Population Health Metrics

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QALY loss associated with unhealthy behaviors: evidence from a multi-center cross-sectional study in Iran

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Abstract

Background Unhealthy lifestyle behaviors such as poor diet, physical inactivity, smoking, and substance use significantly increase the burden of disease and mortality in Iran. These behaviors pose serious challenges to public health and healthcare systems, making it essential to quantify their impact to guide effective health policies and allocate resources efficiently. This study estimates and compares the health burden of unhealthy behaviors in Iran using quality-adjusted life year (QALY) loss.

Method A cross-sectional study was conducted in 2024–2025 involving 3,518 individuals aged 18 and older, selected through multistage sampling across nine provinces in Iran. Data collection included face-to-face interviews using a self-administered questionnaire alongside the Iranian version of the EQ-5D-5 L and EQ-VAS tools to assess health-related quality of life (HRQoL). Generalize linear model (GLM) with gamma distribution and a log link analyzed the impact of each unhealthy behavior including smoking, physical activity, sleep quantity and quality, oral health practices (such as brushing and flossing), breakfast skipping, and dairy consumption on health utility scores. Annual QALY loss per 100,000 individuals was calculated by combining behavior prevalence and health utility data. All data analyses were performed using Stata/MP version 17.

Results In this study, we assessed eight unhealthy lifestyle behaviors among participants: physical activity, smoking status, regular tooth brushing, regular dental flossing, sleep duration, sleep quality, breakfast skipping, and dairy consumption. The prevalence of these behaviors was as follows: 41.79% of participants reported poor physical activity, 25.85% were smokers, 13.19% did not brush their teeth regularly, and 39.57% did not floss regularly. Additionally, 84.22% had insufficient sleep duration (≤ 7 h), 12.48% reported poor sleep quality, 49.81% skipped breakfast, and 25.42% had unsuitable dairy consumption. The study also found that all the unhealthy behaviors were significantly associated with lower EQ-5D-5 L and EQ-VAS scores, with poor sleep quality exhibiting the most substantial negative effect, showing a coefficient of -0.2373 ($p < 0.001$) for the EQ-5D-5 L score and −0.1838 ($p < 0.001$) for the EQ-VAS score. Poor sleep quality also had the largest annual QALY loss per 100,000 individuals at -2961.50 (95% CI: -3407.50 to -2586.52), followed by insufficient sleep duration at -2787.68 (95% CI: -4978.37 to -56.81), breakfast skipping at -2216.55 (95% CI: -3414.74 to -1173.60), and poor physical activity at -2102.04 (95% CI: -3094.81 to -1251.11).

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Conclusion Unhealthy behaviors significantly reduce HRQoL in Iran, with these findings highlighting the high health burden of sleep-related behaviors. These results emphasize the urgent need for targeted public health interventions and prevention strategies to address these behaviors and improve population health.

Keywords Health burden, QALY, Unhealthy behaviors, Disutility

Introduction

Lifestyle choices have a profound impact on health outcomes and can be modified over time. Numerous studies have consistently shown that unhealthy behaviors—such as smoking, physical inactivity, and insufficient sleep—are associated with increased rates of illness and mortality [1–6]. These detrimental behaviors contribute to significant declines in both life expectancy and overall quality of life. For instance, the Global Burden of Disease (GBD) study published in 2022 reported that in 2019, approximately 2.5 million deaths were attributed to cancer (with a 95% uncertainty interval of 2.3 to 2.7 million), alongside 56.4 million Disability-Adjusted Life Years (DALYs) (ranging from 51.3 to 61.7 million) linked to smoking [7]. At the global level, another study [8] indicated that excessive salt consumption is responsible for 4.1 million deaths, while harmful alcohol use accounts for 3.3 million deaths, and poor physical activity contributes an additional 1.6 million deaths. Furthermore, a separate study conducted in Iran [9] suggests that smoking imposes a substantial financial burden on both the healthcare system and society as a whole, with estimates indicating that eliminating smoking could prevent approximately 20% of cancer-related deaths in the country.

To mitigate the adverse effects of unhealthy behaviors on health, morbidity, and mortality within communities, it is essential to enhance preventive and primary care services. Such care plays a critical role in promoting healthier behaviors [10, 11]. Additionally, evaluating the burden associated with unhealthy behaviors is vital for advancing primary healthcare services, as it provides valuable insights that can assist policymakers and planners in designing and implementing cost-effective interventions. Several measures exist for measuring the health burden, ranging from simple indicators such as mortality and morbidity rates to more complex composite measures that offer a comprehensive understanding of health impacts [12–15].

Among these composite measures are quality-adjusted life years (QALYs), which assess health outcomes by considering both the quantity and quality of life lived, and disability-adjusted life years (DALYs), which combine years of life lost due to premature death with years lived with disabilities [16]. Health-adjusted life expectancy (HALE) provides insights into the population's average number of years of life spent in good health [17]. The QALY is a crucial health outcome metric frequently utilized in economic evaluations within the healthcare sector; it is often recommended or required in health technology assessment procedures across many countries and serves as an important tool for comparing various interventions and programs within health systems [18, 19]. The QALY is calculated by multiplying the total years of life by a utility value that reflects the quality of life experienced during those years. This utility value ranges from 0 (indicating death) to 1 (representing perfect health) [20, 21]. Xin-Yi Nie et al. [22] conducted a large cross-sectional study among the general population in China, in which they estimated the health burden attributable to unhealthy lifestyle behaviors by measuring the loss in QALYs using the EQ-5D-5 L instrument.

Studies conducted in other countries have employed the QALY measure to assess the health burden associated with non-communicable diseases and unhealthy behaviors [5, 23, 24]. However, a review of the literature indicates that no such study has been conducted in Iran. To address this gap, the present study aimed to estimate and compare the loss of QALYs associated with unhealthy behaviors within the general Iranian population.

Methods

This cross-sectional study was conducted in 2024–2025 among 3518 individuals aged 18 years and older in nine provinces (Fig. 1) in Iran to estimate and compare the QALYs lost due to unhealthy behaviors. According to projections from the Iranian Statistical Center (ISC) [25], the total population of Iran in 2024-25 is estimated to be approximately 85,961,000. Of this total, the population of the nine provinces included in the study is around 34,876,000, which accounts for 41% of the country's overall population. Samples were selected using multistage sampling methods. First, we divided Iran into 9 regions and randomly selected one province from each region. In each province, the capital city was chosen, and then each city was divided into four areas (north, south, west, and east). We then selected 100 samples from each area using convenience sampling. In Tehran, due to its larger population, we divided the city into five regions (north, south, west, east, and central) and selected 100 samples from each region. We excluded a total of 192 incomplete questionnaires as follows: 3,710 were initial samples (preliminary); 44 samples were excluded due to missing one or more dimensions of the EQ-5D questionnaire; 19 observations were excluded for not reporting the EQ-VAS score; and 129 observations were excluded because the reported age was under 18 years.

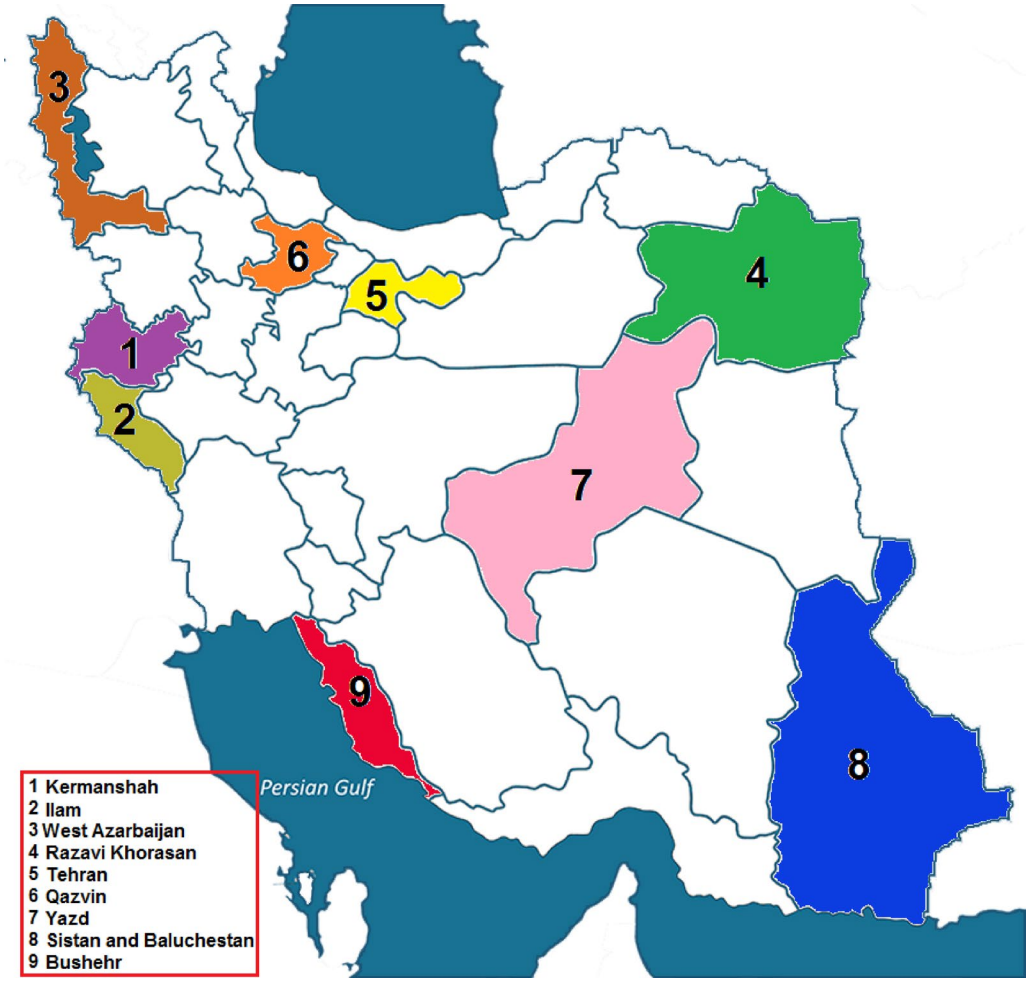

Fig. 1 Provinces included in the study

The eligibility criteria included being 18 years or older, having lived in the selected province for at least five years, being capable of completing the questionnaire independently; however, if a participant was illiterate, the interviewer entered the information into the questionnaire with the participant's consent. Additionally, participants needed to be able to communicate in the language of the study (e.g., Persian) and provide formal consent by signing an informed consent form. The exclusion criteria included unwillingness or lack of consent to participate in the study, severe mental or physical illnesses that hinder participation or questionnaire completion, inability to communicate in the language of the study, and disabilities that significantly impair the ability to respond to the questionnaire. Data were collected through face-to-face interview using a self-administered questionnaire, and the Iranian versions of the EQ-5D-5 L and EQ-VAS questionnaires [26]. The interviewers underwent a comprehensive and structured training program prior to data collection. This training provided detailed explanations of all study instruments to ensure interviewers fully understood the purpose and content of each item. It included practical sessions with mock interviews, allowing interviewers to practice administering the questionnaires under supervision and receive feedback to enhance their interviewing skills. The researcher-developed questionnaire comprised two main sections. The first part includes 15 questions designed to gather specific demographic and health-related information, including age, sex, marital status, health insurance coverage, level of education, household size, place of birth, type of occupation, economic status of the household (monthly costs), presence of chronic diseases, and self-rated health status. The second part includes 8 questions regarding the status of unhealthy behaviors of participants. The EQ-5D-5 L and EQ-VAS questionnaires used in this study were based on the validated Iranian versions developed by Afshari et al. [26], which have shown strong psychometric properties, including good validity and reliability for assessing health-related quality of life in the Iranian population. The questions related to unhealthy behaviors were adapted from previously validated instruments used

in national studies such as the PERSIAN Cohort and IraPEN programs [27, 28], ensuring consistency and reliability in data collection.

This study was conducted and reported in accordance with the STROBE guidelines for cross-sectional studies (supplementary 2) [29].

Measurement of HRQoL

The Iranian versions of the EQ-5D-5 L [26] were used to assess the health-related quality of life (HRQoL) of the participants. The EQ-5D also includes a visual analogue scale (VAS) which measures general health perception on a vertical scale from 0 (worst imaginable health) to 100 (best imaginable health) Participants were asked to evaluate and indicate their current health condition using this scale. Initially, participants completed the EQ-5D-5 L questionnaire, which consists of five dimensions: mobility (MO), self-care (SC), usual activities (UA), pain/discomfort (PD), and anxiety/depression (AD). Each dimension has five response levels: no problems (level 1), slight problems (level 2), moderate problems (level 3), severe problems (level 4), and extreme problems (level 5). The EQ-5D-5 L identifies a total of 3,125 unique health states, ranging from 11,111, representing optimal health, to 55,555, indicating the worst health condition. The health states assessed by the EQ-5D-5 L are converted into a single index "utility" score through a scoring algorithm that reflects societal preferences. According to a previous study conducted in Iran [26], the utility score for the Iranian population can range from − 1.19, representing the worst possible health state (55555), to 1, indicating full health (11111).

Unhealthy behaviors

The eighty unhealthy behaviors included in the study, along with their measurement and categorization, were based on previous studies [22] and national surveys conducted in Iran such as Persian cohort and the IraPEN program [27, 28]. These behaviors included smoking, physical activity, sleep quantity and quality, oral health practices (such as brushing and flossing), breakfast skipping, and dairy consumption. Smoking status was assessed with a single question: "Do you have a smoking habit?" Participants selected from three options: current smoker, former smoker, or never smoker. For analysis, current and former smokers were grouped as smokers, and never smokers as non-smokers. Physical activity was classified as good if individuals reported at least 150 min per week of moderate-intensity or 75 min per week of vigorous-intensity activity, meeting the adult physical activity guidelines. Otherwise, their physical activity level was considered poor. Sleep duration and quality were evaluated using components 3 and 5 of the Brief Version of the Pittsburgh Sleep Quality Index [30, 31]. Participants reported their average nightly sleep duration during the past month, choosing among: less than 5 h, 5–6 h, 6–7 h, or more than 7 h. Sleep durations under 7 h were considered insufficient. Sleep quality was assessed by asking, "How would you rate your overall sleep quality in the past month?" Responses were grouped as good (very good and fairly good) or poor (very bad and fairly bad). Oral health was assessed based on daily dental care habits, specifically brushing and flossing.

Further details and coding procedures for unhealthy behaviors are provided in Supplementary Table S1.

Covariates

The following variables were included as covariates in the analysis: age, gender (male and female), marital status (single, married and others), level of education (primary school, secondary school, bachelor and master and Ph.D.), place of birth (rural and urban), type of health insurance coverage (including basic and supplementary insurance), household economic status (measured by monthly household costs), residential province, self-rated health (very poor, poor, fair, good and very good), BMI (underweight, normal, over weight and obese) and the presence of any chronic health conditions.

Statistical analysis

Descriptive statistics are reported as the mean ± standard deviation (SD) for continuous variables, while categorical variables are represented using frequencies and percentages. To assess the burden of unhealthy behaviors, we followed these steps: First, we estimated the prevalence of each unhealthy behavior by calculating the proportion of participants exhibiting these behaviors within the sample. Next, we employed a generalized linear model (GLM) with a gamma distribution and a log link to examine the effect of each unhealthy lifestyle behavior on EQ-5D-5 L scores while adjusting for multiple covariates, including age, gender, marital status, education level, household size, place of birth, occupation type, job type, basic health insurance coverage, household economic status (measured by monthly costs), province, and the presence of chronic conditions (e.g., hypertension, heart disease, stroke, cancer, diabetes, and others). Since EQ-5D data usually have a skewed distribution and the residuals from regression analyses often exhibit non-normality and heteroscedasticity [32, 33], using a standard linear regression model is inappropriate. To address these issues, we applied the GLM approach with a gamma distribution and a log link to effectively manage skewness and unequal variance. Finally, to assess the burden of unhealthy behaviors at the population level, we calculated the annual QALY loss per 100,000 individuals for each condition using the formula below [22, 24]:

$$\begin{aligned} &\text{Annual } QALY \text{ loss} \\ &= \text{unhealty behaviour prevalence} \\ &\times \text{ disutility score } \times 100.000 \times 1 \text{ year} \end{aligned}$$

Where disutility refers to the coefficient for the condition obtained from the GLM [22].

We entered the data into Excel 2016, and after cleaning the data, it was transferred to Stata/MP 17 (Stata Corporation, USA) for statistical analyses. A p-value of less than 0.05 was considered statistically significant.

Results

The descriptive characteristics of the study population are presented in Table 1. As shown in the table, the mean age of participants was 38.2 years, with a standard deviation of 14.6, and 51.3% of the participants were female. Regarding marital status, 58.1% of the sample was married, while nearly half held a bachelor's degree. A significant majority, at 81.2%, were born in urban areas, and 89.8% had basic health insurance coverage. Among the participants, 24.9% reported having at least one chronic condition. Self-rated health status was predominantly positive, with 45.8% of participants rating their health as good.

Table 2 presents the prevalence of various unhealthy behaviors included in the study, along with their corresponding mean EQ-5D-5 L index scores and EQ-VAS scores. The analysis revealed statistically significant associations ($p < 0.001$) for all behaviors with both HRQoL measures. The results show that individuals who engaged in good physical activity (58.21%) had significantly higher scores (EQ-5D-5 L: 0.82 ± 0.23; EQ-VAS: 75.96 ± 18.14) compared to those with poor physical activity (41.79%) (EQ-5D-5 L: 0.74 ± 0.28; EQ-VAS: 75.96 ± 18.14). Likewise, non-smokers (74.15%) demonstrated better HRQoL outcomes (EQ-5D-5 L: 0.80 ± 0.25; EQ-VAS: 75.48 ± 18.54) than smokers (25.85%) (EQ-5D-5 L: 0.74 ± 0.27; EQ-VAS: 70.92 ± 18.69). Regarding oral hygiene, participants who reported regular tooth brushing (86.18%) had markedly higher scores (EQ-5D-5 L: 0.81 ± 0.23; EQ-VAS: 75.69 ± 17.85) compared to those who did not (13.19%) (EQ-5D-5 L: 0.66 ± 0.34; EQ-VAS: 65.47 ± 21.37). A similar pattern was observed for regular dental flossing (60.43%) (EQ-5D-5 L: 0.82 ± 0.22; EQ-VAS: 77.31 ± 16.94) versus non-flossers (39.57%) (EQ-5D-5 L: 0.73 ± 0.30; EQ-VAS: 69.83 ± 20.18). Sleep-related behaviors were critically important. Participants experiencing poor sleep quality (12.48%) reported the lowest scores of all behaviors (EQ-5D-5 L: 0.59 ± 0.32; EQ-VAS: 61.32 ± 23.03). Similarly, those with insufficient sleep duration (≤ 7 h) (84.22%) had lower scores (EQ-5D-5 L: 0.78 ± 0.26; EQ-VAS: 73.81 ± 18.71) than those with adequate sleep.

The impact of unhealthy behaviors on EQ-5D-5 L and EQ-VAS scores, analyzed using GLM and after controlling for various covariates, is outlined in Table 3. The findings indicate an inverse relationship between unhealthy behaviors and both EQ-5D-5 L and EQ-VAS scores, with statistically significant results for most behaviors, except for smoking status, which was significant at the 10% level. Among the unhealthy behaviors assessed, poor sleep quality had the most substantial negative effect, with a coefficient of −0.2373 ($p < 0.001$) for the EQ-5D-5 L score and −0.1838 ($p < 0.001$) for the EQ-VAS score. As the second most significant factor, irregular tooth brushing was associated with a coefficient of −0.0645 for the EQ-5D-5 L score, while irregular dental flossing showed a coefficient of −0.0517 for the EQ-VAS score.

The results of QALY loss per 100,000 persons per year for the unhealthy behaviors included in the study are presented in Table 4 and Fig. 2. The findings indicate that the four greatest contributors to QALY loss are associated with poor sleep quality (−2961.50 [95% CI: −3407.50 to −2586.52]), insufficient sleep duration (−2787.68 [95% CI: −4978.37 to −56.81]), breakfast skipping (−2216.55 [95% CI: −3414.74 to −1173.60]) and poor physical activity (−2102.04 [95% CI: −3094.81 to −1251.11]).

Discussion

One of the key measures used in studies about the impact of diseases and economic evaluations is the QALY [21, 34]. This measure allows us to look at how diseases and unhealthy behaviors affect both the length and quality of life simultaneously. By using QALYs, health planners and policymakers can assess and compare the effects of different diseases and unhealthy behaviors, considering both how long people live and how well they live during that time. In this study, for the first time in Iran, the health burden of unhealthy behaviors was estimated based on disutility loss and after that QALY loss per 100,000 persons per year for eight unhealthy behaviors. This analysis utilized data from nine provinces, with a sample size of 3,518 individuals aged 18 years and older. Unhealthy behaviors are associated with the prevalence of diseases and mortality, and any interventions aimed at reducing these unhealthy behaviors are expected to lead to improvements in quality of life and overall health among individuals.

The findings of this study highlight the significant prevalence of various unhealthy behaviors among the population, which are critical contributors to health burdens. Notably, poor physical activity was observed in 41.79% of individuals, while the prevalence of smoking (including both current and former smokers) was 25.85%. Additionally, a study in Iran indicates that the prevalence of poor physical activity in the country is approximately 51.3% for the entire population [35]. Behaviors such as irregular

Table 1 Descriptive characteristics of study participants ($n=3518$) in Iran, 2024–2025

	Frequency	Percentage
Total	3815	100
Age ± SD (years)	38.2 ± 14.6	100
Sex		
Male	1714	48.7
Female	1803	51.3
Missing	1	0.03
Marital status		
Single	1293	36.7
Married	2044	58.1
Others	161	4.6
Missing	20	0.6
Level of education		
Illiterate	132	3.8
Primary school	320	9.1
Secondary school	718	20.4
Bachelor	1662	47.2
Master and Ph.D.	648	18.4
Missing	38	1.1
Place of birth		
Urban	2856	81.2
Rural	627	17.8
Missing	35	1.0
Basic health insurance		
Yes	3161	89.8
No	357	10.2
Presence of chronic condition		
Yes	875	24.9
No	2626	74.6
Missing	17	0.5
Monthly household cost		
Less than 5 million IRR	175	5.04
5 to 10 million IRR	526	15.14
10 to 15 million IRR	812	23.37
15 to 20 million IRR	842	24.24
More than 20 million IRR	1119	32.21
Missing	44	1.25
Self-rated health status		
Very poor	35	1.0
Poor	182	5.2
Fair	1015	28.9
Good	1611	45.8
Very good	651	18.5
Missing	24	0.7
BMI		
Under weight	131	3.7
Normal	1501	42.6
Over weight	1237	35.2
Obese	567	16.1
Missing	85	2.4
Province		
Tehran	504	14.33
Kermanshah	400	11.37
Ilam	375	10.66

Table 1 (continued)

	Frequency	Percentage
Yazd	400	11.37
Qazvin	348	9.89
West Azarbaijan	401	11.40
Sistan and Baluchestan	388	11.03
Bushehr	399	11.34
Razavi Khorasan	303	8.61

Some variables had missing data, which has resulted in the sum of categories being less than the total sample size of 3,518

tooth brushing (13.19%) and irregular dental flossing (39.57%) reflect a concerning trend in oral health practices, which can have broader implications for overall health. The high prevalence of insufficient sleep duration (84.22%) and poor sleep quality (12.48%) underscores the importance of addressing sleep-related issues, as these are closely linked to various chronic conditions [36]. Furthermore, breakfast skipping (49.81%) and unsuitable dairy consumption (25.42%) reveal dietary habits that may contribute to nutritional deficiencies and increased health risks. Collectively, these findings underscore the urgent need for comprehensive public health strategies aimed at promoting healthier lifestyle choices and reducing the burden of these unhealthy behaviors on individual and community health.

Our study revealed a statistically significant inverse relationship between unhealthy behaviors and HRQoL scores, as measured by both the EQ-5D-5 L and EQ-VAS scores. This indicates that individuals engaging in unhealthy behaviors tend to report lower HRQoL scores. For instance, participants with poor physical activity levels had a mean EQ-5D-5 L score of 0.74 ± 0.28 and an EQ-VAS score of 72.08 ± 19.17. In contrast, those who engaged in good physical activity reported higher mean scores of 0.82 ± 0.23 for the EQ-5D-5 L and 75.96 ± 18.14 for the EQ-VAS. Supporting our findings, a study conducted in China [22] investigated the effects of various unhealthy behaviors, including alcohol consumption, smoking, sugar-sweetened beverage intake, breakfast skipping, prolonged sitting time, insufficient sleep duration, and poor sleep quality, on EQ-5D-5 L and EQ-VAS scores. Additionally, another study conducted in Iran [37] among the general population found statistically significant positive associations between being physically active and both the EQ-5D-5 L and EQ-VAS scores. In contrast, negative associations were observed between smoking and both the EQ-5D-5 L and EQ-VAS scores. These results indicate that all these unhealthy behaviors are associated with lower index scores, further highlighting their detrimental impact on health-related quality of life.

Our study findings indicate that the most substantial loss in QALY is associated with poor sleep quality, followed by insufficient sleep duration, skipping breakfast, and poor physical activity. Notably, we observed that while the prevalence of poor sleep quality was relatively low at 12.48%, the associated QALY loss was significantly high. Previous research has established a clear link between poor sleep quality, insufficient sleep duration, and lower scores in HRQoL [22, 38]. One explanation for this strong association is that sleep disorders—both in terms of quantity and quality—can severely disrupt daily activities and impact physical and mental energy levels, ultimately leading to increased fatigue [39, 40]. Supporting our findings, Nie et al. [22] reported that poor sleep quality accounted for the highest annual QALY loss per 100,000 individuals, with a loss of −1082.4 QALYs. This was followed by prolonged sitting time at −957.5 QALYs and skipping breakfast at −779.0 QALYs. These results underscore the critical importance of addressing sleep quality as a key factor in improving overall health outcomes and enhancing quality of life.

Our findings also revealed that the loss of QALYs associated with insufficient sleep duration, skipping breakfast, and poor physical activity ranked second, third, and fourth, respectively, among the unhealthy behaviors examined in this study. The connection between lower HRQoL and poor physical activity has been well documented in prior research [41–43]. This highlights the importance of maintaining healthy habits, as both skipping breakfast and poor physical activity can significantly impact overall well-being. Addressing these behaviors could play a crucial role in enhancing HRQoL and reducing the burden of disease in the population. Our study indicates that the health burden associated with suboptimal dietary habits is greater than that linked to smoking and dairy consumption. This finding is largely due to the higher prevalence of poor eating behaviors, which are more widespread than smoking and dairy consumption rates. While much attention has been given to the effects of smoking on health, previous research has rarely explored how specific dietary choices—such as consuming sugar-sweetened beverages and skipping breakfast—affect HRQoL [44, 45]. This gap in the literature suggests a need for more comprehensive studies that examine the broader implications of dietary behaviors on overall well-being. By focusing on these aspects, we can better understand how improving nutrition could enhance quality of life for many individuals.

Table 2 Prevalence of specific unhealthy behaviors included in the study and mean EQ-5D-5 L and EQ-VAS scores in the Iranian population, 2024–2025

Unhealthy behaviors	*N* (%)	EQ-5D-5 L index score		EQ-VAS score	
		Mean ± SD	*p*-value[a]	Mean ± SD	*p*-value[a]
Physical activity					
Good	2048 (58.21)	0.82 ± 0.23	< 0.001	75.96 ± 18.14	< 0.001
Poor	1470 (41.79)	0.74 ± 0.28		75.96 ± 18.14	
Smoking status					
No	2590 (74.15)	0.80 ± 0.25	< 0.001	75.48 ± 18.54	< 0.001
Yes	903 (25.85)	0.74 ± 0.27		70.92 ± 18.69	
Regular tooth brushing					
Yes	3047 (86.18)	0.81 ± 0.23	< 0.001	75.69 ± 17.85	< 0.001
No	463 (13.19)	0.66 ± 0.34		65.47 ± 21.37	
Regular dental flossing					
Yes	2121 (60.43)	0.82 ± 0.22	< 0.001	77.31 ± 16.94	< 0.001
No	1389 (39.57)	0.73 ± 0.30		69.83 ± 20.18	
Insufficient sleep duration					
>7 h	553 (15.78)	0.82 ± 0.25	< 0.001	77.20 ± 18.22	< 0.001
≤ 7 h	2952 (84.22)	0.78 ± 0.26		73.81 ± 18.71	
Poor sleep quality					
No	3065 (87.52)	0.81 ± 0.23	< 0.001	76.13 ± 17.18	< 0.001
Yes	437 (12.48)	0.59 ± 0.32		61.32 ± 23.03	
Breakfast-skipping					
No	1760 (50.19)	0.81 ± 0.25	< 0.001	76.65 ± 18.12	< 0.001
Yes	1747 (49.81)	0.76 ± 0.26		72.00 ± 18.88	
Diary consumption					
Suitable	2620 (74.58)	0.81 ± 0.24	< 0.001	75.81 ± 17.75	< 0.001
Unsuitable	893 (25.42)	0.74 ± 0.30		70.00 ± 20.42	

The Mann–Whitney U test (for two groups) was conducted using the "*ranksum*" command in Stata to explore differences in the EQ-5D-5L index score, EQ-VAS score, and unhealthy behaviors included in the study

Table 3 Generalize linear model (GLM) to predict the effect of unhealthy behaviors included in the study on EQ-5D-5 L and EQ-VAS scores among study participants in Iran, 2024–2025

Unhealthy behaviors	EQ-5D-5 L index score[a]		EQ-VAS score[a]	
	Coefficient	*p*-value	Coefficient	*p*-value
Physical activity				
Good	Ref	< 0.001	Ref	< 0.001
Poor	−0.0503		−0.0332	
Smoking status				
No	Ref	0.057	Ref	0.003
Yes	−0.0261		−0.0321	
Regular tooth brushing				
Yes	Ref	< 0.001	Ref	< 0.001
No	−0.0645		−0.0511	
Regular dental flossing				
Yes	Ref	< 0.001	Ref	< 0.001
No	−0.0513		−0.0517	
Insufficient sleep duration				
>7 h	Ref	0.027	Ref	< 0.001
≤ 7 h	−0.0331		−0.0479	
Poor sleep quality				
No	Ref	< 0.001	Ref	< 0.001
Yes	−0.2373		−0.1838	
Breakfast-skipping				
No	Ref	< 0.001	Ref	< 0.001
Yes	−0.0445		−0.0371	
Diary consumption				
Suitable	Ref	0.001	Ref	< 0.001
Unsuitable	−0.0435		−0.0449	

[a]Generalize linear model (GLM) with gamma distribution and a log link: adjusted for age, gender, marital status, level of education, place of birth, basic health insurance coverage, economic status of the household (measured through monthly household costs), province and the presence of any chronic conditions (e.g., hypertension, heart disease, stroke, cancer, diabetes, and others)

An additional point that warrants attention is the possibility of confounding and reverse causation in the relationship between sleep quality and HRQoL. It is plausible that poor sleep quality does not solely lead to diminished quality of life, but may itself arise from underlying physical or psychological conditions, including chronic illnesses, pain, anxiety, or depressive symptoms. Such health issues could simultaneously affect both sleep quality and HRQoL, making sleep quality a potential mediator or confounder rather than an entirely independent determinant. Although our analyses accounted for several chronic diseases, the presence of residual confounding cannot be completely excluded. Consequently, longitudinal research is required to disentangle these complex pathways and determine whether better sleep quality directly improves HRQoL or primarily reflects overall health status.

While this study has several strengths, it is important to acknowledge its limitations, which underscore the need for caution when interpreting our findings. Firstly,

Table 4 Annual quality-adjusted life-year (QALY) loss per 100,000 persons associated with unhealthy behaviors included in the study among the Iranian population, 2024–2025

Unhealthy behaviors	EQ-5D-5 L index score[a]	Prevalence	QALY loss per 100,000 person per year (95% CI)
Poor physical activity	−0.0503	0.4179	−2102.04 (−3094.81 to −1251.11)
Smoking	−0.0261	0.2585	−674.69 (−1350.19 to 24.33)
Irregular tooth brushing	−0.0645	0.1319	−850.76 (−1277.01 to −362.35)
Irregular dental flossing	−0.0513	0.3957	−2029.94 (−3115.45 to −1259.07)
Insufficient sleep duration	−0.0331	0.8422	−2787.68 (−4978.37 to −56.81)
Poor sleep quality	−0.2373	0.1248	−2961.50 (−3407.50 to −2586.52)
Breakfast-skipping	−0.0445	0.4981	−2216.55 (−3414.74 to −1173.60)
Unsuitable diary consumption	−0.0435	0.2542	−1105.77 (−1713.97 to −463.74)

[a]Generalize linear model (GLM) with gamma distribution and a log link: adjusted for age, gender, marital status, level of education, household size, place of birth, type of occupation, type of job, basic health insurance coverage, economic status of the household (measured through monthly household costs), province and the presence of any chronic conditions (e.g., hypertension, heart disease, stroke, cancer, diabetes, and others). QALY: quality-adjusted life-year, CI confidence interval

the research was conducted across nine provinces in Iran, representing over 40% of the total population. Although this coverage is substantial, it may not fully capture the heterogeneity present across all regions of the country. Socioeconomic, cultural, and environmental differences in the excluded provinces could influence the prevalence and impact of unhealthy behaviors, thereby limiting the generalizability of our results at the national level. Secondly, the cross-sectional design restricts our ability to infer causal relationships between unhealthy behaviors and quality-of-life outcomes, such as EQ-5D-5 L and EQ-VAS scores. The associations observed may be influenced by unmeasured confounding variables or reverse causality, and longitudinal or experimental studies would be required to establish temporal and causal links. Thirdly, a limitation pertains to the estimation of QALYs in this study. The QALY metric incorporates both the quality and quantity of life; however, our analysis was based solely on health-related quality-of-life data and did not account for the potential impact of unhealthy behaviors on premature mortality. As a result, the overall burden of these behaviors may have been underestimated. Future studies integrating mortality data and life expectancy measures could provide a more comprehensive assessment of the total health burden attributable to unhealthy behaviors. Another limitation is that data on unhealthy

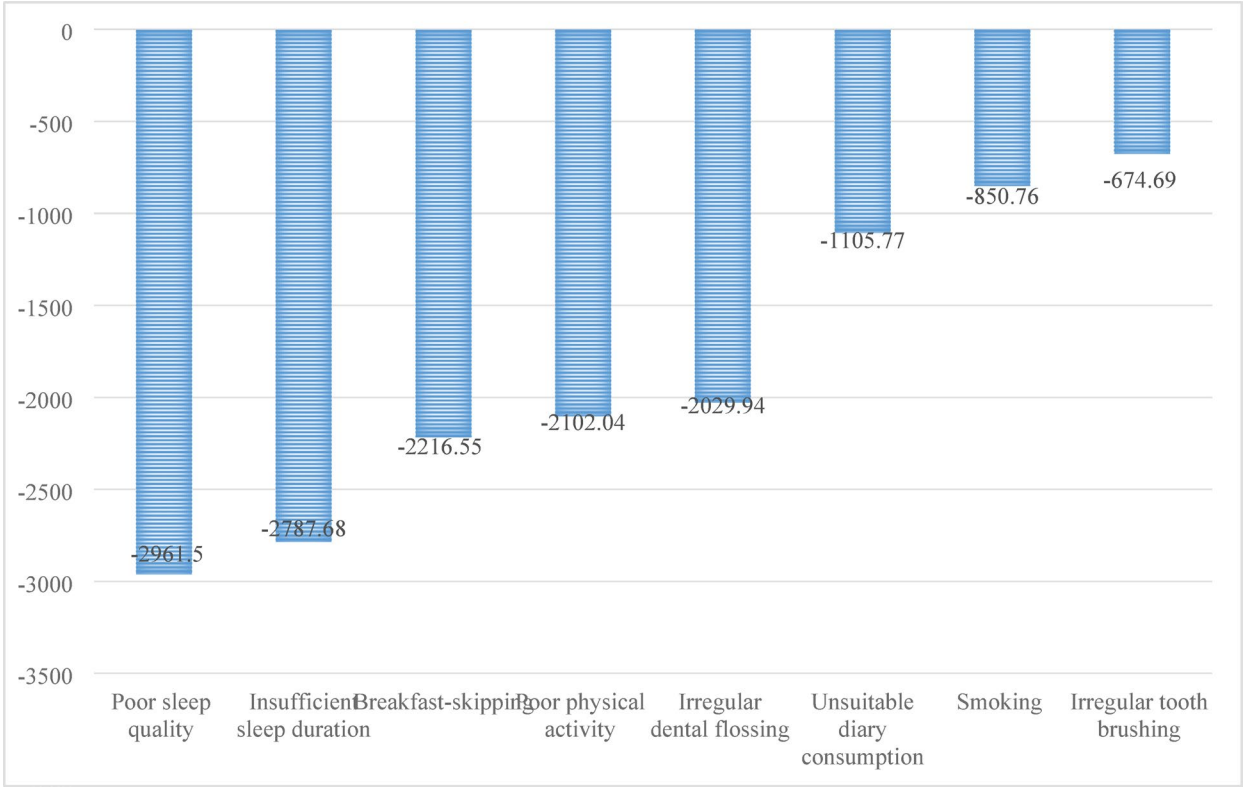

Fig. 2 Annual quality-adjusted life-year (QALY) loss per 100,000 persons due to unhealthy behaviors included in the study in the Iranian population, 2024–2025

behaviors were collected through self-reported responses to a single question per behavior. This approach may reduce measurement accuracy and reliability, as participants could underreport or overreport behaviors due to recall bias, social desirability bias, or misunderstanding of the questions. Furthermore, the lack of detailed behavioral measures (e.g., intensity, frequency, duration) limits the granularity of the analysis and the ability to fully characterize behavior–health relationships. Future research should consider expanding geographic coverage, using longitudinal designs, incorporating validated multi-item instruments for behavior assessment, and including a broader range of demographic and psychosocial variables to strengthen the validity and applicability of the findings.

Conclusion

This national study found a significant association between several unhealthy behaviors and a reduction in HRQoL. Among the behaviors assessed, poor sleep quality, insufficient sleep duration, skipping breakfast, and poor physical activity emerged as the most substantial contributors to the loss of QALYs. The negative impact of these behaviors on HRQoL remained statistically significant even after controlling for key sociodemographic and health covariates. The findings contribute important information that may support the design of targeted prevention strategies and inform health resource allocation decisions. However, due to the cross-sectional nature of the study and reliance on self-reported data, these associations should be interpreted with caution. Further longitudinal research is needed to confirm causal relationships and to explore the potential impact of interventions focused on these behaviors.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Author contributions
S.R., H.S., M.B., N.B., M.R., E.B., SF.I., J.M., and E.K. conceptualized the study, collected and analyzed the data, and drafted the initial report. S.R. critically reviewed the manuscript, providing feedback on the first draft. S.R. collaborated on revisions and finalizing the manuscript. All authors have read and approved the final version of the paper.

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Data availability
The datasets are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The research protocol was approved by the Research Deputy of Kermanshah University of Medical Sciences, with the approval number IR.KUMS.REC.1403.337. The study adhered to the ethical principles outlined in the Declaration of Helsinki. Before data collection, the researchers provided a verbal explanation of the study's purpose to each potential participant, and informed consent was obtained from all subjects. Participants were also informed of their right to withdraw from the study at any time without facing any consequences.

Competing interests
The authors declare no competing interests.

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