Psychology Research and Behavior Management

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ORIGINAL RESEARCH

Sedentary Behavior and Its Association With Psychological Well-Being and Sleep Quality in Adolescents: Evidence from a Propensity Score Analysis

Lirong Zhang[1], Shaocong Zhao[1], Shuangyin Zhao[1], Hua Zheng[2], Yizhen Ke[1], Weichen Yang[1], Mingxing Lei[3,4]

[1]Department of Physical Education, Xiamen University of Technology, Xiamen, Fujian, 361024, People's Republic of China; [2]College of Physical Education and Health Science, Chongqing Normal University, Chongqing, 401331, People's Republic of China; [3]Department of Orthopaedics, Hainan Hospital of Chinese PLA General Hospital, Sanya, 572013, People's Republic of China; [4]Nursing Department, The First Medical Center of Chinese PLA General Hospital, Beijing, 100853, People's Republic of China

Correspondence: Lirong Zhang, Department of Physical Education, Xiamen University of Technology, No. 600, Ligong Road, Jimei District, Xiamen, 361024, Fujian, People's Republic of China, Tel +86 13806063882, Email 22674481@qq.com; Mingxing Lei, Department of Orthopedic Surgery, Chinese PLA General Hospital, Beijing, 100039, People's Republic of China, Tel +86 18811772189, Email leimingxing2@sina.com

Background: Sedentary lifestyles among adolescents have been associated with various health concerns, particularly regarding psychological well-being and sleep quality. However, the associative relationship between sedentary behavior and these health outcomes remains unclear. This study aims to clarify the association between sedentary lifestyle and psychological and sleep health among adolescents through propensity scores matching analysis.

Methods: A total of 2,846 adolescents from three universities participated in the study. Data on demographics, exercise habits, eating patterns, sedentary behavior, psychological health, sleep health, self-esteem, and social support were collected. A sedentary lifestyle was defined as sitting for more than six hours daily. Psychological health was assessed using the Generalized Anxiety Disorder-7 (GAD-7) scale for anxiety and the Patient Health Questionnaire-9 (PHQ-9) for depression, while sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI). Self-esteem was evaluated with the Self-Esteem Scale (SES), and social support was measured using the Social Support Rating Scale (SSRS). Propensity scores matching analysis was employed to investigate the associative relationship between sedentary lifestyles and the measured outcomes.

Results: Prior to propensity scores matching, significant differences were observed in baseline characteristics between participants with and without sedentary lifestyles, including gender (P=0.01), dietary habits (P<0.001), mobile device usage (P<0.001), stress events (P=0.001), physical activity (P<0.001), and chronic diseases (P=0.024). Participants with sedentary lifestyles exhibited higher scores on the GAD-7 (P<0.001), PHQ-9 (P<0.001), and PSQI (P<0.001), along with lower self-esteem (SES, P=0.041) and social support (SSRS, P<0.001) compared to their more active counterparts. Following propensity scores matching, no significant differences in baseline characteristics were found between the two groups (All P>0.282), indicating a successful matching process. Post-matching analysis revealed that individuals with sedentary lifestyles had significantly higher GAD-7 (P=0.002), PHQ-9 (P=0.013), and PSQI scores (P=0.001) than those without sedentary lifestyles, while no significant differences were found in SES (P=0.755) and SSRS (P=0.676).

Conclusion: Our findings indicate that a sedentary lifestyle is associated with poorer psychological health and sleep quality among adolescents, even after controlling for various demographic and lifestyle factors. These results underscore the importance of promoting physical activity and reducing sedentary behavior in this population to enhance their overall well-being.

Keywords: sedentary lifestyle, psychological health, anxiety, depression, sleep health, propensity scores matching analysis

Received: 25 November 2024
Accepted: 27 January 2025
Published: 7 February 2025

Introduction

Sedentary behavior refers to any waking activity characterized by an energy expenditure of 1.5 metabolic equivalents or less while in a sitting or reclining position.[1] With the growing prevalence of technology and screen-based activities, recent studies indicated that sedentary behavior among adolescents has risen significantly,[2] with average daily sedentary time increasing from 8.7 hours to 9.7 hours over the past decade.[3] In China, the average daily sedentary time for young individuals ranges from 10.9 to 11.7 hours.[4,5] Epidemiological studies revealed a troubling trend toward sedentary lifestyles, with substantial data indicating that a significant proportion of adolescents engage in extended periods of sitting,[4,5] whether in classrooms, at home, or during recreational activities. The 2020 World Health Organization Guidelines on Physical Activity and Sedentary Behavior has reported that sedentary behavior poses a major public health concern, with approximately one-third of the global population aged 15 and older failing to meet the recommended levels of physical activity.[6]

A sedentary lifestyle has detrimental effects on various aspects of health, both physiologically and psychologically. Previous research has shown that a sedentary lifestyle can contribute to obesity,[7,8] cardiovascular disease,[9] diabetes,[6] hypertension,[6] osteoporosis,[6] dementia,[10] and even certain types of cancer.[8] Additionally, prolonged sitting can lead to musculoskeletal issues, such as back pain and poor posture.[11] The implications of sedentary behavior extend beyond physical health; emerging evidence suggests that prolonged inactivity may also negatively impact psychological well-being and brain health.[12,13] Some small-sample studies revealed that increased sitting hours correlated with significant rises in anxiety and depression.[14,15] However, a review by Suchert et al[16] concluded that the relationship between sedentary behavior and mental health indicators remains somewhat ambiguous, necessitating further investigation into how sedentary behavior influences psychological outcomes and sleep quality. This lack of clarity underscores the importance of examining the specific impacts of sedentary behavior on adolescents' mental health and sleep patterns, as these outcomes are critical to their overall development and quality of life.

Therefore, this study aims to elucidate the relationship between sedentary behavior, psychological health, and sleep quality among adolescents through propensity score matching analysis. By addressing potential confounding variables, this research seeks to provide a clearer understanding of whether sedentary lifestyles contribute to psychological distress and compromised sleep quality. Through this investigation, we aim to emphasize the necessity of promoting active lifestyles among adolescents to foster better psychological and sleep health outcomes.

Methods

Participants

A cross-sectional study was conducted involving a total of 2,846 adolescents from three universities in China between January 2024 and February 2024. The three universities are located in different regions of China, with one in the eastern part, one in the northern part, and one in the southwestern area, all situated in urban environments. Participants were recruited through university announcements and online surveys. Participants completed questionnaires assessing demographics, exercise, dietary, sedentary lifestyle, psychological health, sleep quality, self-esteem, and social support. Inclusion criteria consisted of currently enrolled university students who voluntarily participated in the study and had no reading or writing disabilities. Exclusion criteria included those unwilling to participate and individuals younger than 18 years old. Participant's flowchart is summarized in Supplementary Figure 1. The study adhered to the principles outlined in the Declaration of Helsinki and received approval from the Academic Committee and Ethics Board of our University. All participants provided informed consent prior to participation, and confidentiality was maintained throughout the study.

Collection of Baseline Characteristics

This study gathered participants' demographic information, including age, gender, academic year, and marital status. Dietary preferences were assessed, focusing on low-salt and low-fat diets, consumption of fatty foods, barbecued items, meat, vegetables, and fruits. Referring to previous literature,[17,18] lifestyle factors included smoking, alcohol consumption, daily screen time (from mobile phones and other electronic devices), monthly

expenses, exposure to stressors, physical activity levels, and medical history, specifically chronic diseases and diagnosed mental disorders. Exposure to stressors is defined as various events experienced in daily life that cause physical and mental stress and difficulties in adaptation, such as the death of a loved one, a breakup, financial difficulties, or significant life changes. A sedentary lifestyle was operationally defined as sitting for more than six hours per day.[19–21]

Evaluation of Psychological Health

Psychological health was assessed using the Generalized Anxiety Disorder-7 (GAD-7) scale for anxiety and the Patient Health Questionnaire-9 (PHQ-9) for depression. The GAD-7 scale is a widely used tool designed to evaluate the severity of generalized anxiety disorder symptoms.[22] It consists of seven items that inquire about the frequency of various anxiety-related symptoms experienced over the past two weeks. Each item is scored on a 0 to 3 scale, where higher scores indicate greater levels of anxiety. This scale has been validated in various populations and is known for its reliability and sensitivity in detecting anxiety disorders. The PHQ-9 is a self-administered questionnaire that assesses the presence and severity of depressive symptoms.[23] It contains nine items, each corresponding to one of the diagnostic criteria for major depressive disorder as outlined in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition. Respondents are asked to rate how often they have experienced specific symptoms over the last two weeks, using a scale ranging from 0 (not at all) to 3 (nearly every day). Like the GAD-7, the PHQ-9 has demonstrated strong psychometric properties and is effective in identifying individuals with depression.[24,25] Additionally, the Cronbach's α for GAD-7 and PHQ-9 was calculated, yielding values of 0.944 and 0.928, respectively, indicating high internal consistency and reliability for both instruments.

Evaluation of Sleep Health

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI),[26] a widely recognized tool for evaluating sleep disturbances and overall sleep quality over the past month. The PSQI comprises 19 items that generate seven component scores, which include subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction. Each component is scored on a scale from 0 to 3, with higher scores indicating greater difficulty or poorer sleep quality. The total PSQI score ranges from 0 to 21, with higher total scores reflecting worse sleep quality. A score greater than 5 is typically used as a threshold to identify individuals with significant sleep disturbances. The PSQI has demonstrated strong psychometric properties, including good reliability and validity,[27–29] making it a valuable tool for both clinical and research settings to evaluate sleep quality and its implications for overall health.

Evaluation of Self-Esteem and Social Support

Self-esteem was evaluated using the Self-Esteem Scale (SES), a widely used instrument designed to measure individual self-esteem levels. Developed by Rosenberg in 1965,[30] the SES consists of 10 items that assess positive and negative feelings about oneself. Respondents indicate their agreement with each statement on a four-point Likert scale, ranging from "strongly agree" to "strongly disagree". The total score can range from 0 to 30, with higher scores indicating higher self-esteem. The SES has demonstrated good reliability and validity across diverse populations, making it an effective tool for assessing self-esteem in both clinical and research contexts. In addition, social support was assessed using the Social Support Rating Scale (SSRS),[31] a tool developed to measure the level of perceived social support and its sources. The SSRS includes 10 items that evaluate various aspects of social support, including subjective support (the perceived availability of support), objective support (the actual support received), and the utilization of support. Respondents rate their experiences on a scale that reflects the frequency and adequacy of support they receive from family, friends, and other social networks. The total score reflects the overall level of social support, with higher scores indicating greater perceived support. The SSRS has been widely validated and is useful in understanding the role of social support in mental health and well-being.

Statistical Analysis

Descriptive statistics were computed for all variables in the study. Qualitative data were presented as proportions, while quantitative data were expressed as means with standard deviations (SD). Before conducting propensity scores matching analysis, the differences between groups in qualitative data were analyzed using the chi-square test, whereas quantitative data were assessed using either the *t*-test or the Mann–Whitney *U*-test, depending on the distribution of the data. To control for potential confounding variables and ensure comparability between participants with and without sedentary lifestyles, propensity scores matching analysis[32] was employed. Propensity scores were calculated using a "psmatch" model that incorporated all relevant confounding factors differing between the two groups before matching. The matching process employed the "nearest neighbor" algorithm, which is well-known for its effectiveness in minimizing selection bias in observational studies. This algorithm was configured with a 1:1 matching ratio and a caliper width of 0.05[33]—a crucial parameter that defines the maximum allowable difference in propensity scores between matched pairs. Additionally, the standardized mean difference (SMD)[34] was calculated for each baseline clinical characteristic both before and after propensity scores matching. The SMD serves as a useful statistic that quantifies the mean differences between the two groups while considering the standard deviations of each group. It is frequently utilized in propensity score analyses to evaluate the balance of baseline characteristics between groups after applying matching techniques. After performing the propensity scores matching analysis, the outcomes for quantitative variables were evaluated using paired t-tests or the Wilcoxon rank test, as appropriate. Two-sided P values were reported. Statistical significance was defined as a p-value of less than 0.05.

Results

Patient's Baseline Characteristics

Among the included 2846 patients, the sample was predominantly male (55.2%), with a mean age of 19.58 years (SD: 1.73) (Table 1). Most participants were in their second year of study (42.9%), followed closely by first-year students (42.2%). A significant majority were single (76.9%), with 22.5% currently dating and a negligible number married (0.6%). In terms of dietary habits, 29.0% preferred low salt and fat diets, while 30.9% consumed diets rich in fats, and 36.5% enjoyed barbecued foods. Notably, 68.0% regularly ate meat, with nearly equal preferences for vegetable (49.0%) and fruit (60.3%) consumption. Smoking was not common, as 90.0% were non-smokers, and 74.0% reported never drinking alcohol, though 22.5% were current drinkers. Participants averaged 6.46 hours of daily screen time (SD: 2.66), with 81.0% spending less than 274 USD monthly. Exposure to stressors was reported by 33.9% of the cohort, and 21.4%

Table 1 Baseline Characteristics Analysis Stratified by Sedentary Lifestyle Before Propensity Score Analysis

Characteristics	Overall	Sedentary Lifestyle		P	SMD
		No	Yes		
n	2846	1887	959		
Gender (male/female, %)	1571/1275 (55.2/44.8)	1082/805 (57.3/42.7)	489/470 (51.0/49.0)	0.001	0.128
Age (years, mean [SD])	19.58 (1.73)	19.56 (1.64)	19.63 (1.90)	0.259	0.044
Grade (%)				0.070	0.113
1st year	1201 (42.2)	823 (43.6)	378 (39.4)		
2nd year	1221 (42.9)	790 (41.9)	431 (44.9)		
3rd year	232 (8.2)	150 (7.9)	82 (8.6)		
4th year	170 (6.0)	114 (6.0)	56 (5.8)		
Delayed graduation	22 (0.8)	10 (0.5)	12 (1.3)		

(*Continued*)

Table 1 (Continued).

Characteristics	Overall	Sedentary Lifestyle		P	SMD
		No	Yes		
Marital status (%)				0.105	0.085
Single	2189 (76.9)	1429 (75.7)	760 (79.2)		
Dating	639 (22.5)	446 (23.6)	193 (20.1)		
Married	18 (0.6)	12 (0.6)	6 (0.6)		
Dietary preferences					
Low salt and fat (no/yes, %)	2022/824 (71.0/29.0)	1290/597 (68.4/31.6)	732/227 (76.3/23.7)	<0.001	0.179
Rich in fats (no/yes, %)	1968/878 (69.1/30.9)	1349/538 (71.5/28.5)	619/340 (64.5/35.5)	<0.001	0.149
Barbecue (no/yes, %)	1808/1038 (63.5/36.5)	1225/662 (64.9/35.1)	583/376 (60.8/39.2)	0.034	0.085
Meat (no/yes, %)	910/1936 (32.0/68.0)	630/1257 (33.4/66.6)	280/679 (29.2/70.8)	0.026	0.090
Vegetable (no/yes, %)	1451/1395 (51.0/49.0)	942/945 (49.9/50.1)	509/450 (53.1/46.9)	0.121	0.063
Fruit (no/yes, %)	1131/1715 (39.7/60.3)	720/1167 (38.2/61.8)	411/548 (42.9/57.1)	0.017	0.096
Smoking (%)				0.418	0.053
Never	2561 (90.0)	1692 (89.7)	869 (90.6)		
Previous	89 (3.1)	57 (3.0)	32 (3.3)		
Current	196 (6.9)	138 (7.3)	58 (6.0)		
Drinking (%)				0.165	0.077
Never	2106 (74.0)	1396 (74.0)	710 (74.0)		
Previous	99 (3.5)	74 (3.9)	25 (2.6)		
Current	641 (22.5)	417 (22.1)	224 (23.4)		
Daily screen time (hours, mean [SD])	6.46 (2.66)	5.91 (2.50)	7.54 (2.64)	<0.001	0.636
Monthly expense (USD, %)				0.430	0.063
Under 274	2304 (81.0)	1531 (81.1)	773 (80.6)		
274 to 548	479 (16.8)	320 (17.0)	159 (16.6)		
548 to 1096	42 (1.5)	25 (1.3)	17 (1.8)		
Above 1096	21 (0.7)	11 (0.6)	10 (1.0)		
Exposure to stressors (yes/no, %)	965/1881 (33.9/66.1)	600/1287 (31.8/68.2)	365/594 (38.1/61.9)	0.001	0.132
Sport (no/yes)	610/2236 (21.4/78.6)	305/1582 (16.2/83.8)	305/654 (31.8/68.2)	<0.001	0.373
Chronic disease (yes/no, %)	106/2740 (3.7/96.3)	59/1828 (3.1/96.9)	47/912 (4.9/95.1)	0.024	0.090
Diagnosis of mental disorders in hospital (yes/no, %)	88/2758 (3.1/96.9)	58/1829 (3.1/96.9)	30/929 (3.1/96.9)	1.000	0.003

Abbreviations: SMD, standardized mean difference; SD, standard deviation.

of participants did not engage in regular sports activities, indicating a trend towards sedentary behavior. Chronic diseases were infrequent (3.7%), and only 3.1% had been diagnosed with mental health issues in a hospital setting. A sedentary lifestyle was reported in 33.7% of participants. The above findings effectively characterized a young, predominantly

single, and relatively healthy population with relatively notable sedentary behavior and specific dietary preferences, providing a foundation for further analysis.

A Comparison of Clinical Characteristics Before Propensity Scores Matching Analysis

Before propensity scores matching analysis, this study compared the characteristics of participants with and without a sedentary lifestyle (Table 1), highlighting notable differences across various factors. The gender distribution indicated a higher proportion of females in the sedentary group (49.0%) compared to the non-sedentary group (42.7%), with a statistically significant difference (P=0.001). In terms of dietary preferences, significant disparities emerged: a greater percentage of the non-sedentary group adhered to low salt and fat diet (31.6% vs 23.7%, P<0.001) and consumed less foods rich in fats (28.5% vs 35.5%, P<0.001) compared to their sedentary counterparts. Additionally, sedentary individuals were more likely to consume barbecue (39.2% vs 35.1%, P = 0.034) and meat (70.8% vs 66.6%, P = 0.026) but less likely to eat fruits (57.1% vs 61.8%, P = 0.017). Furthermore, daily screen time was significantly higher in the sedentary group (7.54 hours) compared to the non-sedentary group (5.91 hours, P<0.001). A larger percentage of the sedentary group reported exposure to stressors (38.1% vs 31.8%, P = 0.001). Participation in sports was considerably lower among the sedentary group (16.2% vs 31.8%, P<0.001), and there was a slight increase in the prevalence of chronic diseases in this group (4.9% vs 3.1%, P=0.024). These findings revealed an obvious imbalance in the baseline characteristics between the two groups, suggesting that the sedentary lifestyle may be associated with various demographic and health-related factors. Such imbalances could potentially confound the association between sedentary behavior and health outcomes, highlighting the need for propensity scores matching analysis to control potential confounding factors.

Anxiety and Depression Outcome Before Propensity Scores Matching Analysis

The analysis of the GAD-7 score revealed significant differences between individuals with sedentary lifestyles and those who are not sedentary (Table 2). The overall mean GAD-7 score was 3.97, with sedentary individuals reporting a notably

Table 2 Outcome Analysis Stratified by Sedentary Lifestyle Before Propensity Score Analysis

Outcome	Overall	Sedentary Lifestyle		P
		No	Yes	
GAD-7 (mean [SD])	3.97 (4.32)	3.56 (3.98)	4.77 (4.82)	<0.001
PHQ-9 (mean [SD])	4.74 (5.05)	4.27 (4.62)	5.67 (5.69)	<0.001
PSQI score (mean [SD])	5.04 (3.21)	4.75 (3.08)	5.60 (3.37)	<0.001
Sleep quality (mean [SD])	0.91 (0.73)	0.86 (0.71)	1.00 (0.77)	<0.001
Sleep latency (mean [SD])	1.09 (0.95)	1.04 (0.91)	1.18 (1.02)	<0.001
Sleep duration (mean [SD])	0.73 (0.88)	0.67 (0.86)	0.84 (0.91)	<0.001
Sleep efficiency (mean [SD])	0.48 (0.84)	0.50 (0.85)	0.45 (0.82)	0.178
Sleep disturbances (mean [SD])	0.75 (0.62)	0.71 (0.61)	0.83 (0.63)	<0.001
Sleep medications (mean [SD])	0.07 (0.37)	0.07 (0.37)	0.07 (0.36)	0.716
Sleep dysfunction (mean [SD])	1.01 (0.93)	0.90 (0.89)	1.23 (0.98)	<0.001
SES (mean [SD])	30.26 (5.03)	30.40 (4.83)	29.99 (5.39)	0.041
SSRS (mean [SD])	26.00 (5.84)	26.30 (5.92)	25.43 (5.65)	<0.001

Abbreviations: GAD-7, generalized anxiety disorder-7; SD, standard deviation; PHQ-9, patient health questionnaire-9; PSQI, Pittsburgh sleep quality index; SES, self-esteem scale; SSRS: social support rating scale.

higher mean score of 4.77 compared to 3.56 for non-sedentary individuals (P<0.001). Similarly, the PHQ-9 score indicated a comparable trend; the overall mean score was 4.74, with sedentary individuals exhibiting a mean score of 5.67, in contrast to 4.27 for their non-sedentary counterparts (P<0.001). These findings suggest that a sedentary lifestyle is associated with increased levels of anxiety and depression.

Sleep Quality Assessment Before Propensity Scores Matching Analysis

The PSQI scores further demonstrated the adverse effects of a sedentary lifestyle on sleep health (Table 2). The overall mean PSQI score was 5.04, with sedentary individuals reporting a significantly poorer sleep score average of 5.60, compared to 4.75 among non-sedentary individuals (P<0.001). To elaborate, subitem metrics, including sleep quality (P<0.001), latency (P<0.001), duration (P<0.001), disturbances (P<0.001), and dysfunction (P<0.001), supported this trend (Figure 1). For instance, the mean sleep latency for sedentary individuals was 1.18, compared to 1.04 for non-sedentary individuals (P<0.001). These results collectively highlight the detrimental impact of sedentary behavior on multiple facets of sleep quality. However, sleep efficiency (P=0.178) and medications (P=0.716) were insignificant, indicating that a sedentary lifestyle does not significantly affect these two aspects.

Self-Esteem and Social Support Before Propensity Scores Matching Analysis

The overall mean SES score was 30.26, with sedentary individuals showing a lower mean score of 29.99 compared to 30.40 for non-sedentary individuals (P=0.041) (Table 2). In terms of social support, as measured by the SSRS, sedentary individuals had a mean score of 25.43, which was significantly lower than the 26.30 reported by non-sedentary individuals (P<0.001). These findings suggest that a sedentary lifestyle is associated with lower SES and reduced social support, potentially compounding the negative effects on mental health and sleep outcomes.

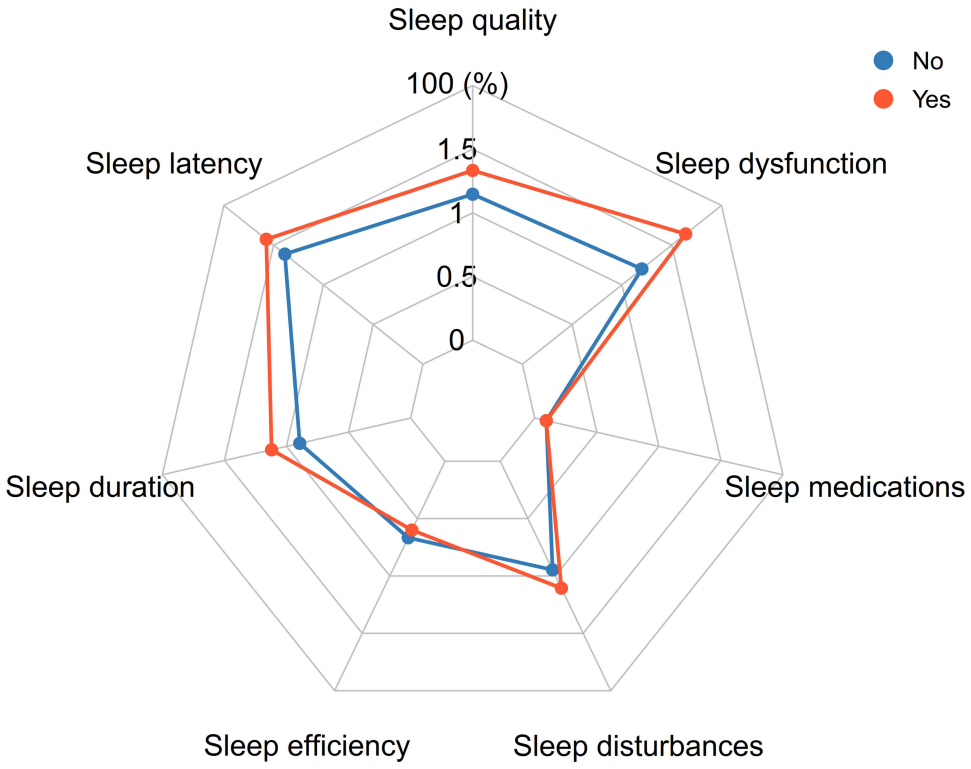

Figure 1 Radar plots for quality of sleep between participants with and without sedentary lifestyle before propensity score matching analysis.

https://doi.org/10.2147/PRBM.S508382

A Comparison of Clinical Characteristics After Propensity Scores Matching Analysis

Following propensity scores matching analysis, no significant differences in baseline characteristics were found between the two groups (All P>0.282), indicating a successful matching process (Table 3). Figure 2 shows that participants with sedentary lifestyles (matched treated units) well matched with participants without sedentary lifestyles (matched control

Table 3 Baseline Characteristics Analysis Stratified by Sedentary Lifestyle After Propensity Score Analysis

Characteristics	Overall	Sedentary Lifestyle		P	SMD
		No	No		
n	1736	868	868		
Gender (male/female, %)	892/844 (51.4/48.6)	444/424 (51.2/48.8)	448/420 (51.6/48.4)	0.885	0.009
Age (years, mean [SD])	19.61 (1.68)	19.62 (1.55)	19.60 (1.80)	0.864	0.008
Grade (%)				0.282	0.108
1st year	680 (39.2)	332 (38.2)	348 (40.1)		
2nd year	786 (45.3)	402 (46.3)	384 (44.2)		
3rd year	143 (8.2)	66 (7.6)	77 (8.9)		
4th year	112 (6.5)	63 (7.3)	49 (5.6)		
Delayed graduation	15 (0.9)	5 (0.6)	10 (1.2)		
Marital status (%)				0.564	0.051
Single	1376 (79.3)	696 (80.2)	680 (78.3)		
Dating	350 (20.2)	168 (19.4)	182 (21.0)		
Married	10 (0.6)	4 (0.5)	6 (0.7)		
Dietary preferences					
Low salt and fat (no/yes, %)	1318/418 (75.9/24.1)	663/205 (76.4/23.6)	655/213 (75.5/24.5)	0.694	0.022
Rich in fats (no/yes, %)	1134/602 (65.3/34.7)	564/304 (65.0/35.0)	570/298 (65.7/34.3)	0.801	0.015
Barbecue (no/yes, %)	1061/675 (61.1/38.9)	528/340 (60.8/39.2)	533/335 (61.4/38.6)	0.844	0.012
Meat (no/yes, %)	506/1230 (29.1/70.9)	249/619 (28.7/71.3)	257/611 (29.6/70.4)	0.712	0.020
Vegetable (no/yes, %)	906/830 (52.2/47.8)	455/413 (52.4/47.6)	451/417 (52.0/48.0)	0.885	0.009
Fruit (no/yes, %)	736/1000 (42.4/57.6)	366/502 (42.2/57.8)	370/498 (42.6/57.4)	0.884	0.009
Smoking (%)				0.945	0.016
Never	1572 (90.6)	788 (90.8)	784 (90.3)		
Previous	59 (3.4)	29 (3.3)	30 (3.5)		
Current	105 (6.0)	51 (5.9)	54 (6.2)		
Drinking (%)				0.693	0.041
Never	1286 (74.1)	643 (74.1)	643 (74.1)		
Previous	56 (3.2)	31 (3.6)	25 (2.9)		
Current	394 (22.7)	194 (22.4)	200 (23.0)		

(*Continued*)

Table 3 (Continued).

Characteristics	Overall	Sedentary Lifestyle		P	SMD
		No	No		
Daily screen time (hours, mean [SD])	7.24 (2.55)	7.22 (2.53)	7.27 (2.58)	0.649	0.022
Monthly expense (USD, %)				0.810	0.047
Under 274	1396 (80.4)	696 (80.2)	700 (80.6)		
274 to 548	299 (17.2)	154 (17.7)	145 (16.7)		
548 to 1096	26 (1.5)	11 (1.3)	15 (1.7)		
Above 1096	15 (0.9)	7 (0.8)	8 (0.9)		
Exposure to stressors (yes/no, %)	651/1085 (37.5/62.5)	327/541 (37.7/62.3)	324/544 (37.3/62.7)	0.921	0.007
Sport (no/yes)	484/1252 (27.9/72.1)	235/633 (27.1/72.9)	249/619 (28.7/71.3)	0.487	0.036
Chronic disease (yes/no, %)	76/1660 (4.4/95.6)	38/830 (4.4/95.6)	38/830 (4.4/95.6)	1.000	<0.001
Diagnosis of mental disorders in hospital (yes/no, %)	51/1685 (2.9/97.1)	23/845 (2.6/97.4)	28/840 (3.2/96.8)	0.570	0.034

Abbreviations: SMD, standardized mean difference; SD, standard deviation.

units). The distribution of propensity score before and after propensity score matching analysis was also summarized, and it revealed the similar trend (Supplementary Figure 2). Regarding SMD, all SMD values became smaller after propensity score matching analysis compared to those before the matching process (Figure 3). In detail, the vast majority of SMDs for potential confounding factors (17/18) fell between 0.00 and 0.10, indicating very improved balance in covariates.

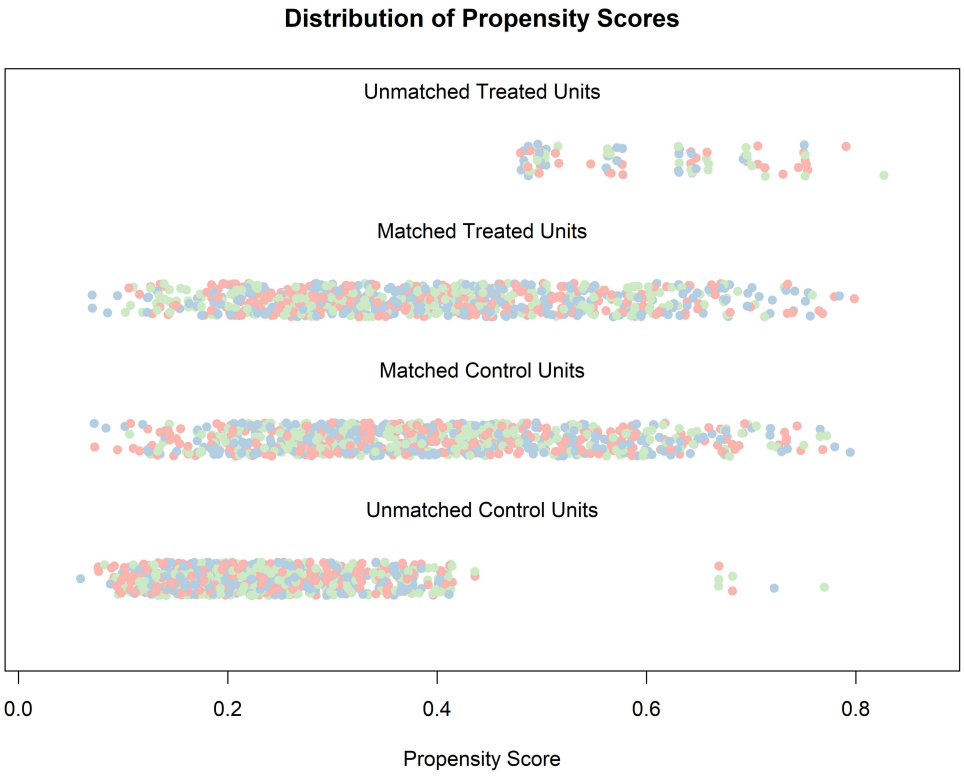

Figure 2 Distribution of propensity scores among matched and unmatched units.

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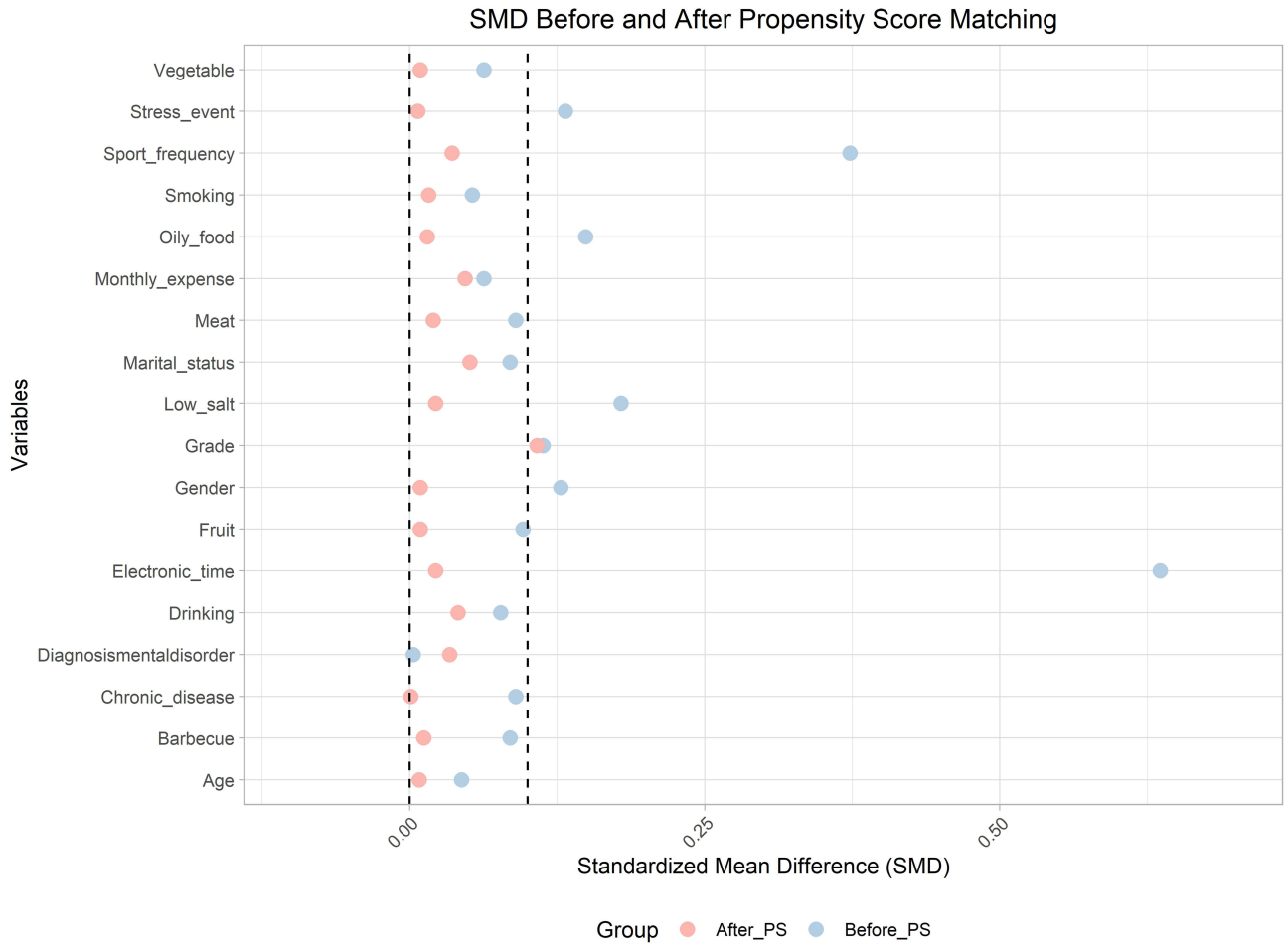

Figure 3 Standardized mean differences before and after propensity score matching analysis.

Outcome After Propensity Scores Matching Analysis

After propensity scores matching analysis, the GAD-7 still revealed a significant increase in anxiety among individuals with a sedentary lifestyle (Table 4), with a mean score of 4.67 compared to 4.01 for non-sedentary individuals (P=0.002, Figure 4A). Similarly, the PHQ-9 indicated a higher mean score of 5.49 in sedentary individuals versus 4.87 in non-sedentary individuals (P=0.013, Figure 4B), reflecting greater depressive symptoms. Additionally, the PSQI score was

Table 4 Outcome Analysis Stratified by Sedentary Lifestyle After Propensity Score Analysis

Outcome	Overall	Sedentary Lifestyle		P
		No	Yes	
GAD-7 (mean [SD])	4.34 (4.43)	4.01 (4.10)	4.67 (4.71)	0.002
PHQ-9 (mean [SD])	5.18 (5.19)	4.87 (4.84)	5.49 (5.50)	0.013
PSQI score (mean [SD])	5.32 (3.23)	5.07 (3.11)	5.57 (3.33)	0.001
Sleep quality (mean [SD])	0.96 (0.74)	0.91 (0.71)	1.00 (0.76)	0.016
Sleep latency (mean [SD])	1.16 (0.98)	1.15 (0.94)	1.16 (1.01)	0.787

(*Continued*)

Table 4 (Continued).

Outcome	Overall	Sedentary Lifestyle		P
		No	Yes	
Sleep duration (mean [SD])	0.76 (0.89)	0.67 (0.87)	0.84 (0.90)	<0.001
Sleep efficiency (mean [SD])	0.49 (0.84)	0.51 (0.86)	0.46 (0.83)	0.191
Sleep disturbances (mean [SD])	0.78 (0.62)	0.75 (0.61)	0.82 (0.63)	0.017
Sleep medications (mean [SD])	0.07 (0.38)	0.07 (0.40)	0.07 (0.37)	0.754
Sleep dysfunction (mean [SD])	1.10 (0.94)	0.99 (0.90)	1.21 (0.97)	<0.001
SES (mean [SD])	30.07 (5.07)	30.03 (4.82)	30.11 (5.32)	0.755
SSRS (mean [SD])	25.64 (5.75)	25.70 (5.85)	25.59 (5.64)	0.676

Abbreviations: GAD-7, generalized anxiety disorder-7; SD, standard deviation; PHQ-9, patient health questionnaire-9; PSQI, Pittsburgh sleep quality index; SES, self-esteem scale; SSRS: social support rating scale.

significantly poorer in sedentary individuals (5.57) compared to their non-sedentary counterparts (5.07) (P=0.001, Figure 4C). However, the analysis found no significant differences in SES (P=0.755) and SSRS (P=0.676, Figure 4D) among participants with and without sedentary lifestyles, indicating that self-esteem and social support may not be significantly influenced by sedentary behavior. Regarding the detailed PSQI subitems, sedentary individuals had higher scores of sleep quality (P=0.016), duration (P<0.001), disturbances (P=0.017), and dysfunction (P<0.001) than non-sedentary individuals (Figure 5). These results underscore the adverse impact of a sedentary lifestyle on mental health and sleep quality. The above findings suggest that sedentary lifestyles are more directly linked to mental health and sleep quality issues, rather than contributing to self-esteem and social support. This also implies that the negative impacts of a sedentary lifestyle may primarily stem from its effects on psychological well-being and sleep patterns, rather than being mediated by factors like self-esteem or social support systems.

Discussion

Principal Findings

This study revealed that a sedentary lifestyle among adolescents was associated with poorer psychological health and sleep quality. Specifically, participants who reported sitting for more than six hours a day exhibited significantly higher levels of anxiety and depression, as measured by the GAD-7 and PHQ-9 scales. Additionally, these individuals experienced poorer sleep quality, as indicated by elevated PSQI scores. After controlling for confounding factors through propensity scores matching, the negative impacts of sedentary behavior on mental well-being and sleep persisted, highlighting the urgent need for interventions to avoid sedentary lifestyle and promote physical activity among adolescents. It is important to note that this study presents associative findings rather than causal relationships, given its cross-sectional design.

Epidemiology of Sedentary Behavior

Sedentary behavior is increasingly common among adolescents, influenced by various factors including the proliferation of television and video devices, lifestyle changes, and limited access to exercise spaces resulting from urbanization. Notably, approximately one-third of the global population aged 15 and older does not meet the recommended levels of physical activity, primarily due to excessive screen time and extended periods of inactivity.[6] Previous research indicates that the average daily sedentary time ranges from approximately 7.7 hours to 11.7 hours in different countries.[4–6] On a global scale, the median daily sitting time was reported to be 4.7 hours, with higher-income nations exhibiting longer durations of sedentary behavior compared to their lower-income counterparts.[35] Additionally, sedentary behavior among

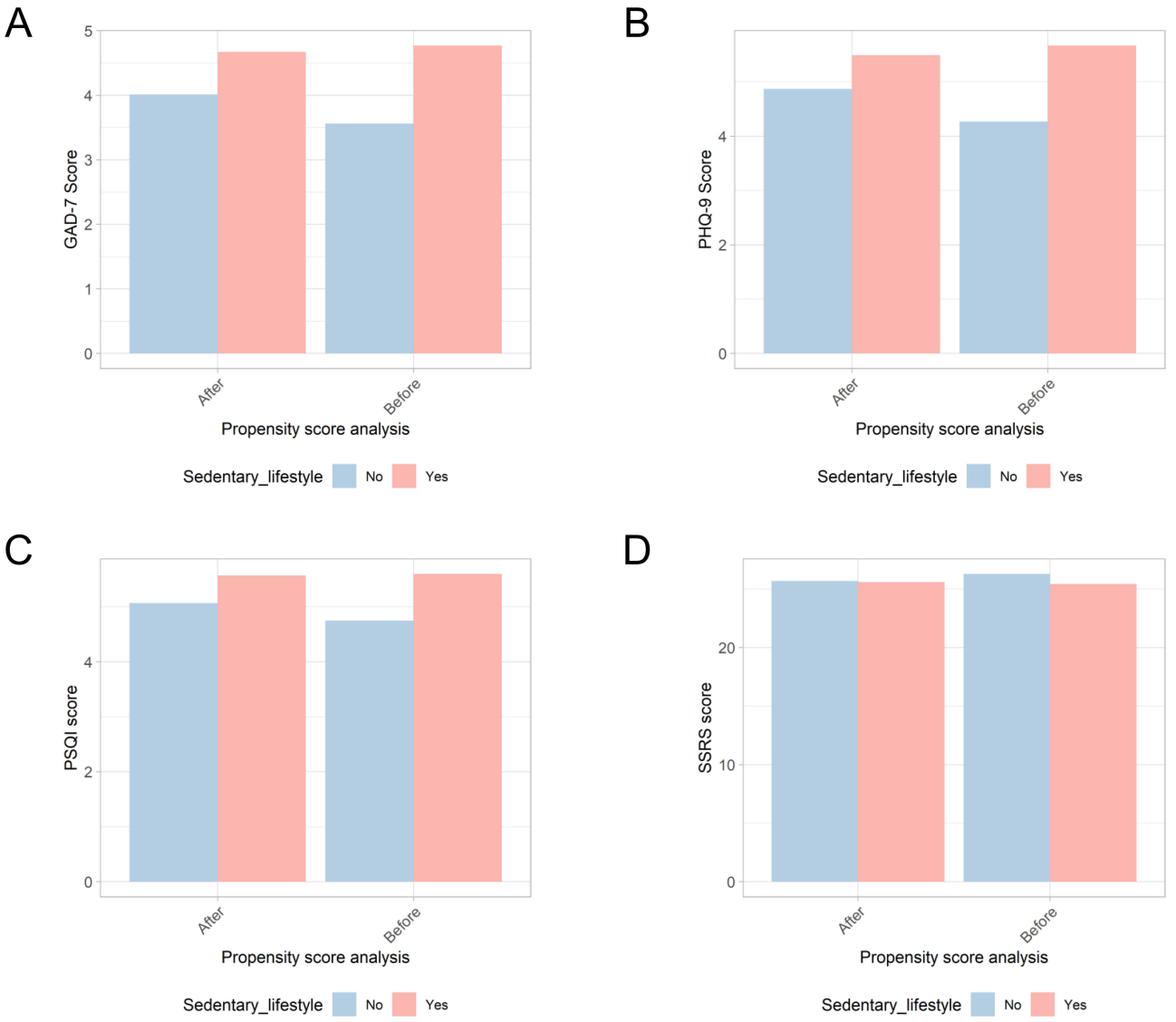

Figure 4 Subgroup analysis of outcomes before and after propensity score matching analysis. (**A**) GAD-7 score; (**B**) PHQ-9 score; (**C**) PSQI score; (**D**) SSRS scores. GAD-7, generalized anxiety disorder-7; PHQ-9, patient health questionnaire-9; PSQI, Pittsburgh Sleep Quality Index; SSRS: social support rating scale.

adolescents has risen significantly, with average daily sedentary time increasing from 8.7 hours to 9.7 hours over the past decade.[3] As the largest developing country in the world, sedentary lifestyles are particularly prevalent among adolescents in China. Studies have revealed that young men in China sat for an average of 10.9 hours per day,[4] while young women average 11.7 hours.[4] Another study also showed that Chinese youth had an average sedentary time of 10.9 hours.[5] This trend highlights the urgent need to address sedentary lifestyles among adolescents.

Defining sedentary behavior has posed challenges, as different studies report varying criteria. In addition, while there is no universally agreed-upon cutoff for sedentary time associated with health risks, a threshold of more than six hours per day is often used to categorize individuals as leading a sedentary lifestyle.[19–21] The possible explanations include that there were studies showing that prolonged sitting (above 6 hours/day) is linked to an elevated risk of various health issues, such as all-cause cancer[20] and increased mortality rates.[19–21] On the other hand, some studies even indicate that exceeding 12 hours of sedentary time daily correlated with higher mortality risk.[36] Recent investigations by Ahmadi et al[37] further revealed that a sedentary duration of 10.5 hours per day significantly raises the likelihood of developing cardiovascular diseases.

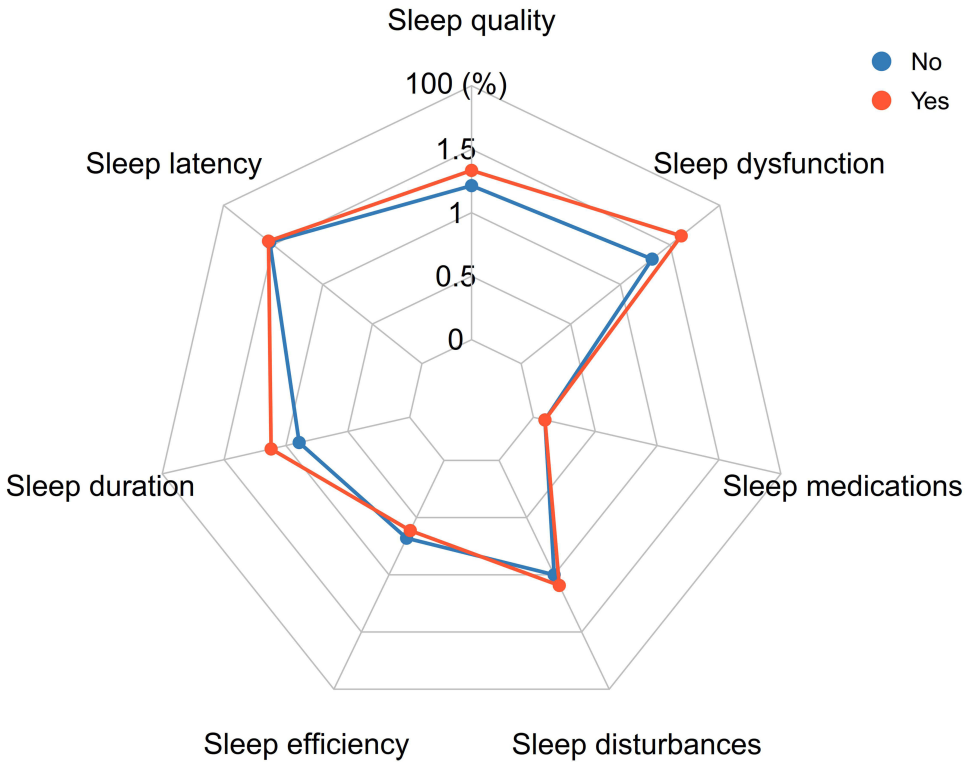

Figure 5 Radar plots for quality of sleep between participants with and without sedentary lifestyle after propensity score matching analysis.

Multiple factors contribute to the prevalence of a sedentary lifestyle. Martins et al[38] conducted a review of 35 articles and identified various determinants associated with increased sedentary time, such as being female, lacking social support, having insufficient physical space, time constraints, low motivation for physical activity, residing in low-income areas, and living in urban environments. Our study corroborated these findings, revealing that a sedentary lifestyle was more prevalent among females, particularly those consuming high-salt and high-fat diets, engaging in more barbecued and meat-heavy meals, eating fewer fruits, experiencing higher screen time exposure, facing more stressors, participating in less physical activity, and suffering from chronic health conditions. Additionally, the relationship between sedentary behavior and its impact on psychological well-being and sleep quality in adolescents is also relevant when considered in the context of the COVID-19 pandemic.[39] During this period, increased sedentary activities, such as screen time and reduced physical activity, have significant implications for the mental health and sleep patterns of young people.[40]

Ultimately, the above data indicates a concerning trend in sedentary behavior among adolescents. What are the specific harms of sedentary behavior, and what are the related mechanisms? The study tries to provide a detailed explanation to the two questions in the following content.

The Impact of Sedentary Lifestyles and Underlying Mechanisms

A sedentary lifestyle poses significant health risks that can affect individuals physically. Specifically, the absence of regular movement is closely linked to obesity,[7,8] as it leads to fewer calories being burned. This increase in sedentary behavior heightens the risk of developing chronic conditions such as cardiovascular disease,[9] type 2 diabetes,[6] hypertension,[6] osteoporosis,[6] dementia,[10] and even certain types of cancer.[8] Additionally, prolonged sitting can lead to musculoskeletal issues, including back pain and poor posture.[11] Notably, the occurrence of these diseases is closely related to the amount of sedentary behavior. For instance, an increase of two hours per day spent sitting while watching television was associated with a 12% reduction in the odds of healthy aging.[41]

The adverse effects of a sedentary lifestyle extend beyond physical health, potentially impacting mental well-being. A systematic review conducted by Rodriguez-Ayllon et al[42] revealed that higher amounts of sedentary behavior were

associated with increased mental distress and lower psychological well-being, such as life satisfaction and happiness. However, another review by Suchert et al[16] concluded that the relationship between sedentary behavior and mental health indicators remains somewhat unclear. Some studies have provided strong, consistent evidence linking both depressive symptoms and psychological distress to time spent using screens for leisure,[43] but the impact of sedentary time on mental health may require further investigation. In a study analyzing 244 university students, Lee et al[14] found that increased sitting hours correlated with significant rises in stress, anxiety, and depression. Similarly, Subiron-Valera et al[15] concluded that the risk of anxiety and depression was associated with the total number of hours spent on sedentary activities after examining 257 university students. While these studies shed light on the relationship between sedentary behavior and mental health, their relatively small sample sizes may limit their generalizability.

Our research, which involved 2,846 Chinese adolescents, illustrated a clear association between sedentary lifestyles and poorer psychological health and sleep quality among this demographic. After controlling for various demographic and lifestyle factors using propensity score matching analysis, we obtained the consistent results. Furthermore, we found that a sedentary lifestyle contributes to deteriorating sleep quality. The findings of our study align with the study conducted by Liu et al,[44] reporting that prolonged sedentary behavior was associated with reduced sleep duration and decreased sleep efficiency after analyzing 220 college students. Additionally, a study found a distinct dose-response relationship between sedentary behavior and mental well-being among college students in China, which might be partially attributed to compromised sleep quality.[45]

Sedentary behaviors have significant physiological implications through various mechanisms. Studies employing various experimental models, such as bed rest and reduced step counts, revealed that excessive sedentary time can lead to negative health outcomes, including insulin resistance, vascular dysfunction, and altered muscle composition, alongside decreases in cardiorespiratory fitness and increases in body fat and inflammation.[6,8,46] Notably, increased sedentary time impairs the gravitostat, the body's weight homeostat, and weight gain, adiposity, and elevated chronic inflammation caused by sedentary behavior are risk factors for cancer.[6,46] Furthermore, a review highlighted the intricate biological mechanisms linking sedentary behavior to the incidence of cancer.[47] These mechanisms involve the influence of sedentary lifestyles on endogenous sex steroids, metabolic hormones, insulin sensitivity, and chronic inflammation. Additionally, several emerging pathways related to oxidative stress, DNA methylation, telomere length, immune function, and the gut microbiome were discussed. Together, these interconnected processes underscore the complex relationship between lifestyle choices and the development of cancer. From a genetic perspective, Wang et al[48] discovered 99 genetic loci associated with moderate-to-vigorous physical activity, leisure screen time, and workplace sedentary behavior. Loci related to leisure screen time were enriched for genes influenced by resistance training. A specific variant in the Alpha-Actinin-3 gene increased flexibility in muscle filaments, reducing force in muscle fibers and potentially protecting against exercise-induced damage. Additionally, the benefits of reduced leisure screen time and increased moderate-to-vigorous physical activity on health were affected by body mass index. These findings highlighted the genetic and biological connections between physical activity, sedentary behavior, and health. You et al[25] concluded that sedentary behavior is a risk factor for sleep disturbances, with blood-cell-based inflammatory biomarkers serving as accessible indicators, and exercise was effective in alleviating sleep disturbances in those with high sedentary behavior. Consequently, reducing sedentary behaviors and enhancing physical activity are crucial for advancing public health.

Intervention Strategies for Sedentary Lifestyle

To effectively address the negative impacts of sedentary behavior, it is essential to implement intervention strategies at multiple levels, including individual, familial, school, and community-based approaches.[49] Herbert et al[50] investigated how exercise can buffer perceived stress and alleviate mental health symptoms, thereby improving overall quality of life for university students. The above study summarized current scientific evidence and introduced a university-based research program that utilized a multimethod approach to analyze the effects of low- to moderate-intensity physical activity. Initial findings indicated a positive correlation between exercise and mental health, suggesting that aerobic exercises and certain activities like yoga could significantly reduce depressive symptoms and perceived stress. Additionally, providing access to fitness facilities and creating supportive environments—such as designated areas for physical activity—can motivate students to engage in more active lifestyles. Universities can foster a culture of

movement by promoting standing or walking discussions among peers and integrating more active breaks into lectures. The WHO recommends that adolescents engage in an average of 60 minutes of moderate to vigorous physical activity daily to combat sedentary behaviors.[51] In addition to aerobic activities, participating in muscle-strengthening exercises of moderate intensity or higher at least two days a week can offer significant health benefits.

Meanwhile, the WHO proposed a Health Promoting Schools framework, which is a holistic, settings-based approach aimed at enhancing both the health and educational outcomes of students.[52] This framework integrates health promotion into the school environment by focusing on three key elements: enriching the curriculum, creating a supportive school ethos or environment, and engaging families and communities. The significance of the framework lies in its potential to improve student health and well-being, which can lead to better academic performance. By addressing various health issues such as nutrition, physical activity, bullying, and mental health, the framework could foster an environment conducive to learning and development. However, while some interventions demonstrate positive effects on certain health outcomes, further rigorous research is still needed to fully understand its impact on academic achievement and other health topics.

Moreover, sufficient sleep combined with moderate exercise has a synergistic effect on enhancing mental health. Therefore, when designing interventions aimed at reducing sedentary behavior, it is crucial to incorporate sleep management and exercise strategies to maximize the benefits for adolescents' mental well-being.[53] Furthermore, educational campaigns are crucial for raising awareness about the risks associated with a sedentary lifestyle and the advantages of regular physical activity. These campaigns should specifically target adolescents and their guardians to create a supportive environment that encourages active living.[50,54] Collaborative efforts among schools, parents, health professionals, and local governments could also be vital in establishing a culture that values physical activity and prioritizes mental well-being.

Limitations

This study has several limitations that should be acknowledged. Firstly, the cross-sectional design limits our ability to draw causal inferences regarding the relationship between sedentary lifestyle and psychological and sleep health outcomes among adolescents. Although propensity score matching was used to control for confounding variables, unmeasured factors such as genetic predispositions, underlying mental health conditions, or environmental influences may still impact the results. Secondly, the reliance on self-reported measures for assessing sedentary behavior, psychological health, and sleep quality introduces the potential for reporting bias. Participants may have underreported their sedentary time or misrepresented their psychological and sleep health status, leading to inaccuracies in the data. Thirdly, the study's sample was drawn from three universities, which may limit the generalizability of the findings to the broader adolescent population. Our data has been exclusively collected from urban areas, highlighting the need for further research that includes rural populations, and this is also important for gaining a more comprehensive understanding of sedentary behavior among adolescents across different environments. Other factors such as socioeconomic status, cultural background, and educational environment may differ significantly in other settings, influencing both sedentary behavior and health outcomes. Lastly, while we defined a sedentary lifestyle as sitting for more than six hours daily, this operationalization may not capture the full spectrum of sedentary behavior. Future studies could benefit from more nuanced measures that include different types of sedentary behavior, as well as the context in which they occur. Despite these limitations, the findings contribute valuable insights into the association between sedentary lifestyle and adolescent psychological and sleep health, highlighting the need for further research in this area.

Conclusions

This study highlights the significant association between sedentary lifestyle and adverse psychological and sleep health outcomes among adolescents. Our findings demonstrate that individuals engaging in prolonged sedentary behavior experience higher levels of anxiety, depression, and poorer sleep quality compared to their more active peers. Future research should explore longitudinal effects and validate the causal relationships, providing further insights into how to effectively mitigate the negative impacts of sedentary behavior on adolescent health.

Abbreviations

GAD-7, generalized anxiety disorder-7; SD, standard deviation; SMD, standardized mean difference; PHQ-9, patient health questionnaire-9; PSQI, Pittsburgh sleep quality index; SES, self-esteem scale; SSRS: social support rating scale.

Data Sharing Statement

The data are available under reasonable request to the corresponding author.

Ethics Approval

The study was approved by the Academic Committee and Ethics Board of the Xiamen University of Technology, and informed consent was obtained from all subjects or legal guardians before filling the questions in the survey. Participants were all informed that their personal information was not identified and collected, and all data were anonymous. The study was abided by the Declaration of Helsinki. All experiments were performed in accordance with relevant guidelines and regulations.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Consent for Publication

Not Applicable.

Consent to Participate

The informed consent was obtained from all subjects or legal guardians before filling the questions in the survey. Participants were all informed that their personal information was not identified and collected, and all data were anonymous.

Funding

This study was funded by the teaching reform research project of Xiamen University of Technology (JYCG202459), National Social Science General Project (24BTY029), and Military Training Injury Prevention and Control Special Project (No. 21XLS38).

Disclosure

The authors declare that they have no conflicts of interest in this work.

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