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Healthy diet habits attenuate the association of poor sleep quality with nonfatal ischemic stroke: A prospective rural cohort

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Objectives: The combined impact of sleep quality and diet habits on ischemic stroke remains unclear, particularly in rural populations. Therefore, this study aimed to estimate the individual and joint associations of sleep quality and diet habits with nonfatal ischemic stroke among rural adults.
Methods: A total of 22 536 participants free of stroke were enrolled from the Henan Rural Cohort. Sleep quality and diet habits were evaluated with the Pittsburgh Sleep Quality Index and food frequency questionnaire, respectively. The ischemic stroke incidence was analyzed using Kaplan-Meier curves. Cox regression and restricted cubic spline were employed to estimate the correlation of sleep quality or diet habits with ischemic stroke.
Results: During an average 3.92 y of follow-up, 665 ischemic stroke patients were identified. The adjusted hazard ratio (95% confidence interval) of ischemic stroke risk compared with good sleep quality was 1.276 (1.057–1.542). The hazard ratio (95% confidence interval) of nonfatal ischemic stroke compared with unhealthy diet habits was 0.693 (0.589–0.814). The restricted cubic spline indicated that the risk of ischemic stroke increased with the increase of the Pittsburgh Sleep Quality Index. And the higher the diet quality score, the lower the risk of ischemic stroke. ($P_{trend} < 0.05$). Further analysis indicated that the association of poor sleep quality with ischemic stroke was alleviated by healthy diet habits ($P < 0.05$). Additionally, a robust correlation remained after excluding individuals with ischemic stroke in the first year.
Conclusions: Poor sleep quality was positively associated with nonfatal ischemic stroke among rural adults, and healthy diet habits attenuated this relationship. Developing healthy diet and sleep habits may have potential health implications for preventing ischemic stroke.
Trial registration: The Henan Rural Cohort Study has been registered at the Chinese Clinical Trial Register (registration no. ChiCTR-OOC-15006699). Date of registration: July 6, 2015.

Introduction

Stroke is a critical global public health problem with significant social and economic implications. It ranks as the second leading cause of death worldwide [1], representing 16.2% of all mortality [2]. In recent years, the incidence rate and burden of stroke have been increasing because of population aging and advancements in medical care [3–5]. The Global Burden of Disease 2019 stroke burden reported that an estimated 101 million people suffered from stroke [2]. In addition, ischemic stroke is the most common type, accounting for 62.4% of new stroke cases. The morbidity of ischemic stroke is higher in rural than in urban populations [6,7]. Therefore, identifying ischemic stroke risk factors is of great significance for providing scientific support for the prevention and treatment of stroke.

A recent review of research on rural health inequality indicated that rural areas have pervasively poorer health behaviors and outcomes [8]. Sleep is widely considered to be the foundation of optimal physical and mental health, making it a leading behavioral risk factor for human health [9,10]. Good sleep quality contributes to better physical health and overall quality of life [11,12]. A study

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indicated that the prevalence of sleep problems is around 7.6% [13], and poor sleep quality is becoming more and more common [14,15]. Poor sleep quality consistently is a detrimental factor in the development of hypertension, diabetes, obesity, hyperlipidemia, and depression [16–20]. Moreover, evidence from previous studies has indicated that poor sleep quality increases ischemic stroke risk. The results from a cross-sectional study that included 10 442 individuals from the National Health and Nutrition Examination Survey suggested that sleep disorders increased the incidence of stroke [21]. A multicenter matched case-control study of eight tertiary hospitals in Korea revealed that young patients dissatisfied with sleep quality were more likely to suffer from ischemic stroke [22]. In addition, another prospective cohort study involving 31 750 subjects from the Dongfeng Motor Corporation confirmed that poor sleep quality contributed to a high risk of ischemic stroke [23]. In summary, existing studies have mainly focused on developed countries or urban or special populations (such as occupational populations or patients), and there is limited evidence of such an association in rural populations.

Diet habits are another potential factor that can influence stroke incidence. A 1:1 matched case-control study carried out at Del Mar Hospital revealed that stroke patients were inclined toward a high-calorie diet rather than a healthy diet [24]. Another Danish cohort study involving 55 338 participants indicated that following a wholesome Nordic diet can be beneficial in reducing stroke risk [25]. Ibsen et al. [26] discovered that an increasing score on the Alternative Healthy Eating Index 2010 was correlated with a reduced risk of ischemic stroke. Similar to fewer rural studies on relationship between sleep quality and ischemic stroke, there is insufficient research on the correlation between diet habits and ischemic stroke in rural areas. In addition, numerous studies have shown a relationship between food intake and sleep quality [27–29]. For instance, foods that contain high levels of tryptophan and melatonin, such as fruits, vegetables, and legumes, are believed to predict positive sleep outcomes [30]. Given the aforementioned evidence, it is reasonable to speculate that a healthy diet may have a significant impact on the link between sleep quality and ischemic stroke occurrence. However, there is a lack of evidence estimating the combined impact of sleep quality and diet habits on ischemic stroke. Therefore, the purpose of this study was to explore the individual and combined impacts of sleep quality and diet habits on nonfatal ischemic stroke incidence through a prospective cohort in a rural population.

Materials and methods

Study population

The participants of this study were derived from the Henan Rural Cohort, which included 39 259 participants ages 18 to 79 who finished the baseline survey from 2015 to 2017. A total of 35 995 participants were followed up between 2018 and 2022 (follow-up rate of 91.7%). The details have been described in previous studies [31–34]. In this study, 22 536 participants were enrolled for analysis. Briefly, 9235 participants were excluded because of not undergoing sleep information surveys at baseline. We further excluded participants for the following reasons: lost to follow-up (n = 2517), death (n = 790), stroke at baseline (n = 1818), night shift status (n = 1346), suffering from cancer (n = 220), missing information on the assessment of sleep quality (n = 209), missing information on the assessment of diet habits (n = 44), unknown outcome of stroke (n = 426), and other outcomes of stroke subtypes (n = 118) (Supplementary Fig. 1).

This study had the approval of the Zhengzhou University Life Science Ethics Committee. All those involved were asked to give informed consent.

Assessment of sleep quality

The Pittsburgh Sleep Quality Index (PSQI) was used to assess the quality of sleep [35]. The initial PSQI showed strong internal consistency, with Cronbach's alpha varying between 0.70 and 0.83 [36]. The PSQI consists of seven dimensions, each of which has a score from 0 to 3, giving a total score of 0 to 21. A PSQI score >5 is identified as poor sleep quality [37–39]. Higher scores indicate poorer sleep quality.

Assessment of healthy diet habits

The diet quality score was established by utilizing the food frequency questionnaire [40]. The diet quality score has a total score of 36 and includes nine main food groups, with each group receiving a score ranging from 0 to 4 [41]. Healthy diet habits were defined as a total diet quality score ≥22 [42].

Assessment of incident nonfatal ischemic stroke

The outcome event was defined as without stroke at baseline and nonfatal ischemic stroke first diagnosed during follow-up. Face-to-face interviews to acquire the data of stroke incidence were performed by trained investigators. Participants who self-reported a diagnosis of ischemic stroke with a history of hospitalization during the follow-up period were considered to have experienced the outcome event [43].

Assessment of covariates

Standardized questionnaires conducted by trained investigators were used to collect data. Covariates included demographics, lifestyle habits, family history of stroke, chronic comorbidity, and body mass index (BMI). Demographics included age, sex, education level (elementary school or less, junior high school, high school or above), marital status (married/cohabitation, unmarried/divorced/widowed) [44], and per capita monthly income (<500, 500∼, ≥1000 renminbi). Lifestyle habits included smoking (current, ever, never) [45], drinking (current, ever, never), physical activity (low, moderate, high), and sleep duration. Chronic comorbidity included hypertension, type 2 diabetes mellitus, and dyslipidemia. Height and weight were also measured to calculate BMI [46].

Statistical analysis

Continuous variables were represented by mean (SD) and difference comparison was performed using Student's t test. Categorical variables were represented by percentages and difference comparison was performed using Pearson's chi-square test. The first occurrence of nonfatal ischemic stroke was taken as the endpoint of follow-up. For new nonfatal ischemic stroke, the diagnosis time of ischemic stroke and the end time of the follow-up survey were compared, and the shortest time was taken as the follow-up time of participants.

Kaplan-Meier curves were employed to plot the cumulative ischemic stroke incidence, and the log-rank test was conducted to assess the differences in nonfatal ischemic stroke among different sleep quality and diet habits groups. In addition, Cox regression was employed to analyze the connection of sleep quality and diet habits with nonfatal ischemic stroke and to drive the hazard ratio (HR) and 95% confidence interval (CI) of nonfatal ischemic stroke risk. Good sleep quality and unhealthy diet habits were utilized as the reference group. Three models were constructed to correct the covariates related to nonfatal ischemic stroke: Model 1 did not make any adjustments, Model 2 had only age and sex adjustments, and Model 3 made more comprehensive adjustments. These included age, sex, education level, marital status, per capita monthly income, smoking status, drinking status, physical activity status, family history of stroke, BMI, chronic comorbidity, and sleep duration. The restricted cubic spline was employed to domenstrated the does-response relationship of the PSQI score and diet quality score with the incidence risk of nonfatal ischemic stroke. PSQI score and diet quality score were token as continuous varibales. The models were adjusted in the same way as cox regression [47]. Furthermore, a combined variable of four groups was constructed to evaluate the simultaneous influence of sleep quality and diet habits. People with poor sleep quality and unhealthy diet habits served as the reference group.

A sensitivity analysis was also performed after excluding individuals suffering a nonfatal ischemic stroke within 1 y of follow-up. All analyses were carried out using the R language software package (version 4.0.4) and SPSS Statistics 21.0, and $P < 0.05$ (two-tailed test) was defined as statistically significant.

Results

Characteristics of participants

Table 1 presents the baseline characteristics. Participants were on average 55.00 ± 12.16 y old, with 38.89% men and 61.11% women. Compared with participants without ischemic stroke, individuals suffering a nonfatal ischemic stroke were more likely to be men, older, less educated, have lower income, have alcohol and tobacco use, suffer from chronic comorbidity, have a higher PSQI score, and have unhealthy diet habits (all $P < 0.05$).

Table 1
Characteristics of participants according to nonfatal ischemic stroke

Characteristic	Total (*N* = 22 536)	Ischemic stroke (*N* = 665)	Nonischemic stroke (*N* = 21 871)	*P* value
Age, y, mean (SD)	54.81 (12.16)	62.27 (8.70)	54.59 (12.17)	< 0.001
Men, *n* (%)	8761 (38.88)	303 (45.56)	8458 (38.67)	< 0.001
Education level, *n* (%)				< 0.001
Primary school or less	9863 (43.77)	385 (57.89)	9478 (43.34)	
Junior high school	8855 (39.29)	220 (33.08)	8635 (39.48)	
High school or above	3818 (16.94)	60 (9.02)	3758 (17.18)	
Marital status, *n* (%)				0.126
Married/cohabitation	20 507 (91.00)	594 (89.32)	19 913 (91.05)	
Unmarried/divorced/widowed	2029 (9.00)	71 (10.68)	1958 (8.95)	
Per capita monthly income, RMB[a], *n* (%)				< 0.001
<500	8085 (35.88)	301 (45.26)	7784 (35.59)	
500~	7185 (31.88)	190 (28.57)	6995 (31.98)	
≥1000	7266 (32.24)	174 (26.17)	7092 (32.43)	
Smoking status, n (%)				0.003
Never	16 552 (73.45)	453 (68.12)	16 099 (73.61)	
Ever	1583 (7.02)	64 (9.62)	1519 (6.95)	
Current	4401 (19.53)	148 (22.26)	4253 (19.45)	
Drinking status, *n* (%)				< 0.001
Never	17 689 (78.49)	499 (75.04)	17 190 (78.60)	
Ever	906 (4.02)	47 (7.07)	859 (3.93)	
Current	3941 (17.49)	119 (17.89)	3822 (17.48)	
Physical activity, *n* (%)				0.887
Low	6768 (30.03)	199 (29.92)	6569 (30.04)	
Moderate	8498 (37.71)	246 (36.99)	8252 (37.73)	
High	7270 (32.26)	220 (33.08)	7050 (32.23)	
Family history of stroke, *n* (%)	1843 (8.25)	57 (8.57)	1786 (8.24)	0.760
BMI, kg/m^2, mean (SD)	24.7 (3.56)	24.94 (3.58)	24.69 (3.56)	0.078
Chronic comorbidity*, *n* (%)	12 138 (54.00)	443 (66.72)	11 695 (53.61)	< 0.001
Sleep duration, hours, mean (SD)	7.68 (1.25)	7.71 (1.33)	7.68 (1.24)	0.589
PSQI global score, mean (SD)	3.71 (2.67)	4.23 (2.78)	3.69 (2.66)	< 0.001
Poor sleep quality, *n* (%)	4685 (20.79)	175 (26.32)	4510 (20.62)	< 0.001
Healthy diet habits, *n* (%)	12 249 (54.35)	234 (35.19)	10 053 (45.96)	< 0.001

BMI, body mass index; PSQI, Pittsburgh Sleep Quality Index; RMB, renminbi.
*Includes hypertension, type 2 diabetes mellitus, and dyslipidemia.
[a]RMB is short for Renminbi which is Chinese money.

Cumulative incidence of nonfatal ischemic stroke

Figure 1 illustrates the cumulative incidence of nonfatal ischemic stroke among different sleep quality and diet habits groups. During an average 3.92 y of follow-up, 665 participants with nonfatal ischemic stroke were identified. Through the log-rank test, the cumulative ischemic stroke incidence showed statistically significant differences based on different sleep quality status and different diet habits ($P < 0.05$).

Independent association of sleep quality and diet habits with nonfatal ischemic stroke

Table 2 displays the correlation of sleep quality and diet habits with incident ischemic stroke. Poor sleep quality was linked to a 27.6% higher risk of nonfatal ischemic stroke compared with good sleep quality (HR, 1.276, 95% CI, 1.057−1.542). Figure 2 illustrates the dose-response association of PSQI score with nonfatal ischemic stroke risk. The risk of nonfatal ischemic stroke incidence increased

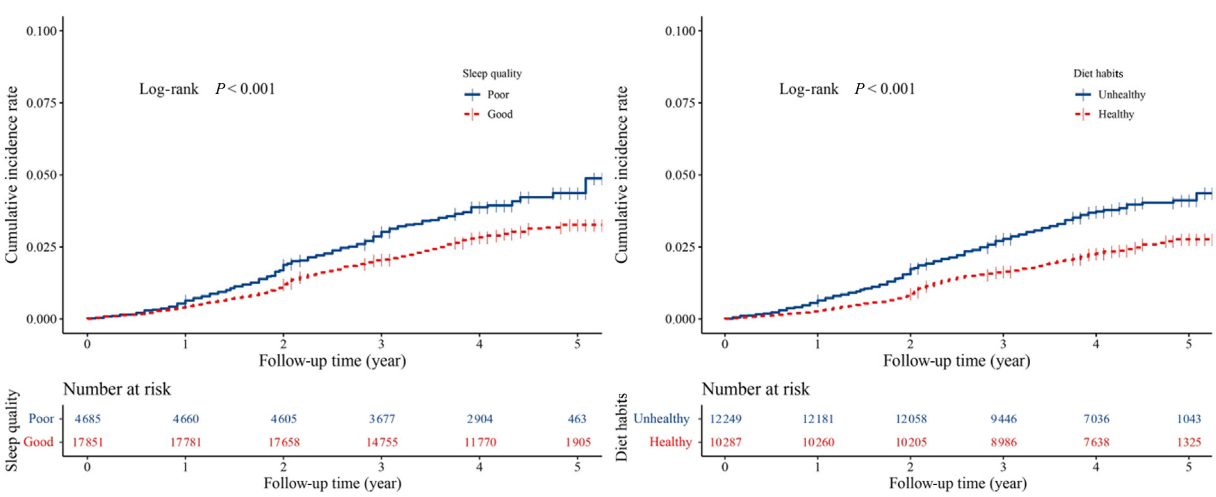

Fig. 1. Kaplan-Meier curves of sleep quality and diet habits with ischemic stroke.

Table 2
Hazard ratios and 95% confidence intervals of sleep quality and diet habits with nonfatal ischemic stroke

Variable	n/N	Model 1 HR (95% CI)	Model 2 HR (95% CI)	Model 3 HR (95% CI)
Sleep quality				
Good	175/4685	Reference	Reference	Reference
Poor	490/17 851	1.385 (1.165–1.646)	1.326 (1.112–1.580)	1.276 (1.057–1.542)
Diet habits				
Unhealthy	431/12 249	Reference	Reference	Reference
Healthy	234/10 287	0.612 (0.522–0.718)	0.661 (0.563–0.775)	0.693 (0.589–0.814)

CI, confidence interval; HR, hazard ratio.
Model 1 unadjusted; Model 2 adjusted for age and sex; Model 3 adjusted for age, sex, marital status, education level, per capita monthly income, smoking status, drinking status, exercise, body mass index, family history of stroke, chronic comorbidity, and nightly sleep duration.

with increasing PSQI score. In addition, a 30.7% reduction in ischemic stroke risk was detected in the healthy diet habits group in comparison with the unhealthy diet habits group (HR, 0.693, 95% CI, 0.589–0.814). A dose-response relationship existed between diet quality score and incidence of ischemic stroke. A higher diet quality score was linked to a lower risk of nonfatal ischemic stroke.

Combined effects of sleep quality and diet habits on nonfatal ischemic stroke

Supplementary Table 1 demonstrates the connection between sleep quality and nonfatal ischemic stroke stratified by diet habits. In participants with unhealthy diet habits, those experiencing poor sleep quality had HR (95% CI) of 1.264 (1.004–1.590). By contrast, the estimated impact of poor sleep quality on nonfatal ischemic stroke risk decreased to 1.211 (0.867–1.689) among participants with healthy diet habits. Figure 3 shows the modification effect of healthy diet habits on the link between sleep quality and nonfatal ischemic stroke. Taking unhealthy diet habits and poor sleep quality as a reference, the HRs (95% CIs) of ischemic stroke risk with unhealthy diet habits and good sleep quality, healthy diet habits and poor sleep quality, and healthy diet habits and good sleep quality were 0.786 (0.628–0.983), 0.671 (0.485–0.928), and 0.556 (0.436–0.710), respectively. These findings indicated that healthy diet habits alleviated the association between sleep quality and nonfatal ischemic stroke.

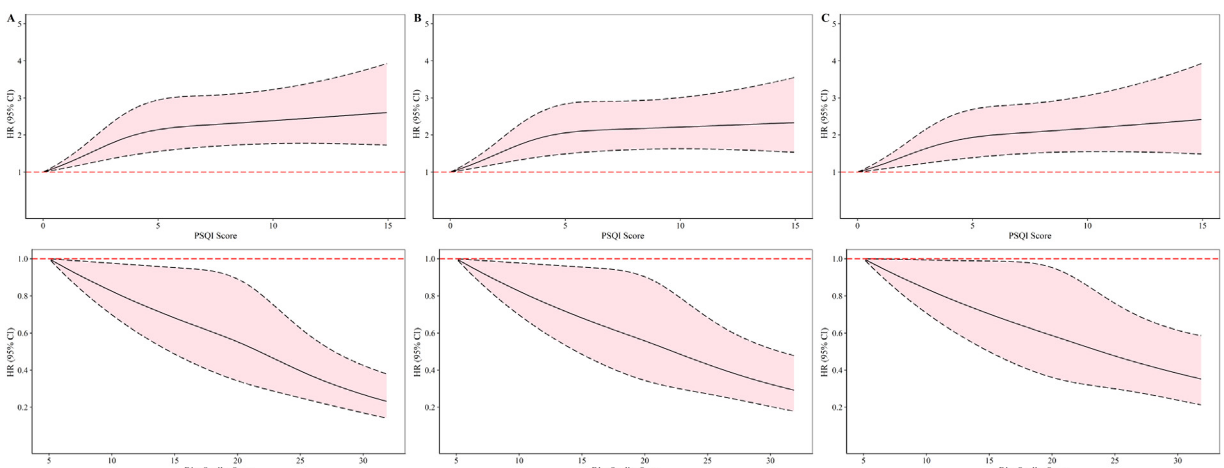

Fig. 2. HRs (solid lines) and 95% CIs (dashed lines) of nonfatal ischemic stroke for PSQI and diet quality score from restricted cubic splines. (A) Model 1: unadjusted. (B) Model 2: adjusted for age and sex. (C) Model 3: adjusted for age, sex, marital status, education level, per capita monthly income, smoking status, drinking status, exercise, body mass index, family history of stroke, chronic comorbidity, and nightly sleep duration. CI, confidence interval; HR, hazard ratio; PSQI, Pittsburgh Sleep Quality Index.

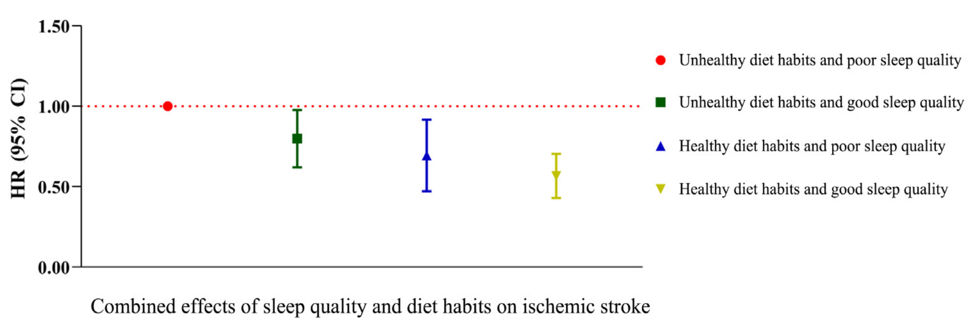

Fig. 3. Combined effects of sleep quality and diet habits on nonfatal ischemic stroke risk. Model was adjusted for age, sex, marital status, education level, per capita monthly income, smoking status, drinking status, exercise, body mass index, family history of stroke, chronic comorbidity, and nightly sleep duration.

Sensitivity analysis

After excluding individuals suffering a nonfatal ischemic stroke in the first year (n = 95), a total of 22 441 participants were included in the sensitivity analysis, among whom 570 ischemic stroke patients were found. The results from the sensitivity analysis did not change significantly from the previous analysis. The robust correlations were verified between sleep quality and nonfatal ischemic stroke, and healthy diet habits were able to mitigate this relationship (Supplementary Tables 2 and 3, Supplementary Figs. 2–4).

Discussion

This was a large-scale prospective study focused on resource-limited areas. Analysis results showed that poor sleep quality increased the incidence risk of nonfatal ischemic stroke in the rural population and healthy diet habits alleviated the effect of poor sleep quality on the incidence risk of nonfatal ischemic stroke. Similar results were also found after excluding individuals with ischemic stroke in the first year. These findings suggest that eating a nutritious diet and enhancing sleep quality significantly contribute to reducing the likelihood of experiencing ischemic stroke.

The link between sleep quality and incidence of nonfatal ischemic stroke demonstrated in this study is consistent with previous studies conducted in different regions and populations. An experimental study in rats showed that sleep disturbances (sleep deprivation for 12 h for consecutive 3 d) increased the growth-inhibiting gene neurocan ($P < 0.001$). The barrier formed by neurocan prevents neurons from reconnecting together with reactive astrocytes, which undoubtedly exacerbates ischemic stroke [48]. Zhang et al. [49] also suggested that poor sleep quality was the fifth of seven risk factors for ischemic stroke from 233 youth ischemic stroke patients (odds ratio, 1.81, 95% CI, 1.12–2.93). In addition, a prospective study in the UK indicated that maintaining good sleep quality can reduce ischemic stroke occurrence (HR, 0.31, 95% CI, 0.15–0.61) [50]. Another study following participants for an average of 7 y indicated that subjective sleep disturbances increased the incidence of stroke in Chinese adults (risk ratio [RR], 2.37, 95% CI, 1.52–3.41) [51]. Similar conclusions have been drawn in other studies as well [52,53].

Several previous studies have also produced results that conflict with the current study. For example, a 14-y German follow-up study found that poor sleep quality (insomnia, trouble falling asleep and difficulty staying asleep) was not significant with regard to total strokes (nonfatal and fatal), nonfatal strokes, or fatal strokes [54]. Another large cohort study of black participants from the Jackson Heart Study followed for 15 y failed to find a link between poor sleep quality and cardiovascular disease (coronary heart disease and stroke) (HR, 1.09, 95% CI, 0.88–1.35) [55]. However, the present study discovered a positive link between sleep quality and ischemic stroke. The reason for this difference may be attributed to different definitions of sleep quality. The German study divided poor sleep quality into different sleep disorders [54] and the study involving black participants defined sleep quality based on a simple question [55], whereas the current study used the PSQI to assess sleep quality. In addition, variations in study populations could contribute to the difference in conclusions. This study was aimed at a population residing in an area with limited resources. The difference in economic status and living habits may also lead to the difference in conclusions. Therefore, standardized sleep quality assessment methods and further large prospective cohort studies with long-term follow-up are indispensable for confirming the causal connection between sleep quality and ischemic stroke.

At present, the mechanisms underlying the correlation between sleep quality and incident ischemic stroke are not completely understood, but several may be involved. First, sleep quality is related to risk factors for ischemic stroke. Numerous studies have shown that poor sleep quality can contribute to hypertension, diabetes, obesity, and dyslipidemia, which are independent risk factors for ischemic stroke [56–60]. Second, poor sleep quality can lead to an inflammatory response, with elevated interleukin-6 concentrations [61]. The role of inflammation in acute cerebrovascular events has been widely investigated and has been recognized as a promising field of stroke management [62–64]. Thus, poor sleep quality may increase inflamatory, which may aggrevate ischemic stroke. Moreover, poor sleep quality may impair glucose tolerance and insulin sensitivity, leading to metabolic disturbances and an increased incidence of stroke [65]. Additionally, poor sleep quality results in increased vascular sympathetic nerve activity and circulating catecholamines, which leads to increased intracranial pressure and stroke as well as increased peripheral vascular resistance [66]. Finally, poor sleep quality might induce endothelial dysfunction, resulting in the formation of blood clots, which can cause stroke [67]. Therefore, improving sleep quality and preventing sleep disorders may be beneficial in stroke prevention and control.

Meanwhile, this analysis results shown that not only healthy diet habits were negatively associated with nonfatal ischemic stroke, but also that healthy diet habits mitigated the connection between poor sleep quality and ischemic stroke risk. Although there is a paucity of studies exploring the combined connection of sleep quality and diet habits with regard to ischemic stroke, several surveys have suggested that healthy diet habits are of great benefit in stroke prevention. According to a cohort study with 26 547 subjects, a high-quality diet decreased the risk of atherothrombotic ischemic stroke (HR, 0.83, 95% CI, 0.72–0.97) [68]. Through a meta-analysis, Hu et al. [69] showed that increasing daily vegetable and fruit intake by 200 g resulted in a respective decrease in stroke incidence of 11% (RR, 0.89, 95% CI, 0.81–0.98) and 32% (RR, 0.68, 95% CI, 0.56–0.82). However, the current findings are contradicted by several previous studies. A case-control study conducted on Iranian adults showed no correlation between the Alternative Healthy Eating Index 2010 and stroke [70], which is inconsistent with this study. Another case-control study conducted on young patients with ischemic stroke showed no discrepancy in the consumption of vegetables between patients and controls [71]. These discrepancies may be attributable to different definitions of diet habits and variations in study populations. Although the mechanisms underlying the correlation between diet habits and incident ischemic stroke are unclear, there are some potential biological pathways. For example, a diet consisting of vegetables, fruits, and other similar food items may reduce the occurrence of risk factors linked to ischemic stroke, such as hypertension, obesity, and cholesterol [72,73]. In addition, nutrients such as folate, vitamin C, and fiber, which are contained in a range of foods, are potentially linked to lower stroke risk [69]. Therefore, adhering to the Dietary Guidelines for Chinese Residents and maintaining a healthy diet can be advantageous in preventing and controlling strokes.

This study has the following strengths. First, based on a large prospective rural cohort study in Henan Province, this study has a large sample size, a low loss of follow-up rate, and a high statistical efficacy. Secondly, this study adjusted a series of confounding factors, including demographic characteristics, smoking, drinking, chronic comorbidities, family history of stroke, etc. to explore the association of sleep quality and dietary habits with ischemic stroke, which is conducive to a more accurate grasp of the relationship of sleep quality and dietary habits with ischemic stroke. Additionally, the PSQI was employed for a comprehensive evaluation of sleep quality. Nevertheless, this study still has some limitations. First, the data on sleep quality and diet quality score were obtained based on a questionnaire survey, which may have information bias. Second, although we included a large number of potential covariates in our analysis, residual or unmeasured covariates may still exist. Therefore, caution should be exercised in the interpretation of causality. Third, the evaluation of nonfatal ischemic stroke was based on hospital diagnosis, which may underestimate the incidence of ischemic stroke as a result of some patients not seeking medical care. Therefore, to authenticate our findings, it is necessary to conduct large prospective population-wide cohort studies in the future.

Conclusions

This study revealed that poor sleep quality and unhealthy diet habits are associated with higher nonfatal ischemic stroke risk in rural populations. Furthermore, this study found that healthy diet habits can attenuate the association between poor sleep quality and nonfatal ischemic stroke. Above findings indicate that maintaining healthy diet habits and developing good sleep quality are potential indicators associated with ischemic stroke prevention.

Ethics approval and consent to participate

Ethics approval was obtained from the Zhengzhou University Life Science Ethics Committee, and written informed consent was obtained for all participants. All participants gave informed consent to participate and be followed up.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

CRediT authorship contribution statement

Hui Zhang: Writing – review & editing, Writing – original draft, Formal analysis. **Jing Yang:** Writing – review & editing, Writing – original draft. **Ruiqi Gu:** Writing – review & editing. **Jiao Yang:** Writing – review & editing. **Xiaokang Dong:** Writing – review & editing. **Zhihan Ren:** Writing – review & editing. **Siyuan Sun:** Writing – review & editing. **Xiaoyu Wang:** Writing – review & editing. **Shouzheng Wei:** Writing – review & editing. **Zhuang Zhuo:** Writing – review & editing. **Zihan Liu:** Writing – review & editing. **Chongjian Wang:** Project administration, Methodology, Funding acquisition.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2024.112485.

References

[1] Lv Y, Mao C, Yin Z, Li F, Wu X, Shi X. Healthy Ageing and Biomarkers Cohort Study (HABCS): a cohort profile. BMJ Open 2019;9:e026513.
[2] Feigin VL, Stark BA, Johnson CO, Roth GA, Bisignano C, Abady GG, et al. Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet Neurol 2021;20:795–820.
[3] Feigin VL, Brainin M, Norrving B, Martins S, Sacco RL, Hacke W, et al. World Stroke Organization (WSO): global stroke fact sheet 2022. Int J Stroke 2022;17:18–29.
[4] Katan M, Luft A. Global burden of stroke. Semin Neurol 2018;38:208–11.
[5] Wafa HA, Wolfe CDA, Emmett E, Roth GA, Johnson CO, Wang Y. Burden of stroke in Europe: thirty-year projections of incidence, prevalence, deaths, and disability-adjusted life years. Stroke 2020;51:2418–27.
[6] Chaudhary D, Khan A, Shahjouei S, Gupta M, Lambert C, Avula V, et al. Trends in ischemic stroke outcomes in a rural population in the United States. J Neurol Sci 2021;422:117339.
[7] Tu WJ, Zhao Z, Yin P, Cao L, Zeng J, Chen H, et al. Estimated burden of stroke in China in 2020. JAMA Netw Open 2023;6:e231455.
[8] Harris JK, Beatty K, Leider JP, Knudson A, Anderson BL, Meit M. The double disparity facing rural local health departments. Annu Rev Public Health 2016;37:167–84.
[9] Baranwal N, Yu PK, Siegel NS. Sleep physiology, pathophysiology, and sleep hygiene. Prog Cardiovasc Dis 2023;77:59–69.
[10] Matsui K, Yoshiike T, Nagao K, Utsumi T, Tsuru A, Otsuki R, et al. Association of subjective quality and quantity of sleep with quality of life among a general population. Int J Environ Res Public Health 2021;18:12835.
[11] Jean-Louis G, Kripke DF, Ancoli-Israel S. Sleep and quality of well-being. Sleep 2000;23:1115–21.
[12] Groeger JA, Zijlstra FR, Dijk DJ. Sleep quantity, sleep difficulties and their perceived consequences in a representative sample of some 2000 British adults. J Sleep Res 2004;13:359–71.
[13] Koyanagi A, Stickley A. The association between sleep problems and psychotic symptoms in the general population: a global perspective. Sleep 2015;38:1875–85.
[14] Jemilohun AC, Fasesan OA, Ajiro TO, Akande KO, Elikwu CJ, Adeleye OO. Sleep quality in a Nigerian community: prevalence of poor sleep quality, risk factors and health-related quality of life. West Afr J Med 2022;39:729–36.
[15] Manzar MD, Bekele BB, Noohu MM, Salahuddin M, Albougami A, Spence DW, et al. Prevalence of poor sleep quality in the Ethiopian population: a systematic review and meta-analysis. Sleep Breath 2020;24:709–16.
[16] Aimo A, Giannoni A, Vergaro G, Emdin M. Longer sleep duration and poor sleep quality as risk factors for hyperlipidaemia. Eur J Prev Cardiol 2019;26:1285–7.
[17] Hur S, Oh B, Kim H, Kwon O. Associations of diet quality and sleep quality with obesity. Nutrients 2021;13:3181.
[18] Song Y, Chang Z, Song C, Cui K, Yuan S, Qiao Z, et al. Association of sleep quality, its change and sleep duration with the risk of type 2 diabetes mellitus: findings from the English longitudinal study of ageing. Diabetes Metab Res Rev 2023;39:e3669.
[19] Tsuno N, Besset A, Ritchie K. Sleep and depression. J Clin Psychiatry 2005;66:1254–69.
[20] Yuan Y, Heizhati M, Wang L, Li M, Lin M, Gan L, et al. Poor sleep quality is associated with new-onset hypertension in a diverse young and middle-aged population. Sleep Med 2021;88:189–96.
[21] Wang J, Ren X. Association between sleep duration and sleep disorder data from the National Health and Nutrition Examination Survey and stroke among adults in the United States. Med Sci Monit 2022;28:e936384.
[22] Kwon HS, Kim C, Kim YS, Koh SH, Kim HY, Lee SH, et al. Long sleep duration and dissatisfaction with sleep quality are associated with ischemic stroke in young patients. Cerebrovasc Dis 2023;52:671–8.
[23] Zhou L, Yu K, Yang L, Wang H, Xiao Y, Qiu G, et al. Sleep duration, midday napping, and sleep quality and incident stroke: the Dongfeng-Tongji cohort. Neurology 2020;94:e345–56.
[24] Rodríguez-Campello A, Jiménez-Conde J, Ois Á, Cuadrado-Godia E, Giralt-Steinhauer E, Schroeder H, et al. Dietary habits in patients with ischemic stroke: a case–control study. PLoS One 2014;9:e114716.

[25] Hansen CP, Overvad K, Kyrø C, Olsen A, Tjønneland A, Johnsen SP, et al. Adherence to a healthy Nordic diet and risk of stroke: a Danish cohort study. Stroke 2017;48:259–64.
[26] Ibsen DB, Christiansen AH, Olsen A, Tjønneland A, Overvad K, Wolk A, et al. Adherence to the EAT-Lancet diet and risk of stroke and stroke subtypes: a cohort study. Stroke 2022;53:154–63.
[27] Binks H, Vincent GE, Gupta C, Irwin C, Khalesi S. Effects of diet on sleep: a narrative review. Nutrients 2020;12:936.
[28] Godos J, Grosso G, Castellano S, Galvano F, Caraci F, Ferri R. Association between diet and sleep quality: a systematic review. Sleep Med Rev 2021;57:101430.
[29] St-Onge MP, Mikic A, Pietrolungo CE. Effects of diet on sleep quality. Adv Nutr 2016;7:938–49.
[30] Zuraikat FM, Wood RA, Barragán R, St-Onge MP. Sleep and diet: mounting evidence of a cyclical relationship. Annu Rev Nutr 2021;41:309–32.
[31] Liu P, Wei D, Nie L, Fan K, Xu Q, Wang L, et al. The correlation between testosterone and stroke and the mediating role of blood pressure: the Henan Rural Cohort Study. J Stroke Cerebrovasc Dis 2022;31:106669.
[32] Mei YX, Zhang ZX, Wu H, Hou J, Liu XT, Sang SX, et al. Health-related quality of life and its related factors in survivors of stroke in rural China: a large-scale cross-sectional study. Front Public Health 2022;10:810185.
[33] Wang Y, Li Y, Liu X, Zhang H, Abdulai T, Tu R, et al. Prevalence and influencing factors of coronary heart disease and stroke in Chinese rural adults: the Henan Rural Cohort Study. Front Public Health 2019;7:411.
[34] Liu X, Mao Z, Li Y, Wu W, Zhang X, Huo W, et al. Cohort profile: the Henan Rural Cohort: a prospective study of chronic non-communicable diseases. Int J Epidemiol 2019;48:1756.
[35] Kadier K, Qin L, Ainiwaer A, Rehemuding R, Dilixiati D, Du YY, et al. Association of sleep-related disorders with cardiovascular disease among adults in the United States: a cross-sectional study based on National Health and Nutrition Examination Survey 2005−2008. Front Cardiovasc Med 2022;9:954238.
[36] Zhuang S, Huang S, Huang Z, Zhang S, Al-Shaar L, Chen S, et al. Prospective study of sleep duration, snoring and risk of heart failure. Heart 2023;109:779–84.
[37] He Q, Ren L, Li H, Wang W, Tao C, Ma L, et al. Genetic insights into the risk of snoring on stroke and ischemic stroke: a single-variable and multivariable Mendelian randomization. Front Neurol 2022;13:1023748.
[38] Shen J, Zhang H, Wang Y, Abdulai T, Niu M, Luo Z, et al. Dose−response association of sleep quality with anxiety symptoms in Chinese rural population: the Henan Rural Cohort. BMC Public Health 2020;20:1297.
[39] Wang Y, Li Y, Liu X, Liu R, Mao Z, Tu R, et al. Gender-specific prevalence of poor sleep quality and related factors in a Chinese rural population: the Henan Rural Cohort Study. Sleep Med 2019;54:134–41.
[40] Xue Y, Yang K, Wang B, Liu C, Mao Z, Yu S, et al. Reproducibility and validity of an FFQ in the Henan Rural Cohort Study. Public Health Nutr 2020;23:34–40.
[41] Liao W, Liu X, Kang N, Song Y, Yuchi Y, Hu Z, et al. Associations between healthy lifestyle score and health-related quality of life among Chinese rural adults: variations in age, sex, education level, and income. Qual Life Res 2023;32:81–92.
[42] Wu X, Liu X, Liao W, Dong X, Li R, Hou J, et al. Healthier lifestyles attenuated association of single or mixture exposure to air pollutants with cardiometabolic risk in rural Chinese adults. Toxics 2022;10:541.
[43] Yang J, Liu X, Zhai Z, Liao W, He Y, Wu X, et al. The independent and combined association of napping and night sleep duration with stroke in Chinese rural adults. Sleep Breath 2023;27:265–74.
[44] Zhai Z, Liu X, Zhang H, Dong X, He Y, Niu M, et al. Associations of midpoint of sleep and night sleep duration with type 2 diabetes mellitus in Chinese rural population: the Henan Rural Cohort Study. BMC Public Health 2021;21:879.
[45] Fan M, Lyu J, He P. Chinese guidelines for data processing and analysis concerning the International Physical Activity Questionnaire. Chin J Epidemiol 2014;35:961–4.
[46] Liao W, Luo Z, Hou Y, Cui N, Liu X, Huo W, et al. Age and gender specific association between obesity and depressive symptoms: a large-scale cross-sectional study. BMC Public Health 2020;20:1565.
[47] Song Y, Dong Q, Chang Z, Song C, Cui K, Wu S, et al. The impact of sleep quality and its change on the long-term risk of stroke in middle-aged and elderly people: Findings from the English Longitudinal Study of Ageing. Sleep Med 2023;107:281–8.
[48] Gao B, Cam E, Jaeger H, Zunzunegui C, Sarnthein J, Bassetti CL. Sleep disruption aggravates focal cerebral ischemia in the rat. Sleep 2010;33:879–87.
[49] Zhang S, Chang C, Zhang J, Song B, Fang H, Xu Y. Correlation analysis of sleep quality and youth ischemic stroke. Behav Neurol 2014;2014:246841.
[50] Song Y, Dong Q, Chang Z, Song C, Cui K, Wu S, et al. The impact of sleep quality and its change on the long-term risk of stroke in middle-aged and elderly people: findings from the English Longitudinal Study of Ageing. Sleep Med 2023;107:281–8.
[51] Ji A, Lou H, Lou P, Xu C, Zhang P, Qiao C, et al. Interactive effect of sleep duration and sleep quality on risk of stroke: an 8-year follow-up study in China. Sci Rep 2020;10:8690.
[52] Pérez-Carbonell L, Bashir S. Narrative review of sleep and stroke. J Thorac Dis 2020;12:S176–90.
[53] St-Onge MP, Grandner MA, Brown D, Conroy MB, Jean-Louis G, Coons M, et al. Sleep duration and quality: impact on lifestyle behaviors and cardiometabolic health: a scientific statement from the American Heart Association. Circulation 2016;134:e367–86.
[54] Helbig AK, Stöckl D, Heier M, Ladwig KH, Meisinger C. Symptoms of insomnia and sleep duration and their association with incident strokes: findings from the population-based MONICA/KORA Augsburg cohort study. PLoS One 2015;10:e0134480.
[55] Butler MJ, Spruill TM, Johnson DA, Redline S, Sims M, Jenkins BC, et al. Suboptimal sleep and incident cardiovascular disease among African Americans in the Jackson Heart Study (JHS). Sleep Med 2020;76:89–97.
[56] Phua CS, Jayaram L, Wijeratne T. Relationship between sleep duration and risk factors for stroke. Front Neurol 2017;8:392.
[57] Covassin N, Singh P. Sleep duration and cardiovascular disease risk: epidemiologic and experimental evidence. Sleep Med Clin 2016;11:81–9.
[58] Gao C, Guo J, Gong TT, Lv JL, Li XY, Liu FH, et al. Sleep duration/quality with health outcomes: an umbrella review of meta-analyses of prospective studies. Front Med (Lausanne) 2021;8:813943.
[59] Tobaldini E, Costantino G, Solbiati M, Cogliati C, Kara T, Nobili L, et al. Sleep, sleep deprivation, autonomic nervous system and cardiovascular diseases. Neurosci Biobehav Rev 2017;74:321–9.
[60] Lo K, Woo B, Wong M, Tam W. Subjective sleep quality, blood pressure, and hypertension: a meta-analysis. J Clin Hypertens (Greenwich) 2018;20:592–605.
[61] Ifergane G, Ovanyan A, Toledano R, Goldbart A, Abu-Salame I, Tal A, et al. Obstructive sleep apnea in acute stroke: a role for systemic inflammation. Stroke 2016;47:1207–12.
[62] Friedman EM. Sleep quality, social well-being, gender, and inflammation: an integrative analysis in a national sample. Ann N Y Acad Sci 2011;1231:23–34.
[63] Kelly PJ, Lemmens R, Tsivgoulis G. Inflammation and Stroke Risk: A New Target for Prevention. Stroke 2021;52:2697–706.
[64] Monsour M, Borlongan CV. The central role of peripheral inflammation in ischemic stroke. J Cereb Blood Flow Metab 2023;43:622–41.
[65] Depner CM, Stothard ER, Wright KP Jr. Metabolic consequences of sleep and circadian disorders. Curr Diab Rep 2014;14:507.
[66] Park M, Martyn-Nemeth P, Hayman LL. Sleep and cardiovascular disease. J Cardiovasc Nurs 2022;37:3–4.
[67] Miller MA. Association of inflammatory markers with cardiovascular risk and sleepiness. J Clin Sleep Med 2011;7:S31–3.
[68] Johansson A, Drake I, Engström G, Acosta S. Modifiable and non-modifiable risk factors for atherothrombotic ischemic stroke among subjects in the Malmö Diet and Cancer Study. Nutrients 2021;13:1952.
[69] Hu D, Huang J, Wang Y, Zhang D, Qu Y. Fruits and vegetables consumption and risk of stroke: a meta-analysis of prospective cohort studies. Stroke 2014;45:1613–9.
[70] Mousavi SM, Milajerdi A, Pouraram H, Saadatnia M, Shakeri F, Keshteli AH, et al. Adherence to Alternative Healthy Eating Index (AHEI-2010) is not associated with risk of stroke in Iranian adults: a case−control study. Int J Vitam Nutr Res 2021;91:48–55.
[71] Saapar M, Vibo R, Schneider S, Kõrv L, Mallene S, Kõrv J. Health behavior of young patients with ischemic stroke in Estonia: a score of five factors. Brain Behav 2023;13:e2908.
[72] Radhika G, Sudha V, Mohan Sathya R, Ganesan A, Mohan V. Association of fruit and vegetable intake with cardiovascular risk factors in urban south Indians. Br J Nutr 2008;99:398–405.
[73] Zhao D, Qi Y, Zheng Z, Wang Y, Zhang XY, Li HJ, et al. Dietary factors associated with hypertension. Nat Rev Cardiol 2011;8:456–65.