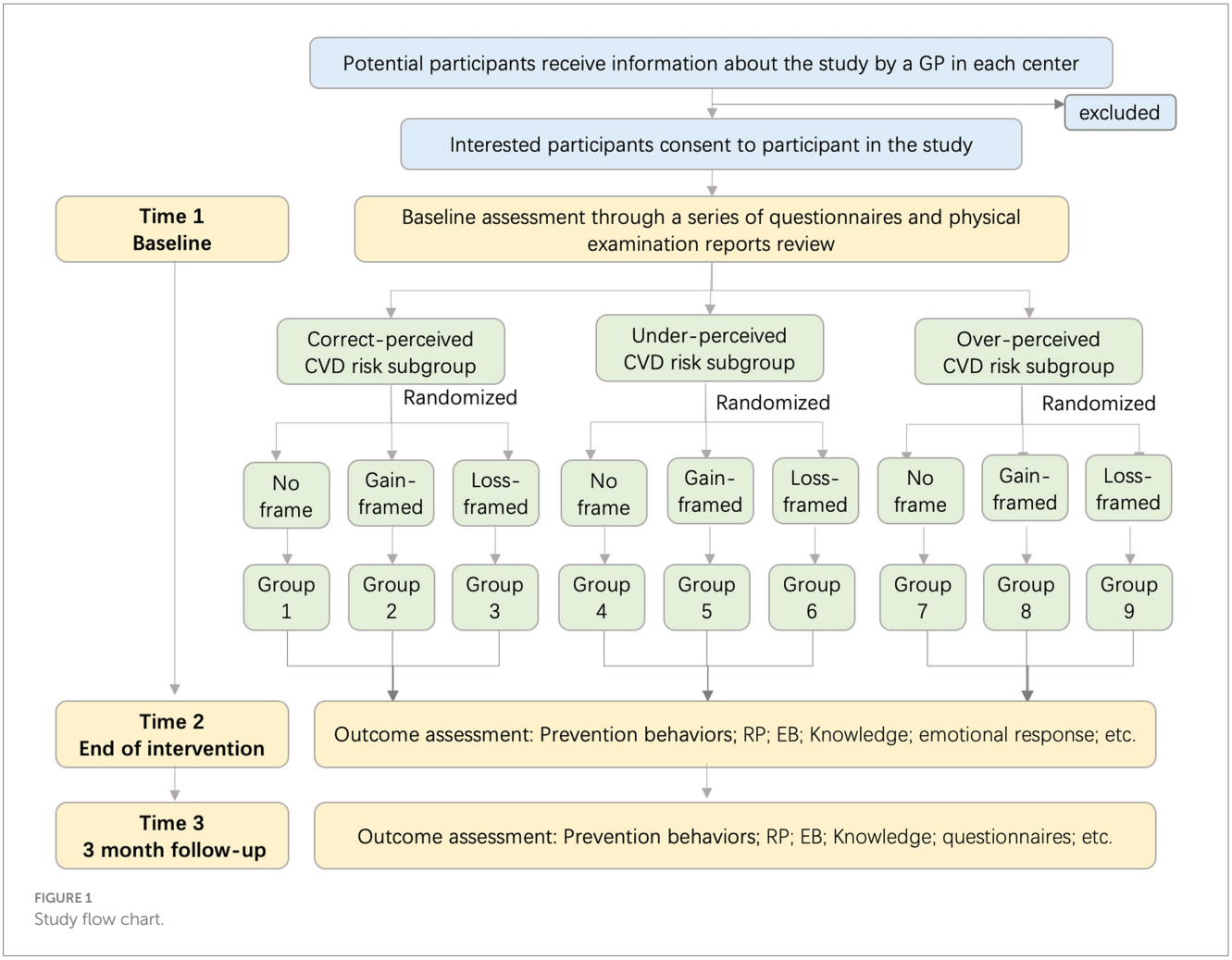


FIGURE 1
Study flow chart.

### 3.4.2 Sample size

Previous risk communication intervention studies were utilized to estimate the sample size. In our previous survey (46), we observed a baseline proportion of healthy lifestyle adherence at approximately 30% among participants with familiar sample characteristics. For the intervention groups, we anticipate a relative increase of at least 50% (47), with an expected difference of 25% between the gain- and loss-framed groups (39). This corresponds to an estimated effect size (W) for Chi-square of 0.20 (48), aligning closely with recommendations from prior studies (38). To achieve a power of 80%, an alpha error rate of 0.05, a standard deviation of 5%, and an estimated effect size (W) of 0.20, a total of 198 participants will be required for our primary outcome, which measures a healthier lifestyle encompassing physical activity, diet, and prevention medication at 3 months. These participants will be evenly distributed into three groups: gain-framed, loss-framed, and no-frame message interventions. However, considering the dropout rate of 20%, a sample size of 240 participants will be required.

### 3.4.3 Recruitment

A total of 240 participants will be recruited at the chronic disease management clinic of each community between October and November 2023. In order to screen eligibility participants effectively, the research team will collaborate with community clinic staff to review medical records of individuals with hypertension, diabetes, or dyslipidemia. The 10-year CVD absolute risk will be estimated individually using the China-PAR model (Prediction for Atherosclerotic cardiovascular disease Risk) through an online calculator.[1] Participants whose risk values exceed 5% will be marked as potentially eligible participants. Patients who meet the eligibility criteria will be contacted by the GP to gage their interest in learning more about this research project. Subsequently, proficient study personnel will reach out to the participants via telephone by the investigators within a two-week timeframe to provide detailed information about the study. Eligible participants will be recruited after signed consent is obtained. Each participant will be assigned a unique identification code, such as JA001. The initial character of the code signifies the study site (e.g., J = Jinhua), the subsequent character represents the risk perception group (A = Under-perceived, B = Over-perceived, C = correct-perceived), and the final three numerical digits correspond to the sequence of enrollment. This code will be used for the purpose of randomization.

1 https://www.cvdrisk.com.cn/ASCVD/Eval

### 3.4.4 Risk perception categories

The risk perception categories (correct perceived, under-perceived or over-perceived CVD risk) are determined by comparing risk perception level (CVD risk perception assessed using ABCD-C) (49) and 10-year CVD risk level (10-year CVD absolute risk calculated using China-PAR) (50, 51) with cross-tabulation using the baseline data, and the details were described in our previous study (19).

## 3.5 Randomization and allocation concealment

The researcher, who is not involved in the recruitment stage using R software to pre-generate a randomization list, which determined participant's allocation to each intervention groups: arm 1(no frame message), arm 2 (gain-framed message) or arm 3 (loss-framed message). Subsequently, sealed envelopes containing group assignments were prepared by an independent researcher. Upon participant enrollment and completion of baseline assessments, an authorized team member opened the sealed envelope corresponding to each participant's unique identification code to determine their group assignment. Furthermore, participants will not be informed of their group allocation until they provide written consent.

## 3.6 The intervention procedure

The cardiovascular risk communication information will be delivered as standard health message about individual's CVD risk and risk coping which not contain any particular message framing (arm 1), gain-framed message (arm 2) and loss-framed message (arm 3). Participants will be given the opportunity to withdraw at any point during the procedure.

### 3.6.1 Arm1: CVD risk communication based on no-framed message (control)

The CVD risk communication content will be derived from the Chinese CVD primary prevention guidelines (2023), CVD risk assessment and management guidelines (2019), Chinese guideline on healthy lifestyle to prevent CVD (2020), comprehensive prevention and treatment guidelines of CVD for community population (2020), Chinese guideline for lipid management (2023), et al., which includes two core message elements: "*why CVD risk is important?*" and "*why CVD risk is relevant to you?*." To be more specific, the first message element includes the definition and etiology of CVD, the importance of CVD risk management; and the second message element includes *Your* CVD risk factors, risk value, risk effect and risk coping. The message elements and contents have been reviewed by 16 experts from the field of Cardiology ($n = 3$), general medicine ($n = 3$), CVD nursing ($n = 4$), community nursing ($n = 3$), public health ($n = 1$), health education and health promotion ($n = 1$), information communication ($n = 1$). Details of the intervention procedure can be found in Supplementary Table S2.

A total of 48 videos will be designed according to those risk communication contents, with 16 videos allocated to each intervention arm. Each video has a duration of 60 to 90 s to achieve optimal communication efficacy (52). The intervention will span a duration of 8 weeks, with participants receiving two sessions per week. These video sessions will be sent on Sunday and Wednesday morning between 7:00 and 9:00 a.m. weekly. This schedule will be tailored to the participants' reading habits and working regulations to ensure the content does not adversely affect their work and sleep. Those videos will be transmitted to each participant through the mobile communication software WeChat. Subsequent to each video, participants will be prompted to respond two specific questions pertaining to the most notable keywords, as well as a central question regarding the content of the video. Their responses will ascertain that they have viewed the video carefully and comprehended its content thoroughly. In order to promote participant compliance, previous research suggests the utilization of financial incentives (47). As per the study protocol, participants who successfully answer both questions will be granted a reward of 1 RMB. After intervention procedure finished, all participants will receive a report of the CVD risk assessment and communication to further read and think aloud if necessary. Two weeks prior to the scheduled follow-up, participants will be sent a message containing details regarding the study procedure, as well as a reminder for the forthcoming 3-month follow-up.

### 3.6.2 Arm 2: CVD risk communication based on gain-framed message

Positive framing differed only in message presentation (40), the content of information was equivalent with the control group. The message will adopt a gain-framed approach, emphasizing the potential positive outcomes associated with a correct understanding of CVD risk and adherence to appropriate risk management behaviors. For instance, in the module titled 'Your CVD risk value', the statement provided to the gain-framed group will state that their risk of developing CVD within the next 10 years is 6.3%. This value exceeds the recommended ideal risk level of 4.4% (with the ideal level of modifiable risk factors). Consequently, out of a group of 100 men with the same age and laboratory results, it is projected that 6 individuals will develop CVD within the next decade. Additionally, two individuals will be exempt from CVD due to effective control of ideal risk factors. This information will be accompanied by two highlighted pictograms illustrating the potential benefits. In the module of 'weight control', the gain-framed group will be presented with the following statement: "Maintaining a healthy weight and waist circumference can be advantageous in controlling blood pressure, glucose, and lipid levels, thereby reducing the risk of CVD. Specifically, a reduction of 1 cm in waist circumference can lead to 1.48 times decrease in the 10-year CVD risk." This statement will be accompanied by an illustrative image depicting individuals with healthy weight and waist circumference. The frequency and timing of video delivery will align with that of the control group.

### 3.6.3 Arm 3: CVD risk communication based on loss-framed message

Negative framing differed only in message presentation (40), and the information will focus on the adverse consequences that arise from a lack of proper understanding of CVD risk and the neglect of preventive behaviors.

For instance, in the module titled "Your CVD risk value," the statement provided to the loss-framed group will state that their

risk of developing CVD within the next 10 years is 6.3%, which exceeds the desired risk level of 4.4%. This indicates that out of a sample of 100 men with the same age and laboratory results, approximately 6 individuals will experience CVD within the next decade. Furthermore, an additional two individuals are expected to develop CVD within the same timeframe due to inadequate control of risk factors. This information will be accompanied by two highlighted pictograms illustrating the potential losses. In the module focused on weight control, the loss-framed group will be presented with the following statement: "Individuals who are overweight and have a higher waist circumference may experience greater difficulty in managing blood pressure, glucose levels, and lipid levels, consequently increasing their risk of cardiovascular disease. Specifically, a 1 cm increase in waist circumference is associated with a 1.48 times higher 10-year cardiovascular disease risk." This information will be accompanied by a visual representation of obesity, particularly central abdominal obesity. The frequency and timing of video delivery will align with those in the control group.

## 3.7 Outcomes and measurements

Two well-trained independent investigators, who are unaware of the group allocation, will conduct the outcome assessment in the chronic disease management clinic of each community. Baseline assessments will include demographic factors such as age, gender, marital status, education level, ethnic group, employment status, monthly income, subjective numerical ability (53) and medical history (hypertension/diabetes/dyslipidemia).

### 3.7.1 Primary outcomes

The primary outcome aims to assess two key aspects: (1) CVD prevention behaviors, encompassing healthy physical activity, a balanced diet, and adherence to preventative medication; and (2) CVD absolute risk.

Healthy physical activity will be assessed using the questionnaire of self-reported International Physical Activity Questionnaire-short version (IPAQ) (54). The responses were processed and aggregated using the IPAQ guidelines for Chinese (55). Participants who achieved a minimum of 150 min of moderate-intensity physical activities or 75 min of vigorous-intensity physical activities per week were considered to have fulfilled the criteria for adequate physical activity (56).

Healthy diet will be assessed through healthy diet score based on the updated Chinese Dietary Guideline (57). The assessment included the weekly consumption of six food groups, namely fresh fruit, fresh vegetables, whole grains, fish and other seafood (consumed more than once per week), bean and bean food (consumed at least four times per week), and red meat (consumed less than seven times per week). The response that met the established criteria received a score of 1 for each food group, and the cumulative score was calculated (with a maximum score of 6). The healthy group was defined as individuals with a total score of 4 or higher (58).

Taking preventative medication will be evaluated through medical prescription for stain/lipid lowering, anticoagulants, antihypertension, glucose-lowering medications (59), based on data obtained from the community physician health check system.

The estimation of CVD absolute risk, including both 10-year and lifetime CVD risk, will be performed using the China-PAR equation (50). Participants will be classified into three groups based on the China-PAR cut-off value specified in the Chinese guidelines (56), namely low risk (<5%), moderate risk (5–9.9%) and high risk (≥10%); for lifetime CVD risk: low risk (<32.8%), and high risk (≥32.8%).

### 3.7.2 Secondary outcomes

Secondary outcomes include CVD risk perception, efficacy belief, CVD related knowledge, major adverse cardiovascular events (MACE), the emotional response, physical indicators (Blood pressure, blood glucose, waist circumference and BMI) and other lifestyle related risk factors [smoking, drinking status, and subjective health status (60)].

CVD risk perception, efficacy belief and CVD related knowledge will be evaluated using the Chinese version of Attitude and Beliefs about Cardiovascular Disease Risk Questionnaire (ABCD-C) (49), which comprises 26 items across four dimensions. Efficacy belief will be assessed using the item 19, 20, 22, and 24, following the recommendation by Rimal and Juon (61). This scale has demonstrated good validity and reliability in both its original and Chinese versions, as evidenced by Cronbach's α values ranging from 0.70 to 0.94. The emotional response will be assessed using two items on a 10-point scale (1–10; with a total range of 2–20), which have been adopted from the existing literature (62). An example of such item is "How concerned are you by reading this information?." MACEs are defined as the composite endpoints of cardiovascular death, spontaneous myocardial infraction, and target vessel revascularization at 3 months follow up (63). The smoking and drinking status, as well as physical indicators, were extracted from the follow-up records of participants by GPs.

### 3.7.3 Other measurements

To assess the manipulation check, participants were asked to rate the extent to which they believed the video messages emphasized the advantages of engaging in CVD risk management or the disadvantages of not doing so. This rating was measured on a scale of 1 to 7, with 1 indicating a greater emphasis on the benefits, 4 indicating an equal focus on both benefits and risks, and 7 indicating a greater emphasis on the disadvantages (34). Participants will be deemed to have passed the manipulation check if they choose the item that aligns with their assigned message condition (64). The level of engagement will be evaluated based on the responses to questions following each video message, with a threshold of more than 75% of responses indicating high engagement (35). The qualitative components of risk communication experience after intervention procedure finished at 8 weeks will be evaluated using semi-structured interviews with the participants. This approach enables us to investigate participants' experiences and delve into the social, cultural, and environmental factors that may impact their responses to the intervention. Such exploration is invaluable for interpreting quantitative findings accurately and enhancing intervention program effectiveness through iterative improvements. Details of the interview outline can be found in Supplementary Table S2. Study participants will be randomly selected at each study site among enrolled samples. The interviews will be stopped once data saturation is reached (Table 1).

TABLE 1 Research activities.

| | Baseline | Post assessment | Follow-up assessment |
|---|---|---|---|
| | T0 | T1 | T2 |
| Informed consent | √ | | |
| Demographic, socioeconomic assessment | √ | | |
| CVD risk factors assessment | √ | √ | √ |
| 10-year CVD risk calculation | √ | | √ |
| Lifetime CVD risk calculation | √ | | √ |
| Physical activity assessment (self-reported) | √ | √ | √ |
| Healthy diet assessment (self-reported) | √ | √ | √ |
| Medication prescription | √ | √ | √ |
| CVD related knowledge | √ | √ | √ |
| CVD risk perception | √ | √ | √ |
| Health related efficacy | √ | √ | √ |
| Subjective health status | √ | √ | √ |
| Major adverse cardiovascular events (MACE) | | | √ |
| Emotional response | | √ | |
| Manipulation check | | √ | |
| Participants engagement | | √ | |
| Interviews with participants | | √ | |

## 3.8 Statistical analysis

### 3.8.1 Data analysis

Descriptive statistical analysis will be conducted for all measurements. The distributions of categorical baseline variables will be compared using $\chi^2$ test among the three intervention groups. The difference in continuous variables will be analyzed using either one-way analysis of variance (ANOVA) or a non-parametric rank-sum test. The differential changes in the primary (i.e., healthy behaviors) and secondary (i.e., risk perception) outcomes at T1 and T2, relative to T0, across the three groups will be assessed using generalized estimating equations (GEE) models. GEE methods were applied to estimate model parameters using a binomial distribution for the variance function, a logit link function, and accounting for clustering via an assumed exchangeable working correlation structure (65). The outcomes will be used as dependent variables (one for each model) and, as independent variables, the intervention arms (no-framed, gain-framed, loss-framed message), the factors time (T0, T1, T2), the covariates (risk perception categories) and their corresponding interaction term. The other potential confounders (i.e., variables with baseline imbalances, study sites) will be added as independent variables to adjust GEE model. An exchangeable working correlation structure will be assumed in order to assess the association between factors and outcomes. The statistical significance of each parameter in the model will be analyzed using a Wald test. To account for the potential occurrence of type 1 errors, a Bonferroni correction will be implemented for all GEE models, with a $p$-value threshold of less than 0.003 indicating statistically significant differences (66). The final model's results will be presented as estimated odds ratio (*OR*) and 95% confidence interval (*CI*) for each significant prognostic variable. We will also conduct the sensitivity analysis to assess the non-response mechanism (67) and an attrition analysis (68) to identify the differential dropout rates and dropout by group interaction on sociodemographic and pretest variables that may pose a threat the equity of the findings (69). Subgroup analysis was performed for cases that did not pass the manipulation check. The principle of "intention to treat (ITT)" will be applied in conducting all primary and secondary outcome analyses. Moreover, the patterns of missingness would be recorded across variables and time points to provide insight into non-random missingness. Statistical significance will be determined by results with $p < 0.05$ in two-sided tests. The analysis will be carried out using SPSS software for MAC (version 26.0) and R software (version 4.3.1).

The interview transcripts will be recorded, double transcribed, checked, and entered into NVIVO version 11 for analysis. Content analysis framework approach will be employed to analyze the qualitative data. To minimize potential bias, two experienced researchers will independently code the data. The identified concepts will be grouped into categories and themes.

### 3.8.2 Missing data plan

Although we aim to retain the majority of participants, missing data is inevitable when subjects withdraw for reasons beyond our control. To avoid the missing data, the researcher will systematically examine each post-video question to identify instances where subjects have not been filled and subsequently issue reminders. Besides, we set the outcome assessments on site, and the researchers will check the questionnaire to remind participants to fill in the missing data immediately. In addition, the physical examination data will be extracted from medical recordings of the community health care system to minimize missing data. The GEE model will be employed due to its ability to generate unbiased estimates, even when missing

data is present, assuming the missing is completely random. Reasons for non-adherence and non-retention will be recorded.

### 3.8.3 Data quality control

To ensure the dependability of data collection, all researchers across the study sites will undergo standardized training on the study protocol and quality control techniques for data collection. The data will be anonymized and stored on a secure server that enables immediate updates and maintains confidentiality. Only the principal investigator can access to the master copy of the data. Access and utilization of the anonymized data will be restricted solely to authorized members of the research team. In addition, it is critical to avoid contamination to ensure data accuracy. The intervention messages will be conveyed through WeChat software, it is possible that the participants from the same community might discuss these contents. To minimize contamination, participants will be instructed not to send, share or exchange those messages with others until the conclusion of study. If necessary, we will resort to contamination-adjusted ITT analysis using instrumental variables analysis (70).

## 4 Discussion

A number of evidence-based guidelines exist for CVD primary prevention (56, 71). however, effectively incorporating risk-based treatment paradigms into clinical practice necessitates the implementation of strategies that accurately convey risk information to individuals (72). We systematically designed CVD risk communication message from the message element, subjects and outlines based on related guidelines and expert's consultation to ensure the reliability. While the use of visual aids, charts, and protocols has been suggested to facilitate discussions about CVD risk, it is evident that a standardized approach may not be suitable for all individuals (73). This discrepancy in risk information preferences underscores the significance of tailoring risk communication to accommodate variations in risk perception. Therefore, we stratified the risk population into distinct subgroups based on a comparison of their risk perception and objective risk level. Subsequently, the risk communication message will be delivered using gain-, loss-, or no-framed formats. Finally, an experimental study design will be employed to ascertain the most effective matching strategy between risk perception subgroups and risk information format. To the best of our knowledge, this will be the inaugural RCT to establish the optimal health communication strategies that consider both individuals' risk characteristics and information preference in the context of CVD risk management. This research holds significant value for primary CVD practice in China and other resource-limited regions.

CVD risk communication was not only risk assessment and risk value disclosure, but also about the risk coping guidance. Previous studies have demonstrated the importance of engaging in a conversation regarding individual CVD risk between patients and healthcare professionals in order to maximize the impact of the risk information provided (74). However, effectively delivering comprehensive and consistent risk communication to a large population at risk of CVD poses a significant challenge for healthcare providers and the healthcare system, particularly in China (75). The scarcity of primary healthcare providers further complicates the task of dedicating sufficient time to conduct detailed and in-depth health communication. Our intervention study has the potential to offer health providers in community or clinic settings with dependable and efficient health communication information for the purpose of carrying out CVD risk management. This intervention study can provide health providers in community or clinic with reliable and effective health communication information to conduct CVD risk management. Based on recent research results, we will further develop CVD risk communication software that intelligently aligns risk perception categories with optimal risk communication information, thereby significantly enhancing CVD primary prevention practice.

Several systematic reviews have reported contradictory results, failing to favor either loss-framed or gain-framed messages for specific behaviors (36, 37). Scholars have advised that moderators, including the subjective meaning individuals assign to risk, should be tested (44). According to prospect theory (24), the perceived risk associated with the recommended behavior determines the relative persuasiveness of gain- and loss-framed messages. Given the significance of CVD risk reduction, there exists a theoretical rationale for investigating the influence of risk perception and message framing effects on CVD preventive behaviors. Risk perception is a multifaceted construct that encompasses subjective evaluations influenced by cultural and individual value systems (28). Misconceptions or inaccurate attitudes toward risk can greatly affect how people respond to it (18). For instance, someone who underestimates the dangers might engage in risky activities without precautions. Regrettably, previous investigations (43) have predominantly concentrated on the variable of risk perception without assessing its accuracy—a crucial aspect that might elucidate the modest impact of framed message, thus, addressing this gap in the literature is imperative. Furthermore, cultural and value attributes can influence not only how risks are perceived but also how they are communicated and managed (28). Effective risk communication strategies must consider cultural differences to reach diverse audiences effectively. Thus, it is valuable to figure out the potential interaction between message framing and risk perception on health behavior in non-western cultural context. Significantly, our study aims to delineate the optimal matching strategy between risk perception categories and framework information, providing an empirical foundation for individuals with diverse perception characteristics to personalize risk communication and decision-making support. This tailored approach holds promise for healthcare personnel in enhancing the management of cardiovascular diseases more effectively. Building upon this work, future investigations can refine the content of framed message to align with local cultural nuances and the values of the target audience. Additionally, exploring optimal matching pattern across varied cultural backgrounds will yield invaluable insights for further mitigating the global burden of cardiovascular disease.

However, it is important to acknowledge several limitations associated with this pilot study. First of all, the assessment of outcomes was conducted over a relatively brief period based on practical reasons, necessitating further investigation into the long-term effectiveness of the intervention. Secondly, our intervention will be implemented online through smartphone (WeChat App), potentially introducing selection bias. However, there were more than 1.3 billion WeChat active users worldwide in 2023 (76) and more than one-third of individuals regularly obtained health information by WeChat in China (77), WeChat has been increasingly used for disseminating health information. In addition, the representativeness of samples was improved in our study through enrolled participants

from urban and rural areas, as well as different educational level. Third, the utilization of self-report forms to assess physical activity and diet may be susceptible to recall bias. Subsequent research will explore the adoption of accelerometers (78) or image recognition technique (79) to detect the actual status of lifestyle changing. However, we did conduct objective measurements such as blood pressure, blood glucose, total cholesterol, high-density lipoprotein, etc. at the stage of pre- and post-intervention, and calculated the 10-year risk of CVD. Comparing changes in these measures also offers a way to reflect the impact of lifestyle modifications. Finally, our study was conducted in several communities within a city in southeast China, yet the sample remains non-representative of the entire population. Given the significance of cultural nuances in health communication, further research is warranted to determine the substantial impact of message framing on the improvement of risk perception and modifiable behaviors across various regions in China.

## Ethics statement

The studies involving humans were approved by The Institutional Review Board of the second affiliated hospital of Zhejiang University School of Medicine. 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

ZG: Conceptualization, Methodology, Writing – original draft. QW: Data curation, Investigation, Resources, Writing – review & editing. XiW: Conceptualization, Methodology, Writing – review & editing. YD: Data curation, Resources, Writing – review & editing. YM: Data curation, Investigation, Writing – review & editing. YQ: Methodology, Writing – review & editing. YZ: Conceptualization, Formal Analysis, Methodology, Project administration, Writing – review & editing. XuW: Data curation, Methodology, Writing – review & editing. JJ: Conceptualization, Funding acquisition, Methodology, Supervision, 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 funded by Hospital Management soft science research project of Kangenbei in Zhejiang province (2023ZHA-KEB104), and the Health Commission of Zhejiang Province (Grant No. 2023KY759). The funder had no involvement in the study design, data collection, analysis, interpretation, writing, or decision to submit the manuscript for publication.

## 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.2024.1308745/full#supplementary-material

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TYPE Systematic Review
PUBLISHED 10 April 2024
DOI 10.3389/fpubh.2024.1387658



OPEN ACCESS

EDITED BY
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RECEIVED 18 February 2024
ACCEPTED 26 March 2024
PUBLISHED 10 April 2024

CITATION
Du L, Xi H, Zhang S, Zhou Y, Tao X, Lv Y, Hou X and Yu L (2024) Effects of exercise in people with multiple sclerosis: a systematic review and meta-analysis.
*Front. Public Health* 12:1387658.
doi: 10.3389/fpubh.2024.1387658



# Effects of exercise in people with multiple sclerosis: a systematic review and meta-analysis

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**Background:** A growing body of studies have examined the effect of exercise in people with multiple sclerosis (MS), while findings of available studies were conflicting. This meta-analysis aimed to explore the effects of exercise on balance, walking ability, walking endurance, fatigue, and quality of life in people with MS.

**Methods:** We searched PubMed, Web of Science, Scopus, and Cochrane databases, through March 1, 2024. Inclusion criteria were: (1) RCTs; (2) included an intervention and control group; (3) had people with MS as study subjects; (4) had balance, walking ability, walking endurance, fatigue, or quality of life as the outcome measures. Exclusion criteria were: (1) non-English publications; (2) animal model publications; (3) review articles; and (4) conference articles. A meta-analysis was conducted to calculate weighted mean difference (WMD) and 95% confidence interval (CI). Cochrane risk assessment tool and Physiotherapy Evidence Database (PEDro) scale were used to evaluate the methodological quality of the included studies.

**Results:** Forty studies with a total of 56 exercise groups ($n$ = 1,300) and 40 control groups ($n$ = 827) were eligible for meta-analysis. Exercise significantly improved BBS (WMD, 3.77; 95% CI, 3.01 to 4.53, $P < 0.00001$), TUG (WMD, −1.33; 95% CI, −1.57 to −1.08, $P < 0.00001$), MSWS-12 (WMD, −2.57; 95% CI, −3.99 to −1.15, $P = 0.0004$), 6MWT (WMD, 25.56; 95% CI, 16.34 to 34.79, $P < 0.00001$), fatigue (WMD, −4.34; 95% CI, −5.83 to −2.84, $P < 0.00001$), and MSQOL-54 in people with MS (WMD, 11.80; 95% CI, 5.70 to 17.90, $P = 0.0002$) in people with MS. Subgroup analyses showed that aerobic exercise, resistance exercise, and multicomponent training were all effective in improving fatigue in people with MS, with resistance exercise being the most effective intervention type. In addition, a younger age was associated with a larger improvement in fatigue. Furthermore, aerobic exercise and multicomponent training were all effective in improving quality of life in people with MS, with aerobic exercise being the most effective intervention type.

**Conclusion:** Exercise had beneficial effects in improving balance, walking ability, walking endurance, fatigue, and quality of life in people with MS. Resistance exercise and aerobic exercise are the most effective interventions for improving fatigue and quality of life in people with MS, respectively. The effect of exercise on improving fatigue was associated with the age of the participants, with the younger age of the participants, the greater the improvement in fatigue.

**Systematic review registration:** https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=371056, identifier: CRD42022371056.

KEYWORDS

**exercise, multiple sclerosis, balance, walking ability, walking endurance, fatigue, quality of life**

# Introduction

Multiple sclerosis (MS) is a disabling neurological disease common in young and middle-aged adults with a mean age of onset of 29 years (1, 2). The manifestations of people with MS include physical symptoms such as muscle weakness, muscle spasms, decreased mobility and balance, and increased sensitivity to pain, with psychiatric episodes and fatigue leading to severe disability and deterioration of physical condition, mobility, cognition, and quality of life (3–7). In fact, 50–80% of people with MS, even in its mild stages, will result in impaired walking performance, further reducing their quality of life as the disease progresses (8).

People with MS usually use pharmacologic strategies that down-regulate immune activation to halt disease progression, prevent relapse, or partially reverse disability (9). However, pharmacologic treatments are often accompanied by adverse effects such as infection, headache, and diarrhea (10). In recent years, exercise has been found to be beneficial in improving aerobic capacity, muscle strength, flexibility, balance, fatigue, and cognitive function in people with MS (11).

A growing body of studies have examined the effect of exercise in people with MS, while findings of available studies were conflicting. Kubsik et al. (12) showed that exercise not only contributes to the physical abilities of people with MS, but also to their mood and attitude toward exercise. In addition, Grazioli et al. (13) reported that multicomponent training was effective in improving quality of life, walking ability, and balance, as well as reducing depression, fatigue, and disease severity in people with MS. Furthermore, Feys et al. (14) showed that running improved aerobic capacity, functional mobility, spatial memory, fatigue, and quality of life in people with MS. However, a meta-analysis showed no significant differences in step count and moderate to vigorous physical activity among individuals with MS, both within and between groups receiving physical activity interventions (14). To the best of our knowledge, Arntzen et al. (15) included only eight randomized controlled trials (RCTs) and the number of included studies was quite small, and the authors included one study in which participants in the control group also received exercise intervention. Another study evaluated the effects of Pilates on balance in people with MS, which included only seven RCTs (16). However, the authors included studies in which control group participants also received exercise interventions such as home exercises (two studies), relaxation exercises (one study), aerobic exercises (one study), and traditional exercises (one study), which may have had some impact on their findings. Therefore, we conducted a comprehensive systematic review and meta-analysis of RCTs to explore the effects of exercise on balance, walking ability, walking endurance, fatigue, and quality of life in people with MS.

# Methods

This systematic review and meta-analysis was done in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA, 2020) guidelines (17) and the implementing PRISMA in exercise, rehabilitation, sport medicine, and sports science (PERSiST) guidance (18). The protocol was registered with PROSPERO (CRD42022371056).

## Search strategy

We searched the PubMed, Web of Science, Scopus, and Cochrane databases for RCTs relating to the effect of exercise on balance, gait, fatigue, and quality of life in patients with MS from the inception dates to March 1, 2024 (Supplementary Table 1). We also manually searched references listed in the identified systematic reviews and meta-analyses, in addition to the reference lists of identified studies included in the screening. Two authors (L.D. and H.X.) independently completed the article screening using a standardized form.

## Inclusion and exclusion criteria

Inclusion criteria were: (1) RCTs; (2) included an intervention and control group; (3) had people with MS as study subjects; (4) had balance, walking ability, walking endurance, fatigue, or quality of life as the outcome measures. Exclusion criteria were: (1) non-English publications; (2) animal model publications; (3) review articles; and (4) conference articles.

## Data extraction

Two authors (L.D. and H.X.) independently performed the data extraction, mainly including: (1) study characteristics (surname of the first author, year of publication, and sample size); (2) intervention characteristics (intensity, duration, and frequency); (3) participant characteristics (gender, disease stage, and disease duration); (4) treatment effects [mean and standard deviation (SD) values reflecting changes in balance, walking ability,

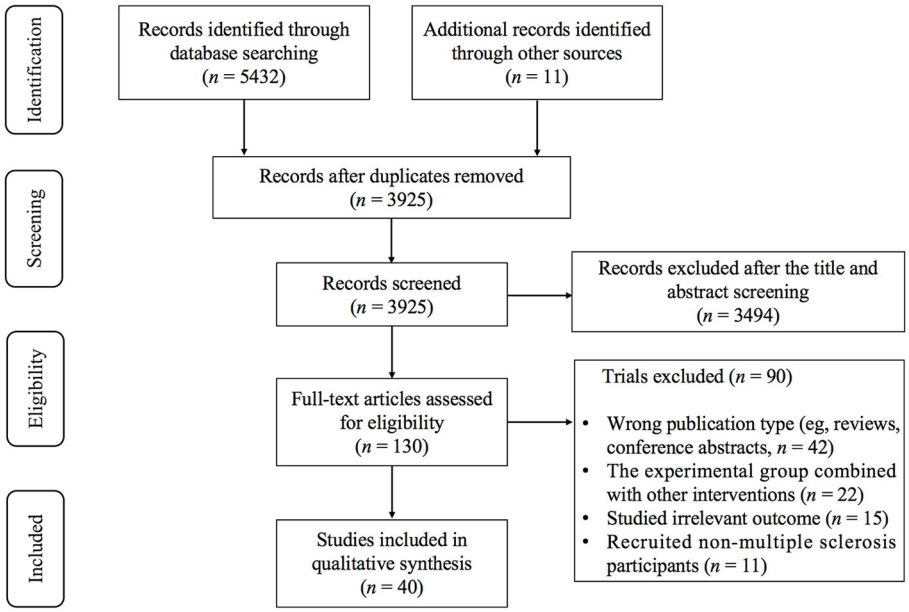


FIGURE 1
PRISMA flow diagram of the study selection process.

walking endurance, fatigue, and quality of life from baseline to post intervention].

## Methodological quality assessment

The methodological quality for the included studies was independently assessed by two authors (L.D. and H.X.) based on the Cochrane risk of bias tool (RoB2) (19) and Physiotherapy Evidence Database (PEDro) scale (20, 21). If there was disagreement between the two authors, a third author (LY) would join the discussion until the three reach a consensus. RoB2 was assessed mainly from seven items: random sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective reporting (reporting bias), and other biases. PEDro scale is an 11-item scale used to evaluate the quality of the RCTs of the physical therapy studies, where studies scoring <4, 4–5, 6–8, and >9 points are considered poor quality, average, good, and excellent, respectively (21).

## Statistical analysis

We extracted the mean and SD values reflecting changes in timed up and go test (TUG), Berg balance scale (BBS), multiple sclerosis walking scale-12 (MSWS-12), 6-minute walk test (6MWT), fatigue severity scale (FSS), modified fatigue impact scale (MFIS), and multiple sclerosis quality of life-54 (MSQOL-54) from baseline to post-intervention from each study for pooling effects. Weighted mean difference (WMD) and 95% confidence interval (CI) were used to estimate the effects of exercise on balance, walking ability, walking endurance, fatigue, and quality of life in people with MS. For studies reporting standard error (SE) or 95% confidence interval (CI), SD was calculated using the previously described formula. Otherwise, PlotDigitizer online software (www.plotdigitizer.com) was used (22). The $I^2$ static was used to assess heterogeneity, where $I^2 < 25\%$ indicates no significant heterogeneity, $25\% < I^2 < 50\%$ indicates low heterogeneity, $50\% < I^2 < 75\%$ indicates moderate heterogeneity, and $I^2 > 75\%$ indicates high heterogeneity (23). If there was a high heterogeneity ($I^2 > 60\%$), meta-regression analysis, subgroup analysis, and sensitivity analysis were used to interpret the results (19).

For subgroup analyses, we examined the effects of intervention type (aerobic exercise, resistance exercise, and multicomponent exercise), participants' age (young, <45 years old; and middle-aged and older adult, ≥45 years old), and type of fatigue detection (FSS and MFIS) on fatigue and intervention type (aerobic exercise and multicomponent exercise) on quality of life in people with MS. Meta-regressions were conducted based on the participants' age, disease duration, duration of intervention, session duration, and weekly time. The analysis result, funnel plot, and forest plot were generated using RevMan 5.2 software. Statistical significance was considered for outcomes with a $P < 0.05$.

# Results

## Study selection

As shown in Figure 1, 5,432 records were initially identified from the databases and 11 records from other sources. Three

thousand nine hundred and twenty-five studies remained after excluding duplicates and 130 potentially eligible studies remained after the title and abstract screening. Ninety studies were excluded by reading the full text: (1) wrong publication type (e.g., reviews, conference abstracts, $n = 42$); (2) the experimental group combined with other interventions ($n = 22$); (3) studied irrelevant outcome ($n = 15$); (4) recruited non-multiple sclerosis participants ($n = 11$). Finally, 40 studies (24–63) were considered eligible for systematic review and meta-analysis.

## Characteristics of the included studies

The main characteristics of participants and interventions were shown in Table 1. Among the included studies, there were 1,300 people with MS in the 56 exercise groups and 827 people with MS in the 40 control groups. Six studies involved women, 1 study involved men, and 30 studies involved both men and women. The mean age of the participants ranged from 16.3 to 61.6 years. Thirty-seven studies (24–28, 30–32, 34–49, 51–63) involved participants with mean age <60 years, and three studies (29, 33, 50) involved participants with mean age ≥60 year. Most interventions specified aerobic exercise ($n = 16$) (24–26, 30, 33, 34, 36, 38, 39, 45, 46, 51, 53, 56, 58, 63), balance training ($n = 10$) (29, 37, 43, 47, 50, 52, 54, 55, 59, 61), resistance exercise ($n = 6$) (27, 28, 32, 41, 44, 49), or other types of exercise [such as multicomponent training ($n = 5$) (31, 35, 42, 48, 62) water sports ($n = 2$) (40, 57); interval training ($n = 1$) (60)]. Of the 40 studies, 26 studies provided data for balance, which was tested by BBS (20 studies) (24, 29, 34, 36–40, 42–44, 46, 49, 50, 52–54, 58, 59, 61) and TUG (17 studies) (25–27, 33, 34, 37, 38, 42–44, 50, 51, 54–56, 59, 61, 62). In addition, 17 studies provided data for gait, which was tested by MSWS-12 (walking ability, eight studies) (29, 30, 34, 47, 50, 55, 60, 61) and 6MWT (walking endurance, 14 studies) (25, 28, 30, 39, 40, 42, 45, 48, 51, 53, 54, 56, 60, 61). Furthermore, 17 studies provided data for fatigue, which was tested by FSS (nine studies) (24, 26, 28, 42, 44, 51–54) and MFIS (eight studies) (30, 32, 33, 39, 41, 43, 50, 57). Moreover, six studies provided data for quality of life (24, 31, 45, 48, 57, 63), which was tested by MSQOL-54.

## Meta-analysis results

### Effects of exercise on balance in people with MS

The balance of people with MS was detected by BBS and TUG, with 20 studies providing BBS data and 20 studies providing TUG data. Our results showed that exercise had a significant effect on improving BBS (WMD, 3.77; 95% CI, 3.01 to 4.53, $P < 0.00001$, $I^2 = 50\%$, Figure 2) and TUG (WMD, −1.33; 95% CI, −1.57 to −1.08, $P < 0.00001$, $I^2 = 34\%$, Figure 3) in people with MS.

### Effects of exercise on walking ability and walking endurance in people with MS

MSWS-12 was used to test walking ability and 6MWT was used to test walking endurance of people with MS. It was found that exercise had a significant effect on improving MSWS-12 (WMD, −2.57; 95% CI, −3.99 to −1.15, $P = 0.0004$, $I^2 = 19\%$, Figure 4) and 6MWT (WMD, 25.56; 95% CI, 16.34 to 34.79, $P < 0.00001$, $I^2 = 47\%$, Figure 5) in people with MS.

### Effects of exercise on fatigue in people with MS

The fatigue of people with MS was detected by FSS and MFIS. As shown in Figure 6, exercise had a significant effect on improving fatigue in people with MS (WMD, −4.34; 95% CI, −5.83 to −2.84, $P < 0.00001$, $I^2 = 79\%$).

### Effects of exercise on quality of life in people with MS

The fatigue of people with MS was detected by MSQOL-54. As shown in Figure 7, exercise had a significant effect on improving MSQOL-54 in people with MS (WMD, 11.80; 95% CI, 5.70 to 17.90, $P = 0.0002$, $I^2 = 66\%$).

Our meta-analysis results showed high heterogeneity in fatigue ($I^2 = 78\%$) and quality of life ($I^2 = 66\%$), to explain the heterogeneity between included studies and find modifiable factors of exercise, meta-regression analysis, subgroup analysis, and sensitivity analysis were further performed.

## Meta-regression analysis

Meta-regression analyses were performed on intervention characteristics (duration of intervention, weekly time, and session duration) and participant characteristics (age and disease duration). There was no significant association between age ($P = 0.782$), duration of intervention ($P = 0.124$), weekly time ($P = 0.730$), session duration ($P = 0.124$), or disease duration ($P = 0.559$) and fatigue (Supplementary Figure 1). In addition, no significant associations were observed between duration of intervention ($P = 0.086$), weekly time ($P = 0.583$), session duration ($P = 0.878$), age ($P = 0.172$), or disease duration ($P = 0.289$) and quality of life (Supplementary Figure 2).

## Subgroup analysis

### Fatigue

We conducted three different subgroup analyses by participants' age, type of fatigue detection, and type of intervention. Subgroup analysis indicated that a younger age was associated with larger improvement in fatigue (young, age < 45, WMD, −6.67; 95% CI, −9.57 to −3.60, $P < 0.0001$, $I^2 = 91\%$; middle-aged and older adult, age ≥ 45, WMD, −1.76; 95% CI, −3.29 to −0.24, $P = 0.02$, $I^2 = 22\%$, Supplementary Figure 3).

Stratifying the analysis by type of fatigue detection, the improvement in fatigue scores remained significant in FSS (WMD, −2.75; 95% CI, −4.27 to −1.24, $P = 0.0004$, $I^2 = 81\%$) and MFIS (WMD, −5.84; 95% CI, −9.28 to −2.40, $P = 0.0009$, $I^2 = 65\%$, Supplementary Figure 4).

In addition, aerobic exercise (WMD, −7.07; 95% CI, −11.25 to −2.88, $P = 0.0009$, $I^2 = 81\%$), resistance exercise (WMD, −8.03; 95% CI, −11.84 to −4.22, $P < 0.0001$, $I^2 = 0\%$), and

TABLE 1 Characteristics of the studies included in this meta-analysis.

| References | Sample size | Sex | Age (y) | EDSS | Disease duration (y) | Intervention | Details of interventions | Outcome measures |
|---|---|---|---|---|---|---|---|---|
| Ahmadi et al. (24) | IG = 11 | 11 W | IG: 32.3 (8.7) | IG: 2.0 (1.1) | IG: 4.7 (5.6) | Yoga | 8 weeks, 60–70 min, each position for 10–30 s, group rest for 30–60 s, 3 times/week | FFS and MSQOL-54 |
| | CG = 10 | 10 W | CG: 36.7 (9.3) | CG: 2.3 (1.3) | CG: 5.0 (3.1) | Usual care | | |
| Androwis et al. (25) | IG = 6 | 3 M and 3 W | IG: 46.5 (5.2) | NR | NR | Walking | 4 weeks, 30 min, 2 times/week | TUG and 6MWT |
| | CG = 4 | 1 M and 3 W | CG: 55.0 (9.6) | NR | NR | Rehabilitation nursing | | |
| Cakt et al. (26) | IG = 14 | 5 M and 9 W | IG: 36.4 (10.5) | NR | IG: 9.2 (5.0) | Bicycle | 8 weeks, 30–35 min, 30–40 W low resistance, twice/week | TUG and FFS |
| | IG = 10 | 2 M and 8 W | IG: 43.0 (10.2) | NR | IG: 6.2 (2.2) | Balance training | 8 weeks, 30–35 min, 2 times/week | |
| | CG = 9 | 3 M and 6 W | CG: 35.5 (10.9) | NR | CG: 6.6 (2.4) | Usual care | | |
| Andreu-Caravaca et al. (27) | IG = 18 | 10 M and 8 W | IG: 44.9 (10.6) | IG: 3.2 (1.7) | NR | Strength training | 10 weeks, 40% 1 RM, 3 times per week | TUG |
| | CG = 12 | 5 M and 7 W | CG: 48.4 (10.2) | CG: 3.3 (1.3) | NR | Usual care | | |
| Andreu-Caravaca et al. (28) | IG = 18 | 10 M and 8 W | IG: 44.9 (10.6) | IG: 3.2 (1.7) | NR | Strength training | 10 weeks, 40% 1 RM, 3 times per week | 6MWT and FSS |
| | CG = 12 | 5 M and 7 W | CG: 48.4 (10.2) | CG: 3.3 (1.3) | NR | Usual care | | |
| Carling et al. (29) | IG = 25 | 6 M and 19 W | IG: 61.6 (11.3) | IG: 6.2 (0.5) | NR | Balance training | 7 weeks, 60 min, 2 times/week | BBS, TUG, and MSWS-12 |
| | CG = 26 | 10 M and 16 W | CG: 54.7 (8.2) | CG: 6.1 (0.5) | NR | Usual care | | |
| Langeskov-Christensen et al. (30) | IG = 43 | 17 M and 26 W | IG: 44.0 (9.5) | IG: 2.7(1.4) | IG: 10.9 (7.9) | Aerobic training | 24 weeks, 30–60 min, 65–95% maximum heart rate, twice/week | MFIS, FSS, 6MWT, and MSWS-12 |
| | CG = 43 | 17 M and 26 W | CG: 45.6 (9.3) | CG: 2.8(1.6) | CG: 8.6 (6.0) | Usual care | | |
| Correale et al. (31) | IG = 14 | 14 W | IG: 45.4 (7.2) | NR | NR | Combination training | 12 weeks, 45–60 min, 50–70% reserve heart rate, 2 times/week | MFIS and MSQOL-54 |
| | CG = 9 | 9 W | CG: 48.3 (6.1) | NR | NR | Usual care | | |
| Dodd et al. (32) | IG = 36 | 10 M and 26 W | IG: 47.7 (10.8) | NR | NR | Strength training | 10 weeks, 45 min, 2 sets per action, 10–12 times, 2 times per week | MFIS |
| | CG = 35 | 9 M and 26 W | CG: 50.4 (9.6) | NR | NR | Usual care | | |
| Fleming et al. (33) | IG = 29 | 29 W | IG: 45.3 (8.6) | NR | NR | Pilates | 8 weeks, repeat actions 4–10 times, 2 times/week | MFIS |

*(Continued)*





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TABLE 1 (Continued)

| References | Sample size | Sex | Age (y) | EDSS | Disease duration (y) | Intervention | Details of interventions | Outcome measures |
|---|---|---|---|---|---|---|---|---|
| | CG = 34 | 34 W | CG: 48.2 (9.8) | NR | NR | Usual care | | |
| Forsberg et al. (34) | IG = 35 | 28 M and 7 W | IG: 52.0 (10) | NR | IG: 15.0 (9.0) | Core training | 7 weeks, 50–60 min, 2 times/week | BBS, TUG, and MSWS-12 |
| | CG = 38 | 31 M and 7 W | CG: 56.3 (11) | NR | CG: 16.0 (11.0) | Usual care | | |
| Garrett et al. (35) | IG = 63 | 13 M and 50 W | IG: 51.7 (10) | NR | IG: 9.8 (7.0) | Physical therapy | 10 weeks, 12 actions per action, with/2–5% increase in load during easy times, 60 min per week | MFIS and 6MWT |
| | IG = 67 | 22 M and 45 W | IG: 50.3 (10) | NR | IG: 10.5 (6.9) | Combination training | 10 weeks, 60 min per week | |
| | IG = 63 | 19 M and 44 W | IG: 49.6 (10) | NR | IG: 11.6 (8.0) | Yoga | 10 weeks, action duration 30–90 s, 60 min per week | |
| | CG = 49 | 6 M and 43 W | CG: 48.8 (11) | NR | CG: 10.6 (8.2) | Usual care | | |
| Gervasoni et al. (36) | IG = 15 | NR | IG: 49.6 (9.4) | NR | IG: 14.5 (9.7) | Treadmill | 2 weeks, 45 min, 11–12 RPE intensity, completed 10–12 times in 2 weeks | BBS and FSS |
| | CG = 15 | NR | CG: 45.7 (8.9) | NR | CG: 15.5 (10.3) | Usual care | | |
| Eftekharsadat et al. (37) | IG = 15 | 5 M and 10 W | IG: 33.4 (8.1) | NR | IG: 5.8 (3.9) | Stability training | 12 weeks, 20 min, 2 times/week | BBS and TUG |
| | CG = 15 | 3 M and 12 W | CG: 37.0 (8.3) | NR | CG: 8.3 (4.3) | Usual care | | |
| Gheitasi et al. (38) | IG = 15 | 15 M | IG: 30.6 (5.3) | IG: 4.6 (1.6) | IG: 5.5 (1.1) | Pilates | 12 weeks, 60 min, 3 times/week | TUG |
| | CG = 15 | 15 M | CG: 32.1 (6.3) | CG: 4.5 (1.1) | CG: 4.0 (1.0) | Usual care | | |
| Hogan et al. (39) | IG = 35 | 15 M and 20 W | IG: 52.0 (11.0) | NR | IG: 13.0 (8.0) | Personal balance training | 10 weeks, 60 min per week | MFIS, BBS, and 6MWT |
| | IG = 48 | 18 M and 30 W | IG: 57.0 (10.0) | NR | IG: 18.0 (9.0) | Group balance training | 10 weeks, 60 min per week | |
| | IG = 13 | 5 M and 8 W | IG: 58.0 (8.0) | NR | IG: 15.0 (8.0) | Yoga | 10 weeks, 60 min per week | |
| | CG = 15 | 2 M and 13 W | CG: 49.0 (6.0) | NR | CG: 10.0 (3.0) | Usual care | | |
| Kargarfard et al. (40) | IG = 17 | NR | IG: 36.5 (9.0) | IG: 3.4 (1.1) | IG: 6.4 (2.3) | Water sports | 8 weeks, 30–40 min | 6MWT, BBS, MFIS, and MSQOL-54 |
| | CG = 15 | NR | CG: 36.2 (7.4) | CG: 3.7 (1.0) | CG: 6.1 (2.0) | Usual care | | |
| Learmont et al. (42) | IG = 20 | 5 M and 15 W | IG: 51.4 (8.06) | IG: 6.1 (0.4) | IG: 13.4 (6.4) | Aerobic, resistance, and balance training | 12 weeks, 45–60 min | 6MWT, BBS, TUG, and FSS |
| | CG = 12 | 4 M and 8 W | CG: 51.8 (8.0) | CG: 5.8 (0.5) | CG: 12.6 (8.1) | Usual care | | |
| Najafi et al. (43) | IG = 28 | 28 W | IG: 38.4 (4.6) | IG: 2.5 (1.2) | NR | Stability training | 8 weeks, 60–80 min, 3 times/week | TUG and BBS |
| | CG = 28 | 28 W | CG: 36.4 (3.5) | CG: 2.4 (0.8) | NR | Usual care | | |
| Negahban et al. (44) | IG = 12 | NR | IG: 36.7 (6.7) | IG: 3.5 (1.1) | IG: 8.5 (6.8) | Strength training | 5 weeks, 30 min, 3 times/week | FSS, BBS, and TUG |

*(Continued)*





10.3389/fpubh.2024.1387658

TABLE 1 (Continued)

| References | Sample size | Sex | Age (y) | EDSS | Disease duration (y) | Intervention | Details of interventions | Outcome measures |
|---|---|---|---|---|---|---|---|---|
| | CG = 12 | NR | CG: 36.8 (8.7) | CG: 3.8 (1.4) | CG: 7.2 (2.9) | Usual care | | |
| Ozkul et al. (45) | IG = 17 | 4 M and 13 W | IG: 35.9 (9.7) | IG: 1.5 (0.7) | IG: 7.2 (6.1) | Pilates | 8 weeks, 50–60 min, 60–80 maximum heart rate, 3 times per week | 6MWT and MSQOL-54 |
| | CG = 17 | 4 M and 13 W | CG: 36.8 (9.0) | CG: 1.7 (0.9) | CG: 5.7 (4.9) | Usual care | | |
| Pan et al. (46) | IG = 30 | 8 M and 22 W | IG: 42.2 (5.1) | IG: 3.0 (0.7) | IG: 6.2 (2.3) | Baduanjin | 24 weeks, 60 min per day | BBS |
| | IG = 30 | 9 M and 21 W | IG: 40.9 (4.8) | IG: 2.8 (0.9) | IG: 5.2 (2.0) | Yoga | 24 weeks, 60 min per day | |
| | CG = 20 | 6 M and 14 W | CG: 42.3 (4.5) | CG: 2.9 (0.8) | CG: 5.4 (2.8) | Usual care | | |
| Robinson et al. (47) | IG = 20 | 6 M and 14 W | IG: 52.6 (6.1) | NR | NR | Balance game | 4 weeks, 40–60 min, 2 times/week | FSS and MSWS-12 |
| | IG = 19 | 7 M and 12 W | IG: 53.9 (6.5) | NR | NR | Balance training | 4 weeks, 40–60 min, 2 times/week | |
| | CG = 17 | 5 M and 12 W | CG: 51.9 (4.7) | NR | NR | Usual care | | |
| Romberg et al. (48) | IG = 47 | 17 M and 30 W | IG: 43.8 (6.3) | NR | IG: 6.0 (6.5) | Combination training | 26 weeks, 3–4 times/week | MSQOL-54 |
| | CG = 48 | 17 M and 31 W | CG: 43.9 (7.1) | NR | CG: 5.5 (6.4) | Usual care | | |
| Sokhangu et al. (49) | IG = 10 | 10 W | IG: 38.7 (7.2) | IG: 1.8 (0.7) | IG: 4.2 (2.1) | Strength training | 8 weeks, 60 min, 8–15 times per action, 3 times per week | BBS |
| | CG = 10 | 10 W | CG: 40.1 (5.6) | CG: 1.9 (0.7) | CG: 4.4 (2.0) | Usual care | | |
| Sosnoff et al. (50) | IG = 13 | 3 M and 10 W | IG: 60.1 (6.3) | IG: 5.5 (2.5) | IG: 13.9 (6.7) | Balance training | 12 weeks, 1–3 groups, 8–12 times, 45–60 min | TUG, 6MWT, BBS, and MSWS-12 |
| | CG = 14 | 3 M and 11 W | CG: 60.1 (6.0) | 5.5 (3.5) | 17.7 (11.3) | Usual care | | |
| Straudi et al. (51) | IG = 8 | 4 M and 4 W | IG: 49.6 (12.0) | IG: 5.8 (0.8) | IG: 17.1 (12.0) | Gait practice | 6 weeks, 30 min, 2 times/week | 6MWT and TUG |
| | CG = 8 | 1 M and 7 W | CG: 60.0 (8.8) | CG: 5.7 (0.7) | CG: 18.6 (10.8) | Usual care | | |
| Tarakci et al. (52) | IG = 51 | 17 M and 34 W | IG: 41.5 (9.4) | IG: 4.9 (1.4) | IG: 9.0 (4.7) | Balance training | 12 weeks, 60 min, 3 times/week | BBS and FSS |
| | CG = 48 | 18 M and 30 W | CG: 39.7 (11.2) | CG: 4.2 (1.4) | CG: 8.4 (5.4) | Usual care | | |
| Tollár et al. (53) | IG = 14 | 2 M and 12 W | IG: 48.2 (5.5) | NR | IG: 12.1 (2.7) | Agility training | 5 weeks, 60 min, 5 times/week | BBS and 6MWT |
| | IG = 14 | 2 M and 12 W | IG: 46.9 (6.5) | NR | IG: 13.6 (4.1) | Balance training | 5 weeks, 60 min, 5 times/week | |
| | IG = 14 | 2 M and 12 W | IG: 48.1 (5.7) | NR | IG: 13.2 (4.4) | Bicycle | 5 weeks, 60 min, 5 times/week | |
| | CG = 12 | 1 M and 11 W | CG: 44.4 (6.8) | NR | CG: 14.0 (4.11) | Usual care | | |
| Grubić Kezele et al. (41) | IG = 13 | 5 M and 8 W | IG: 50.0 (9.3) | IG: 3.8 (1.8) | NR | Strength training | 8 weeks, 60 min, 2 times/week | MFIS |
| | CG = 11 | 5 M and 6 W | CG: 53.8 (13.8) | CG: 4.0 (2.0) | NR | Usual care | | |
| Yazgan et al. (54) | IG = 15 | 2 M and 13 W | IG: 47.5 (10.5) | IG: 4.2 (1.4) | IG: 12.1 (6.6) | Balance game | 8 weeks, 60 min, 2 times/week | BBS, TUG, and FSS |

*(Continued)*





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TABLE 1 (Continued)

| References | Sample size | Sex | Age (y) | EDSS | Disease duration (y) | Intervention | Details of interventions | Outcome measures |
|---|---|---|---|---|---|---|---|---|
| | IG = 12 | 12 W | IG: 43.1 (8.7) | IG: 3.8 (1.5) | IG: 14.9 (6.6) | Balance training | 8 weeks, 60 min, 2 times/week | |
| | CG = 15 | 2 M and 13 W | CG: 40.7 (8.8) | CG: 4.1 (1.3) | CG: 11.1 (5.1) | Usual care | | |
| Young et al. (56) | IG = 27 | 5 M and 22 W | IG: 49.7 (9.4) | NR | IG: 13.6 (8.3) | Strength training | 12 weeks, 60 min, 3 times/week | TUG and 6MWT |
| | IG = 26 | 6 M and 20 W | IG: 48.4 (10.0) | NR | IG: 11.0 (5.6) | Yoga | 12 weeks, 60 min, 3 times/week | |
| | CG = 28 | 4 M and 24 W | CG: 47.3 (10.3) | NR | CG: 13.4 (8.5) | Usual care | | |
| Kargarfard et al. (57) | IG = 10 | NR | IG: 33.7 (8.6) | IG: 2.9 (0.9) | IG: 4.9 (2.3) | Aquatic exercise | 8 weeks, 60 minutes, 3 times/week | MFIS |
| | CG = 11 | NR | CG: 31.6 (7.7) | CG: 3.0 (0.7) | CG: 4.6 (1.9) | Usual care | | |
| Nilsagård et al. (55) | IG = 41 | 10 M and 31 W | IG: 50.0 (11.5) | NR | IG: 12.5 (8.0) | Balance training | 6 weeks, 30 min, 2 times/week | TUG and MSWS-12 |
| | CG = 39 | 10 M and 29 W | CG: 49.4 (11.1) | NR | CG: 12.2 (9.2) | Usual care | | |
| Ahadi et al. (63) | IG = 10 | 10 W | IG: 50.0 (11.5) | NR | NR | Running | 8 weeks, 30 min, 3 times/week | MSQOL-54 |
| | IG = 11 | 11 W | IG: 50.0 (11.5) | NR | NR | Yoga | 8 weeks, 30 min, 3 times/week | |
| | CG = 10 | 10 W | CG: 49.4 (11.1) | NR | NR | Usual care | | |
| Abadi Marand et al. (61) | IG = 32 | 17 M and 15 W | IG: 40.4 (6.0) | IG: 4.1 (1.1) | IG: 14.4 (5.2) | Balance training | 5 weeks, 60–70 min, 3 times/week | BBS, TUG, and MSWS-12 |
| | CG = 32 | 18 M and 14 W | CG: 40.7 (6.2) | CG: 3.8 (1.0) | CG: 12.8 (5.9) | Usual care | | |
| Monjezi et al. (59) | IG = 17 | 3 M and 14 W | IG: 38.1 (9.5) | IG: 4.8 (1.0) | IG: 9.7 (6.3) | Balance Training | 4 weeks, 20 min, 3 times/week | BBS and TUG |
| | CG = 17 | 3 M and 14 W | CG: 35.1 (8.0) | CG: 4.6 (0.7) | CG: 8.9 (5.2) | Usual care | | |
| Vural et al. (62) | IG = 10 | 2 M and 8 W | IG: 16.3 (1.6) | IG: 1.2 (0.8) | IG: 2.3 (1.2) | Combination training | 8 weeks, 60 min, 2 times/week | FSS, TUG, and 6MWT |
| | IG = 10 | 2 M and 8 W | IG: 16.3 (1.6) | IG: 1.2 (0.8) | IG: 2.3 (1.2) | Combination training | 32 weeks, 60 min, 2 times/week | |
| | CG = 10 | 1 M and 9 W | CG: 17.4 (1.8) | CG: 1.7 (0.8) | CG: 2.3 (1.7) | Usual care | | |
| Lysogorska et al. (58) | IG = 15 | 5 M and 10 W | IG: 39.0 (10.4) | NR | IG: 12.6 (8.4) | Yoga | 12 weeks, 60–75 min, 2 times/week | BBS and 6MWT |
| | IG = 9 | 9 W | IG: 46.1 (10.3) | NR | IG: 18.1 (12.3) | Combination training | 12 weeks, 60–75 min, 2 times/week | |
| | CG = 12 | 1 M and 11 W | CG: 46.2 (10.4) | NR | CG: 18.5 (7.9) | Usual care | | |
| Riemenschneider et al. (60) | IG = 42 | 13 M and 29 W | IG: 37.3 (10.1) | IG: 1.4 (0.9) | IG: 0.9 (0.6) | Interval training | 24 weeks, 30–60 min, 2 times/week | 6MWT and MSWS-12 |
| | IG = 42 | 13 M and 29 W | IG: 37.3 (10.1) | IG: 1.4 (0.9) | IG: 0.9 (0.6) | Interval training | 48 weeks, 30–60 min, 2 times/week | |
| | CG = 42 | 8 M and 34 W | CG: 37.4 (9.7) | CG: 1.8 (1.1) | CG: 0.9 (0.6) | Usual care | | |

IG, intervention group; CG, control group; M, male; W, woman; NR, no report; TUG, timed up and go test; BBS, Berg balance scale; 6MWT, 6-minute walk test; MSIS-12, The 12-Item MS Walking Scale; FSS, Fatigue Severity Scale; MFIS, modified fatigue impact scale; MSQOL-54, Quality of Life−54 Questionnaire.
Data were presented as mean (standard deviation).





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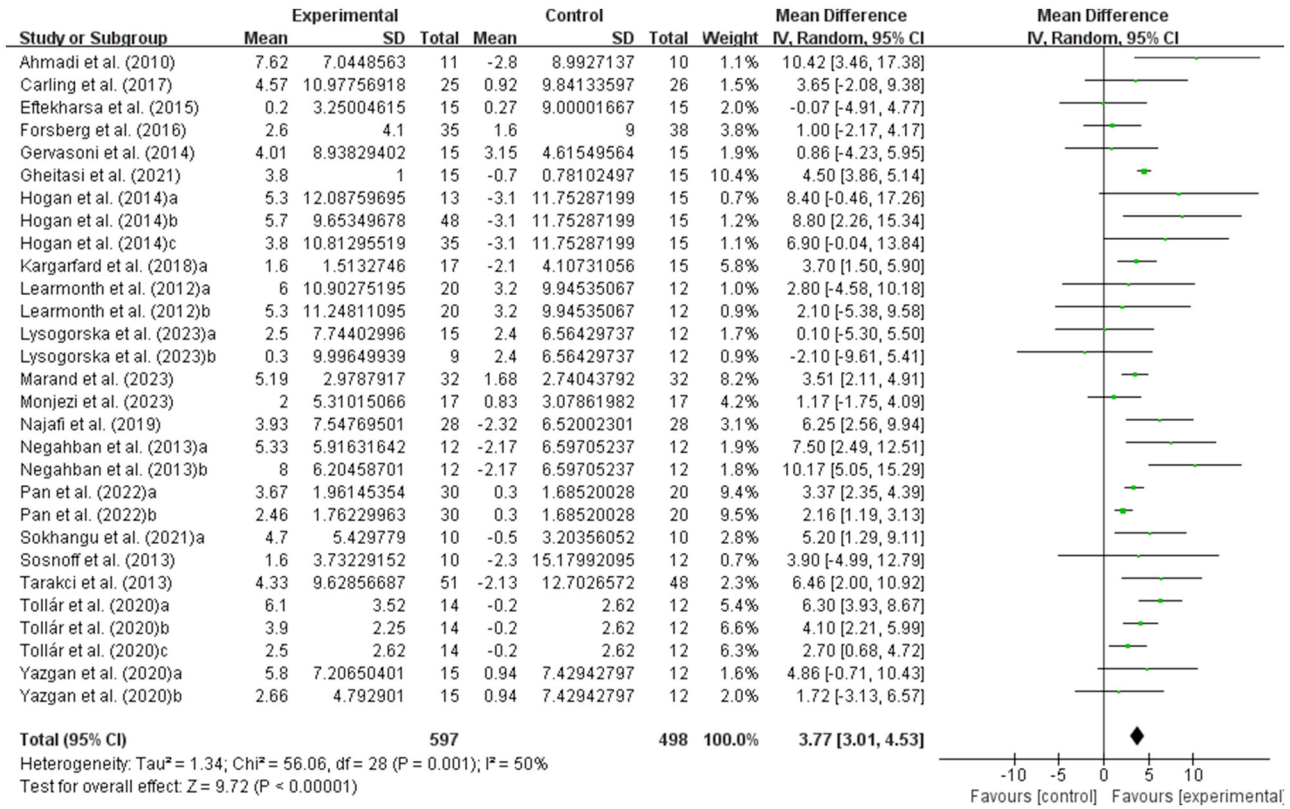


FIGURE 2
Meta-analysis results of the effects of exercise on Berg balance scale (BBS) in people with MS. Exercise had a significant effect on improving BBS in people with MS ($P < 0.00001$).

multicomponent training (WMD, −2.54; 95% CI, −4.44 to −0.65, $P = 0.009$, $I^2 = 80\%$) were effective in improving fatigue in people with MS, with resistance exercise being the most effective intervention type (Supplementary Figure 5).

## Quality of life

We conducted a subgroup analysis by type of intervention. Aerobic exercise (WMD, 11.68; 95% CI, 5.31 to 18.05, $P = 0.0003$, $I^2 = 0\%$) and multicomponent training (WMD, 7.28; 95% CI, 2.77 to 11.79, $P = 0.002$, $I^2 = 24\%$) were effective in improving quality of life in people with MS, with aerobic exercise being the most effective intervention type (Supplementary Figure 6).

## Sensitivity analysis

Sensitivity analyses showed that there is no change in the direction or level of compatibility of the overall effect of exercise on fatigue (Supplementary Figure 7) and quality of life (Supplementary Figure 8) in people with MS when any of the included studies are omitted.

## Risk of bias

The quality of included studies was assessed by the Cochrane Collaboration tool in terms of selection bias, performance bias, attrition bias, reporting bias, detection bias, and other bias (Supplementary Figure 9). The results of PEDro scale showed that of the 40 included studies, 39 were of good quality and one was of fair quality (Supplementary Table 2).

## Publication bias

Possible publication bias was assessed by examining the funnel plot (Supplementary Figure 10). Visual inspection of the funnel plot suggested the absence of funnel plot asymmetry. The results of the egger's test indicated that the small sample size studies were not enough to affect the final results (TUG, $P = 0.575$; BBS, $P = 0.705$; 6MWT, $P = 0.586$; MSWS-12, $P = 0.137$; quality of life, $P = 0.791$; Supplementary Table 3), with the exception of fatigue ($P = 0.002$). Therefore, we performed the Dsuval and Tweedie's trim and fill procedure, and the results indicated that no evidence of publication bias was found for fatigue.

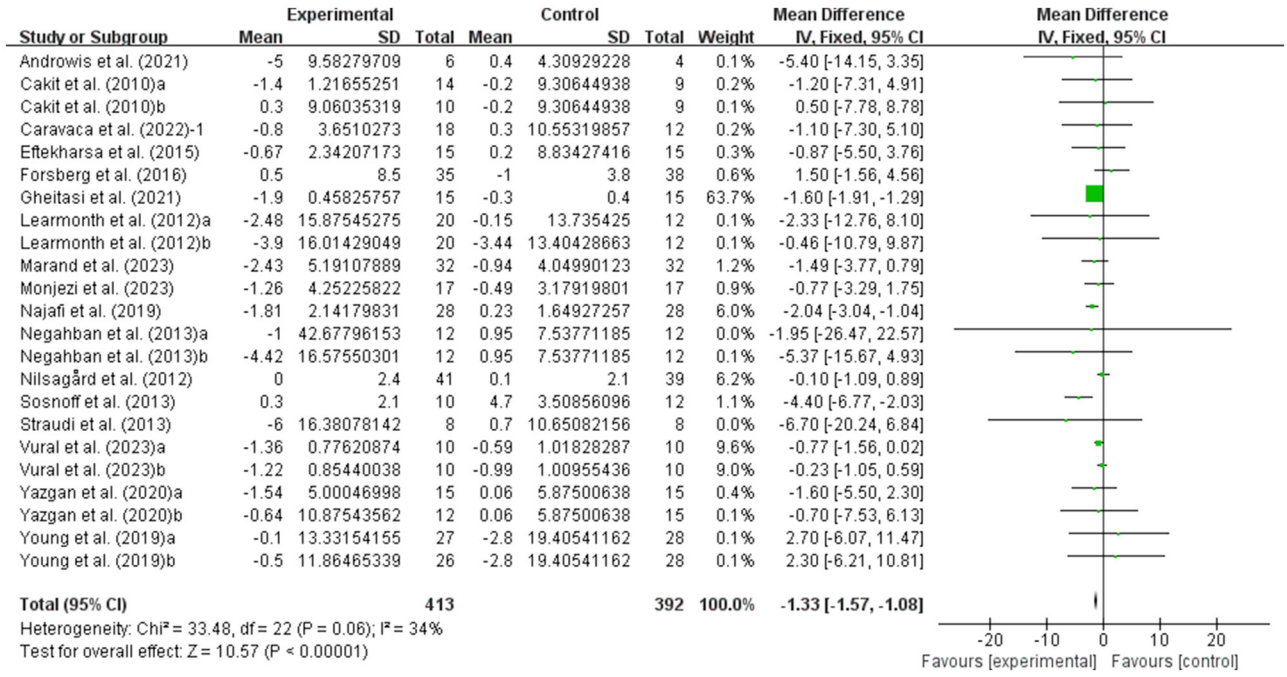


FIGURE 3
Meta-analysis results of the effect of exercise on timed up and go test (TUG) in people with MS. Exercise had a significant effect on improving TUG in people with MS ($P < 0.00001$).

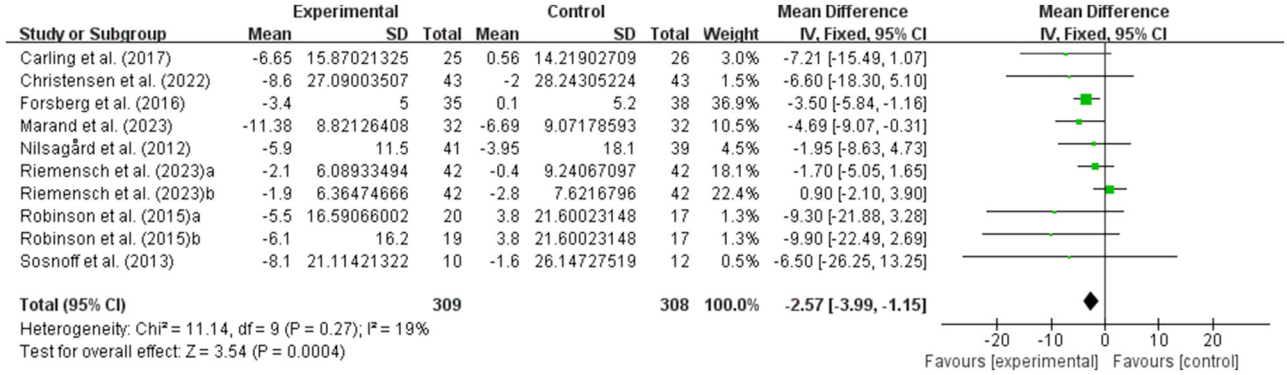


FIGURE 4
Meta-analysis results of the effects of exercise on walking ability in people with MS. Exercise had a significant effect on improving walking ability in people with MS ($P = 0.0004$).

## Discussion

In this systematic review and meta-analysis, exercise significantly improved balance, walking ability, walking endurance, fatigue, and quality of life in people with MS. Subgroup analyses showed that a younger age was associated with larger improvement in fatigue. In addition, resistance exercise and aerobic exercise were the most effective interventions for improving fatigue and quality of life, respectively.

Loss of balance and walking ability are two of the primary impairments of MS that leads to increased fatigue perception and disease severity, and loss of autonomy (13). Imbalance, gait dysfunction and falls are common in people with MS, with the overwhelming majority having abnormal postural control and gait even early in the course of the disease. It has been reported that 50–80% people with MS have balance and gait dysfunction and over 50% fall at least once each year (64). Exercise has been shown to improve physical function and psychological rehabilitation in people with MS, and to help reduce the risk of falls (65, 66). Our study showed that exercise significantly improved balance function (TUG and BBS) in people with MS, which was consistent with a previous study (13), showing that the combination of resistance and aerobic exercise training is effective in improving balance in people with MS and supports functional and psychological

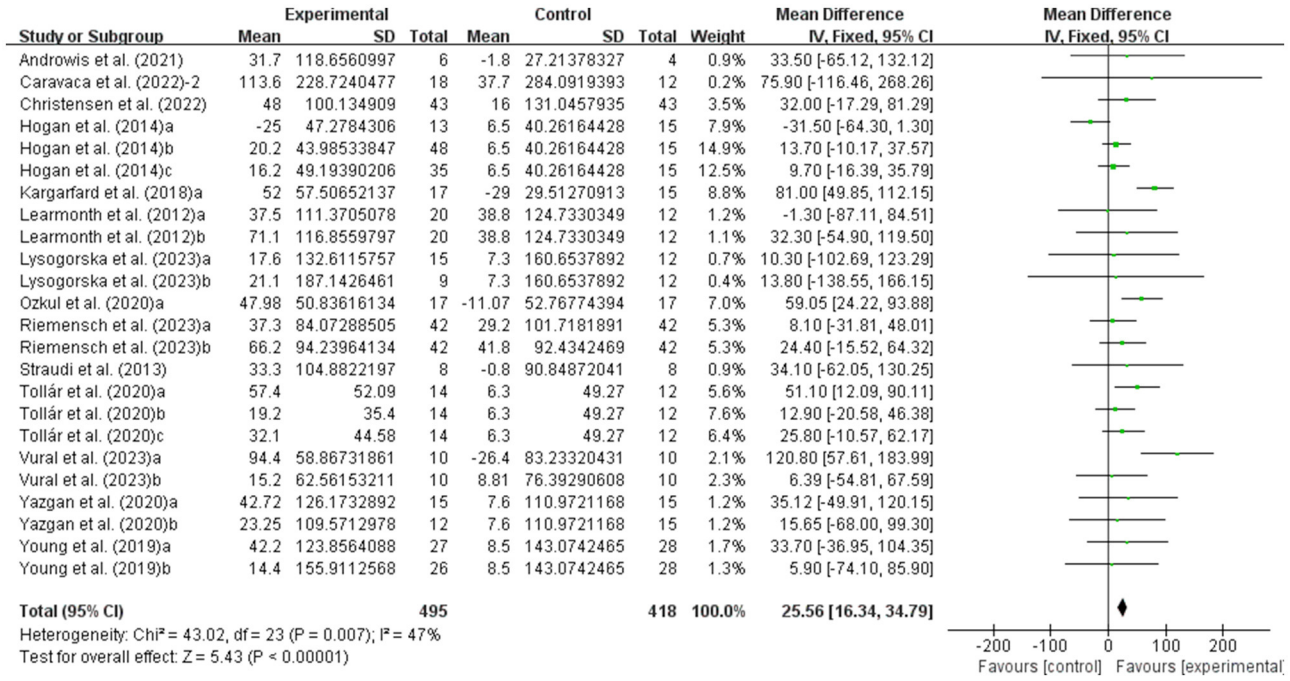


FIGURE 5
Meta-analysis results of the effects of exercise on walking endurance in people with MS. Exercise had a significant effect on improving walking endurance in people with MS ($P < 0.00001$).

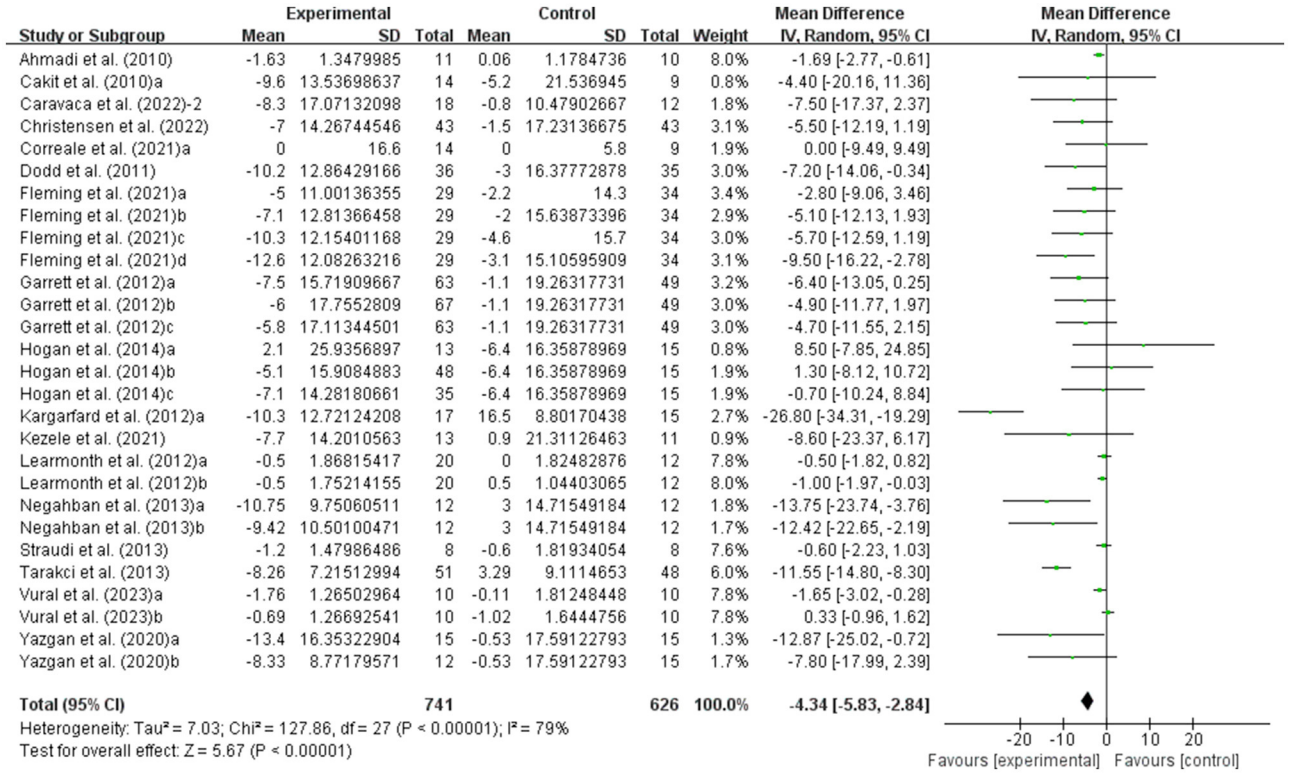


FIGURE 6
Results of the effects of exercise on fatigue in people with MS. Exercise had a significant effect on improving fatigue in people with MS ($P < 0.00001$).

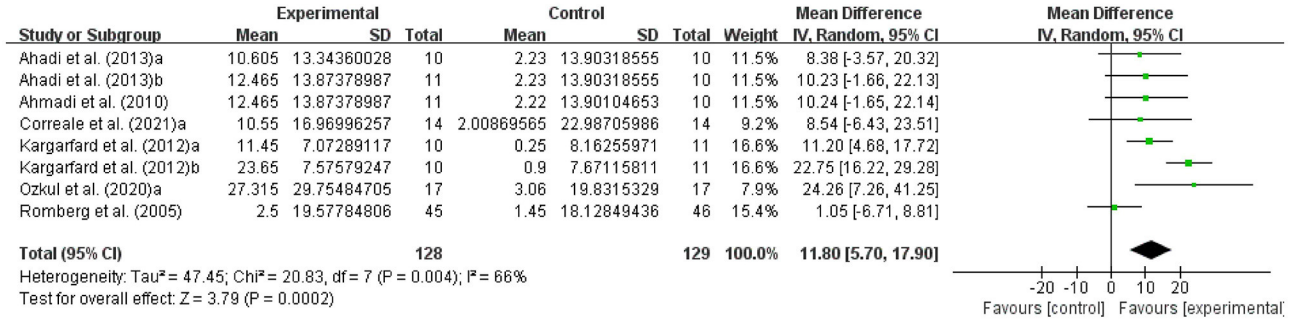


FIGURE 7
Results of the effects of exercise on quality of life in people with MS. Exercise had a significant effect on improving quality of life in people with MS ($P = 0.0002$).

therapeutic effects through exercise. In addition, a meta-analysis showed that yoga was the best intervention to improve static and dynamic balance, and aquatic training was the best intervention to improve walking ability in people with MS (67). The mechanisms by which exercise improves balance may be that exercise improves neurological control of muscles, increases unconscious deliberate muscle responses to dynamic joint stabilization signals, and enhances core area muscle strength to strengthen body stability.

Our results showed that exercise significantly improved walking ability (MSWS-12) and walking endurance (6MWT) in people with MS, which was in agreement with previous studies, showing that aerobic exercise, aquatic exercise, virtual reality training, and assisted gait training significantly improved walking ability (67–69), as well as that Pilates, aerobic exercise, resistance exercise, high-intensity training, and intermittent walking training significantly improved walking endurance in people with MS (28, 68, 70–72). Furthermore, fast-velocity concentric resistance training may have a greater effect on walking endurance with greater neural adaptations in a shorter period of time (28). A meta-analysis showed that walking training programs significantly improved functional ability (mobility, walking endurance, and gait speed), possibly due to improved walking economy (68). The mechanisms by which exercise improves walking ability and walking endurance in people with MS may be improvements in maximal oxygen uptake, muscular strength, and fitness. The increase in muscle strength is due to improved firing and synchronization of motor units and improved synergistic coordination of agonists and antagonists (73). Moreover, another mechanism may be increased bilateral symmetry, which reduces the amount of time the lower limbs are supported on the ground (74).

Early fatigue in people with MS presents with common symptoms such as decreased endurance and muscle strength (75). Statistically, fatigue affects approximately two-thirds of people with MS (76). Current evidence suggests that pharmacological interventions are largely ineffective and that exercise significantly reduces fatigue in people with MS (77, 78). Our results showed that exercise significantly improved fatigue in people with MS, which was consistent with the results of Taul-Madsen et al. (79), showing that aerobic exercise is effective in reducing perceived fatigue in people with MS. The mechanism by which exercise improves fatigue may be an improvement in cardiorespiratory fitness, which increases available energy reserve and reduces fatigue. In addition, exercise may induce upregulation of neuroendocrine growth factor secretion, which increases neuronal plasticity and thus may improve compensatory cortical activation (80, 81). Furthermore, exercise-induced upregulation of anti-inflammatory cytokines may have beneficial effects on fatigue (82–84).

Resistance exercise has been reported to be an effective intervention to ameliorate physical and generalized fatigue and result in significant changes in muscle strength and postural stability (85). Subgroup analysis showed that aerobic exercise, resistance exercise, and multicomponent training were effective in improving fatigue in people with MS, with resistance exercise being the most effective intervention type, which may be due to the fact that resistance exercise is well-tolerated in people with MS, restores the ability to respond quickly to stimuli, and improves autonomy when walking (13). Previous studies have shown that motor and cognitive function deteriorate with age in adult people with MS and that older people with MS exhibit worse cognitive performance (86–89). Therefore, we conducted a subgroup analysis based on the participants' age and the results showed that a younger age was associated with larger improvement in fatigue. Horton et al. (90) showed that with age, people with MS develop a sedentary lifestyle, which increases the risk of secondary disease. Although exercise is an effective therapy, dyskinesia is common in older adult patients. Increased fatigue is a severe barrier when exercise energy expenditure is relatively high, and older patients can lose confidence in their ability to exercise and may feel at risk of injury, especially when exercise equipment is involved (91–94).

In addition, exercise significantly improved the quality of life in people with MS, which was consistent with a previous study, showing that exercise seems to be the most effective way to improve the quality of life in people with MS by increasing strength and balance, thereby reducing the risk of falls (94). Previous studies have shown that multicomponent training is well-tolerated and can effective in improving the quality of life in people with MS (13), and that group exercise is an effective intervention for people with MS to cope with fatigue, with the Baduanjin playing a more prominent role in improving the quality of life through respiration and psychology (46). Improvements in quality of life may be related to exercise-induced increases in fitness, mobility, balance, muscle strength, and sleep quality (53, 95). Subgroup analysis showed

that aerobic exercise and multicomponent training were effective in improving quality of life, with aerobic exercise being the most effective intervention type, which was in agreement with previous studies, showing that aerobic exercise increases aerobic capacity and improves physical and mental health, thereby enhancing functional independence and fatigue resistance in people with MS (96). In addition, aerobic exercise may stimulate the activity of the sympathetic nervous system and activate the activity of the parasympathetic nervous system, which leads to the release of acetylcholine, resulting in a sedative effect (97).

### Strengths and limitations of this systematic review

In this systematic review and meta-analysis, we included studies on the effect of exercise on balance, walking ability, walking endurance, fatigue, and quality of life in people with MS, and excluded studies where participants in the control group received exercise interventions, which can better reflect the effect of exercise interventions. Our findings provide an alternative treatment strategy for people with MS, clinically recommending engagement in resistance exercise and aerobic exercise, respectively, to alleviate fatigue and enhance quality of life.

However, this study has some limitations that should be noted. First, the heterogeneity between each of the original studies is unavoidable (the proportion of male and female participants from different regions, the age of subjects, etc.), which may affect the scientific validity of the meta-analysis. Second, many of the included studies had small sample sizes, which may have had some impact on the results. Finally, it was not possible to exclude a placebo effect, as blinding could not be performed during the exercise intervention. Future reviews could reduce the heterogeneity between included studies by restricting the inclusion criteria more strictly.

## Conclusion

This meta-analysis revealed that exercise had beneficial effects in improving balance, walking ability, walking endurance, fatigue, and quality of life in people with MS. The effect of exercise on improving fatigue was associated with the age of the participants, with the younger the age, the greater the improvement in fatigue. To improve fatigue and quality of life, this meta-analysis provides clinicians with evidence to recommended that people with MS participate in resistance exercise and aerobic exercise, respectively.

## 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.

## Author contributions

LD: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. HX: Data curation, Formal analysis, Investigation, Methodology, Software, Writing – review & editing. SZ: Data curation, Formal analysis, Investigation, Methodology, Software, Writing – review & editing. YZ: Data curation, Formal analysis, Investigation, Visualization, Writing – review & editing. XT: Data curation, Formal analysis, Investigation, Writing – review & editing. YL: Data curation, Formal analysis, Investigation, Writing – review & editing. XH: Data curation, Funding acquisition, Investigation, Project administration, Resources, Software, Writing – review & editing. LY: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

## Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This study was supported by the National Key R&D Program of China (2022YFC3600201) and the Chinese Universities Scientific Fund (2021QN001 and 2022QN015).

## 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.2024.1387658/full#supplementary-material

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frontiers | Frontiers in Medicine

TYPE Original Research
PUBLISHED 12 April 2024
DOI 10.3389/fmed.2024.1342792



OPEN ACCESS

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RECEIVED 16 December 2023
ACCEPTED 25 March 2024
PUBLISHED 12 April 2024

CITATION
Hou K, Zhang H, Song W, Li S, Liu J and Ma Z (2024) Association between life's essential 8 and periodontitis: a study based on NHANES 2009–2014.
*Front. Med.* 11:1342792.
doi: 10.3389/fmed.2024.1342792



# Association between life's essential 8 and periodontitis: a study based on NHANES 2009–2014

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**Background:** This research aims to investigate the relationship between Life's Essentials 8 (LE8), the American Heart Association's latest indicator, and periodontitis. The purpose is to provide guidance on preventative measures.

**Methods:** Data for our investigation were obtained from the National Health and Nutrition Examination Survey (NHANES) 2009–2014, with a total of 8,784 participants eligible. LE8 scores were compiled from 8 index scores (the score for each component of diet, physical activity, nicotine exposure, sleep duration, body mass index, blood lipids, blood glucose, and blood pressure). Periodontitis was classified by the Centers for Disease Control and Prevention and American Academy of Periodontology (CDC/AAP). The study utilized multivariable logistic analyses to investigate the potential correlation.

**Results:** After controlling for all covariates, LE8 was discovered to have a significant negative correlation with periodontitis prevalence [0.91 (0.88, 0.94)]. This trend continued to hold statistical significance even after converting LE8 into a categorical variable. Furthermore, a noteworthy adverse correlation was discovered across both genders, specifically males [0.35 (0.22, 0.55)] and females [0.39 (0.25, 0.60)], as well as for the majority of categorical classifications, namely ethnicity, age, education level, and marital status. However, only the age subgroups displayed some degree of significant difference from each other.

**Conclusion:** Life's essential 8 was negatively associated with periodontitis, but more prospective trails are needed to confirm our findings.

KEYWORDS

**periodontitis, life's essential 8, NHANES, epidemiology, risk factor(s)**

## 1 Introduction

Periodontitis is a chronic inflammatory disease that damages the supporting tissue of the teeth, leading to the pathological resorption of the alveolar bone around the teeth, recession of the gingival tissues, and even loss of the teeth (1, 2). This condition poses a public health concern, impacting the oral and overall health of individuals across the world (3).

Matlila 's report represented the first reference to the relationship between oral infection and acute myocardial infarction (4). Subsequent research has shown that periodontitis not only affects systemic diseases but can also be influenced by them (5). Diseases such as cardiovascular disease trigger an immune response in the host, and the resulting metabolic dysfunction can cause chronic metabolic inflammatory disease. This, as one of the risk factors for periodontitis, can increase its morbidity (6, 7). Both periodontitis and cardiovascular disease are multifactorial conditions triggered by genetic, environmental, and lifestyle habits. Common risk factors for both diseases include increasing age, smoking, alcohol misuse, ethnicity, education and socioeconomic status, male gender, diabetes, and obesity. Several cross-sectional studies, case analyses, and epidemiological investigations indicate a significant correlation between chronic periodontitis and cardiovascular disease (8–11).

In 2010, the American Heart Association (AHA) defined "ideal cardiovascular health" as the presence of seven factors and behaviors that increase the chances of living a life free of cardiovascular disease and stroke (12). These seven factors and behaviors, including diet, physical activity, smoking, body mass index, total cholesterol, blood pressure, and blood glucose are known as "life's simple 7 (LS7)," and are considered to be the core elements of building a healthier life (12). Studies have consistently demonstrated that higher LS7 scores are associated with greater cardiovascular health and reduced all-cause mortality in various populations (13–15). In 2022, the American Heart Association (AHA) established the Life's Essential 8 (LE8) score, building upon the LS7 framework by introducing sleep as a novel cardiovascular health (CVH) determinant. According to the AHA, Life's Essential 8 serves as a pivotal indicator for enhancing and preserving CVH, which can lower the incidence of heart disease, stroke, and other significant medical conditions (16–18). However, studies have not yet existed that have explored the relationship between LE8 and the incidence of periodontitis.

Hence, this study's primary goal was to investigate this relationship, using nationally representative data from the National Health and Nutrition Examination Survey (NHANES).

# 2 Methods

## 2.1 Study population

The research data for this study were obtained from the NHANES survey from 2009–2014. NHANES is a population-based survey designed to collect health and nutritional information on the household population in the U.S.A (19). All participants provided written informed consent to conduct all survey procedures by relevant guidelines and standards.[1] Over the 6 years of data from 2009–2014, as shown in Figure 1, a total of 8,784 respondents were finally included in the analysis of the study, with the following inclusion criteria: 18 years of age or older; having complete baseline information on the population; having received the NHANES "Oral Health-Periodontal Examination" and having recorded all measurements as required by the periodontal classification algorithm; and having the eight indicators as are necessary for a complete LE8.

1 https://www.cdc.gov/nchs/data_access/restrictions.htm

## 2.2 Assessment of LE8

The LE8 metrics comprised four health behaviors and four health factors, namely diet, physical activity, nicotine exposure, sleep health, body mass index (BMI), non-high-density lipoprotein (HDL) cholesterol, blood glucose, and blood pressure (BP). These factors were evaluated as shown in Supplementary Table S1, where the HEI-2015 (The Healthy Eating Index-2015) was used to assess dietary levels on a scale from 0–100. Higher HEI scores indicated better diet quality (20). Day 1 total nutrient intake (DR1TOT) from NHANES was employed to compute the 13 elements of the HEI-2015 (21). Supplementary Table S2 provides specific guidance on how to calculate HEI-2015. The remaining 7 components can be derived directly from NHANES. LE8 scores were classified as low (0–49), moderate (50–79), or high (≥80) (15, 22).

## 2.3 Assessment of periodontitis

The program titled "Oral Health - Periodontal Screening" under the NHANES 2009–2014 performs measurements in six regions of every tooth with a maximum of 28 teeth. It contains two sets of clinical periodontal measurements - clinical attachment loss (CAL) and probing depth (PD). The periodontitis classification system was established based on case definitions from the Centers for Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP). Severe periodontitis was determined by the presence of ≥2 interproximal areas with a CAL of ≥6 mm that were not on the same tooth and the presence of ≥1 interproximal area with a PD of ≥5 mm. Moderate periodontitis was defined as the presence of two or more interproximal sites with a probing pocket depth exceeding or equal to 5 mm, not located on the same tooth, or two or more interproximal sites with clinical attachment level exceeding or equal to 4 mm, not found on the same tooth, as previously established (23, 24). Moderate/severe periodontitis cases were identified as patients with periodontitis, while all other cases (no/mild periodontitis) were classified as the reference group (24, 25).

## 2.4 Treatment of covariates

Covariates included age (<40, 40–60, >60), gender (male, female), race (Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, different race/including multiracial), marital status (divorced/separated/married, married/cohabiting with a partner, never married), poverty-to-income ratio (categorized as low-income <1. 3, moderate-income 1.3–3.5, high income ≥3.5) (26), and educational attainment (less than high school, high school, some college or above).

## 2.5 Statistical analyze

All analyses were performed using R (version 4.2) and Empowerstats (version 5.0) (27, 28), and all statistical analyses were weighted according to the NHANES guidelines. Participants with high LE8 scores were considered to have LE8 scores of 80–100, moderate LE8 scores of 50 ~ 79, and low LE8 scores of 0 ~ 49 (16). We used

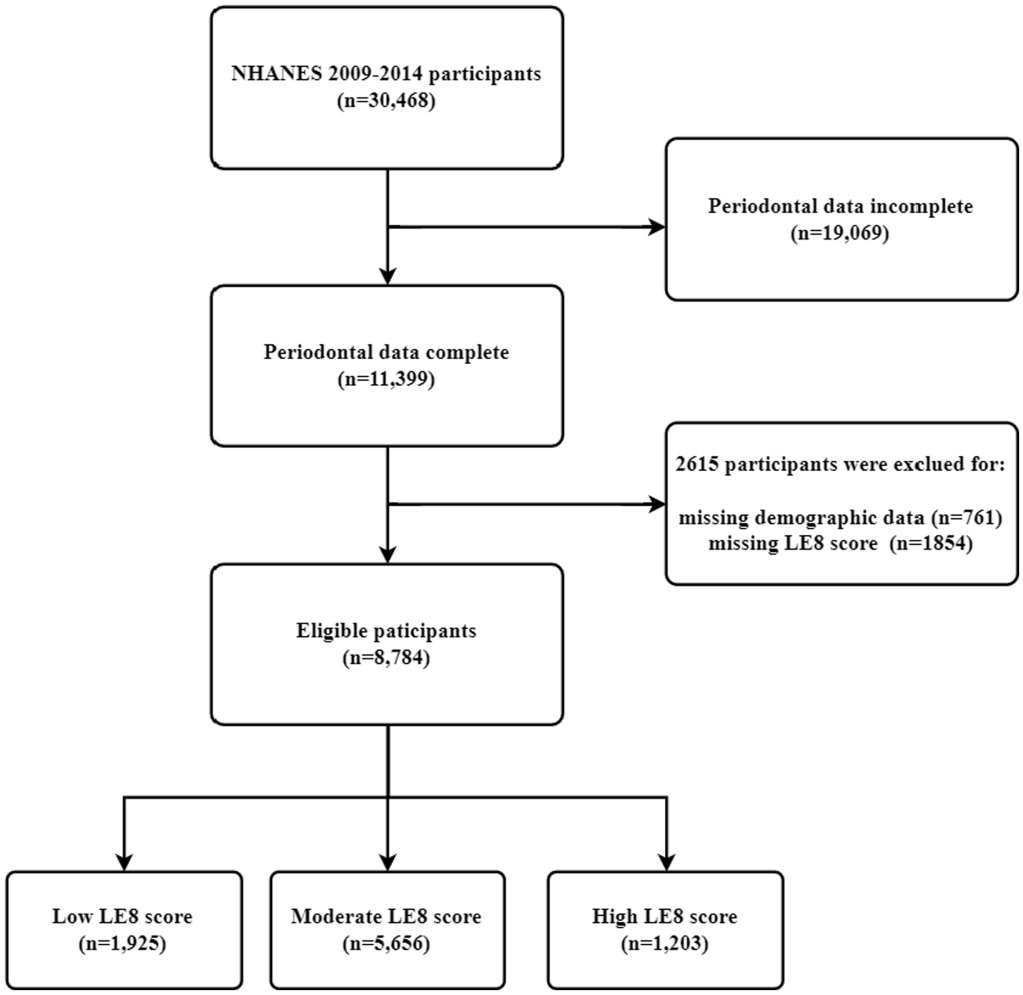


FIGURE 1
Study population selection ($N$ = 8,784). NHANES, National Health and Nutrition Examination Survey; LE8, Life's Essential 8.

chi-square tests and t-tests for LE8 trichotomous tests to assess demographic characteristics. To investigate the correlation between LE8 and periodontitis, we conducted a series of multiple linear regression analyses, examining the relationship between LE8 scores (per 10 points) and the prevalence of periodontitis. Finally, we conducted subgroup analyses to determine any differences in the above correlations based on gender, age, race, income, education, and marital status.

# 3 Results

## 3.1 Baseline characteristics

A study comprising 8,784 participants with an average age of 51.65 years was conducted, with 50.59% of the sample being male, as displayed in Table 1. The population prevalence of periodontitis was 49.44%. The LE8 scores were classified into low, medium, and high groups (0–49, 50–79, and 80–100) in agreement with the requirements prescribed by AHA. Overall, the prevalence of moderate to severe periodontitis was 49.44%. This decreased consistently with increasing LE8 group scores: 58.56% for the low group, 49.68% for the medium, and 33.25% for the high ($p < 0.001$). Moreover, higher LE8 scores were associated with a higher likelihood of being female, having higher education and income levels, and displaying significant differences in race and marital status.

## 3.2 The association between LE8 and periodontitis

The relationship between LE8 and periodontitis is presented in Table 2. It was found that LE8 scores had a negative association with the prevalence of periodontitis in all models. In the unadjusted model 1, the prevalence of periodontitis in the high LE8 group was 0.35 (95% confidence interval, 0.3, 0.4). In Model 3, after controlling for all covariates, including age, gender, race, income, marital status, and education level, the study revealed that the risk of periodontitis was reduced by 0.09% for every increase of 10 points in the LE8 score. In the high LE8 group, the risk decreases by 0.3%, and the results are statistically significant. Figure 2 illustrates the non-linear correlation between LE8 and periodontitis.

TABLE 1 Participants' Characteristics by LE8 Score.

| LE8 score | Total (*n* = 8,784) | Low (*n* = 1,925) | Moderate (*n* = 5,656) | High (*n* = 1,203) | *p* value |
|---|---|---|---|---|---|
| Age (years) | 51.65 ± 13.34 | 54.17 ± 12.59 | 51.89 ± 13.50 | 46.50 ± 12.35 | <0.001 |
| *Gender, n* (%) | | | | | <0.001 |
| Male | 4,444(50.59%) | 1,005(52.21%) | 2,952 (52.19%) | 487 (40.48%) | |
| Female | 4,340(49.41%) | 920 (47.79%) | 2,704 (47.81%) | 716 (59.52%) | |
| *Race, n* (%) | | | | | <0.001 |
| Mexican American | 1,220(13.89%) | 266(13.82%) | 844 (14.92%) | 110 (9.14%) | |
| Other Hispanic | 841 (9.57%) | 166 (8.62%) | 574(10.15%) | 101(8.40%) | |
| Non-Hispanic White | 3,957(45.05%) | 846(43.95%) | 2,471(43.69%) | 640 (53.20%) | |
| Non-Hispanic Black | 1824(20.77%) | 551(28.62%) | 1,168(20.65%) | 105(8.73%) | |
| Other Race/Including Multi-Racial | 942 (10.72%) | 96 (4.99%) | 599(10.59%) | 247(20.53%) | |
| *Marital status, n* (%) | | | | | <0.001 |
| Divorced/Separated/ Widowed | 2,103(23.94%) | 573(29.77%) | 1,362(24.08%) | 168 (13.96%) | |
| Married/Living with a partner | 5,671(64.56%) | 1,124(58.39%) | 3,648(64.50%) | 899(74.73%) | |
| Never married | 1,010(11.50%) | 228(11.84%) | 646 (11.42%) | 136 (11.31%) | |
| *Education level, n* (%) | | | | | <0.001 |
| Less than high school | 2062(23.47%) | 689 (35.79%) | 1,292 (22.84%) | 81 (6.73%) | |
| High school | 1941(22.10%) | 542 (28.16%) | 1,285 (22.72%) | 114 (9.48%) | |
| Some college or above | 4,781(54.43%) | 694 (36.05%) | 3,079 (54.44%) | 1,008 (83.79%) | |
| Poverty-to-income ratio | 2.61 ± 1.66 | 1.95 ± 1.44 | 2.62 ± 1.64 | 3.62 ± 1.56 | <0.001 |
| *Periodontitis (%)* | | | | | |
| Moderate /Severe | 4,343(49.44%) | 1,133 (58.86%) | 2,810 (49.68%) | 400 (33.25%) | |
| None/mild | 4,441(50.56%) | 792 (41.14%) | 2,846 (50.32%) | 803 (66.75%) | |
| *LE8 score* | 62.23 ± 15.27 | 41.57 ± 6.46 | 64.08 ± 8.22 | 86.59 ± 5.06 | <0.001 |
| Health behaviors score | | | | | <0.001 |
| HEI-2015 diet score | 45.81 ± 32.38 | 26.16 ± 26.23 | 46.88 ± 31.13 | 72.24 ± 26.03 | |
| Physical activity score | 43.29 ± 46.59 | 9.88 ± 27.17 | 45.02 ± 46.40 | 88.65 ± 26.31 | |
| Nicotine exposure score | 69.52 ± 36.7 | 46.35 ± 38.95 | 72.71 ± 34.88 | 91.60 ± 18.12 | |
| Sleep health score | 79.89 ± 26.18 | 65.42 ± 30.84 | 82.28 ± 24.12 | 91.82 ± 15.55 | |
| *Health factors score* | | | | | <0.001 |
| Body mass index score | 57.63 ± 33.55 | 36.12 ± 30.90 | 59.05 ± 31.77 | 85.32 ± 20.75 | |
| Blood lipids score | 60.96 ± 30.57 | 45.76 ± 30.04 | 62.03 ± 29.24 | 80.25 ± 24.74 | |
| Blood glucose score | 78.14 ± 27.44 | 59.61 ± 30.09 | 80.68 ± 25.26 | 95.86 ± 12.47 | |
| Blood pressure score | 62.57 ± 32.27 | 43.27 ± 30.21 | 63.94 ± 30.82 | 86.97 ± 21.78 | |

LE8: life's essential 8; HEI: healthy eating index; Data were presented as weighted percentages or means (95% confidence intervals); A low score was defined as a LE8 score of 0 to 49, a moderate score of 50–79, and a high score of 80–100.

## 3.3 Subgroup analyses by potential effect modifiers

We conducted subgroup analyses of each covariate to determine potential effect factors. To illustrate the correlation between the two variables, we analyzed the association between LE8 score(per 10 points)and periodontitis. Table 3 presents results indicating age altering the association between LE8 scores and periodontitis. While several factors, including gender, race, income, education level, and marital status, had statistically significant effects within subgroups,

TABLE 2 Association between LE8 and periodontitis.

| LE8 | Model 1 OR(95%CI) *p* value | Model 2 OR(95%CI) *p* value | Model 3 OR(95%CI) *p* value |
|---|---|---|---|
| Life's Essential 8 (per 10 points) | 0.79 (0.77, 0.82) <0.0001 | 0.84 (0.82, 0.87) <0.0001 | 0.91 (0.88, 0.94) <0.0001 |
| *LE8 classification* | | | |
| Low (0–49) | Ref | Ref | Ref |
| Moderate (50–79) | 0.69 (0.62, 0.77) <0.0001 | 0.72 (0.64, 0.80) <0.0001 | 0.84 (0.75, 0.94) 0.0018 |
| High (80–100) | 0.35 (0.30, 0.40) <0.0001 | 0.48 (0.41, 0.57) <0.0001 | 0.70 (0.59, 0.82) <0.0001 |
| *P* for trend | <0.0001 | <0.0001 | <0.0001 |

Model 1 adjust for: None; Model 2 adjusts for Age; Gender, Race; Model 3 adjusts for Age, Gender, Race, PIR, Marital Status, and Education Level.

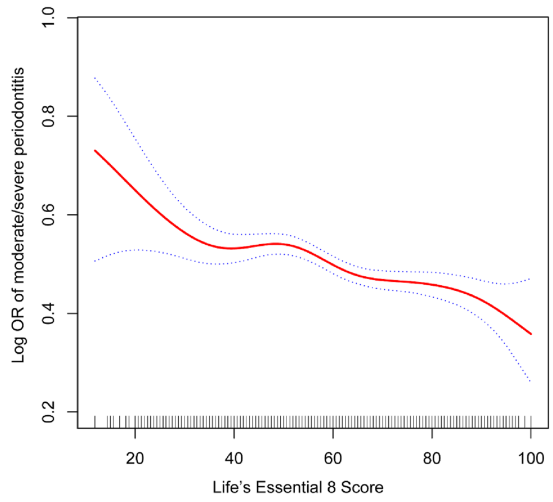


FIGURE 2
The association between life's essential 8 and periodontitis. The solid red line represents the smooth curve fit between variables. Blue bands represent the 95% confidence interval from the fit.

they did not modify the correlation between LE8 and periodontitis between subgroups.

## 4 Discussion

In this cross-sectional study of large-scale, population-based survey data, we identified a negative association between LE8 scores and periodontitis. The negative association between LE8 scores and periodontitis was more significant in participants aged 40–60, according to subgroup analyses. As LE8 is a recent improvement for assessing cardiovascular health, the current report enhances the considerable evidence of an association between cardiovascular health and periodontitis (16). Improving LE8 scores may offer clinical benefits as a viable and effective means to promote periodontal well-being.

Cardiovascular health is a broader, more positive concept than simply the lack of illness. To measure cardiovascular health, the American Heart Association established LS7 and LE8 in 2010 and 2022 as tools for defining and quantifying cardiovascular health (16). The most recent LE8 employs a combination of two domains and eight metrics to determine one's cardiovascular health. These metrics cover various health behaviors, including physical activity, diet, sleep health, and nicotine exposure, alongside health factors like blood pressure, blood glucose, blood lipids, and BMI.

A large number of studies have reported significant associations between most of the health factors and health behavior indicators in LS7 or LE8 and periodontitis individually, such as blood glucose (29), blood pressure (30), lipids (31), BMI (32), nicotine exposure (32, 33), and diet (34). However, to our knowledge, no study has evaluated the association between LS7 or LE8 as independent factors and periodontitis.

Healthy behaviors, such as a balanced diet and reduced nicotine exposure, can potentially prevent periodontitis. A cross-sectional study examining data from the US NHANES between 2009 and 2014 found that most identified dietary patterns were not correlated with periodontitis severity. However, a diet comprising mainly salads, fruits and vegetables, and plain water or tea was associated with reduced levels of CAL (34). Further data from the Hamburg City Health Study (HCHS), which examined 6,209 participants, indicated a noteworthy correlation between increased adherence to both the DASH diet and the Mediterranean diet and reduced likelihood of periodontal disease. It is essential to note that the Mediterranean Eating Pattern for Americans (MEPA) tool and the Healthy Eating Index scores-2015 (HEI-2015) in the LE8 scores can determine dietary healthiness. However, it is imperative to understand that these metrics do not assess the healthiness of all dietary patterns of individuals or populations (16). Nicotine exposure is described as using combustible tobacco, inhaling nicotine-delivery systems (NDS), or being exposed to secondhand smoke (16). A 2018 systematic review and meta-regression analysis reported an 85% increase in the risk of periodontitis due to cigarette smoking (35). Another study based on Mendelian randomization found a robust and reliable association between genetic predisposition to smoking and periodontitis (32). Exposure to environmental tobacco smoke has been positively linked to periodontitis endpoints, as demonstrated by prior research (33).

Interestingly, the risk of developing or progressing periodontitis in ex-smokers was not significantly different from that in never-smokers. The precise molecular mechanisms responsible for the negative correlation between smoking and periodontal tissue health are not fully understood (36). Still, current research suggests that it may be linked to smoking or nicotine exposure disrupting inflammation and the host's response to periodontal pathogens, alterations to the subgingival microbial community, and hindered tissue healing potential (37).

Health factors such as good body mass index, lipids, blood glucose, and blood pressure contribute to maintaining periodontal health. In 2021, the results of a systematic total and meta-analysis based on a cohort study by Stöhr et al. (38) showed that there is a bi-directional positive correlation between periodontal disease and diabetes mellitus, i.e., diabetes mellitus increases the risk of

TABLE 3 Subgroup analyses by potential effect modifiers.

| | LE8 (per 10 points) | P for interaction |
|---|---|---|
| *Gender* | | 0.7235 |
| Male | 0.35 (0.22, 0.55) | |
| Female | 0.39 (0.25, 0.60) | |
| *Age* | | 0.0004 |
| <40 | 0.88 (0.82, 0.95) | |
| 40–60 | 0.86 (0.82, 0.90) | |
| >60 | 1.02 (0.97, 1.09) | |
| *Race* | | 0.7546 |
| Mexican American | 0.87 (0.79, 0.96) | |
| Other Hispanic | 0.96 (0.86, 1.07) | |
| Non-Hispanic White | 0.89 (0.85, 0.94) | |
| Non-Hispanic Black | 0.89 (0.83, 0.95) | |
| Other Race/Including Multi-Racial | 0.90 (0.81, 1.00) | |
| *Poverty-to-income ratio* | | 0.3296 |
| <1.3 | 0.93 (0.87, 0.98) | |
| 1.3–3.5 | 0.89 (0.84, 0.94) | |
| >3.5 | 0.89 (0.84, 0.94) | |
| *Education level* | | 0.2825 |
| Less than high school | 0.92 (0.86, 0.99) | |
| High school | 0.92 (0.86, 0.98) | |
| Some college or above | 0.88 (0.85, 0.92) | |
| *Marital status* | | 0.6032 |
| Divorced/Separated/Widowed | 0.90 (0.84, 0.96) | |
| Married/Living with a partner | 0.91 (0.88, 0.95) | |
| Never married | 0.89 (0.82, 0.98) | |

*Each stratification was adjusted for age (continuous), sex (male, female), race (Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Other Race/Including Multi-Racial), marital status (divorced/separated/widowed, married/living with a partner, and never married), poverty income ratio (classified as low income<1.3, middle income 1.3–3.5, and high income≥3.5), educational level (less than high school, 9–11th grade, high school, some college or above, ≥college graduate) except the stratification factor itself.

periodontitis, and periodontal inflammation negatively affects blood glucose control. The association between diabetes and periodontal disease is underpinned by various factors, including hyperglycemia, genetic, microbial, and lifestyle co-predisposing factors, which culminate in advanced glycosylation end products (39). Additionally, poorly controlled diabetes can lead to elevated levels of IL1-β, TNF-α, IL-6, RANKL/OPG, and oxygen metabolites in the gingiva, which can contribute to the destruction of periodontal tissues (40). In addition, associations between obesity, hypertension, and dyslipidemia have also been reported with periodontal diseases (31, 41–44). On the other hand, improvement in systemic blood pressure and lipid levels is expected with periodontal treatment (30, 31).

The study discovered a link between LE8 (a marker of cardiovascular health) and periodontal health outcomes. This confirms previous research linking periodontitis and cardiovascular disease (45). Patients with periodontitis have an elevated risk of developing coronary heart disease and atherosclerosis (46–48). Effective periodontal care can significantly decrease the likelihood of experiencing cardiovascular events, including cardiac death and myocardial infarction, according to a report (49). The correlation between periodontitis and cardiovascular disease may be linked to bacteremia caused by the entry of periodontal pathogenic bacteria into the vascular system, an increase in the systemic inflammatory response due to periodontitis, genetic factors, and environmental risk factors (47).

Our research expands on the LE8, a clinical cardiovascular health assessment tool that is comprehensive and easy to use to indicate periodontal health outcomes. Adherence to the ideal Lifestyle Index 8 could be suitable for preventing and managing periodontal disease and cardiovascular health.

Our study has several strengths. First, NHANES utilizes a complex multistage probability sampling design that draws a representative noninstitutionalized resident population to ensure higher data quality. As a result, extrapolating the results to the entire U.S. civilian noninstitutional population is highly reliable. Second, we investigated for the first time the association between a new indicator, LE8, and periodontitis, which increases the feasibility of self-determination of periodontitis risk by people in their daily lives, increasing periodontitis prevention awareness and decreasing morbidity.

However, there are several limitations to the present study. Firstly, it is limited due to the cross-sectional nature of NHANES, which precludes the inference of causality and necessitates support from numerous future prospective studies. Secondly, data on health behaviors such as diet, exercise, sleep, and smoking are self-reported and may be prone to recall bias. Lastly, there are some unmeasured influences, and the experimental data may have errors.

## 5 Conclusion

In summary, the proposed LE8 index by the American Heart Association revealed a negative correlation with the risk of periodontitis. Furthermore, the association was stronger in participants aged between 40 and 60 years, and LE8 exhibited a nonlinear correlation with the incidence of periodontitis. These findings imply that improving the LE8 index could be an effective measure for the tertiary prevention of periodontitis.

## 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 author.

## Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements.

Written informed consent to participate in this study was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and the institutional requirements.

## Author contributions

KH: Writing – original draft. HZ: Data curation, Writing – review & editing. WS: Software, Writing – original draft. SL: Investigation, Writing – review & editing. JL: Methodology, Writing – original draft. ZM: Writing – review & editing.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This research was funded by Capital Health Development Research Program, Award number: SF-2022-4-7101 and Beijing Shunyi District Research and Development Program, Award Number: Shunyi2023Q06.

## 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.

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## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2024.1342792/full#supplementary-material

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PUBLISHED 23 April 2024
DOI 10.3389/fpubh.2024.1271409



OPEN ACCESS

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RECEIVED 02 August 2023
ACCEPTED 08 April 2024
PUBLISHED 23 April 2024

CITATION
Shi HY and Zhang YR (2024) Development and validation of Chinese compensatory health beliefs scale.
*Front. Public Health* 12:1271409.
10.3389/fpubh.2024.1271409



# Development and validation of Chinese compensatory health beliefs scale

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Compensatory Health Beliefs (CHBs), the notion that healthy behaviors can offset the negative effects of unhealthy actions, have been widely explored in Western contexts. Yet, their relevance within the Chinese cultural milieu remains underexplored. The primary objective of this research was to develop and validate a Chinese version of the CHBs scale (CHBs-C), addressing the gap in the literature regarding the applicability of CHBs within the Chinese cultural context. A multi-stage translation (from English to Chinese) was first completed, and exploratory factor analysis was conducted ($n$ = 476), yielding the 14-item scale (CHBs-C scale). Confirmatory factor analysis was conducted to assess the validity, and the 2-week test–retest reliability, internal consistency and convergent validity of the scale were also assessed ($n$ = 308). Predict validity was verified through testing the relationships between CHBs and health behaviors and habits ($n$ = 274). Factor analysis showed a different factor structure in Chinese context, with only one factor identical to the original version. The fitness index of the new factor structure was good. However, while the scale exhibited acceptable internal consistency and high test–retest reliability, its convergent validity and predictive validity was found to be limited on a general level. Despite this, significant correlations at the subscale level were identified, highlighting nuanced interactions between CHBs and specific health behaviors within the Chinese population. This study not only establishes the CHBs-C scale as a valid and reliable instrument for assessing compensatory health beliefs in China but also lays the groundwork for further exploration of its applications and the potential cultural adaptability of CHBs.

KEYWORDS

**compensatory health beliefs, scale validation, Chinese cultural context, factor analysis, cross-cultural adaptation**

## Introduction

Compensatory Health Beliefs (CHBs) are defined as the notion that the negative consequences of unhealthy behaviors—especially those offering immediate gratification—can be offset by engaging in healthy activities (1, 2). A classic example of this mindset is thinking, "I can have a piece of cake now because I plan to exercise later." Research has shown that in the context of preventing chronic diseases like cardiovascular disease and obesity, which are linked to unhealthy habits, individuals harboring CHBs tend to engage in compensatory health behaviors (3, 4). However, the appeal of CHBs may also lead some individuals to abandon healthy routines in favor of indulgent, unhealthy behaviors (4–8).

Rabiau et al. have proposed a theoretical model to explain CHBs, which can not only explain why people hold CHBs, but also predict people's behavioral decisions when there is a

conflict between emotional states (such as desire) and motivations (i.e., health goals) (2). According to the CHBs model, individuals confronted with such conflicts might adopt one of three strategies: resisting the temptation, altering their perception of risk or expected outcomes, or activating CHBs. Engaging in CHBs allows individuals to succumb to immediate desires while planning to counteract the negative effects later, essentially rationalizing their unhealthy choices as temporarily acceptable. Although the original purpose of CHBs theory is to further improve the intention of health compensation behavior and promote the appearance of health behavior by guiding the public's CHBs, the actual occurrence of compensation behavior is still full of great uncertainty.

In recent years, the 'Healthy China 2030 Strategy' has underscored the importance of health in China, a focus further intensified by the COVID-19 pandemic in 2020. Despite this, the constant presence of temptations in daily life has sparked a surge in CHBs, particularly among China's post-90s generation, who are addicted to 'punk health maintenance'. For them, 'going to the gym only after overeating', 'having beer with wolfberry and cola with codonoposis', etc. seem to become a fashion trend. Faced with this phenomenon, the strategy of promoting public health by arousing CHBs and encouraging compensatory behavior has been questioned.

Addressing these concerns, scholars have conducted extensive empirical research, including the development and validation of CHBs scales and their specific subscales (1, 9–12). Most of these studies have utilized the CHBs scale developed by Knäuper et al. (1). According to their factor analysis results, Knäuper et al. demonstrated that the CHB construct composed four factors, i.e., (1) substance use, including six items summarizing compensatory behaviors related to drinking, coffee and smoking; (2) sleep/eating habits, including four items reflecting beliefs related to behaviors that can make up for sleep loss, skipping breakfast, and eating freely at dinner; (3) stress, including four items related to behaviors to compensate for the negative effects of stress; (4) weight management, including three items related to behaviors that can compensate for high calorie intake. The Cronbach's α value of the overall CHBs scale was 0.80, and the retest reliability was 0.75 ($n = 141$), indicating that the overall CHBs scale had high stability in a long period of time.

As interest in CHBs grows, researchers have tested the reliability and validity of CHBs subscales and their revised version across various health behaviors such as diet (3, 6, 13, 14), exercise (12, 15), tobacco and alcohol intake (16–18). The existing results showed that the reliability and validity of the CHBs scale and the subscales were good, which could be used to predict the possibility of the occurrence of individual unhealthy behaviors. However, the empirical tests of these scales have mainly focused on European and North American cultural contexts, and the Chinese population has not been discussed in depth. Our study aims to fill this gap by developing a Chinese version of the CHBs scale and assessing its psychometric properties. Unlike prior research that primarily focused on CHBs' behavioral implications, our study contributes to the theoretical understanding by examining the cultural adaptability of CHBs, exploring how cultural nuances influence the manifestation and operationalization of CHBs, thereby enriching the theoretical discourse on health beliefs across diverse cultural landscapes. Firstly, with reference to the English version of CHBs scale, the Chinese version is determined, and factor analysis is carried out in the context of Chinese culture. Then, the reliability and validity of the overall scales and subscales are testified according to the online survey results. Finally, the structural differences between CHBs scale in Chinese cultural background and other cultural background are discussed. This exploration not only broadens the theoretical application of CHBs but also provides a foundational step for future research to explore the intricate dynamics between cultural context and health behavior theories.

# Materials and methods

## Development of Chinese CHBs scale (CHBs-C)

The creation of the CHBs-C was grounded in the original 40-item scale developed by Knäuper et al. (1). The cross-cultural adaptation of the CHBs scale in this study followed the guidelines for the adaptation of health-related items in other contexts and/or cultures proposed by Guillemin et al. (19) and Beaton et al. (20), in addition to the back-translation process. Initially, two PhD students translate independently (one researcher and one non-researcher in the field). Subsequently, seven Chinese scholars and two PhD students from different disciplines (psychology and behavioral decision making) combined the translations into the Chinese CHBs scale. The expert group discussed the draft of the scale, compared each item in the English and Chinese versions, checked whether the word semantics were equivalent, whether the expression or terminology was equivalent, whether the translation was applicable to the Chinese cultural context, and whether there were differences in the meaning between concepts. For example, experts discussed the word *diet*. In both English and Western cultures, the word is mostly used to refer to dieting, or keeping weight under control by consuming fewer calories. But in Chinese context and culture, this word refers not only to dieting, but also to people's daily eating plans or habits. Translation items had been adopted by consensus of the experts. Finally, 10 PhD students in related majors were invited to evaluate the comprehensibility and correctness of each item in CHBs-C scale, and the 40-item CHBs-C scale was determined through communication and discussion with two experts.

## Respondents and procedures

Sample 1 consisted of 476 participants, who were recruited via an online survey service, Credamo.[1] Participants were briefed on the survey's topic before being asked to anonymously complete an electronic questionnaire in April 2021. We conducted an item analysis for scale structure and exploratory factor analysis. Items not adhering to a normal distribution were removed, and the remaining items underwent principal axis factor analysis (PFA), resulting in the initial version of CHBs-C. Subsequently, 308 of these participants (Sample 2) retook the same questionnaire two weeks later to facilitate a confirmatory factor analysis (CFA), thereby finalizing the CHBs-C version. We explored differences in factor structures between the original CHBs and the CHBs-C. Assessments of internal consistency,

1 https://www.credamo.com

test–retest reliability, and both convergent and discriminant validity were conducted to ascertain the scale's stability and reliability. These analytical procedures largely mirrored those used by Knäuper et al. (1) and Kaklamanou and Armitage (10). Furthermore, to further assess the predictive validity of the CHBs-C among the Chinese population, we recruited an additional 274 participants (Sample 3) from the Credamo platform in August 2021, and conducted a correlation analysis.

## Measures

### Compensatory health beliefs scale

CHBs in sample 1 and sample 2 were measured using Knäuper et al.'s original 40-item scale (1). CHBs in sample 3 were measured using the final version of CHBs-C for Chinese adults, which consisted of 14 items (see Table 1 for specific questions). Participants responded to each item based on five-point Likert scales, with one point indicating complete disagreement and five points indicating complete agreement.

### Goal conflict and health motivation

Goal conflict was assessed using Goal Conflict Scale (21), as well as measures concerning the importance of health goals and hedonic goals (1, 22). Measures related to risk perception, health motivation and hedonic motivation were adapted from existing studies (1, 11, 23). All items were assessed on five-point Likert scales.

### Health behaviors and habits

Health behaviors and habits were assessed using measures adapted from Downey and Chang's and Bishop and Yardley's scales (24, 25). Eight items measured about sport and exercise, regular sleep schedule, regular diet, balanced nutrition, work and rest, getting rid of disease-causing habits, relieving stress, good mentality. All items were assessed on five-point Likert scales.

## Statistical analyses

Descriptive statistics were used to describe the sample characteristics and calculate the preference percentages. Firstly, frequency distribution, item discrimination test, inter-item and item-total correlations, and principal axis factor analysis (PAF) was performed, to reduce the number of items and identify the initial version of the CHBs-C. Kruskal–Wallis tests were applied for the comparison of independent mean values, based on whether there was a normal distribution or not. Secondly, a validity assessment was carried out through CFA to confirm the validity of the CHBs-C and finalize its version. Diagonally weighted least square (DWLS) was chosen, because it was confirmed to provide more accurate parameter estimates and more robust fit indices when dealing with non-normality and different data type (26–28). We assessed the model's fit using a three-step process recommended by Kline (29) and Stone (30). The model fit indices utilized encompassed the scaled Chi-square ($\chi^2$), degree of freedom (df), scaled $p$-value, scaled Standardized Root Mean Square Residual (SRMR), number of correlated residuals with an absolute value above 0.10, and number of standardized residuals above 1.96 (29–33). Thirdly, internal consistency reliability was evaluated utilizing McDonald's ω (34, 35), while Spearman correlation analysis was employed to assess the test–retest reliability. Finally, convergence validity was evaluated using the reliability combination (CR) value and average extraction variance (AVE) value, and the square root of AVE and correlation values were used to evaluate the discriminant validity. Predictive validity was

TABLE 1 CHBs-C: item wording and factor loadings ($n$ = 476).

| Factor and items | 1 | 2 | 3 |
|---|---|---|---|
| Factor 1: exercising/eating/sleeping habits | | | |
| 1. Not eating vegetables can be made up for by eating fruits. | **0.482** | 0.099 | −0.147 |
| 2. Exercising during the spring and summer can compensate for not exercising during the winter. | **0.602** | 0.156 | −0.118 |
| 3. Not working out regularly is OK if the person is active in everyday life. | **0.624** | −0.020 | −0.066 |
| 4. Eating sweets is OK because it reduces stress. | **0.439** | 0.019 | 0.207 |
| 5. If one exercises, then one can eat without much restriction. | **0.602** | 0.074 | −0.006 |
| 6. Eating junk food is OK if the person exercises regularly. | **0.637** | 0.071 | −0.014 |
| 7. It is OK to go to bed late if one can sleep longer the next morning (only the number of hours count). | **0.700** | −0.154 | 0.091 |
| 8. Too little sleep during the week can be compensated for by sleeping in on weekends. | **0.444** | −0.003 | 0.176 |
| Factor 2: drinking/smoking | | | |
| 9. The bad effects of smoking and drinking can be reduced by getting a good night's sleep. | 0.010 | **0.556** | 0.110 |
| 10. Red wine counteracts the effects of fatty food. | 0.066 | **0.602** | 0.028 |
| 11. Fresh air counteracts the bad effects of smoking. | 0.042 | **0.651** | −0.047 |
| Factor 3: stress | | | |
| 12. The bad effects of stress can be made up for by exercising. | −0.176 | 0.262 | **0.450** |
| 13. A stressful day can be compensated for by relaxing in front of the TV. | −0.002 | −0.019 | **0.701** |
| 14. Stress during the week can be made up for by relaxing on the weekend. | 0.141 | −0.083 | **0.543** |

Loadings were taken from the pattern matrix. Loadings in bold are values above 0.40.

TABLE 2 Demographic characteristics of participants.

| Variable | | Sample 1 $n = 476$ (%) | Sample 2 $n = 308$ (%) | Sample 3 $n = 274$(%) |
|---|---|---|---|---|
| Gender | Male | 266 (55.9) | 130 (42.2) | 149 (54.4) |
| | Female | 210 (44.1) | 178 (57.8) | 125 (45.6) |
| Age (years) | ≤20 | 16 (3.4) | 10 (3.2) | 8 (2.9) |
| | 21–30 | 223 (46.8) | 142 (46.1) | 152 (55.5) |
| | 31–40 | 198 (41.6) | 128 (41.6) | 101 (36.9) |
| | 41–50 | 30 (6.3) | 22 (7.1) | 10 (3.6) |
| | ≥51 | 9 (1.9) | 6 (1.9) | 3 (1.1) |
| Monthly income (CNY) | ≤2000 | 33 (6.9) | 22 (7.1) | 18 (6.6) |
| | 2001–6,000 | 145 (30.5) | 98 (31.8) | 83 (30.3) |
| | 6,001–10,000 | 181 (38.0) | 120 (39.0) | 87 (31.8) |
| | 10,001–20,000 | 91 (19.1) | 52 (16.9) | 69 (25.2) |
| | ≥20,001 | 26 (5.5) | 16 (5.2) | 17 (6.2) |

*n* indicates the size of the sample.

examined through Spearman's correlation analysis between the CHBs-C and constructs including goal conflict (21), the significance of health goals and hedonic goals (1, 22), risk perception, health motivation, hedonic motivation (1, 11, 23), as well as health behaviors and habits (24, 25).

All data analysis was performed using SPSS 22.0 and R version 4.3.1 software (36).

# Results

## Descriptive statistics

In sample 1, 44.1% of the participants were female (male, $n = 266$; female, $n = 210$). As shown in Table 2, most of the respondents were aged from 21 to 30 (46.8%, $n = 223$) and 31 to 40 (41.6%, $n = 198$), and the majority of the respondents' monthly income level concentrated in 2001 to 10,000 yuan (68.5%, $n = 326$). In sample 2, a total of 57.8% were female ($n = 178$) and 42.2% were male ($n = 130$). Participants' ages ranged from 21 to 30 (46.1%) and monthly income level between 6,001 and 10,000 yuan (39%) held the majority share. In sample 3, 45.6% ($n = 125$) of the participants were female, 55.5% ($n = 152$) were between the ages of 21 and 30, and 31.8% ($n = 87$) earned between 6,001 and 10,000 yuan a month.

## Factor analysis

### Analysis of item distribution

Like Knäuper et al. did within the item elimination (1), we made a criterion according to the results of item distribution. If the item distribution was skewed or unbalanced, it would be deleted, thereby retaining items that showed sufficient variability and would elicit a quite large range of responses. This process left 30 items out of the 40 items for subsequent analyses, and 12 were overlapped with the Knäuper et al.'s (1) 17-item scale.

### Principle axis factor analysis

Preliminary analysis showed that all items were correlated with each other, and the correlation coefficient was below 0.90. In addition, the Kaiser-Meyer-Olkin statistic was greater than 0.50 (0.923) and Barlett's sphericity test was significant ($p < 0.001$), indicating that the data were applicable to factor analysis. Then, consistent with Knäuper et al. (1), the 30 items were subjected to a PAF. The latent variables may be slightly correlated, so we employed an oblique rotation (promax) rather than orthogonal rotation (37, 38), resulting in six factors being extracted explaining 50.6% of the total variance. We scrutinized items that exhibited low loadings (< 0.40) onto a certain factor and dropped the redundant or relatively unimportant ones. This procedure led to the elimination of five items.

The factor analysis was repeated with the remaining 25 items, and four factors emerged explaining 47.4% of the total variance. Eleven items were removed due to the low loadings (< 0.40) and the same steps of analysis were repeated. Three factors were extracted from this last analysis accounting for 50.6% of the total variance, with loadings of all items on the related factor higher than 0.40 (see in Table 1). We labeled factors 1 to 3 according to the item contents in each factor: exercising/eating/sleeping habits, drinking/smoking, and stress, respectively. Each factor represented different health aspects in which consumers had the beliefs that it could be compensated.

Initial CHBs-C (see in Table 1) contained 14 items with Cronbach's alpha values (0.801) above the recommended threshold value of 0.70 (38, 39).

### Confirmatory factor analysis

After the PAF, we subjected the 14-item scale to a CFA through R version 4.3.1, using the data from sample 2 ($n = 308$). DWLS was chosen to account for the 3-factor model. In the first step, we fitted the model to the data. As shown in Table 3, the model failed the exact fit test, so it was tentatively rejected. In the second step, we examined standardized and correlational residuals. Based on the modification indices, we correlated error variances between items with nearly identical wording-specifically, item 7 ("It is OK to go to bed late if one

TABLE 3 Model fit index ($n = 308$).

| Measure | Value | | | |
|---|---|---|---|---|
| | 3-factor model | Modified 3-factor model | Higher-order model | Modified higher-order model |
| $\chi^2$ | 119.856 | 61.063 | 119.856 | 68.721 |
| df | 62 | 52 | 62 | 53 |
| *p*-value | 0.000 | 0.182 | 0.000 | 0.072 |
| SRMR | 0.063 | 0.042 | 0.063 | 0.045 |
| Number of Correlated Residuals >0.10 | 9 | 3 | 9 | 5 |
| Number of Standardized Residuals >1.96 | 15 | 6 | 15 | 8 |

*n* indicates the size of the sample.

can sleep longer the next morning (only the number of hours count)") and item 8 ("Too little sleep during the week can be compensated for by sleeping in on weekends")-or that addressed the same concept, such as item 4 ("Eating sweets is OK because it reduces stress") and item 14 ("Stress during the week can be made up for by relaxing on the weekend"). Finally, we fitted the modified 3-factor model to the data. Results showed that the modified model was acceptable, the *p*-value (0.182) was higher than 0.05 ($\chi^2 = 61.063$, df = 52), and SRMR (0.042) was less than 0.08 (29–33, 40). Additionally, we evaluated the higher-order model. In the first step, it failed the exact fit test and the fit indices were the same as those of the original 3-factor model (see in Table 3), so we testified the modified model. The results (see in Table 3) showed that the modified model was acceptable. Therefore, we consider the total scale to be acceptable, and we concluded that the final 3-factor CHBs-C, to some extent, represented three dimensions of compensatory health beliefs in Chinese culture context.

## Reliability

### Internal consistency

We estimated McDonald's ω separately for the overall CHBs-C scale and each subscales using the data collected in samples 1 and 2 (represented in Table 4). The overall McDonald's ω value of sample 1 and sample 2 were 0.779 ($n = 476$) and 0.709 ($n = 308$), respectively. Though the ω value was lower than 0.80, it was still acceptable, indicating good internal consistency. However, ω values of subscales were around 0.70, indicating low internal consistency.

### Test-retest correlations

We calculated test–retest reliability (2-week interval) on data from sample 1 and sample 2. The Pearson correlation coefficient was 0.89 ($p < 0.001$, $n = 308$), indicating high test–retest reliability.

## Convergent validity

As shown in Table 5, the average extraction variance (AVE) value was lower than 0.50 for all factors, and the reliability combination (CR) value for factor 1 and 2 was higher than 0.70, but the other one was lower than 0.70, which not confirmed the good convergent validity. However, the square root of AVE is higher than the correlation value with other factors, so the discriminant validity of the CHBs-C was confirmed.

TABLE 4 Internal consistency: CHBs-C subscales.

| CHBs-C | | |
|---|---|---|
| Subscales | McDonald's ω | |
| | $n = 476$ | $n = 308$ |
| Factor 1: exercising/eating/sleeping habits | 0.774 | 0.688 |
| Factor 2: drinking/smoking | 0.668 | 0.639 |
| Factor 3: stress | 0.576 | 0.630 |

*n* indicates the size of the sample.

TABLE 5 Convergent validity and discriminant validity of CHBs-C ($n = 308$).

| Variable | CR | AVE | Factor 1 | Factor 2 | Factor 3 |
|---|---|---|---|---|---|
| Factor 1 | 0.783 | 0.355 | 0.596 | | |
| Factor 2 | 0.706 | 0.448 | 0.204** | 0.669 | |
| Factor 3 | 0.679 | 0.414 | 0.086** | 0.118** | 0.643 |

**$p < 0.01$.

## Predict validity

### Correlations with goal conflict and health motivation

Table 6 displays the inter-correlations among CHBs-C and goal conflict perception, health goals, hedonic goals, risk perception, health motivation and hedonic motivation. Results showed that 'exercising/eating/sleeping habits' significantly negatively correlated with health goals ($r = -0.12$, $p = 0.047$, $n = 274$), and health motivation ($r = -0.17$, $p = 0.005$, $n = 274$), though relatively weak. This means that the more exercising/eating/sleeping is believed to be compensatory, the lower degrees of health importance and motivation are perceived. As to the overall CHBs-C, there was none statistically significantly correlation.

### Correlations with Chinese adults' health behaviors and habits

Table 7 reports the inter-correlations among CHBs-C and Chinese adults' health behaviors and habits. Consistent with other studies, some statistically significant correlations were found. Firstly, the overall CHBs-C scale correlated significantly with the good mentality ($r = 0.123$, $p = 0.041$, $n = 274$), showing that the more CHBs-C, the better the mentality. Besides, exercising/eating/sleeping habits significantly negatively correlated with the overall health intention

TABLE 6 Correlations of CHBs-C scale with goal conflict and health motivation ($n = 274$).

| | Exercising/eating/sleeping habits | Drinking/smoking | Stress | CHBs-C scale |
|---|---|---|---|---|
| Goal conflict perception | 0.063 | 0.018 | 0.010 | 0.037 |
| Health goals | −0.120* | 0.012 | 0.051 | −0.008 |
| Hedonic goals | 0.081 | −0.033 | 0.071 | 0.043 |
| Risk perception | −0.033 | −0.029 | −0.057 | −0.057 |
| Health motivation | −0.170** | 0.112 | 0.092 | 0.057 |
| Hedonic motivation | 0.087 | 0.021 | 0.045 | 0.065 |

*$p < 0.05$; **$p < 0.01$.

TABLE 7 Correlations of CHBs-C scale with health behaviors and habits ($n = 274$).

| | Exercising/eating/sleeping habits | Drinking/smoking | Stress | CHBs-C scale |
|---|---|---|---|---|
| Sport and exercise | −0.039 | 0.075 | 0.018 | 0.042 |
| Regular sleep schedule | −0.128* | 0.026 | 0.042 | −0.006 |
| Regular diet | −0.240** | −0.042 | −0.012 | −0.112 |
| Balanced nutrition | −0.150* | −0.010 | −0.078 | −0.096 |
| Work and rest | −0.055 | 0.016 | 0.096 | 0.040 |
| Getting rid of disease-causing habits | −0.102 | 0.134* | 0.008 | 0.052 |
| Relieving stress | −0.004 | −0.108 | 0.096 | −0.019 |
| Good mentality | −0.010 | 0.084 | 0.150* | 0.123* |
| Overall health intention | −0.176** | 0.043 | 0.069 | 0.001 |

*$p < 0.05$; **$p < 0.01$.

($r = -0.176$, $p = 0.003$, $n = 274$), and specific behaviors including regular sleep schedule ($r = -0.128$, $p = 0.034$, $n = 274$), regular diet ($r = -0.240$, $p < 0.001$, $n = 274$), and balanced nutrition ($r = -0.150$, $p = 0.013$, $n = 274$). This indicates that the more individuals believed that negative effects of lack of exercising, nutrients, or sleeping can be compensated, the lower the intention of health behaviors, the more irregular the sleep, the more irregular the diet, and the less balanced the nutrition. Thirdly, drinking/smoking and getting rid of disease-causing habits were significantly correlated ($r = 0.134$, $p = 0.026$, $n = 274$), meaning that believing that drinking/smoking could be compensated for was correlated with greater resolution to break the bad habits. Finally, stress was significantly associated with good mentality ($r = 0.150$, $p = 0.013$, $n = 274$), showing that greater compensation for stress was correlated with better mentality.

## Discussion

This study evaluated the Chinese version of the CHBs scale in the Chinese cultural context through factor analysis, reliability analysis, convergent validity analysis and predict validity analysis. In this study, only three factors emerged, namely, exercising/eating/sleeping habits, drinking/smoking and stress, not providing much evidence of reliability or validity of the English 17-item CHBs scale.

The results of factor analysis showed that the CHBs-C scale had some similarity with the English version: the factor 'stress' were basically the same, and items related to sleeping habits in the English version all clustered in factor 'exercising/eating/sleeping habits'. However, there were differences in the other dimensions. Specifically, items 'It is OK to skip breakfast if one eats more during lunch or dinner' and 'Eating whatever one wants in the evening is OK if one did not eat during the entire day' did not appear in CHBs-C scale due to low factor loadings (< 0.40). Instead, items 'Not eating vegetables can be made up for by eating fruits', 'Eating sweets is OK because it reduces stress', 'If one exercises, then one can eat without much restriction', and 'Eating junk food is OK if the person exercises regularly' loaded on factor 'exercising/eating/sleeping habits'. This shift likely reflects the profound importance of food in Chinese culture, where meals are rarely skipped, and there's a stronger inclination toward finding reasons to eat more and better.

Additionally, in our study, items 'Not working out regularly is OK if the person is active in everyday life' and 'Exercising during the spring and summer can compensate for not exercising during the winter' clustered in factor 'exercising/eating/sleeping habits'. These results were partially consistent with conclusions of Kaklamanou and Armitage (10), though different with Knäuper et al. (1). One possible explanation is that at the beginning of 2021, the COVID-19 pandemic suddenly got worse, thus arousing the public's attention to exercising (41). What is more, in such a special time, considering the inconvenience of certain sports and outdoor activities, various indoor activities had become popular on the Internet, which makes the Chinese believe that lack of exercising can be compensatory. Besides, most of our surveys were undertaken around April to August of 2021, in which time the epidemic situation had been improved in China. This may also awaken the belief that less exercises in winter can be compensated for doing more during the summer.

Third, the focus of factor 'drinking/smoking' in our study was the same with the factor 'substance use' in English version in essence, which means the Chinese also believed in that harmful effects of drinking alcohol and smoking cigarettes could be reduced through certain behaviors. Nevertheless, items in CHBs-C scale, focusing more on effortless behaviors, were totally different from those in English version. One possible interpretation may be that the popularization of the harmful effects of tobacco and alcohol in China is a little later than that in western countries, so Chinese residents are reluctant to expend too much energy responding to such risky behaviors. In the meanwhile, item concerned with coffee was not included in the CHBs-C scale. This result may be due to the fact that coffee is not consumed on a daily basis in Chinese culture and is considered more of a common drink than an addictive substance. Moreover, coffee has been a fashion trend among the Chinese young and middle aged, and they insist that the benefits of coffee far outweigh the disadvantages. Therefore, there is no need to compensate for drinking coffee.

To sum up, the differences in factor structure found in this study can be mostly attributed to the influence of cultural differences between China and foreign countries. Meanwhile, the similar factor structure also confirms that CHBs scale reflect the Chinese people's beliefs about health compensation to a certain extent.

The study concludes that the CHBs-C scale demonstrates acceptable reliability and predictive validity for measuring CHBs in the Chinese context. Particularly, we have obtained a high Pearson correlation coefficient ($r = 0.89$) in the retest reliability analysis, indicating that the CHBs-C scale was very stable in assessing CHBs. The higher retest reliability of the CHBs-C scale in this study compared to the English version ($r = 0.75$) may be due to the shorter time interval between the two tests (only two weeks), while interval in English version was 4.5 to 5 months. Furthermore, though the English version of CHBs subscale is not fully applicable in specific areas, such as weight regulation, eating habits, and tobacco and alcohol intake, the predict validity of the new subscales are good. The findings suggest that higher CHBs related to exercising, eating, and sleeping correlate with fewer healthy behaviors, while those related to drinking, smoking, and stress correlate with more positive health attitudes. These results align with some existing research (1, 2, 9) but challenge the direct relationship between conflict and CHBs posited by CHB theory, indicating a need for further validation and potential theory optimization in specific contexts.

Our research marks a significant theoretical contribution to the field of health psychology by extending the application of the CHBs model to a non-Western context. Through the development and validation of the CHBs-C scale, this study illuminates the influence of cultural factors on health beliefs and behaviors. The findings suggest that the underlying structure of CHBs may vary across cultures, indicating a need for a more nuanced theoretical model that incorporates cultural variability. This work not only validates the CHBs model within the Chinese cultural context but also challenges and expands the existing theoretical framework by highlighting the role of cultural specificity. By doing so, it opens new avenues for theoretical exploration and practical application in the promotion of health behaviors across diverse populations. The adaptation and validation process undertaken in this study underscore the importance of cultural considerations in the theoretical development and empirical investigation of health beliefs, offering valuable insights for future research aimed at tailoring health interventions to specific cultural contexts.

## Limitations and future directions

Our findings have illuminated significant challenges in the internal consistency and convergent validity of the CHBs-C scale, as evidenced by lower omega (ω) values and AVE values. Several factors contribute to these challenges, offering invaluable insights for future research and scale development.

A key factor identified is the complex interaction between cultural nuances and the conceptualization of health beliefs within the Chinese context. The current items of the CHBs-C scale might not adequately reflect the intricate nature of health perceptions and behaviors influenced by cultural diversity. This gap poses significant challenges in ensuring the scale's reliability and validity when adapting it across different cultural settings. Addressing this issue, future research should aim to expand the scale through qualitative research incorporating diverse focus groups. This would involve engaging with individuals from a wide spectrum of ages and income levels to identify underlying themes, which could then inform the development of new items. Such an approach is expected to not only broaden the scale's dimensional coverage but also enhance its applicability and relevance to a more diverse segment of the Chinese population, thereby ensuring a more comprehensive and nuanced understanding of health beliefs within the cultural context of China.

Furthermore, the choice of a 0.4 cutoff for item deletion during the PAF process, inspired by the research of Knäuper et al. (1), might have contributed to the lower AVE values. While this criterion aimed to ensure the retention of significantly contributing items, it also highlights the delicate balance required in item selection to maintain construct integrity without overly narrowing the scale's conceptual breadth.

Additionally, our sample's demographic constraints, mainly encompassing individuals aged 21 to 40 with incomes ranging from 2001 to 10,000 yuan, highlight the importance of a more inclusive sampling strategy in future studies. Broadening the demographic representation is essential for enhancing the scale's generalizability and validating its applicability across the diverse Chinese population.

In response to these findings, we advocate for a prudent approach to the scale's application, especially recommending the initial use of the first factor as a provisional measure until further validation and refinement of the subsequent factors are achieved. This strategy underscores our dedication to the rigorous development of the CHBs-C scale. Future research should employ the CHBs-C scale in large-scale surveys to explore its factor structure and assess its reliability and validity among different demographic groups. Such endeavors are crucial for identifying the determinants of health beliefs and their correlations with unhealthy behaviors, offering a solid basis for targeted health promotion strategies in China. Through empirical studies, this tool can significantly advance our understanding of CHBs and their impact on behaviors such as Internet addiction (42) in the Chinese context, providing theoretical and practical insights for health promotion efforts.

## 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 human participants were reviewed and approved by the Academic Board of the School of Economics and Management, Shanghai Institute of Technology. All participants provided their electronic informed consent to participate in this study, as the recruitment was conducted online.

## Author contributions

HYS: Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft. YRZ: Funding acquisition, Project administration, Supervision, Writing – review & editing.

## Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research was supported by Humanity and Social Science Youth foundation of Ministry of Education of China (Grant No. 22YJC630117); Science and Technology Commission of Shanghai Municipality (Grant No. 22692107500); and Shanghai Institute of Technology (Grant Nos. YJ2020-33, ZQ2020-16).

## Acknowledgments

Special thanks are expressed to Bärbel Knäuper for providing us with the 40-item compensatory health beliefs questionnaire. We also extend our heartfelt gratitude to the peer reviewers for their constructive feedback and suggestions, which significantly improved our manuscript. Additionally, thanks to all the respondents who participated in the online studies.

## 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



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frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 26 April 2024
DOI 10.3389/fpubh.2024.1348416



OPEN ACCESS

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RECEIVED 02 December 2023
ACCEPTED 02 April 2024
PUBLISHED 26 April 2024

CITATION
Tao Y, Wu J, Huang L, Zheng K, Liu H, Tian H and Peng L (2024) The relationship between health-promoting behaviors and negative emotions in college freshmen: a cross-lagged analysis. *Front. Public Health* 12:1348416. doi: 10.3389/fpubh.2024.1348416



# The relationship between health-promoting behaviors and negative emotions in college freshmen: a cross-lagged analysis

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**Background:** The prevalence of mental health issues has been gradually increasing among college students in recent years. Improvements in mental health can be achieved through changes in daily behavior and the use of psychological counseling. This study aims to investigate the relationship between health-promoting behaviors and negative emotions among college freshmen as they enter the university. It also examines the impact of various sub-dimensions of health-promoting behaviors and other factors on the negative emotions (stress, anxiety, and depression) experienced by college freshmen.

**Methods:** Using the Negative Emotion and Health-Promoting Behavior scales, a 7-month longitudinal study was conducted on 4,252 college freshmen, with collection of data at two time points (T1: November 12, 2021; T2: June 17, 2022). Out of this longitudinal study, 3,632 valid samples were obtained. This research aimed to explore the association and impact between negative emotions and the level of health-promoting behaviors among college students during their time at the university.

**Results:** ① There were significant differences in the levels of health-promoting behaviors and negative emotions over the course of 7 months ($P < 0.05$). Health-promoting behaviors were found to have a significant negative correlation with negative emotions ($P < 0.05$). ② Negative emotions at T1 significantly negatively predicted health-promoting behaviors at T2 ($\beta = -0.11$, $P < 0.01$), while health-promoting behaviors at T1 significantly negatively predicted negative emotions at T2 ($\beta = -0.12$, $P < 0.001$). ③ Stress management ($\beta = -0.104$, $P < 0.05$; $\beta = -0.087$, $P < 0.05$), self-actualization ($\beta = -0.282$, $P < 0.01$; $\beta = -0.260$, $P < 0.05$), health responsibility ($\beta = -0.057$, $P < 0.05$; $\beta = -0.088$, $P < 0.05$), and interpersonal relations ($\beta = 0.068$, $P < 0.01$; $\beta = 0.138$, $P < 0.05$) were important components in improving stress and anxiety. Self-actualization ($\beta = -0.437$, $P < 0.001$), exercise ($\beta = 0.048$, $P < 0.001$), nutrition ($\beta = 0.044$, $P < 0.001$), and interpersonal relations ($\beta = 0.065$, $P < 0.001$) were important components in improving depression. ④ Gender, place of household registration, and whether the individual is the only child were significant factors affecting negative emotions in college freshmen.

**Conclusion:** The level of health-promoting behaviors is an important indicator for assessing the negative emotional states of college freshmen. Enhancing health-promoting behaviors across various dimensions can help alleviate different types of negative emotions. Gender, place of household registration, and being the only child are significant factors that influence negative emotions.

KEYWORDS

**psychology, cross-lagged analysis, health-promoting behaviors, negative emotions, college students**

# 1 Introduction

In recent years, the college student population has been experiencing severe mental health issues, which is rising and attributable to unfamiliar living environments, intense academic pressures, and complex job market trends. As a result, there has been a spurt in research focusing on the psychological health issues faced by college students (1). According to statistics from the World Health Organization (WHO), over one billion people worldwide suffer from mental disorders as of June 2023, with more than one-eighth of the affected population comprising adults and adolescents. The current level of mental health services are vastly inadequate to meet the steadily increasing mental health needs. In high-income countries, only 70% of those in need can access mental health services, whereas in low-income countries, a mere 12% of the population is able to receive psychiatric treatment (2).

According to reports, the incidence of psychological disorders among Chinese university students has been rising annually and is higher than that of the general population in China. Moreover, psychological issues among Chinese students are showing a continuously increasing trend (3, 4). Although relatively severe social safety issues may occur infrequently within this group, the level of psychological problems continues to escalate (5). Chinese university students represent a unique demographic, particularly those in their 1st year, as they are at a pivotal stage transitioning from adolescence to adulthood. They encounter learning methods distinct from their high-school experiences, along with changes in diet, exercise, academic pressure in university, social interactions with peers, and uncertainties about the future. All these factors may contribute to the accumulation and even eruption of mental health issues within this group (6–9). Research indicates that negative emotions are significant indicators of mental health, primarily manifesting as a combination of anxiety, depression, and stress. However, the accumulation of negative emotions may also become a major risk factor for physical health (10). For instance, the isolation resulting from pandemic control measures has led to more severe negative emotions among college students compared to non-lockdown periods. Studies have found that during the pandemic, 22.4% of college students reported symptoms of anxiety, 35.1% reported symptoms of depression (11), and 7.2% exhibited suicidal tendencies (12). In light of these findings, given the gradual increase in the level of negative emotions among college freshmen and the significant challenge such a trend poses to public safety, it is imperative to promptly address the mental health concerns and negative emotional states of this particular group. If their psychological issues continue to be overlooked, allowing them to accumulate, it could lead to unpredictable and potentially severe consequences.

At the same time, some studies suggest that there is an extremely close relationship between the level of negative emotions in the college student population and their health-promoting behaviors (13, 14), although the specific effects are not clear. Health-promoting behaviors refer to an individual's lifestyle choices that promote health, which includes various actions such as exercise, nutrition, and others, and can be defined as "multi-dimensional, self-initiated continuous, daily activity undertaken with the deliberate aim of maintaining or enhancing the level of an individual's health, wellbeing, and self-actualization." Research has found that college students with higher levels of physical activity tend to have lower levels of anxiety and depression (15, 16). Additionally, a higher quality of interpersonal relationships can lead to lower levels of anxiety and stress (17). Furthermore, longitudinal studies have found that the level of interpersonal relationships among college students can directly predict their levels of depression (18, 19). Additionally, there is evidence to suggest a link between diet and negative emotions. Studies have shown that poor dietary habits among college students are associated with increased levels of depression and anxiety (20, 21). This evidence underscores the potential role of health-promoting behaviors in the early prevention of mental health issues and the management of negative emotions among college students. Therefore, it is important to conduct research into the relationship between health-promoting behaviors and negative emotions to determine how different levels and aspects of these behaviors impact anxiety, depression, and stress. Such research is essential for enhancing the psychological wellbeing of college students.

With this context in mind, the primary aim of this study is to explore the relationship between negative emotions (namely, depression, anxiety, and stress) and health-promoting behaviors and its impact among new university students in China through two longitudinal surveys of freshmen (T1: November 12, 2021; T2: June 17, 2022) as they acclimate to campus life. Compared to existing research on negative emotions and mental health among college students, this study aims to longitudinally analyze the predictive impact of health-promoting behaviors on college students' negative emotions using a cross-lagged panel model. Concurrently, by employing cross-sectional regression models, it will analyze the protective factors and improvement effects of demographic variables and health-promoting behaviors, along with their subdimensions, on college students' negative emotions. This approach is intended to provide ample evidence and a theoretical basis for reducing the levels of negative emotions and improving mental health issues among college students. Building on previous research findings, this study hypothesizes that as college freshmen enhance their sense of agency, health consciousness, and health capabilities during their time at the university, their levels of health-promoting behaviors will increase, which in turn will alleviate the negative emotions associated with college life. The results of this study are expected to have significance for the prevention and improvement of psychological issues among college students and aid in exploring pathways for the prevention and treatment of mental health issues in this population.

# 2 Objects/data sources and methods

## 2.1 Objects/data sources

This study focuses on freshmen at Southwest University in Chongqing, China. Through simple random sampling, a questionnaire survey was conducted on a randomly selected sample of 4,252 freshmen from this university. The questionnaire consisted of three parts: demographic information (such as gender, age,

etc.), health-promoting behaviors, and a negative emotion scale. The specific survey details are as follows: the randomly selected students completed two rounds of questionnaire surveys at the Physical Fitness Test Center of Southwest University, with a 7-month interval between the two surveys (T1: November 12, 2021; T2: June 17, 2022). The same questionnaire was used and the same batch of participants were involved in both the surveys. Based on the sample size formula, which is 20 times the number of questionnaire items (80 questions) plus 10% for invalid questionnaires, the minimum sample size for this survey was 1,760. After the test concluded, a total of 4,252 samples were obtained, which meets the minimum sample size requirement for this survey. To ensure the authenticity and reliability of the data, this study filtered the obtained data from 4,252 participants. The inclusion criteria were: (1) the questionnaire was completed in 5–15 min and (2) the participants took part in both rounds of the complete test and their student ID and name matched in both the surveys. After filtering and matching the samples, a total of 3,632 valid samples were obtained, with a sample loss of 620, resulting in an effectiveness rate of 85.42%. Among the valid samples, there were 1,340 men (36.8%) and 2,292 women (63.1%); 1,550 were the only child in the family (42.68%) and 2,082 were not the only child in the family (57.32%); 1,823 urban residents (50.19%) and 1,809 rural residents (49.81%). After screening, the average age of the students was 18.92 ± 0.50 years. This experiment was approved by the Ethics Committee of Southwest University (Approval No.: SWH202011281421), and all participants signed an informed consent form before the experiment.

## 2.2 Methods

### 2.2.1 Negative emotion scale

The Chinese version of the Depression Anxiety Stress Scales (DASS-21) was originally developed by Lovibond et al. (22) and has since been translated into multiple languages. It is now widely used in China and has proven to be effective in measuring levels of negative emotions and its various dimensions. The Chinese version of the DASS has good reliability and validity, with the internal consistency coefficients (Cronbach's alpha) for the depression, anxiety, and stress subscales being 0.83, 0.80, and 0.82, respectively, and 0.92 for the total DASS score (23–25). The scale consists of three dimensions: anxiety, depression, and stress. Each of them have seven items, making it a total of 21 items. The questionnaire adopts a four-point scoring: "0" represents "never;" "1" represents "sometimes;" "2" represents "often;" and "3" represents "almost always." The higher the scale score, the more serious the negative emotions. The scoring criteria are as follows: for the depression dimension, 0–9 is "normal;" 10–13 is "mild;" 14–20 is "moderate;" 21–27 is "severe;" and 28+ is "extremely severe;" for the anxiety dimension, 0–7 is "normal;" 8–9 is "mild;" 10–14 is "moderate;" 15–19 is "severe," and 20+ is "extremely severe;" for the stress dimension, 0–14 is "normal;" 15–18 is "mild;" 19–25 is "moderate;" 26–33 is "severe;" and 34+ is "extremely severe." In this study, the Cronbach's $\alpha$-values of the two tests were 0.895 and 0.935, respectively.

### 2.2.2 Health promotion behavior scale

The Health-Promoting Lifestyle Profile II (HPLP-II) scale was developed by Walker et al. (26), based on Pender's Health Promotion Model, and is designed to effectively measure health-promoting behaviors and their various dimensions. The Chinese version of the HPLP-II has demonstrated good reliability and validity and has been widely used for evaluating the lifestyle of university students. The Cronbach's alpha coefficients for the subscales of the questionnaire are as follows: self-actualization (0.904), health responsibility (0.814), physical activity (0.809), nutrition (0.757), interpersonal support (0.800), stress management (0.702), and for the overall Health-Promoting Lifestyle Profile (HPLP) (0.922) (26–28). The scale was a relatively mature health behavior assessment instrument at home and abroad, including self-actualization (nine items), health responsibility (nine items), physical activity (eight items), nutrition (nine items), interpersonal relations (nine items), and stress management (eight items), making it a total of 52 items. The Likert four-level scoring method (1 = never, 2 = sometimes, 3 = often, 4 = routinely) is adopted for this measure, with scores ranging from 52 to 208. The scoring is done as follows: "poor" for a score of 52–90, "general" for a score of 91–129, "good" for a score of 130–168 for, and "excellent" for a score of 169–208 for. Higher scores represented higher levels of health behavior, and each dimension within the scale could be employed independently of the other dimensions. In this study, the Cronbach's $\alpha$ values of the two tests were 0.932 and 0.955, respectively.

## 2.3 Statistical processing

Statistical data analysis was conducted using SPSS 25.0 and Amos 24.0 software. Initially, the data was subjected to a normality test and a common method bias test. Subsequently, a one-way analysis of variance (ANOVA) was utilized to examine if there were differences in the levels of negative emotions and health-promoting behaviors between the two measurement points. The effect size, variance among groups, and significance level were represented by $\eta p2$, $F$, and $p$-values, respectively. Additionally, correlation analysis was employed to investigate the relationship between negative emotions and health-promoting behaviors across the different time points.

A structural equation model was constructed using Amos24.0 to analyze and verify the cross-lagged model. The $\chi^2$ statistical index and the root mean square error of approximation (RMSEA) were utilized as the absolute fitting measures. Incremental fit index (IFI), Tucker–Lewis index (TLI), and goodness of fit index (GFI) were used as incremental fit indexes. $\chi^2/df < 5$, RMSEA $< 0.08$, IFI, TLI, and GFI values $> 0.9$ indicated that the model fitted well. Finally, a generalized linear regression model was established with depression, anxiety, and stress symptoms as the dependent variables and health behavior factors significantly related to one or more symptoms as independent variables. The data were presented

TABLE 1 Correlation analysis of negative emotions and health behavior.

| Variables | Time points | Negative emotions | | Health behavior | |
|---|---|---|---|---|---|
| | | T1 | T2 | T1 | T2 |
| Negative emotions | T1 | 1 | 0.316*** | −0.032* | −0.108*** |
| | T2 | | 1 | −0.136*** | −0.371*** |
| Health behavior | T1 | | | 1 | 0.295*** |
| | T2 | | | | 1 |

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

in the form of mean plus or minus standard deviation (M ± SD). The significance level of statistical analysis was set as $p < 0.05$ for statistical difference, $p < 0.01$ for significant statistical difference, and $p < 0.001$ for the extremely significant statistical difference.

# 3 Results

## 3.1 Sample randomization test and common method bias

Due to the use of questionnaire surveys to assess the levels of negative emotions and health-promoting behaviors among college freshmen, the selected sample may have errors compared to the original sample. Therefore, through the analysis and testing of the sample, it was found that there were no significant differences between the selected sample and the original sample in terms of the levels of negative emotions and health-promoting behaviors, as well as their demographic factors ($P > 0.05$). As this study adopted self-reported data, there may be common method bias. This study took advantage of confirmatory factor analysis in Amos to test the common method bias of all self-evaluation items. The results showed that the model fitting was poor ($\chi^2$/df = 407.03, CFI = 0.441, GFI = 0.424, AGFI = 0.270, NFI = 0.440, RMSEA = 0.263). The original model was $\chi^2$/df = 43.78, CFI = 0.943, GFI = 0.884, AGFI = 0.848, NFI = 0.942, RMSEA = 0.085, so there was no common method bias in the study.

## 3.2 Correlation analysis of negative emotions and health behavior among college students

Correlation analysis between negative emotions and health-promoting behaviors across the two measurements is presented in Table 1. The results of the two measurements indicated that health-promoting behaviors and negative emotions were correlated with each other. The correlation for negative emotions was significant with $r = 0.316$ ($p < 0.001$), and for health-promoting behaviors, it was also significant, with $r = 0.295$ ($p < 0.001$). Health-promoting behaviors were negatively correlated with negative emotions, with significant correlations at T1 and T2 for negative emotions and health behaviors at $r = -0.032$ ($p < 0.001$) and $r = -0.371$ ($p < 0.001$), respectively. The correlation between negative emotions at T1 and health-promoting behaviors at T2 was significant at $r = -0.108$ ($p < 0.001$), and the correlation between negative emotions at T2 and health-promoting behaviors at T1 was significant at $r = -0.136$ ($p < 0.001$). The correlation between negative emotions and health behaviors was significant, meeting the prerequisite conditions for cross-lagged analysis.

## 3.3 Differences in negative emotions and health behavior among college students at T1 and T2

In this study, negative emotions and three dimensions, health behavior and six dimensions, and gender were used as dependent variables, and measurement time T1 and T2 were used as the factors. One-way analysis of variance was performed on the data at two measurement time points. The results showed that the total scores of negative emotions ($F = 21.18$, $P < 0.001$), anxiety ($F = 43.13$, $P < 0.001$), depression ($F = 31.68$, $P < 0.001$), stress ($F = 33.91$, $P < 0.001$), health promotion behavior ($F = 14.36$, $P < 0.001$), self-realization ($F = 13.64$, $P < 0.001$), physical activity ($F = 14.64$, $P < 0.001$), nutrition ($F = 13.84$, $P < 0.001$), interpersonal relations ($F = 13.61$, $P < 0.001$), stress management ($F = 19.11$, $P < 0.001$), and health responsibility ($F = 5.43$, $P < 0.001$) had significant main effects on time (see Table 2). The above results indicated that college students showed distinct differences in their total and individual dimension scores of negative emotions and health behavior in both tests during the pandemic period when controls were in place. Specific analysis of each dimension showed a significant improvement in overall negative emotions ($\Delta = -1.02$) over time and a sharp decrease in both anxiety ($\Delta = -1.12$) and stress ($\Delta = -0.1$), but an increasing tendency for depression instead ($\Delta = 0.18$). The overall health behavior ($\Delta = -1.31$) decreased significantly, with noteworthy decreases in the dimensions of self-actualization ($\Delta = -0.98$), interpersonal relations (−0.97), and stress management (−0.09) and an increasing trend in the dimensions of nutrition ($\Delta = 0.03$) and health responsibility ($\Delta = 0.72$).

## 3.4 The relationship between negative emotions and health behavior

After establishing a significant correlation between negative emotions and health behaviors, this study used a cross-lagged model to analyze the data from two assessments within a year, examining if there is a bidirectional effect between negative emotions and health-promoting behaviors. The model was constructed using the three dimensions of negative emotions—stress, depression, and anxiety—and the six dimensions of the health-promoting behaviors scale—stress management, nutrition, exercise, self-actualization, interpersonal relationships, and health responsibility—as manifest variables. Before conducting the cross-lagged panel model analysis, autoregressive and single cross-lagged models were established to verify the stability of the cross-lagged model. Specific path coefficients and their significance are shown

TABLE 2 One-way ANOVA ($M \pm SD$) analysis for each dimension of negative emotions and health behavior.

| Dimensions | T1 | T2 | $\eta p2$ | $F$ | $P$ | Differential value |
|---|---|---|---|---|---|---|
| Negative emotions | 31.43 ± 8.79 | 30.41 ± 8.88 | 0.210 | 21.18 | 0.000 | −1.02 |
| Anxiety | 11.05 ± 3.30 | 9.93 ± 2.88 | 0.152 | 43.13 | 0.000 | −1.12 |
| Depression | 9.72 ± 2.90 | 9.9 ± 3.14 | 0.143 | 31.68 | 0.000 | 0.18 |
| Stress | 10.67 ± 3.45 | 10.57 ± 3.39 | 0.145 | 33.91 | 0.000 | −0.10 |
| Health behavior | 132.49 ± 22.09 | 131.18 ± 23.09 | 0.172 | 14.36 | 0.000 | −1.31 |
| Self-actualization | 24.61 ± 4.77 | 23.63 ± 4.60 | 0.093 | 13.64 | 0.000 | −0.98 |
| Health responsibility | 21.03 ± 4.49 | 21.75 ± 4.80 | 0.097 | 14.64 | 0.000 | 0.72 |
| Physical activity | 19.34 ± 4.06 | 19.34 ± 4.05 | 0.089 | 13.84 | 0.000 | 0.00 |
| Nutrition | 22.11 ± 4.00 | 22.14 ± 4.15 | 0.094 | 13.61 | 0.000 | 0.03 |
| Interpersonal relations | 24.9 ± 4.29 | 23.93 ± 4.37 | 0.089 | 19.11 | 0.000 | −0.97 |
| Stress management | 20.49 ± 3.88 | 20.4 ± 3.84 | 0.113 | 5.43 | 0.000 | −0.09 |

in Table 3, and all paths' fit indices met the standards ($\chi^2$/df $< 5$, RMSEA $< 0.08$, IFI, TLI, and GFI values $> 0.9$). After validating the autoregressive and single cross-lagged models, a double cross-lagged model was established. The specific model is shown in Figure 1. To simplify the model, latent variable residuals and predictive paths between latent variables are not displayed in the figure. The model was constructed using Amos 24.0 and examined for fit using maximum likelihood estimation. The results indicated that the fit indices for each indicator were good ($\chi^2$/df $= 4.010$, CFI $= 0.995$, NFI $= 0.993$, TLI $= 0.991$, RFI $= 0.989$, RMSEA $= 0.023$). From the cross-lagged path diagram, it can be seen that the autoregressive coefficients for negative emotions and health-promoting behaviors at the two measurement time points were stable and highly significant, with $\beta = 0.43$ ($P < 0.001$) and $\beta = 0.36$ ($P < 0.001$), respectively. At both T1 ($\beta = -0.04$, $P < 0.05$) and T2 ($\beta = -0.30$, $P < 0.001$) time points, there was a negative correlation between negative emotions and health-promoting behaviors. After controlling for the autoregression of negative emotions and health behaviors, as well as the correlation between the two variables at the same measurement time point, the results showed that negative emotions measured at T1 significantly negatively predicted health-promoting behaviors at T2 ($\beta = -0.11$, $P < 0.01$). Similarly, health-promoting behaviors measured at T1 significantly negatively predicted negative emotions at T2 ($\beta = -0.12$, $P < 0.001$). The results indicate that there is a mutual negative influence between negative emotions and health-promoting behaviors.

## 3.5 Protective factors for college students to reduce negative emotions

As indicated in Table 4, generalized linear regression analysis was performed after including demographic factors such as gender, age, place of household registration, and being the only child as covariates. This analysis aimed to assess the impact of the subdimensions of health-promoting behaviors (self-actualization, health responsibility, exercise, nutrition, interpersonal relations, and stress management) on the levels of anxiety, depression, and stress among college freshmen. The results indicated that stress management, self-actualization, and health responsibility all had a negative effect on the stress and anxiety levels of college freshmen, while interpersonal relations had a positive effect on these levels. Specifically, higher levels of stress management ($\beta = -0.104$, $P < 0.05$; $\beta = -0.087$, $P < 0.05$), self-actualization ($\beta = -0.282$, $P < 0.01$; $\beta = -0.260$, $P < 0.05$), and health responsibility ($\beta = -0.057$, $P < 0.05$; $\beta = -0.088$, $P < 0.05$) were associated with lower levels of stress and anxiety among college freshmen. On the other hand, a higher level of interpersonal relations ($\beta = 0.068$, $P < 0.01$; $\beta = 0.138$, $P < 0.05$) was associated with higher levels of stress and anxiety. Furthermore, self-actualization was found to negatively impact the depression levels of college freshmen. In contrast, exercise, nutrition, and interpersonal relations were found to positively affect these levels. Specifically, higher self-actualization scores ($\beta = -0.437$, $P < 0.001$) were associated with lower levels of depression among college freshmen. Conversely, higher levels of exercise ($\beta = 0.048$, $P < 0.001$), nutrition ($\beta = 0.044$, $P < 0.001$), and interpersonal relations ($\beta = 0.065$, $P < 0.001$) were associated with higher levels of depression. In summary, stress management, self-actualization, health responsibility, and interpersonal relations are important predictive factors affecting the stress and anxiety levels of college freshmen, while self-actualization, exercise, nutrition, and interpersonal relations are important protective factors influencing their depression levels. Additionally, the results for demographic covariates indicated that gender, place of household registration, and whether one is the only child are also major factors influencing the stress, anxiety, and depression levels of college freshmen.

# 4 Discussion

This study examined the longitudinal predictive relationship between negative emotions and health-promoting behaviors among college freshmen, as well as the cross-sectional impact of health-promoting behaviors and demographic factors on negative emotions, by employing cross-lagged and generalized

TABLE 3 Overview of the standardized stability and cross-lagged coefficients.

| Model | Autoregressive path | $\beta$ | Cross-lagged path | $\beta$ |
|---|---|---|---|---|
| | **Autoregressive model** | | | |
| Model 1 | (HPLP-II) T1-(HPLP-II) T2 | 0.450*** | | |
| | (Negative emotions) T1-(Negative emotions) T2 | 0.392*** | | |
| | **Single lagged dependent variable model** | | | |
| Model 2 | (HPLP-II) T1-(HPLP-II) T2 | 0.472*** | (HPLP-II) T1-(Negative emotions) T1 | −0.476*** |
| | (Negative emotions) T1-(Negative emotions) T2 | 0.352*** | (HPLP-II) T1-(Negative emotions) T2 | −0.096*** |
| Model 3 | (Negative emotions) T1-(HPLP-II) T1 | −0.480*** | (HPLP-II) T1-(HPLP-II) T2 | 0.419*** |
| | (Negative emotions) T1-(HPLP-II) T2 | −0.161*** | (Negative emotions) T1-(Negative emotions) T2 | 0.382*** |
| | **Double lagged dependent variable Model** | | | |
| Model 4 | (HPLP-II) T1-(HPLP-II) T2 | 0.362*** | (HPLP-II) T1-(Negative emotions) T1 | −0.432*** |
| | (Negative emotions) T1-(Negative emotions) T2 | 0.428*** | (HPLP-II) T1-(Negative emotions) T2 | −0.095*** |
| | | | (Negative emotions) T1-(HPLP-II) T1 | −0.432*** |
| | | | (Negative emotions) T1-(HPLP-II) T2 | −0.159*** |

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

TABLE 4 Generalized linear model analysis of negative emotions and health behavior.

| | Stress | | | Anxiety | | | Depression | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\beta$ | $P$ | [95% CI] | $\beta$ | $P$ | [95% CI] | $\beta$ | $P$ | [95% CI] |
| Stress management | −0.104 | 0.000*** | −0.157, −0.052 | −0.087 | 0.001** | −0.136, −0.037 | 0.025 | 0.283 | −0.021, 0.071 |
| Self-actualization | −0.282 | 0.000*** | −0.327, −0.237 | −0.260 | 0.000*** | −0.303, −0.218 | −0.437 | 0.000*** | −0.476, −0.398 |
| Health responsibility | −0.057 | 0.006** | −0.098, −0.016 | −0.088 | 0.000*** | −0.126, −0.050 | −0.032 | 0.067 | −0.068, 0.002 |
| Physical activity | 0.035 | 0.099 | −0.007, 0.077 | 0.004 | 0.854 | −0.036, 0.043 | 0.048 | 0.010* | 0.011, 0.084 |
| Nutrition | 0.032 | 0.121 | −0.008, 0.073 | 0.008 | 0.664 | −0.030, 0.047 | 0.044 | 0.013* | 0.009, 0.080 |
| Interpersonal relations | 0.068 | 0.003** | 0.023, 0.114 | 0.138 | 0.000*** | 0.095, 0.182 | 0.065 | 0.002** | 0.025, 0.105 |
| Gender | 0.897 | 0.000*** | 0.683, 1.111 | 0.718 | 0.000*** | 0.516, 0.920 | 0.554 | 0.000*** | 0.367, 0.740 |
| Age | 0.002 | 0.924 | −0.048, 0.053 | 0.006 | 0.818 | −0.042, 0.053 | 0.022 | 0.317 | −0.021, 0.066 |
| Household registration | −0.354 | 0.001** | −0.571, −0.136 | −0.342 | 0.001** | −0.548, −0.137 | −0.366 | 0.000*** | −0.555, −0.177 |
| Only child | 0.254 | 0.023* | 0.034, 0.473 | 0.275 | 0.009** | 0.069, 0.482 | 0.242 | 0.013* | 0.052, 0.433 |
| History of smoking and drinking | 0.088 | 0.838 | −0.758, 0.934 | −0.223 | 0.584 | −1.020, 0.574 | 0.371 | 0.323 | −0.365, 1.107 |

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

linear models. The main findings revealed that over the course of 7 months, there were significant changes in the levels of negative emotions and health-promoting behaviors and their subdimensions. Specifically, the assessed levels of negative emotions and their anxiety dimension, as well as health-promoting behaviors and their subdimensions of self-actualization, interpersonal relationships, and stress management, significantly decreased. The results of the cross-lagged model indicated that there is a negative longitudinal bidirectional relationship between college freshmen's negative emotions and their levels of health-promoting behaviors. The generalized linear regression results demonstrated that within health-promoting behaviors, stress management, self-actualization, health responsibility, and interpersonal relations, as well as demographic factors such as gender, place of household registration, and whether one is the only child, are all significant predictive factors for stress and anxiety in college freshmen. Furthermore, self-actualization, exercise, nutrition, interpersonal relations, and demographic

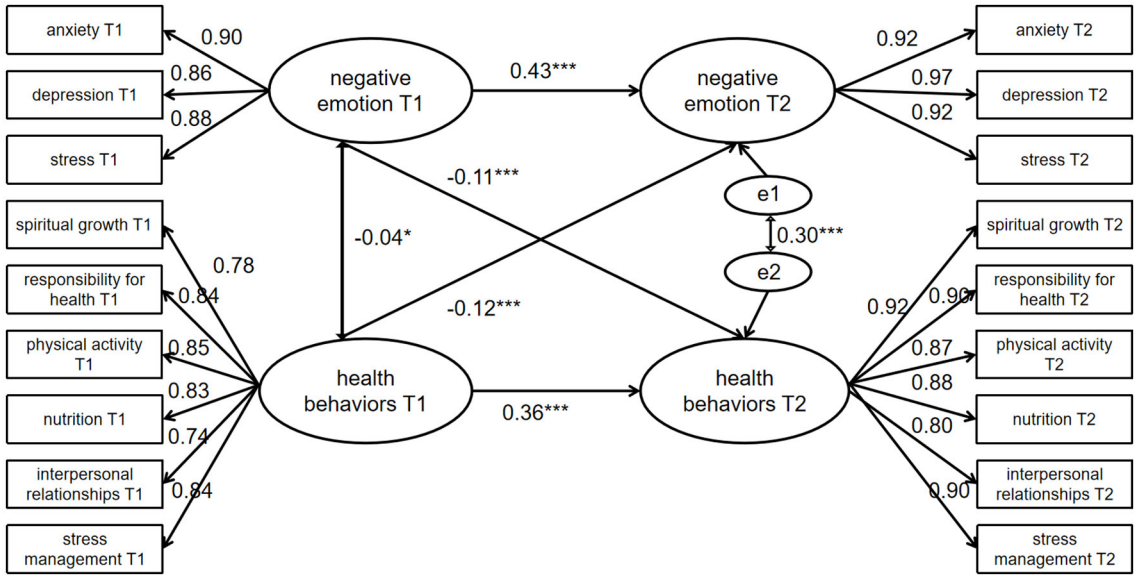


FIGURE 1
The cross-lagged analysis of negative emotions and health behavior. $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

factors such as gender, place of household registration, and only-child status are also significant protective factors against depression in college freshmen.

Our research found that there were significant differences in the levels of negative emotions and health-promoting behaviors, as well as their subdimensions, among college students at T1 and T2, with both levels decreasing over time. It should be noted that as time progresses, one of the potential factors contributing to the reduction in negative emotions among college freshmen could be their growing familiarity with college life. However, this is not the only influencing factor, as during this period, no interventions were conducted on the participants. The analysis was based on the assessment of the levels of health behavior factors. Therefore, it is likely that other exposure factors, such as sleep quality, could have an impact on negative emotions. It is important to note that the complexity of human emotions and behaviors is influenced by a multifaceted array of factors, not just those measured or observed in a given study. During the second measurement of negative emotions among college freshmen, it was observed that only the level of depressive emotions showed a significant increase. This suggests that within the spectrum of negative emotions experienced by college freshmen, particular attention should be paid to the level of depression. The inference drawn from the second assessment of college freshmen suggests that the increase in the level of depression may be associated with a decrease in the levels of interpersonal relations, self-actualization, and stress management. This implies that these factors could potentially be key areas for intervention to mitigate depression among college students. To further explore the factors influencing the level of depressive emotions, this study also conducted a related analysis using generalized linear regression. The research found that self-actualization, exercise, nutrition, interpersonal relations, gender, place of household registration, and whether one is the only child are all significant protective factors against depression in college freshmen. This substantiates the previous inference and aligns with existing research, indicating that the level of depression among college students is associated with communication with peers and teachers, setting goals for self-actualization (29, 30), and self-management of academic stress (31–33). This suggests that, compared to other negative emotions and mental health issues (such as anxiety and stress) experienced by college freshmen, depression appears to be a more severe issue and requires more attention. Concurrently, the results from the correlational analysis revealed a significant negative relationship between negative emotions and the level of health-promoting behaviors. This finding is consistent with the majority of results from previous studies (34–36), which indicate that certain health behaviors (such as exercise and nutrition) are negatively correlated with negative emotions. This suggests that engaging in healthy behaviors can potentially reduce the occurrence or intensity of negative emotions such as depression, anxiety, and stress among college students.

In previous research, studies investigating the impact of health-promoting behaviors on the levels of negative emotions among college students have been relatively scarce. To further explore the longitudinal predictive relationship between these two major factors, a cross-lagged model was employed for analysis. The results showed that there is a bidirectional negative predictive relationship between negative emotions and health-promoting behaviors in college freshmen. This is consistent with the findings from researchers like Liu et al., Cao et al., and Zhang et al. (9, 36, 37). They found that higher levels of self-efficacy, physical activity, and self-control contribute to reducing the accumulation of negative emotions such as depression, releasing stress, and stabilizing mood. In addition, our study identified important protective factors for improving stress, depression, and anxiety, providing significant evidence for predicting mental health levels

in college freshmen. The research has revealed that if negative emotions among current college freshmen are not alleviated and addressed in a timely manner, they will continue to accumulate, leading to a reduction in health-promoting behaviors, which in turn can cause a further accumulation of more severe negative emotions. However, since an increase in health-promoting behaviors can improve negative emotions in college freshmen, maintaining a certain level of such behaviors can serve as a preventative measure against emotional outbursts and reduce the buildup of negative emotions. In fact, there have been studies based on the health promotion model that explain the connection with negative emotions, suggesting that when people engage in behaviors that are detrimental to their health, it could lead to the onset of psychological issues, while the converse could contribute to the improvement of such issues (30, 38, 39). Building on this theoretical foundation, our study explored the relationship between the psychology and daily behaviors (health-promoting behaviors) of college freshmen and further analyzed the protective factors against negative emotions.

Through the analysis using a generalized linear regression model, it was observed that within the subdimensions of health-promoting behaviors, lower levels of stress management, self-actualization, and health responsibility behaviors were associated with higher levels of stress and anxiety. Conversely, an increase in interpersonal relationship behaviors was found to help reduce stress and anxiety. In the study of depression, it was observed that more self-actualization behaviors could increase depressive emotions. However, an increase in nutrition, exercise, and interpersonal relationship behaviors could effectively reduce depression. This is similar to previous studies which suggested that adequate nutrition, exercise, and interpersonal relationships are one of the effective ways to improve and protect students' mental health (16, 36). However, the difference lies in that these studies seemed to focus only on individual factors, such as the impact of physical activity, diet, or mindfulness, with only a few discussing the interactive effects of these factors on negative emotions. Among demographic factors, gender, household registration location (urban vs. rural), and whether an individual is the only child were identified as significant factors affecting negative emotions, with large regression coefficients. This is consistent with existing research which indicates that being women, from a rural area, and not being the only child can lead to higher levels of negative emotions (12, 40, 41).

In summary, this study analyzed the negative predictive relationship between negative emotions and health-promoting behaviors among college freshmen through both longitudinal and cross-sectional research. It also delved into the effects of subdimensions of health-promoting behaviors and demographic factors on the stress, anxiety, and depression experienced by college freshmen. This research has practical significance for the prevention and improvement of negative emotions among college students. At the school and societal levels, the role of healthy behaviors in moderating the emotions of college freshmen can be further emphasized to help students understand the practical importance of health-promoting behaviors, encouraging and monitoring the increase of such behaviors to alleviate negative emotions and prevent significant public safety issues. From a government macro-control perspective, reducing the rural–urban divide, advocating for gender equality, and liberalizing birth policies may help to reduce levels of stress, anxiety, and depression among the college student population.

## 5 Advantages and limitations

This study assessed the health-promoting behaviors and levels of negative emotions among college freshmen using the Health-Promoting Lifestyle Profile II (HPLP-II) and Depression Anxiety Stress Scales (DASS-21) scales. A cross-lagged model was employed to explore the impact of health-promoting behaviors and their subdimensions on negative emotions. Additionally, a generalized linear model was used to investigate the protective factors of health-promoting behaviors and their subdimensions against negative emotions. The goal was to identify predictive factors of daily health behavior suitable for reducing negative emotions and alleviating mental health issues among college freshmen. These findings play an important role in protecting and preventing psychological health issues in this population.

In addition to its strengths, this study also has some limitations. For instance, while health-promoting behaviors encompass most aspects of college freshmen's lives, and we have accounted for the regression impact of demographic variables on negative emotions through covariates, it is important to acknowledge that there are many other exposure factors that may affect negative emotions. These include family stress, financial pressure, friendly relationships between the sexes, and even factors such as weather, all of which require extensive research to infer and analyze their impact on negative emotions. Secondly, this study only included two time points, and the 7-month period may not be representative of the entire academic life of 1st-year college students (although this possibility is small). Future studies could consider including more measurement time points and shorter intervals, which would likely reduce research errors. Finally, the sample of over 3,000 students in this study may not be perfectly representative of the national population, which could introduce a certain degree of error in terms of representativeness. Based on this, future research will require more studies from different regions to validate these results.

## 6 Conclusions

College freshmen's negative emotions and health-promoting behaviors are significantly negatively correlated. The longitudinal analysis indicates that initial negative emotions and health-promoting behaviors can significantly negatively predict subsequent levels of negative emotions. Within health-promoting behaviors, stress management, self-actualization, health responsibility, and interpersonal relationship dimensions are significant protective factors against stress and anxiety. Self-actualization, exercise, nutrition, and interpersonal relationships are significant protective factors against depressive emotions. Gender, household registration location, and whether one is the only child are significant factors affecting the negative emotions of college freshmen.

## 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 author.

## Ethics statement

The studies involving humans were approved by Ethics Review Committee of Southwest University Hospital, Chongqing, China. 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. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

## Author contributions

YT: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. JW: Data curation, Writing – review & editing. KZ: Supervision, Writing – review & editing. LH: Conceptualization, Data curation, Supervision, Writing – review & editing. HL: Data curation, Supervision, Writing – review & editing. HT: Data curation, Supervision, Writing – review & editing. LP: Funding acquisition, Writing – review & editing.

## Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research primarily received funding from the China National Social Science Fund Project. Identifier: 21BTY092. Project Title: Research on the Community-Integrated Healthcare Model for Promoting Healthy Behaviors in Chronic Patients. It also received additional funding from Chongqing Natural Science Foundation. Identifier: cstc2020jcyj-msxmX1025. Project Title: Investigation of Gut Microbiota Mechanisms in Type 2 Diabetes through Exercise Intervention; and Southwest University graduate research innovation project. Identifier: SWUS23036.

## 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



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frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 02 May 2024
DOI 10.3389/fpubh.2024.1402801



OPEN ACCESS

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RECEIVED 18 March 2024
ACCEPTED 19 April 2024
PUBLISHED 02 May 2024

CITATION
Mu F-z, Liu J, Lou H, Zhu W-d, Wang Z-c and Li B (2024) Influence of physical exercise on negative emotions in college students: chain mediating role of sleep quality and self-rated health.
*Front. Public Health* 12:1402801.
doi: 10.3389/fpubh.2024.1402801



# Influence of physical exercise on negative emotions in college students: chain mediating role of sleep quality and self-rated health

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**Background:** Negative emotions in college students are a significant factor affecting mental health, with suicide behaviors caused by negative emotions showing an annual increasing trend. Existing studies suggest that physical exercise is essential to alleviate negative feelings, yet the intrinsic mechanisms by which it affects negative emotions have not been fully revealed.

**Objective:** Negative emotions in college students represent a significant issue affecting mental health. This study investigates the relationship between physical exercise and negative emotions among college students, incorporating sleep quality and self-rated health (SRH) as mediators to analyze the pathway mechanism of how physical exercise affects students' negative emotions.

**Methods:** A cross-sectional study design was utilized, employing online questionnaires for investigation. The scales included the Physical Activity Rating Scale-3 (PARS-3), the Depression Anxiety Stress Scales-21 (DASS-21), the Pittsburgh Sleep Quality Index (PSQI), and the 12-Item Short Form Health Survey (SF-12), resulting in the collection of 30,475 valid questionnaires, with a validity rate of 91%. Chain mediation tests and Bootstrap methods were applied for effect analysis.

**Results:** The proportions of university students engaged in low, medium, and high levels of physical exercise were 77.6, 13.1, and 9.3%, respectively. The proportions of students experiencing "very severe" levels of stress, anxiety, and depression were 4.5, 10.9, and 3.6%, respectively. Physical exercise was significantly positively correlated with self-rated health ($r = 0.194$, $p < 0.01$), significantly negatively correlated with sleep quality ($r = -0.035$, $p < 0.01$), and significantly negatively correlated with stress, anxiety, and depression ($r = -0.03$, $p < 0.01$; $r = -0.058$, $p < 0.01$; $r = -0.055$, $p < 0.01$). Sleep quality was significantly negatively correlated with self-rated health ($r = -0.242$, $p < 0.01$). Mediation effect testing indicated that sleep quality and self-rated health partially mediated the relationship between physical exercise and negative emotions, with total effect, total direct effect, and total indirect effect values of −1.702, −0.426, and − 1.277, respectively.

**Conclusion:** College students primarily engage in low-intensity physical activity. Sleep quality and self-rated health mediate the impact of physical exercise on students' negative emotions. A certain level of physical activity can directly affect students' emotional states and indirectly influence their negative emotions via sleep and self-rated health. Regular engagement in physical activities primarily positively impacts emotional states by enhancing mood stability and overall emotional resilience.

10.3389/fpubh.2024.1402801

KEYWORDS

physical exercise, self-rated health, sleep quality, chain mediation model, college student

## Introduction

Negative emotions in college students are a vital factor significantly impacting mental health (1). College students are at a crucial transition from students to societal individuals, with factors such as interpersonal relationships, academic pressure, job prospects, and social adaptation making them susceptible to various mental health issues (2). Negative emotions refer to an individual's adverse attitudinal experience toward objective matters and corresponding behavioral responses, often leading to intense physiological and behavioral reactions, including tension, sadness, fear, guilt, anger, contempt, and disgust (3). Anxiety and depression are two common negative emotions among college students, with numerous studies indicating that stress, arising from an inability to adapt to environmental demands, leads to negative feelings and pessimistic beliefs, with symptoms of anxiety and depression quickly emerging under stress (4). In 2023, the Institute of Psychology, Chinese Academy of Sciences, published the 2022 "Mental Health Blue Book" titled "China National Mental Health Development Report (2021–2022)," revealing that the detection rate of depressive emotions among Chinese college students was 10.6%, and the anxiety risk detection rate was 15.8%, with the 18–24 age group showing a depression risk detection rate of 24.1%, significantly higher than other age groups (5). Consequently, the mental health of college students requires heightened attention. More importantly, identifying effective mental health predictors is crucial for preventing negative emotions.

Prior studies have found that physical exercise is crucial for alleviating negative emotions (6–8). Physical exercise is a crucial and effective method for promoting physical health and can also serve as a green, healthy intervention to prevent aggressive behaviors among college students (9). Dollard's Frustration-Aggression Theory posits that when individuals encounter frustrations leading to unachieved goals and unsatisfied motivations, they exhibit a series of adverse psychological and behavioral reactions (10). Increasing physical exercise can enhance individuals' resilience, promote the maintenance of positive emotions, and offer a rational explanation for reducing self-harm and aggressive behaviors among (11). This offers a rational explanation for how sports activities can reduce self-harm and aggressive behaviors among individuals. Scholars have conducted electrophysiological measurements on women performing emotional regulation tasks, where the late positive potential in these measurements indicates that women who frequently engage in physical exercise perform better in controlling negative emotions (12, 13). Further research indicates that as college students increase their exercise levels, their scores for emotional disorders tend to decrease gradually, demonstrating the varied impacts of exercise intensity on emotional health (14). Moderate aerobic exercise has been found to reduce negative emotional responses, particularly in individuals who struggle with emotional regulation (15). The involution of education prevents college students from releasing negative attitudes into positive energy through moderate physical activity in their daily lives. This lack of physical activity can lead to reduced dopamine activity and elevated cortisol levels, resulting in various degrees of negative emotions among college students (16). Synthesizing the above research provides evidence for the preventive role of physical exercise against the emergence of negative emotions in college students. Yet, there remains a lack of robust empirical evidence on the internal mechanisms by which physical exercise can influence negative emotions.

Previous studies suggest that one of the reasons physical activity alleviates unpleasant feelings could be related to the quality of sleep (17, 18). Sleep quality is often associated with a high co-occurrence rate of negative emotions, and sleep disturbances usually become quickly apparent in most case (19). Herman's circadian rhythm theory suggests the existence of an endogenous biological rhythm system within the human body, regulating the cyclic changes in physiological and behavioral activities within 24 h (20). By combing through the literature on behavioral tendencies and neurological changes, researchers have found that sleep influences mood production and emotion regulation through several potential mechanisms. Lack of sleep and sleep disturbances are identified as common symptoms and risk factors for a variety of mental illnesses, especially closely related to anxiety and mood disorders (21–23). Sleep and emotion regulation share common mechanisms at the neurobiological level. A study indicates that emotional events during the day significantly impact sleep, while the quality of sleep at night indirectly affects individuals' emotional responses to new events the next day (24–26). The effects of exercise on sleep quality and emotional well-being differed between men and women, and poorer sleep quality was strongly associated with daytime dysfunction in individuals (27, 28). Another research focused on the common issues of insufficient sleep, emotional problems among college students, and their negative attitudes toward participation in physical activities. The intervention group showed potential improvements in sleep and mental health after a 6-week program consisting of three 30-min gaming sessions per week (29).

How does self-rated health further impact college students' negative emotions? Self-rated health is an individual's subjective evaluation and cognition of their disease burden and an expectation for their overall health status (30, 31). It can stimulate and guide individuals to actively perceive pain and discomfort that are difficult to observe through external means, thereby reducing the risk of illness and death (32). Extensive research indicates that self-rated health status has a strong predictive power for an individual's risk of death, and there is significant heterogeneity in the responses to self-rated health among different populations (30). Age and gender significantly

Abbreviations: PARS-3, Physical Activity Rating Scale; DASS-21, Depression Anxiety and Stress Scale; PSQI, the Pittsburgh Sleep Quality Index; SF-12, Self-rated health Status Scale; SD, Standardized deviation; Boot SE, The standard error of 95% Bootstrap confidence interval; Boot LLCI, Lower limits of 95% Bootstrap confidence interval; Boot ULCI, Upper limits of 95% Bootstrap confidence interval.

influence self-rated health status; as individuals age and accumulate life experiences, their assessment of their health tends to become more pessimistic. Concerns about one's health status may also affect the likelihood of diseases and accidents occurring (33, 34). To a certain extent, individuals' expectations of self-rated outcomes govern changes in their behavior. Research shows that mind–body main complaints are essential for developing a framework for rating students' mental health (35, 36). Psychosomatic complaints are associated with university students' choices and reflections on the future, as well as the negative emotions they experience when facing real-life challenges (37). Therefore, shaping a positive health perspective among college students is very important. Additionally, the reduction in sleep duration and interpersonal issues among peers can lead to the emergence of anxiety and suicidal thoughts. This evidence supports the association between sleep deprivation and potential mental health issues among the youth and elucidates an intrinsic relationship between individual sleep patterns and self-rated health. Such a relationship aligns with the findings of researchers like Meer (38). Research by Chinese scholar Dong Hanyu and others has also confirmed that higher negative emotions correlate with poorer self-rated health status (39). After interaction analysis, there is an additive interaction between negative emotions and physical exercise (40). Shaping the correct health perspective and enhancing cognitive and thinking abilities regarding health can reduce the negative impact of negative emotions on the organism.

A bidirectional relationship exists between sleep quality and self-rated health, with better self-rated health status associated with improved sleep quality (41, 42). A dynamic relationship exists between subjective sleep quality and the emotional state the following day (43). A longitudinal study indicated that graded assessments of patients based on psychological changes and the severity of mental disorders, using mental health self-rated questionnaires and the Pittsburgh Sleep Quality Index, can help patients find inner balance and good health status. A study utilizing brain imaging found that specific brain regions related to emotions are associated with negative emotions and affect the sleep quality of young people (44). Additionally, research has found that sleep deprivation can directly predict physiological problems in female college students, and the decline in self-rated health due to insufficient sleep can lead to increased stress among this group (45).

In summary, this study is based on the framework of psychological and physiological mechanisms by which physical exercise affects college students' emotions, as described in the existing literature, attempting to establish the pathway through which physical exercise impacts negative emotions in college students. Based on this, the study proposes Hypothesis *H1: Participation in bodily exercise can effectively regulate negative emotions in college students and improve their mental health status.* To further explore the mechanism by which physical exercise affects negative emotions in college students, based on the principles of sleep medicine and psychometrics, starting from college students' beliefs in health and overcoming illness and their motivation for taking action, it's essential to understand the role of positive health behaviors in reducing the risk of mental illness. Thus, the study proposes Hypothesis *H2: Physical exercise regulates negative emotions and enhances mental health by improving sleep quality in college students.* Faced with the challenges posed by anxiety and depression, individuals with higher levels of self-rated health believe they can overcome setbacks and will adopt a series of positive health behaviors to cope with adverse life events and reasonably regulate their emotional changes. From this, Hypothesis *H3 is proposed: Sleep quality and self-rated health play a chained mediating role in preventing negative emotions among college students through physical exercise.*

# Materials and methods

## Procedure and participants

The survey targets students enrolled in general higher education institutions in mainland China, and the list of general higher education institutions refers to the Ministry of Education's "List of National General Higher Education Institutions (as of September 30, 2021)." Inclusion Criteria: Ordinary university students from first to fourth year with good listening, speaking, reading, and writing skills, possessing the cognitive abilities and intelligence required to understand and complete the questionnaire, and participating in this study is voluntary. Exclusion Criteria: Severe personality disorders, such as individuals with significant physical illnesses, prevent them from completing the questionnaire.

## Sampling methods

The survey subjects were selected using stratified, cluster, and multi-stage sampling methods.

## Determination of sampling locations

To ensure the representativeness of the monitoring subjects, each province and city was allocated three sampling locations. The specific practice was as follows: cities under the jurisdiction of each province or autonomous region were selected as sampling locations. Among them, the provincial capital cities were categorized as "Type 1" sampling locations; the other two sampling locations were determined based on the geographical location of the province or autonomous region, selecting one city with an average level of socio-economic development as "Type 2" and one with relatively poor socio-economic development as "Type 3." The sampling did not adhere strictly to the above principles in municipalities directly under the central government. Still, it was primarily random cluster sampling, with consideration given to the number of sampling locations.

## Determination of sampling units

When selecting sampling units, three primary considerations were taken into account: first, the higher education institutions should be formally established and recorded by the Ministry of Education, including higher vocational colleges; second, units that meet the sampling requirements (such as age, number of participants, grade distribution, etc.); third, units with a specific person responsible for distributing questionnaires who are willing to participate in the monitoring over the long term.

## Grouping and sample size

Participants were divided into two groups based on gender and then into eight categories by grade, with a minimum of 45 participants in each category (e.g., first-year male students). The total sample size for each province (or municipality directly under the central government) was 1,080 participants, with an expected total of 33,480 participants nationwide (excluding Hong Kong, Macao, and Taiwan). In September 2022, the Questionnaire Star software was used for an electronic survey based on administrative classes, yielding 33,369 completed questionnaires. The number of valid questionnaires was 30,475.

## Survey quality control

First, standardization of research protocols and survey implementation, with specific training for investigators before the official survey, creation of standardized introductions, proficiency with questionnaire content, and cautionary notes for filling out the questionnaire. Investigators include student counselors or teachers. The second is establishing data cleaning rules to ensure the external validity of the analysis data. In data preprocessing, entries with logical errors, omissions, inaccuracies, or undistinguishable responses are retested or excluded to ensure data authenticity and validity. The third is conducting tests for common method bias before applying data analysis. During the administration to college students, the principal investigator emphasizes the anonymity and confidentiality of the questionnaire, explaining that the data is solely for scientific research to control for sources of standard method bias as much as possible. Harman's single-factor test method is also used to test common method bias. The result found that there are 10 factors with eigenvalues greater than 1, and the first common factor explained 38.549% of the variance, which is below the critical standard of 40%. This indicates no severe homologous bias in this study.

# Research tools

## Physical activity rating scale (PARS-3)

The Physical Activity Rating Scale (PARS-3) was compiled by the Japanese scholar Takao Hashimoto and revised by Liang et al. (46). The scale examines the amount of physical activity, including intensity, frequency, and workout time. It uses them to measure the level of participation in physical activity. The physical activity score = intensity × (time-1) × frequency and each aspect was divided into five levels, scored on a scale of 1 to 5, with a scale of ≤19 points for small exercise, 20–42 points for medium exercise, and ≥43 points for extensive training. The PARS-3 scale comprises three dimensions: Intensity, frequency, and duration. Physical activity level = Intensity x Duration x Frequency, with Intensity and frequency graded from 1 to 5, each assigned 1–5 points respectively, and duration graded from 1 to 5, each assigned 0–4 points, respectively. The highest score is 100 points, and the lowest score is 0 points. Physical activity level assessment standards: ≤19 points are classified as fluctuating activity level; 20–42 points as moderate activity level; ≥43 points as high activity level. In the "Exercise Intensity" dimension, the number 1 signifies "Minimal Intensity," the number 2 "Low Intensity," the number 3 "Moderate Intensity," the number 4 "High Intensity," and the number 5 "Maximum Intensity." In the "Frequency" dimension, the number 1 represents "Less than once a month," the number 2 "3 to 5 times a week," the number 3 "2 to 3 times a month," the number 4 "Approximately once a day," and the number 5 "1 to 2 times a week." In the "Duration" dimension, the number 0 indicates "Less than once a month," the number 1 "3 to 5 times a week," the number 2 "2 to 3 times a month," the number 3 "Approximately once a day," and the number 4 "1 to 2 times a week." The results of the PARS-3 represent the amount of physical activity of the subjects, and its retest reliability was 0.82. In previous studies, Javalle and Cheng used the exercise scale measure to measure the physical activity participation of different age groups and the status of physical exercise levels. They verified the scale's reliability, and its reliability level is high (0.70–0.80) (47).

## Depression anxiety and stress scale (DASS-21)

The Depression-Anxiety-Stress Self-rated Scale in Simplified Chinese (DASS-21), compiled by Lovibond et al. (48), revised by Antony et al. (49), and translated by Yuan, was used for the measurement. The Chinese scale version is reliable and valid for the Chinese adolescent population. The scale consists of 21 items, with three subscales for depression, anxiety, and stress, each containing seven items. Scoring ranges from "0" (not applicable) to "3" (always applicable), with higher scores indicating a more substantial presence of these emotions. In the Likert 4-point scoring system, the number "0" represents "Did not apply to me at all"; "1" represents "Applied to me to some degree or some of the time"; "2" represents "Applied to me to a considerable degree, or a good part of the time"; "3" represents "Applied to me very much, or most of the time." In the dimensions of depression, anxiety, and stress, higher scores on the survey indicate a more severe level of these negative emotions. Analysis of 543 valid preliminary survey questionnaires revealed that the scale's Cronbach's alpha coefficient is 0.891, KMO value is 0.925, and the Cronbach's alpha coefficients for the depression, anxiety, and stress subscales are 0.774, 0.743, and 0.752 respectively, indicating good reliability and validity of the scale (50, 51).

## Pittsburgh sleep quality index (PSQI)

A revised questionnaire based on the Pittsburgh Sleep Quality Index Scale compiled by Buysse was used to assess the sleep quality of college students Liu (52, 53). The scale covers seven dimensions with a total of 19 measurement entries, and a score of 0–3 was used to assess the scores of the measurement entries. The scale was scored reversely, with higher overall scores representing more severe sleep quality problems in individuals, and the scores were generally in the range of 0–21 points. In past studies, sleep quality questionnaires were commonly used among healthcare workers, high-pressure groups, the older adult, and special sleep disorder groups, and the level of reliability and validity was also high (0.77–0.88), reaching the range defined by social science research (54, 55).

## Self-rated health status (Short Form Health Survey-12, SF-12)

Using a single entry from the Short Form Health Survey-12 (SF-12) (Overall, what do you think your current health status is?) Conduct a Self-rating of your health (55). Participants were asked to rate their perceived health (1 = poor, 2 = fair, 3 = good, 4 = very sound, 5 = very good), categorizing self-rated health scores as ≥3 (good, very good, or excellent) and < 3 (poor or fair). The scale's internal consistency reliability, Cronbach's alpha, is 0.84. The correlation coefficients between each dimension and the total score are above 0.50, except for physical functioning (PF) at 0.43. Cronbach's alpha coefficients for all dimensions exceed 0.70, remaining above 0.70 even after the respective dimensions are removed. The scale's construct validity was confirmed with a 100% success rate in both convergent and discriminant validity calibration experiments (56). Confirmatory factor analysis of the theoretical structure model yielded a model consistent with original assumptions, with fit indices showing a non-normal fit index (NNFI) of 0.95, a comparative fit index (CFI) of 0.96, an adjusted goodness of fit index (AGFI) of 0.96, and a root mean square error of approximation (RMSEA) of 0.06. Furthermore, the reliability of the SF-12, compared to PCS-12 and MCS-12, was validated, ranging from 0.63 to approximately 0.91 (57).

## Data analysis

### Data preprocessing in excel

Initially, you use Excel to preprocess the data obtained from Questionnaire Star, addressing missing or problematic data through retesting or deletion.

### Common method bias test

To prevent issues related to common method bias, you perform tests specifically designed to identify this type of bias, ensuring the validity of your findings.

Analysis of Core Variables with ANOVA and Chi-Square Tests: You conduct a one-way ANOVA and chi-square tests to analyze core variables. The Cramer's V coefficient, which ranges from 0 to 1, assesses the strength and correlation between two variables. A higher difference suggests a more substantial effect and correlation between the variables.

### Kendall's rank correlation analysis

This analysis tests the correlations between physical exercise, sleep quality, self-rated health, stress, anxiety, and depression. Kendall's W coefficient, ranging from 0 to 1, interprets the degree of correlation between variables based on familiar statistical measures. Values closer to 1 indicate a higher degree of correlation.

The mediation analysis was carried out through model 6 in plug-in process 4.0, and the mediation model was tested with the help of the Bootstrap method for the relevant core variables.

# Results

## Descriptive analysis

Before examining the mechanisms by which physical exercise affects negative emotions in college students, a description of the essential characteristics of each variable was provided, including sample size, percentage, chi-square value, and Cramér's V coefficient. Results from Table 1 indicate that physical exercise among college students is primarily of low intensity, accounting for 77.6%. Gender-wise, female students have significantly lower physical activity levels than males ($V = 0.311$, $p < 0.001$), with a statistically significant difference. The proportion of low-intensity exercise reached 87.9%, while high-intensity exercise accounted for only 3.3%. Considering the distribution across grades, there is a statistically significant difference in the levels of physical exercise between male and female students across different grades ($V = 0.021$, $p < 0.001$).

Regarding stress levels, there is a statistically significant difference between male and female college students ($\eta^2 = 0.013$, $p < 0.001$), with means and standard deviations of $13.51 \pm 5.86$ and $12.29 \pm 4.67$, respectively. The correlation in anxiety levels between male and female college students is weak. The difference in depression levels across genders is statistically significant ($\eta^2 = 0.019$, $p < 0.001$), with means and standard deviations of $13.03 \pm 5.89$ and $11.56 \pm 4.65$, respectively, indicating a higher correlation than for anxiety. The difference in DASS (Depression, Anxiety, and Stress Scale) scores between genders is statistically significant ($\eta^2 = 0.0155$, $p < 0.001$), with a low correlation. Evaluating across different grades, first-year students and sophomores exhibit higher levels of depression, with less variability and stable changes ($p < 0.001$), which is statistically significant (Table 2).

## Correlation analysis

The Kendall rank correlation analysis of the variables, as shown in Table 3, indicates significant negative correlations between physical exercise and stress, anxiety, and depression.

## Analysis of mediating effects

The following model was established based on hierarchical regression analysis: physical exercise, self-rated health, and sleep quality as independent variables; gender, grade, smoking, and drinking as control variables; and negative emotion as the dependent variable. The model was designed to test for main, direct, and indirect effects. The results of the hierarchical regression analysis for chained mediation effects are presented in Table 4.

The table below shows that controlling for variables such as gender, grade, smoking, and drinking, physical exercise significantly negatively predicts negative emotions, $\beta = -0.071$, $SE = 0.143$, $t = -11.894$, $p < 0.001$, confirming the main effect. Physical exercise significantly negatively predicts sleep quality, $\beta = -0.044$, $SE = 0.039$, $t = -7.306$, $p < 0.001$, and significantly positively predicts self-assessed health status, $\beta = 0.225$, $SE = 0.009$, $t = 39.422$, $p < 0.001$. It also significantly negatively predicts negative emotions, $\beta = -0.018$, $SE = 0.131$, $t = -3.251$, $p < 0.01$. Self-assessed health significantly negatively predicts negative emotions, $\beta = -0.154$, $SE = 0.079$, $t = -28.734$, $p < 0.001$; sleep quality significantly positively predicts negative emotions, $\beta = 0.389$, $SE = 0.019$, $t = 74.068$, $p < 0.001$.

This study utilized a bias-corrected percentile Bootstrap method (with 5,000 Bootstrap samples) and model 6 from Hayes's (58) *SPSS* macro program, *PROCESS 4.0*. A chained mediation

TABLE 1 Descriptive statistic variables.

| Norm | Assemble | Gender | | | | | | Grade | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male (*n* = 12,440) | | Female (*n* = 18,035) | | Freshman(*n* = 9,718) | | Sophomore (*n* = 11,941) | | Junior (*n* = 6,406) | | Senior (2410) | |
| | | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % |
| Physical activity level | | | | | | | | | | | | | | | |
| | Low | 23,643 | 77.6 | 7786 | 62.5 | 15857 | 87.9 | 7518 | 77.4 | 9235 | 77.3 | 5025 | 78.4 | 1865 | 77.4 |
| | Middle | 3986 | 13.1 | 2408 | 19.4 | 1578 | 8.8 | 1351 | 13.9 | 1587 | 13.3 | 738 | 11.6 | 310 | 12.9 |
| | High | 2846 | 9.3 | 2246 | 18.1 | 600 | 3.3 | 849 | 8.7 | 1,119 | 9.4 | 643 | 10 | 235 | 9.7 |
| | $\chi 2$ | | | 2952.305 | | | | 25.775 | | | | | | | |
| | *p* | | | <0.001 | | | | <0.001 | | | | | | | |
| | Cramer's V | | | 0.311 | | | | 0.021 | | | | | | | |
| Self-rated health | | | | | | | | | | | | | | | |
| | Terrible | 867 | 2.8 | 463 | 3.7 | 404 | 2.2 | 239 | 2.5 | 351 | 2.9 | 186 | 2.9 | 91 | 3.8 |
| | After a fashion | 11139 | 36.6 | 4247 | 34.1 | 6892 | 38.2 | 3523 | 36.3 | 4526 | 37.9 | 2225 | 34.7 | 865 | 35.8 |
| | Fine | 10070 | 33.1 | 3784 | 30.4 | 6,286 | 34.8 | 3239 | 33.3 | 3999 | 33.5 | 2047 | 32 | 785 | 32.6 |
| | Excellent | 5405 | 17.7 | 2424 | 19.5 | 2981 | 16.5 | 1794 | 18.4 | 1993 | 16.7 | 1192 | 18.6 | 426 | 17.7 |
| | Super | 2994 | 9.8 | 1522 | 12.3 | 1472 | 8.3 | 923 | 9.5 | 1072 | 9 | 756 | 11.8 | 243 | 10.1 |
| | $\chi 2$ | | | 294.695 | | | | 76.992 | | | | | | | |
| | *p* | | | <0.001 | | | | <0.001 | | | | | | | |
| | Cramer's V | | | 0.098 | | | | 0.029 | | | | | | | |
| Sleep quality | | | | | | | | | | | | | | | |
| | Pretty good | 13821 | 45.3 | 5931 | 47.7 | 7890 | 43.7 | 4780 | 49.2 | 5,258 | 44.1 | 2686 | 41.9 | 1097 | 45.5 |
| | General | 11,554 | 37.9 | 4339 | 34.9 | 7215 | 40 | 3652 | 37.6 | 4550 | 38.1 | 2505 | 39.1 | 847 | 35.1 |
| | Poorly | 5100 | 16.8 | 2170 | 17.4 | 2930 | 16.3 | 1,286 | 13.2 | 2133 | 17.8 | 1215 | 19 | 466 | 19.4 |
| | $\chi 2$ | | | 82.387 | | | | 169.414 | | | | | | | |
| | *p* | | | <0.001 | | | | <0.001 | | | | | | | |
| | Cramer's V | | | 0.052 | | | | 0.053 | | | | | | | |
| Pressure rating | | | | | | | | | | | | | | | |

*(Continued)*





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TABLE 1 (Continued)

| Norm | Assemble | Gender | | | | | | Grade | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male (*n* = 12,440) | | Female (*n* = 18,035) | | Freshman(*n* = 9,718) | | Sophomore (*n* = 11,941) | | Junior (*n* = 6,406) | | Senior (2410) | |
| | | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % |
| | Normalcy | 15888 | 52.1 | 5931 | 47.7 | 9957 | 55.2 | 5566 | 57.3 | 5901 | 49.4 | 3250 | 50.7 | 1171 | 48.6 |
| | Mildly | 8880 | 29.1 | 3510 | 28.2 | 5370 | 29.8 | 2784 | 28.6 | 3629 | 30.4 | 1778 | 27.8 | 689 | 28.6 |
| | Moderately | 4352 | 14.3 | 2101 | 16.9 | 2251 | 12.5 | 1131 | 11.6 | 1786 | 15 | 1022 | 15.9 | 413 | 17.1 |
| | Severe | 1355 | 4.5 | | | 898 | 7.2 | 237 | 2.4 | 625 | 5.2 | 356 | 5.6 | 137 | 5.7 |
| | $\chi 2$ | | | 549.805 | | | | 294.585 | | | | | | | |
| | *p* | | | <0.001 | | | | <0.001 | | | | | | | |
| | Cramer's V | | | 0.134 | | | | 0.057 | | | | | | | |
| Anxiety level | | | | | | | | | | | | | | | |
| | Mildly | 11024 | 36.2 | 4359 | 35.1 | 6665 | 36.9 | 3547 | 36.5 | 4112 | 34.4 | 2476 | 38.7 | 889 | 36.9 |
| | Moderately | 8491 | 27.9 | 2944 | 23.7 | 5547 | 30.8 | 3264 | 33.6 | 3138 | 26.3 | 1495 | 23.3 | 594 | 24.6 |
| | Severe | 7616 | 25 | 3191 | 25.6 | 4425 | 24.5 | 2247 | 23.1 | 3187 | 26.7 | 1599 | 25 | 583 | 24.2 |
| | Very Serious | 3344 | 10.9 | 1946 | 15.6 | 1398 | 7.8 | 660 | 6.8 | 1504 | 12.6 | 836 | 13 | 344 | 14.3 |
| | $\chi 2$ | | | 561.824 | | | | 463.129 | | | | | | | |
| | *p* | | | <0.001 | | | | <0.001 | | | | | | | |
| | Cramer's V | | | 0.136 | | | | 0.071 | | | | | | | |
| Depression level | | | | | | | | | | | | | | | |
| | Normalcy | 6806 | 22.3 | 2680 | 21.6 | 4126 | 22.9 | 2258 | 23.2 | 2494 | 20.9 | 1491 | 23.3 | 563 | 23.4 |
| | Mildly | 9492 | 31.1 | 3300 | 26.5 | 6192 | 34.3 | 3639 | 37.4 | 3404 | 28.5 | 1814 | 28.3 | 635 | 26.3 |
| | Moderately | 10276 | 33.8 | 4202 | 33.8 | 6074 | 33.7 | 3050 | 31.4 | 4296 | 36 | 2125 | 33.2 | 805 | 33.4 |
| | Severe | 2807 | 9.2 | 1512 | 12.2 | 1,295 | 7.2 | 604 | 6.3 | 1218 | 10.2 | 692 | 10.8 | 293 | 12.2 |
| | Very Serious | 1094 | 3.6 | 746 | 5.9 | 348 | 1.9 | 167 | 1.7 | 529 | 4.4 | 284 | 4.4 | 114 | 4.7 |
| | $\chi 2$ | | | 686.888 | | | | 525.039 | | | | | | | |
| | *p* | | | <0.001 | | | | <0.001 | | | | | | | |
| | Cramer's V | | | 0.15 | | | | 0.076 | | | | | | | |





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TABLE 2 Descriptive statistical analysis.

| | | Assemble | | Gender | | | | Grade | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male ($n$ = 12,440) | | Female ($n$ = 18,035) | | Freshman ($n$ = 9,718) | | Sophomore ($n$ = 11,941) | | Junior($n$ = 6,406) | | Senior(2410) | |
| | | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Stresses | | 12.79 | 5.23 | 13.51 | 5.86 | 12.29 | 4.67 | 12.17 | 4.56 | 13.08 | 5.41 | 13.02 | 5.57 | 13.21 | 5.63 |
| | *F* | | | 408.052 | | | | 68.57 | | | | | | | |
| | *p* | | | <0.001 | | | | <0.001 | | | | | | | |
| | $\eta^2$ | | | 0.013 | | | | 0.007 | | | | | | | |
| Apprehensive | | 12.39 | 5.1 | 13.08 | 5.77 | 11.91 | 4.51 | 11.82 | 4.34 | 12.71 | 5.31 | 12.54 | 5.47 | 12.7 | 5.58 |
| | *F* | | | 389.71 | | | | 60.727 | | | | | | | |
| | *p* | | | <0.001 | | | | <0.001 | | | | | | | |
| | $\eta^2$ | | | 0.013 | | | | 0.006 | | | | | | | |
| Despondent | | 12.16 | 5.24 | 13.03 | 5.89 | 11.56 | 4.65 | 11.29 | 4.477 | 12.57 | 5.443 | 12.5 | 5.578 | 12.75 | 5.679 |
| | *F* | | | 587.165 | | | | 135.544 | | | | | | | |
| | *p* | | | <0.001 | | | | <0.001 | | | | | | | |
| | $\eta^2$ | | | 0.019 | | | | 0.013 | | | | | | | |
| Total DASS score | | 37.335 | 15.21 | 39.62 | 17.21 | 35.76 | 13.43 | 35.27 | 12.9 | 38.36 | 15.86 | 38.06 | 16.332 | 38.65 | 16.57 |
| | *F* | | | 479.984 | | | | 89.318 | | | | | | | |
| | *p* | | | <0.001 | | | | <0.001 | | | | | | | |
| | $\eta^2$ | | | 0.016 | | | | 0.009 | | | | | | | |





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TABLE 3 List of results of correlation analysis.

| | Variant | | Physical exercise | Stresses | Apprehensive | Despondent | Self-rated health | Sleep quality |
|---|---|---|---|---|---|---|---|---|
| Kendall (name) | Physical exercise | *r* | 1 | | | | | |
| | Stresses | *r* | −0.030** | 1 | | | | |
| | Apprehensive | *r* | −0.058** | 0.770** | 1 | | | |
| | Despondent | *r* | −0.055** | 0.761** | 0.774** | 1 | | |
| | Self-rated health | *r* | 0.194** | −0.248** | −0.280** | −0.299** | 1 | |
| | Sleep quality | *r* | −0.035** | 0.322** | 0.341** | 0.330** | −0.242** | 1 |

In the text, ** represents $p < 0.01$ and *** represents $p < 0.001$.

effect analysis was conducted controlling for gender and grade to investigate the mediating roles of self-rated health and sleep quality between physical exercise and negative emotions in college students. The Bootstrap chained mediation effect analysis results are presented in Table 5. The main effect of physical exercise on negative emotions was −1.702, with a 95% confidence interval of [−1.983, −1.422], not crossing zero, indicating that the total effect is significant. The total indirect effect was-1.277, with a 95% confidence interval of [−1.421, −1.128], not crossing zero, accounting for 75.5% of the effect. The total direct effect was −0.426, with a 95% confidence interval of [−0.683, −0.169], not crossing zero, accounting for 24.5% of the effect, thus confirming the direct effect. Specifically, the indirect effect of physical exercise → sleep quality → self-rated health → *DASS* was −0.039, with a 95% confidence interval of [−0.051, −0.027], indicating that the model constitutes a partial chained mediation (Table 5).

## Discussion

This study examined the roles of sleep quality and self-rated health in the effects of physical exercise on negative emotions of Chinese college students and the relationship between physical exercise and negative emotions of college students, which supports hypotheses 1, 2, and 3. Furthermore, this study reveals that college student has potential benefits in enhancing emotional health through active participation in physical activity. Physical exercise can affect negative emotions through the chain mediating effects of sleep quality and self-rated health, which means that the effects of physical exercise on college student's mental health are interfered with by the chain mediating roles of sleep and self-cognition, which provides a scientific basis for the design of intervention programs for college students' mental health (Figure 1).

### Correlation of physical activity, sleep quality, self-rated health, and negative emotions among college students

This study found that physical exercise is negatively correlated with college students' stress, anxiety, and depression, negatively correlated with sleep quality, and positively correlated with self-rated health. After incorporating mediating variables, the predictive role of physical exercise on negative emotions in college students remained significant, thus confirming hypothesis *H1*. Academic activities occupy a crucial position in the lives of college students. At the same time, participation in physical exercise offers opportunities to enhance individual self-esteem levels, subjective well-being, and interpersonal skills (59). Sleep is fundamental for college students to maintain normal physiological functions and social activities. Poor sleep habits, such as staying up late, frequent napping, and excessive reliance on sleeping pills, can affect their daily life, learning, and peer relationships (60). Self-rated health is based on individuals' understanding of their physiological, psychological, and social adaptability, integrating subjective and objective health information to form an overall perception of their health status (30, 61, 62). The results of this study show a negative correlation between sleep quality and self-rated health. An influential relationship exists between sleep duration and brain cognitive function, emotional activities, and the duration of social interactions (63). However, support from longitudinal data or follow-up survey data is needed to verify these causal relationships. Internationally, based on Brown's theory, research on sleep quality and self-rated health often focuses on responses to different stresses, handling emergencies, and preventing aggressive behaviors (64). Rarely do studies treat sleep quality and self-rated health among youth as continuous variables to examine their relationship with negative emotions. Therefore, physical exercise can promote the development of mental health in college students and prevent the occurrence of negative emotions.

### The direct effect of sports on negative emotions of Chinese college students

The findings of this study demonstrate that physical activity can significantly positively affect college students' negative emotions. The neuroprogression hypothesis suggests that long-term, regular physical exercise can significantly counteract the progression of mood disorders by enhancing the expression of neurotrophic factors in the brain and reducing stress-induced neuroinflammatory responses (65). The key motivation for college students to persist in physical exercise is self-efficacy and self-esteem. Gaining a sense of achievement and belief can help reduce psychological stress among college students. According to Rosenberg's self-esteem theory, individual participation in exercise, achievement of exercise goals, and completion of corresponding challenges can provide a psychological buffer and enhance positive emotional experiences through perceived self-worth (66). According to Ulrich's Stress Recovery Theory, when college students engage in outdoor physical

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TABLE 4 Hierarchical regression analysis of chained mediation effects.

| Regression equation | | | Overall fit index | | | Significance of regression coefficients | | |
|---|---|---|---|---|---|---|---|---|
| Outcome variable | Predictor variable | | $R$ | $R^2$ | $F$ | $\beta$ | $SE$ | $t$ |
| DASS | | | 0.169 | 0.029 | 178.672*** | | | |
| | Gender | | | | | −0.132 | 0.193 | −21.128*** |
| | Grade | | | | | 0.075 | 0.094 | 13.160*** |
| | Cigarette smoking | | | | | 0.055 | 0.26 | 9.055*** |
| | Drinking wine | | | | | 0.01 | 0.16 | 1.698 |
| | Physical exercise | | | | | −0.071 | 0.143 | −11.894*** |
| DASS | | | 0.477 | 0.227 | 1280.918*** | | | |
| | Gender | | | | | −0.139 | 0.172 | −24.915*** |
| | Grade | | | | | 0.053 | 0.084 | 10.340*** |
| | Cigarette smoking | | | | | 0.026 | 0.232 | 4.830*** |
| | Drinking wine | | | | | −0.032 | 0.143 | −5.952*** |
| | Physical exercise | | | | | −0.018 | 0.131 | −3.251** |
| | Sleep quality | | | | | 0.389 | 0.019 | 74.068*** |
| | Self-rated health | | | | | −0.154 | 0.079 | −28.734*** |
| Sleep quality | | | 0.135 | 0.018 | 113.446*** | | | |
| | Gender | | | | | 0.014 | 0.053 | 2.166* |
| | Grade | | | | | 0.063 | 0.026 | 11.021*** |
| | Cigarette smoking | | | | | 0.067 | 0.071 | 10.963*** |
| | Drinking wine | | | | | 0.081 | 0.044 | 13.389*** |
| | Physical exercise | | | | | −0.044 | 0.039 | −7.306*** |
| Self-rated health | | | 0.337 | 0.114 | 650.186*** | | | |
| | Gender | | | | | −0.007 | 0.0124 | −1.13 |
| | Grade | | | | | 0.03 | 0.0061 | 5.446*** |
| | Cigarette smoking | | | | | −0.002 | 0.017 | −0.322 |
| | Drinking wine | | | | | −0.051 | 0.01 | −8.819*** |
| | Physical exercise | | | | | 0.225 | 0.009 | 39.422*** |
| | Sleep quality | | | | | −0.242 | 0.001 | −44.530*** |

In the text, *** represents $p < 0.001$, ** represents $p < 0.01$, and * represents $p < 0.05$.

TABLE 5 Chain-mediated effects analysis of stress, anxiety, depression, and DASS by Bootstrap method.

| Effect (scientific phenomenon) | Efficiency value | BootSE | 95% CIlower limit | 95% CI upper limit | Proportion of effect |
|---|---|---|---|---|---|
| Aggregate effect | −1.702 | 0.143 | −1.983 | −1.422 | |
| Total direct effect | −0.426 | 0.131 | −0.683 | −0.169 | 24.50% |
| Total indirect effect | −1.277 | 0.075 | −1.421 | −1.128 | 75.50% |
| Physical activity → sleep quality → DASS | −0.408 | 0.06 | −0.523 | −0.287 | 55.40% |
| Physical activity → Self-rated health → DASS | −0.829 | 0.04 | −0.907 | −0.751 | 8.03% |
| Physical activity → Sleep quality → Self-rated health → DASS | −0.039 | 0.006 | −0.051 | −0.027 | 28.05% |

exercises, the natural environment can help replenish cognitive resources depleted by prolonged focus (67). Once the duration and intensity of physical exercise reach a certain level, individuals can alleviate fatigue, restore attention, and enhance their emotional regulation abilities in the natural setting (68).

## Mediating effects of sleep quality

The results of this study indicate that sleep quality mediates the relationship between physical exercise and negative emotions among college students. Physical activity can directly influence

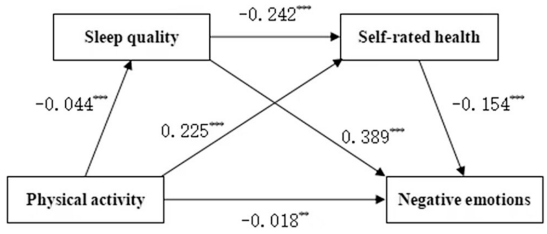


FIGURE 1
Shows the chain-mediated route coefficients of unpleasant emotions.

students' negative emotions and indirectly affect their psychological health through good sleep quality, thus confirming research hypothesis *H2*. Siegel's cross-cultural study suggests that the function of sleep may be to enhance behavioral efficiency during periods when biological activity is no longer beneficial by optimizing time use and reducing energy consumption (69). Under neural regulation, improving individual perception and physiological functions helps mitigate the adverse effects on the body caused by sleep-disordered breathing and circadian rhythm disorders (70). According to circadian rhythm theory, college students who achieve higher sleep quality through physical exercise have an enhanced ability to monitor and accept current psychological experiences, enabling them to cope with negative emotional experiences triggered by negative stimuli more quickly (71). Alexander Borbély's Two-Process Model of sleep regulation corroborates the two main processes of sleep modulation, sleep propensity, and circadian rhythms, laying a solid foundation for enhancing mental health quality (72). Shang's research indicates that engaging in aerobic exercise with peers reduces sensitivity and bias in interpersonal relationships (73). Improving interpersonal relations can help alleviate evening anxiety and stress, enhance sleep quality, and reduce the physical and mental fatigue caused by stress and anxiety in the college student population.

## The mediating role of self-rated health

The results of this study show a strong correlation between self-rated health and physical exercise. The path analysis between self-rated health and negative emotions reveals a significant effect of self-rated health. Studies have shown that the overall self-rated health score is positively correlated with the total health literacy score; the higher the self-rated health score, the higher the individual's level of health literacy (74). Individuals with high health literacy are more likely to adopt positive health behaviors and coping strategies when facing mental health issues. There are statistically significant differences in the frequency of participation in physical exercise, self-rated health status, lifestyle, and behavioral literacy levels among college students of different ages, genders, and grades show statistically significant differences (75, 76). Strengthening education on healthy lifestyles, behaviors, and primary health skills among college students can effectively enhance their awareness and ability to prevent infectious and chronic diseases. Other studies analyze individuals' subjective perceptions of their health status from the perspectives of intergenerational relationships and social support, where emotional resonance from relatives and financial assistance from the government or society partially mediate between self-rated health and anxiety (77, 78). This study examines the understanding of health definitions among college students and the importance of self-rated of health status. Forming health awareness and good health concepts among college students can help cultivate regular rest, a reasonable diet, and moderate exercise habits.

## Analysis of the chain mediating role of sleep quality and self-rated health in physical activity on negative emotions among college students

This study constructed a mediation model for the impact of physical exercise on negative emotions among college students, with sleep quality and self-rated health as mediating variables. According to the test of chained mediation effects, physical exercise can not only directly negatively predict college students' negative emotions but can also indirectly influence negative emotions through the mediating roles of sleep quality and self-rated health, thus confirming hypothesis *H3*. The symptoms of depression and anxiety represented by negative emotions partially explain the association between sleep quality and self-rated health. This association operates to some extent through an increase in the levels of depression and anxiety symptoms (79). According to the resource depletion theory, student groups under significant daily stress experience greater consumption of emotional and physical energy resources, leading to varying degrees of impact on their self-control abilities (80, 81). The emergence of stress results from college students being exposed to excessive external stimuli over time, which elevates their sensitivity to adverse life events and diminishes their capacity for emotional expression and control. Given the intrinsic link between physical exercise and anxiety, short-term moderate to high-intensity physical exercise can produce instantaneous emotional improvement (82). This efficient, emotional enhancement positively affects sleep quality. Ensuring adequate sleep duration significantly influences college students' perception of their health (14, 83, 84).

However, a meta-analysis indicated that sleep duration—whether equal to, exceeding, or less than 8 h—impacts self-rated health to various extents and is associated with increased rates of fatigue and depression (85). Upon entering college, students' independence and psychological resilience are challenged, leading to an unavoidable decrease in subjective well-being due to the social environment. Short-term experiences of "flow" can produce feelings of pleasure and self-efficacy, alleviating anxiety and stress (86, 87). The dense college life, filled with opportunities and challenges, can lead to a decline in mood when students do not achieve good results in exams and other competitions. The downturn in emotions suppresses the release of monoamine neurotransmitters (88). Engaging in sports can effectively divert the attention of the college student group from adverse events, producing the pleasure of exercise.

Spiritual abundance can enhance the college student group's satisfaction with life and reduce the occurrence of negative emotions (89). According to Symbolic Interaction Theory, an individual's self-cognition is primarily constructed through interactions with others (90). Frequent and effective interactions can satisfy an individual's psychological needs, improving self-rated health (91). To properly handle the negative impact of negative emotions, college students need to maintain long-term exercise compliance and sufficient sleep, manage themselves appropriately and promptly, and reduce levels of physical stress hormones. Only in this way can a lasting impact on college students' mental and physical health be achieved.

### Research limitations

The study's limitations are that self-reporting can obtain participants' subjective feelings and opinions and can quickly and easily convey the study results. Still, there may be response bias in the reported data, and the individual's cognitive level and emotional state may affect the results to a certain extent. In addition, cross-sectional studies do not yield exact causal relationships, so researchers need to expand the sample size and incorporate current big data technology to design better interventions for negative emotions among college students and improve the efficiency of the study.

## Conclusion

This study aims to understand whether engaging in physical activities can improve emotional states by enhancing sleep and the overall health perception of students, thereby reducing their experience of negative emotions such as stress, anxiety, and depression. Physical exercise has a positive impact on negative emotions in university students. Moreover, sleep quality and self-rated health play a chain mediating role in the effect of physical exercise on these negative emotions. This study extends existing research on the relationship between physical exercise and mental health by exploring the interactions among physical exercise, sleep quality, self-rated health, and negative emotions, providing new insights into how physical exercise impacts emotions through multiple pathways.

The study introduces a chain mediation model to demonstrate how sleep quality and self-rated health act as mediating variables in the influence of physical exercise on negative emotions in university students, enriching the theoretical framework of the psychological effects of physical exercise and providing new hypotheses for future research. Additionally, this study encourages higher education institutions and policymakers to increase their focus on university students' lifestyles, behavioral habits, and stress resilience and to consider the potential moderating factors in the bidirectional interaction between physical activity and mental health when designing personalized emotional intervention plans.

## Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: Since this data contains some privacy related to college students' mental health issues, it can be obtained from the corresponding author if necessary. Requests to access these datasets should be directed to wangqiulibo@163.com.

## Ethics statement

The studies involving humans were approved by General Program of Education of the National Social Science Fund of China: "Research on sports regulation mechanism and intervention scheme of middle school students' psychological pressure." 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

F-zM: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. JL: Methodology, Resources, Writing – review & editing. HL: Funding acquisition, Resources, Writing – review & editing. W-dZ: Data curation, Validation, Writing – review & editing. Z-cW: Methodology, Writing – review & editing. BL: Data curation, Funding acquisition, Methodology, Resources, Writing – review & editing.

## Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. General Program of Education of the National Social Science Fund of China: "Research on sports regulation mechanism and intervention scheme of middle school students' psychological pressure" (BLA210215). 2022 Jiangsu Province Education Science Planning Project. (B/2022/01/173).

## Acknowledgments

We are grateful to the participants and their universities for the cooperation and participation 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

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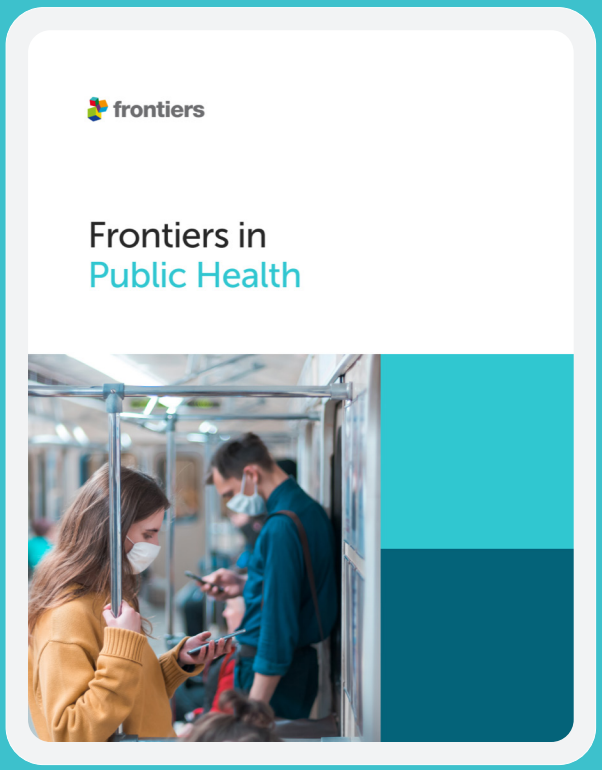


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