Hindawi
Indoor Air
Volume 2024, Article ID 9943687, 11 pages
https://doi.org/10.1155/2024/9943687

Research Article

Associations of Indoor Ventilation Frequency with Depression and Anxiety in Chinese Older Adults

Jing Du, Yan Cui, Ling Yang, Ying Duan, Qi Qi, and Huaqing Liu

School of Public Health, Bengbu Medical University, Bengbu, China

Correspondence should be addressed to Huaqing Liu; lhqbbmc@163.com

Received 4 August 2023; Revised 8 January 2024; Accepted 1 February 2024; Published 20 February 2024

Academic Editor: Xiaohu Yang

Depression and anxiety carry an important public health burden. Indoor air pollution is associated with depression and anxiety. Ventilation can reduce the concentration of indoor air pollution and improve indoor air quality. This study explored the relationship between indoor ventilation frequency and depression and anxiety in older adults using the data from the 2018 Chinese Longitudinal Healthy Longevity Survey. Compared with older people with low indoor ventilation frequency, those with high indoor ventilation frequency had 51% lower odds of depression (OR = 0.49, 95% CI: 0.43 to 0.57) and 37% lower odds of anxiety (OR = 0.63, 95% CI: 0.43 to 0.91), and those with intermediate indoor ventilation frequency had 35% lower odds of depression (OR = 0.65, 95% CI: 0.56 to 0.75) and 45% lower odds of anxiety (OR = 0.55, 95% CI: 0.37 to 0.82). The results were similar across the seasons. However, there were sex, age, lifestyle, and cooking fuel use-specific differences in these associations. The findings emphasize that high ventilation frequency may be conducive to improving mental health in older adults, especially women, the old elder, nonsmokers, nondrinkers, and those who do not exercise and cooked at home.

1. Introduction

Depression is characterized by feelings of sadness, emptiness, and irritability and involves a wide variety of cognitive and somatic symptoms [1, 2]. Approximately 6% of individuals worldwide experience depression, as do at least 11.5% of older adults of ≥65 years [3]. In Asian countries, the prevalence of depression ranged from 5.5% to 25.7%, although the prevalence among older adults (those aged 65 or above) is likely to be underestimated [4, 5]. Additionally, depression is a primary cause of disability [6].

Anxiety disorders, which are also fairly prevalent worldwide, are characterized by hyperarousal and excessive fear and worry [7]. The global prevalence rates of anxiety disorders are estimated to be between 3.8% and 25% in the population at large and up to 70% in people with chronic illnesses [8]. Anxiety disorders affect quality of life, daily functioning, and overall happiness [9], which are the sixth leading cause of disability globally, accounting for 260 000 disability-adjusted life years [10]. In summary, depression and anxiety disorders constitute a public health burden.

In recent decades, indoor air pollution has become a growing focus. Indoor air pollution can result from the use of disinfectants, pesticides, and unclean fuels, including solid fuels and biofuels. Indoor living environments are very important for human health, especially among older people, who typically spend more time indoors than do younger adults owing to that fact that older adults are more likely to have retired and that individuals who have retired tend to spend more time indoors than outdoors [3, 11, 12]. Environmental factors, including air pollution, are risk factors for mental health conditions. Several studies have shown that airborne pollutants, including volatile organic pollutants and particulate matter, are associated with depression and anxiety [13–15]. Ventilation, which involves supplying air into indoor environments through mechanical or natural forces (i.e., air conditioning and windows, respectively), can reduce the concentration of indoor air pollution, such as volatile organic compounds, formaldehyde, and radon [16, 17], improve indoor air quality, and is beneficial to cognitive function and respiratory health for older adults [17, 18]. However, to date, the relationship of indoor ventilation with depression and anxiety has not been reported. This study therefore is aimed at assessing the relationship between frequency of indoor ventilation with open windows and depression and anxiety by using a large representative population of older adults nationwide.

2. Materials and Methods

2.1. Settings and Participants. Data came from the 2018 Chinese Longitudinal Healthy Longevity Survey (CLHLS). Participants with the age of 65 years and older from 23 provinces of China, an area representing approximately 85% of the country's population, were selected using multistage random-cluster sampling. This sampling method was chosen to ensure adequate representativeness. The CLHLS has a systematic data collection process that involves trained staff interviewing older adults face to face. The details of CLHLS have been published on other places [19]. The Biomedical Ethics Committee of Peking University approved the CLHLS (IRB00001052-13074), and each participant provided written informed consent prior to their participation in this study.

A total of 15 874 individuals were interviewed in the 2018 CLHLS. After the exclusion of cases with missing data related to depression ($n = 3414$), anxiety ($n = 74$), indoor ventilation ($n = 206$), and individuals aged <65 years ($n = 84$), 12 096 participants were included for analysis.

2.2. Indoor Ventilation Frequency. Indoor ventilation frequency was obtained by asking the participants how frequently they opened their windows. Specifically, the participants were asked how many times they opened their windows per week in each season. Items were rated on a 3-point Likert scale including 0 (never), 1 (1 to 5 times), and 2 (>5 times). Total scores ranged from 0 to 8. Total scores of 0 to 3, 4 to 5, and 6 to 8 were classified as low, intermediate, and high ventilation frequency, respectively. Lowess smooth plots were used to evaluate the unadjusted associations of continuous indoor ventilation frequency scores with depression and anxiety to determine the cutoff score for indoor ventilation frequency [18].

2.3. Depression and Anxiety. Depression was evaluated using the 10-item Center for Epidemiological Studies Depression scale, which was demonstrated to be valid and reliable when used in a Chinese cultural context [20, 21]. The scale includes ten items by a 4-point Likert scale from 0 (rarely or never) to 3 (all of the time). Scores for positive questions were reversed before summation. Total scores of ≥10, ranging from 0 to 30, indicate depression. It has adequate internal consistency with Cronbach's alpha of 0.738.

Anxiety was evaluated using the 7-item Generalized Anxiety Disorder (GAD-7) scale [22]. GAD-7 comprises seven indicators by a 4-point Likert scale ranging from 0 (not at all) to 3 (almost every day). Total GAD-7 scores were from 0 to 21, with higher scores representing a greater likelihood of anxiety symptoms [23]; if the total score is ≥10, an individual is considered as having anxiety [24]. GAD-7 was demonstrated to be valid in a Chinese cultural context and to have strong psychometric properties. Cronbach's alpha value for this scale was 0.920 in this study.

2.4. Covariates. A spectrum of potentially confounding factors was controlled to obtain robust results, including sociodemographic factors, lifestyle factors, and chronic diseases. Data were collected for age group (65 to 74, 75 to 84, or ≥85), sex, urbanization level (urban, town, or rural), educational level (0, 1 to 6, or >6 years of study), marital status (married and living with spouse or other), occupation type (formal or informal), drinking status (current drinker or not), smoking status (current smoker or not), exercise habits (yes or no), and the number of chronic diseases self-reported (0, 1, or ≥2 of hypertension, diabetes, stroke, heart disease, bronchitis, cataracts, and arthritis).

2.5. Statistical Analyses. Descriptive analysis was performed to summarize the characteristics of the study sample. A chi-square test was conducted to examine differences in indoor ventilation status, depression, and anxiety according to age group, sex, urbanization level, marital status, educational level, occupational status, current drinking status, current smoking status, exercise habits, and the number of chronic diseases. Multiple logistic regression analysis was performed to calculate odds ratios (OR) with its 95% confidence intervals (CI) for depression and anxiety for multiple indoor ventilation statuses. All data were analyzed by using SPSS. Statistical significance was indicated by $P < 0.05$.

3. Results

3.1. General Characteristics. Of the 12 096 participants in this study, 259 (2.14%) had anxiety symptoms, and 3277 (27.09%) had depression symptoms. More than half of the participants (58.56%) ventilated their homes 6 to 8 times per week, and 32.62% of the participants ventilated their homes 4 to 5 times per week (Table 1). In total, nearly half of the participants were ≥85 years old, 46.59% of the participants were men, 53.41% were women, 43.85% lived in rural areas, 74.04% were engaged in informal employment, and 44.59% were married and living with their spouse.

The participants were more likely to ventilate their homes if they were young, exercised frequently, had a high educational level, had a formal occupation, lived in an urban area, and had no chronic diseases. Smoking status and alcohol consumption status were not significantly correlated with ventilation frequency. Participants were more likely to have depression symptoms if they were women, had a low educational level (no more than 6 years of education), exercised infrequently, lived in a rural or town area, had an informal occupation, were unmarried, or had at fewest one chronic disease. Differences in anxiety levels across the study population were largely consistent with those in depression levels.

3.2. Relationships of Indoor Ventilation Frequency with Depression and Anxiety. The participants who never ventilated their homes were more probably to have depression or anxiety than those who ventilated their homes at fewest once per week, regardless of the season ($P < 0.001$; Table 2).

The OR for depression and anxiety according to ventilation frequency in each season are presented in Table 3.

Table 1: Indoor ventilation frequency, depression, and anxiety among the participants.

Characteristics	N	Indoor ventilation status (n, %) Low	Intermediate	High	χ^2	P value	Depression (n, %)	χ^2	P value	Anxiety (n, %)	χ^2	P value
Total	12096	1066 (8.81)	3946 (32.62)	7084 (58.56)			3277 (27.09)			259 (2.14)		
Age group					32.924	<0.001		84.573	<0.001		4.847	0.089
65-74	3034	200 (6.59)	1008 (33.22)	1826 (60.18)			635 (20.93)			59 (1.94)		
75-84	3749	321 (8.56)	1221 (32.57)	2207 (58.87)			1039 (27.71)			69 (1.84)		
≥85	5313	545 (10.26)	1717 (32.32)	3051 (57.43)			1603 (30.17)			131 (2.47)		
Sex					5.089	0.079		117.775	<0.001		30.220	<0.001
Male	5635	462 (8.20)	1860 (33.01)	3313 (58.79)			1262 (22.40)			77 (1.37)		
Female	6461	604 (9.35)	2086 (32.29)	3771 (58.37)			2015 (31.19)			182 (2.82)		
Current smoking status					4.221	0.121		22.000	<0.001		16.516	<0.001
Nonsmoker	10022	893 (8.91)	3302 (32.95)	5827 (58.14)			2799 (27.93)			238 (2.37)		
Current smoker	1954	164 (8.39)	605 (30.96)	1185 (60.64)			445 (22.77)			18 (0.92)		
Current drinking status					2.691	0.260		48.528	<0.001		8.061	0.005
Nondrinker	10071	895 (8.89)	3302 (32.79)	5874 (58.33)			2848 (28.28)			231 (2.29)		
Current drinker	1836	152 (8.28)	576 (31.37)	1108 (60.35)			375 (20.42)			23 (1.25)		
Exercise habits		1047 (8.78)	3891 (32.63)	6987 (58.59)	246.493	<0.001	3227 (27.06)	286.754	<0.001	254 (2.13)	20.061	<0.001
Yes	4111	243 (5.91)	1063 (25.86)	2805 (68.23)			722 (17.56)			54 (1.31)		
No	7814	804 (10.29)	2828 (36.19)	4182 (53.52)			2505 (32.06)			200 (2.56)		
Years of education					201.415	<0.001		212.540	<0.001		24.086	<0.001
0	5362	649 (12.10)	1842 (34.35)	2871 (53.54)			1796 (33.49)			152 (2.83)		
1-6	4162	303 (7.28)	1332 (32.00)	2527 (60.72)			956 (22.97)			76 (1.83)		
More than 6	2458	103 (4.19)	724 (29.45)	1631 (66.35)			488 (19.85)			30 (1.22)		
Occupation					277.962	<0.001		65.685	<0.001		21.329	<0.001
Formal	3140	112 (3.57)	829 (26.40)	2199 (70.03)			677 (21.56)			35 (1.11)		
Informal	8956	954 (10.65)	3117 (34.80)	4885 (54.54)			2600 (29.03)			224 (2.50)		
Resident area					405.446	<0.001		59.641	<0.001		14.740	0.001
Urban	2786	56 (2.01)	717 (25.74)	2013 (72.25)			606 (21.75)			35 (1.26)		
Town	4006	396 (9.89)	1267 (31.63)	2343 (58.49)			1207 (30.13)			104 (2.60)		
Rural	5304	614 (11.58)	1962 (36.99)	2728 (51.43)			1464 (27.60)			120 (2.26)		
Marital status					13.163	0.001		119.559	<0.001		7.595	0.006
Married and living with spouse	5394	419 (7.77)	1789 (33.17)	3186 (59.07)			1193 (22.12)			94 (1.74)		
Others	6583	635 (9.65)	2119 (32.19)	3829 (58.16)			2043 (31.03)			163 (2.48)		
Number of chronic diseases					43.981	<0.001		61.758	<0.001		3.674	0.159
0	4452	424 (9.52)	1508 (33.87)	2520 (56.60)			1059 (23.79)			84 (1.89)		
1	4007	384 (9.58)	1344 (33.54)	2279 (56.88)			1070 (26.70)			84 (2.10)		
≥2	3637	258 (7.09)	1094 (30.08)	2285 (62.83)			1148 (31.56)			91 (2.50)		

Table 1: Continued.

Characteristics	N	Indoor ventilation status (n, %)			χ^2	P value	Depression (n, %)	χ^2	P value	Anxiety (n, %)	χ^2	P value
		Low	Intermediate	High								
Fuels					343.515	<0.001		77.519	<0.001		32.869	<0.001
Never cooked in the home	141	17 (12.06)	58 (41.13)	66 (46.81)			52 (36.88)			1 (0.71)		
Clean fuels	4384	241 (5.50)	1243 (28.35)	2900 (66.15)			1051 (23.97)			80 (1.82)		
Biomass fuels	3090	468 (15.15)	1127 (36.47)	1495 (48.38)			1000 (32.36)			105 (3.40)		
Others	4158	337 (8.10)	1444 (34.73)	2377 (57.17)			1059 (25.47)			66 (1.59)		

Table 2: Prevalence of depression and anxiety according to seasonal ventilation frequency.

Seasonal ventilation frequency	N	Depression (n, %)	χ^2	P value	Anxiety (n, %)	χ^2	P value
Spring ventilation frequency	12096	3277 (27.09)	156.596	<0.001	259 (2.14)	20.618	<0.001
0 time/week	562	244 (43.42)			27 (4.80)		
1–5 times/week	4786	1465 (30.61)			90 (1.88)		
>5 times/week	6748	1568 (23.24)			142 (2.10)		
Summer ventilation frequency	12096	3277 (27.09)	120.458	<0.001	259 (2.14)	25.525	<0.001
0 time/week	303	120 (39.60)			19 (6.27)		
1–5 times/week	2597	891 (34.31)			56 (2.16)		
>5 times/week	9196	2266 (24.64)			184 (2.00)		
Autumn ventilation frequency	12096	3277 (27.09)	131.978	<0.001	259 (2.14)	18.886	<0.001
0 time/week	488	200 (40.98)			24 (4.92)		
1–5 times/week	4652	1446 (31.08)			91 (1.96)		
>5 times/week	6956	1631 (23.45)			144 (2.07)		
Winter ventilation frequency	12096	3277 (27.09)	89.382	<0.001	259 (2.14)	16.862	<0.001
0 time/week	2409	812 (33.71)			77 (3.20)		
1–5 times/week	4986	1373 (27.54)			87 (1.74)		
>5 times/week	4701	1092 (23.23)			95 (2.02)		
Overall ventilation index	12096	3277 (27.09)	182.170	<0.001	259 (2.14)	14.693	0.001
0–3 (low)	1066	444 (41.65)			40 (3.75)		
4–5 (intermediate)	3946	1182 (29.95)			75 (1.90)		
6–8 (high)	7084	1651 (23.31)			144 (2.03)		

Table 3: Likelihood of depression and anxiety according to indoor ventilation frequency.

	Depression OR (95% CI)	P value	Anxiety OR (95% CI)	P value
Spring ventilation frequency				
0 time/week	1		1	
1–5 times/week	0.63 (0.52-0.76)	<0.001	0.43 (0.27-0.67)	<0.001
>5 times/week	0.47 (0.39-0.57)	<0.001	0.52 (0.34-0.81)	0.003
Summer ventilation frequency				
0 time/week	1		1	
1–5 times/week	0.93 (0.71-1.21)	0.572	0.40 (0.23-0.69)	0.001
>5 times/week	0.62 (0.48-0.79)	<0.001	0.38 (0.23-0.62)	<0.001
Autumn ventilation frequency				
0 time/week	1		1	
1–5 times/week	0.71 (0.58-0.87)	0.001	0.44 (0.27-0.70)	0.001
>5 times/week	0.51 (0.42-0.63)	<0.001	0.47 (0.30-0.75)	0.001
Winter ventilation frequency				
0 time/week	1		1	
1–5 times/week	0.83 (0.74-0.92)	0.001	0.63 (0.46-0.87)	0.005
>5 times/week	0.70 (0.62-0.79)	<0.001	0.74 (0.53-1.03)	0.072
Overall ventilation index				
0–3 (low)	1		1	
4–5 (intermediate)	0.65 (0.56-0.75)	<0.001	0.55 (0.37-0.82)	0.003
6–8 (high)	0.49 (0.43-0.57)	<0.001	0.63 (0.43-0.91)	0.015

Multiple logistic regression analysis was applied to estimate the ORs and 95% CIs for depression and anxiety according to indoor ventilation frequency after adjustment for age, sex, urbanization level, educational level, occupational status, marital status, smoking status, drinking status, exercise habits, number of chronic diseases, and fuels. CI: confidence interval; OR: odds ratio.

Compared with the participants with low indoor ventilation frequency, those with high indoor ventilation frequency had 51% lower odds of depression (OR: 0.49, 95% CI: 0.43 to 0.57), and those with intermediate indoor ventilation frequency had 35% lower odds of depression (OR: 0.65, 95% CI: 0.56 to 0.75) after adjustment for confounders; furthermore, those with high indoor ventilation frequency had 37% lower odds of anxiety (OR: 0.63, 95% CI: 0.43 to 0.91), and those with intermediate indoor ventilation frequency had 45% lower odds of anxiety (OR: 0.55, 95% CI: 0.37 to 0.82). The results were largely similar across the seasons. Compared to participants with low indoor ventilation, there was 28% to 53% lower odds of depression in those with intermediate indoor ventilation and was 43% to 67% in those with high indoor ventilation, regardless of sex, age group, smoking status, and alcohol consumption status. In terms of exercise, compared to low ventilation frequency, moderate ventilation frequency reduced the odds of depression by 38% only among participants who did not exercise and not yet among those who exercised, while at high indoor ventilation frequency, the odds of depression were reduced regardless of whether or not they exercised.

However, although participants who cooked with fuels had 31%-54% lower odds of depression, this negative association between indoor ventilation and depression did not appear in those who never cooked at home (OR: 1.10, 95% CI: 0.31 to 3.93 for intermediate indoor ventilation and OR: 0.88, 95% CI: 0.25 to 3.16 for high indoor ventilation) (Figure 1).

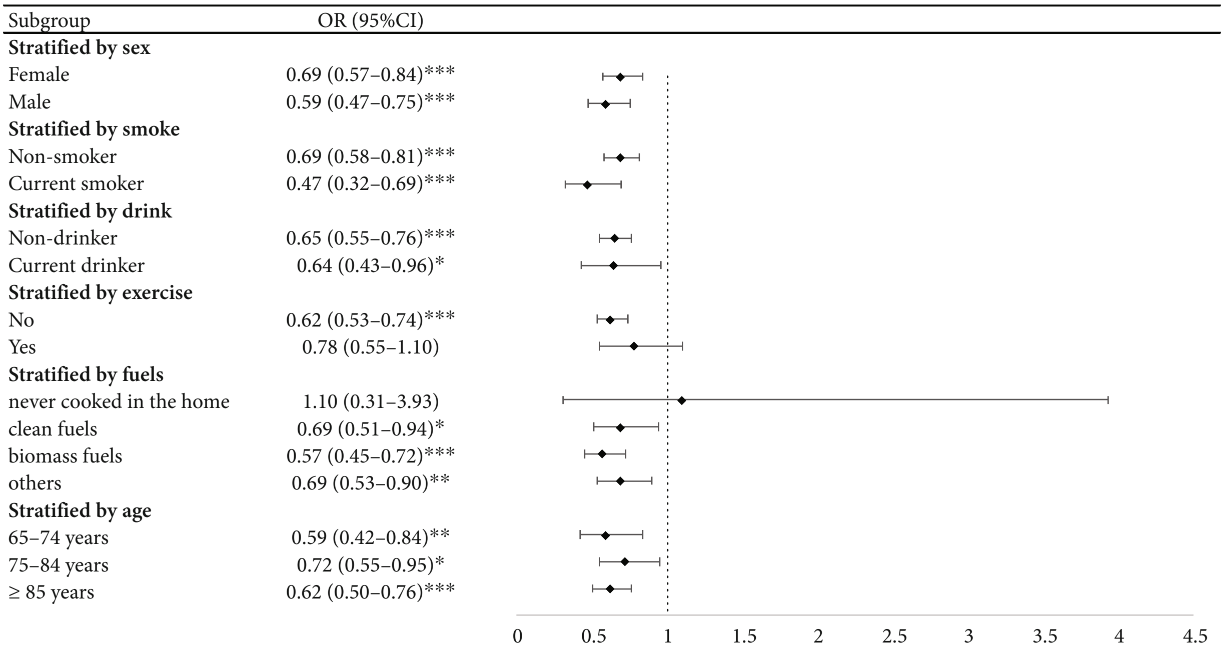
High indoor ventilation frequency had 36%-50% lower odds of anxiety among women (OR: 0.57, 95% CI: 0.37 to 0.87), nonsmokers (OR: 0.58, 95% CI: 0.40 to 0.85), nondrinker (OR: 0.64, 95% CI: 0.43 to 0.95), and those who did not exercise (OR: 0.50, 95% CI: 0.33 to 0.74), but not among men (OR: 0.84, 95% CI: 0.37 to 1.87), smokers (OR: 2.24, 95% CI: 0.29 to 17.60), current drinkers (OR: 0.49, 95% CI: 0.15 to 1.66), and those who exercised (OR: 5.29, 95% CI: 0.71 to 39.23). For age groups, those aged 85 years and older had 47% and 40% lower odds of anxiety in intermediate and high indoor ventilation, respectively, compared with low indoor ventilation; however, this effect did not appear in other age groups (Figure 2). The association applied to intermediate indoor ventilation frequency.

4. Discussion

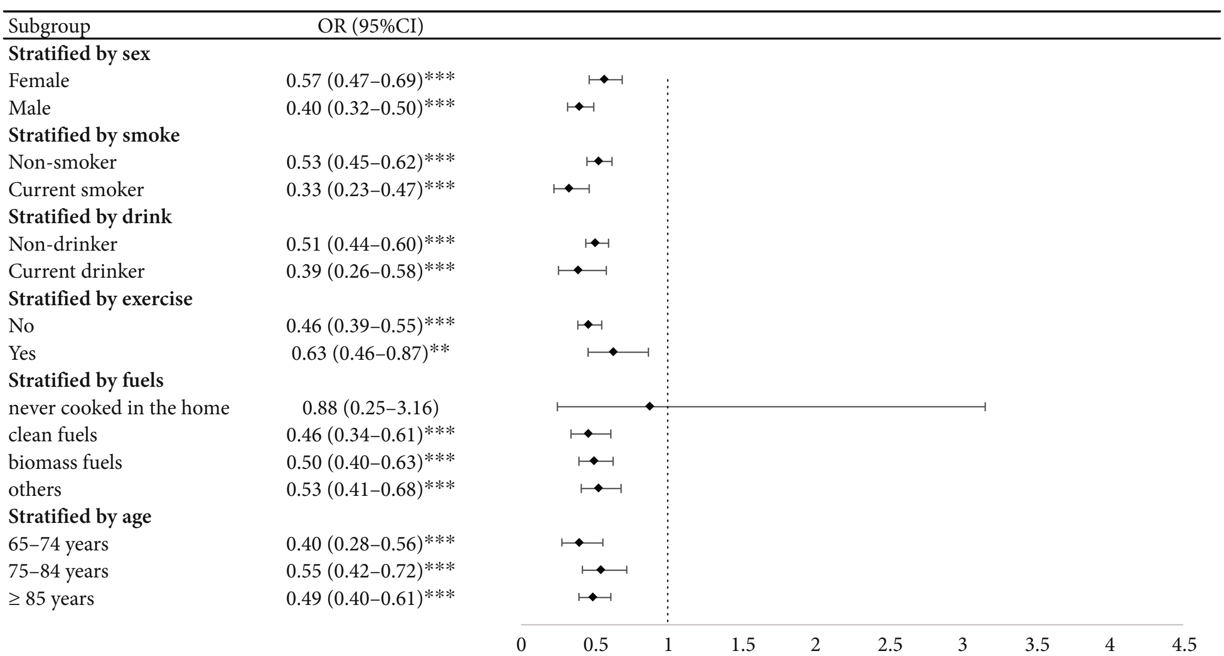
This study explored the relationship between frequency of indoor ventilation and depression and anxiety by using a large representative group of older people in China. A relatively high frequency of indoor ventilation shows a significantly negative association with depression and anxiety among older people. Several studies have reported that air pollution caused by CO_2 [25, 26], cooking [12], and humidity and mold [27] may be related to depression and anxiety in older people [28, 29]. Indoor ventilation, in the absence of pollution of the outdoor air and in a better climate, can effectively improve the quality of indoor air and reduce pollutants [30]. Natural ventilation alone can reduce 80-90% of indoor particulate matter [31]; opening a 30 cm window and a 10 cm door for half an hour reduces CO_2 to about 1/3 of the concentration and about 1/10 in about an hour, and increasing the number of openings is more effective than increasing the degree of opening fewer windows and doors for the same area [32]. Reasonable indoor ventilation may improve mental health by reducing pollutants among older adults. However, our study does not refute the possible reverse effect since our data do not allow us to draw a causal relationship. That is, people with depression may themselves tend to lose control over their environment due to low environmental triggers and are less inclined to open windows and ventilate their homes; thus, not opening windows may be a consequence of their mental state rather than a cause [33]. Moreover, it is worth noting that not high concentrations of carbon dioxide may instead be able to activate cognitive functions and have beneficial effects on improving depression [26, 34]. Therefore, perspective follow-up studies are needed to further characterize the effects of specific substances in indoor air on depression and anxiety.

Notably, our study showed that the negative association between ventilation and depression was observed in older adults who cooked with any fuel but did not appear in those who never cook at home. It might be associated with the fact that the effect of cooking fuels on indoor air quality is nonexistent in the situation of never cooking at home, and therefore, the effect of ventilation on improving indoor air quality is relatively limited and not significant. The pollutants produced by either type of cooking fuel use are associated with depression in adults [3, 12, 18]. Moreover, large numbers of people in developing countries around the world, including China, use biofuels, coal, or kerosene, which are more likely to produce pollutants, to meet their basic energy needs than cleaner cooking facilities [35]. Using solid fuels for cooking in poorly ventilated homes can lead to exposure to indoor air pollution and become a major environmental and public health challenge in developing countries [36]. Therefore, older people who need to cook at home are prompted to pay more attention to ventilation to reduce the health effects of pollutants from cooking. Moreover, ventilation practices may vary by region, and in cold weather conditions, individuals tend to keep their doors and windows closed; this may lead to a lack of fresh air indoors and thus worsen indoor air quality; therefore, improving the ventilation systems in areas prone to air quality problems, such as kitchen, is very important to promote indoor air circulation [37].

Our study showed that the relationship between ventilation and anxiety differed across subgroups. Specifically, the negative relationship between them was only observed in women, nonsmokers, nondrinkers, and nonexercising older adults. The prevalence of anxiety disorders seems to be higher in women. It may be linked with the fact that women are more susceptible to negative emotions [38]; moreover, testosterone in men may have a protective effect against anxiety [39]. In general, smoking and drinking are harmful to health; however, a higher prevalence of anxiety was found in nonsmokers and nondrinkers in the present study, and the negative correlation between ventilation and anxiety was present only in nonsmokers and nondrinkers. In fact, smoking and drinking may also be beneficial for



(a) Intermediate indoor ventilation



(b) High indoor ventilation

Figure 1: Relationships of indoor ventilation frequency with depression disorders stratified by lifestyle, sex, fuel use, and age. Results adjusted for age, sex, urbanization level, educational level, occupational status, marital status, smoking status, drinking status, exercise habits, number of chronic diseases, and fuels. CI: confidence interval; OR: odds ratio. $^{*}P < 0.05$, $^{**}P < 0.01$, and $^{***}P < 0.001$.

psychiatric symptoms [40, 41], and moderate alcohol consumption may also be able to reduce anxiety in older adults [42]. Our study also showed that the association between indoor ventilation and anxiety was relatively strong in nonexercising populations. Exercise is often considered to be an anxiety [43] protection, which improves respiratory function and counteracts the effects of low indoor ventilation frequency on depression and anxiety. In summary, individuals with healthy lifestyles are more likely to understand the benefits of good indoor air quality and so are more likely to open their windows frequently [44] than individuals with unhealthy lifestyles. However, healthy lifestyles themselves

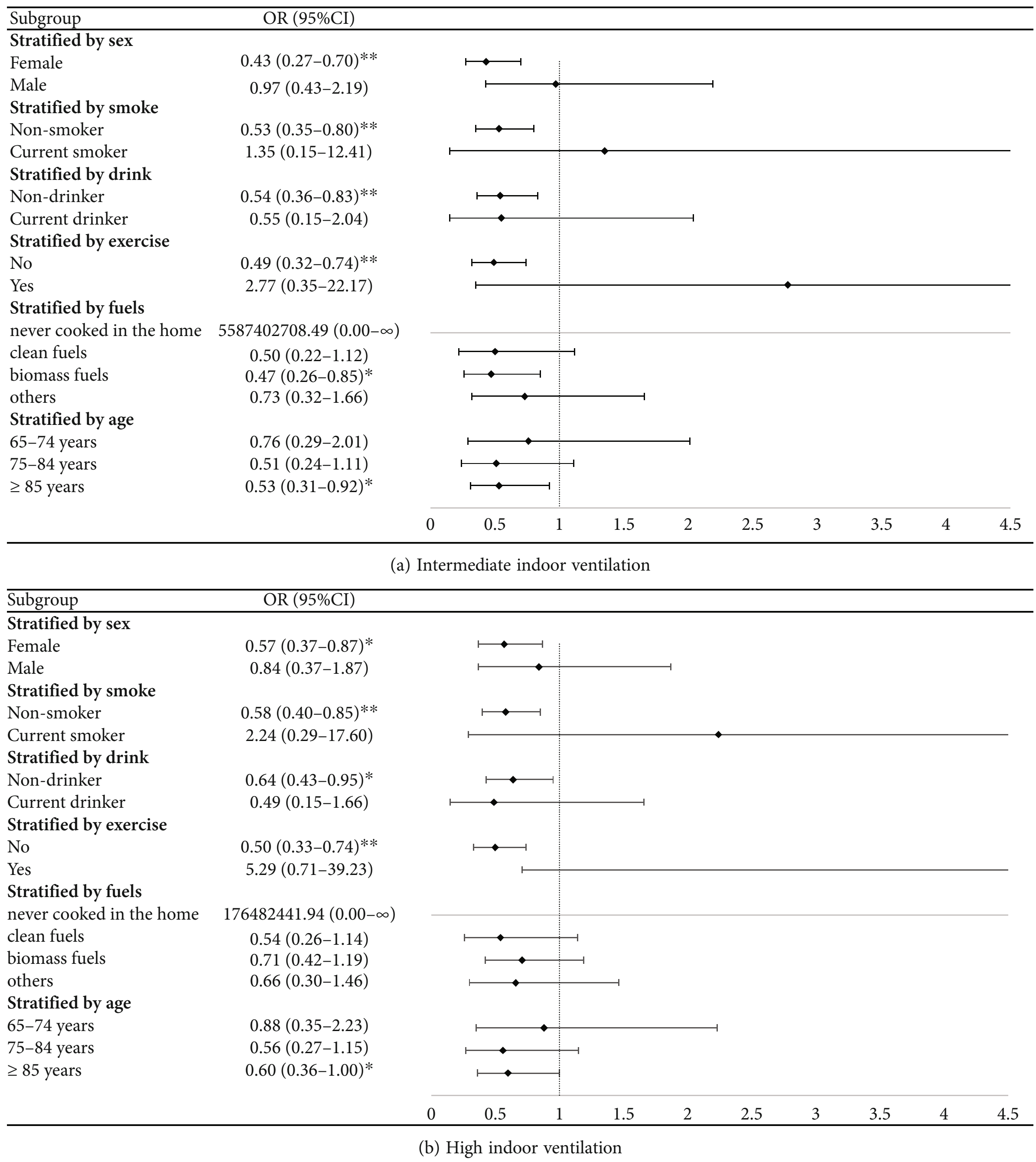


Figure 2: Relationships of indoor ventilation frequency with anxiety disorders stratified by lifestyle, sex, fuel use, and age. Results adjusted for age, sex, urbanization level, educational level, occupational status, marital status, smoking status, drinking status, exercise habits, number of chronic diseases, and fuels. CI: confidence interval; OR: odds ratio. $^{*}P < 0.05$, $^{**}P < 0.01$, and $^{***}P < 0.001$.

can also improve mental health and reduce the incidence of depression and anxiety [45]. So more in-depth research is needed to determine the specific relationships.

This study also found that the higher the age of the elderly, the higher the prevalence of depression and anxiety, and the correlation between ventilation and anxiety was also only shown in ≥85 years old and not yet found in other age groups. This may be due to the fact that the relatively younger elderly may be healthier overall in terms of their physical and mental state, whereas as they grow older, their health deteriorates, and the elderly may become anxious because of their aging bodies [46] or depressed because of the loss of friends and peers [47]. Moreover, older adults may be afraid of outdoor activities due to illness or other reasons [48], making them spent more time in living indoors. Thus, indoor air pollution may have a greater potential impact on the health for these older adults. Reducing indoor pollutants through ventilation thereby may reduce depression and anxiety, especially for the old elder. Hence, ventilation by frequently opening windows is encouraged for older people to improve indoor air quality and promote better mental health.

Our study showed that older people living in rural areas had higher prevalence of depression and anxiety compared with those in urban areas; it may be associated with lower ventilation in rural areas. It is noted that urban areas generally have higher densities, taller buildings, and more pollution; ventilation is more important for people's health in urban areas than in rural areas because it is influenced by building density and height [49]. However, the natural environment can also have a positive impact on mental conditions such as depression, and simply looking at the greenery outside a window may have mental health benefits [50]. Therefore, further research is needed to investigate the potential mechanism about the impact of ventilation by opening windows on older people's health.

This study has several limitations. First, the cross-sectional study design failed to capture changes in depression, anxiety, and indoor ventilation and did not provide a direct causal relationship. Thus, further prospective study is required to elucidate the causal relationships of indoor ventilation frequency with depression and anxiety. Second, the study only considered open window ventilation frequency; however, ventilation time, ventilation location, and other types of ventilation (e.g., air conditioning) were not included and need further research; for example, it is needed to explore the impact of different ventilation durations or time periods or specific ventilation location (living room or/and kitchen) on depression and anxiety. Third, pollutants from the outdoor environment may also affect depression and anxiety symptoms in older people [51, 52], and ventilation may cause pollutants that were originally outside to enter the house instead. Further study is needed to control for outdoor environmental factor to assess the true association between ventilation and health.

5. Conclusions

High frequency of indoor ventilation was negatively associated with depression and anxiety regardless of seasons. Our findings suggested that frequent ventilation may be an effective measure to improve mental health in the elderly. Moreover, there are sex, age, and lifestyle-specific differences in the association between ventilation and anxiety, suggesting that more attention should be paid to women, nonsmokers, nonalcohol users, and older adults who do not exercise when making ventilation-targeted interventions or policy to improve older people's anxiety. Also, the negative association between ventilation and depression appears only in older adults who cooked with any fuel rather than those who do not cook, suggesting that older people who need to cook at home are prompted to pay more attention to ventilation to reduce the health effects of pollutants from cooking.

Data Availability

The data that support the findings of this study may be available from the corresponding author, upon reasonable request.

Ethical Approval

The Biomedical Ethics Committee of Peking University approved the CLHLS (IRB00001052-13074).

Consent

Informed written consent was obtained from the participants or their legal representatives participating in the study.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Acknowledgments

The data used in this study were obtained from the CLHLS, which was managed by the Peking University Center for Healthy Aging and Development Studies. This survey was jointly funded by the National Natural Science Foundation of China (Nos. 71233001 and 71110107025), NIH (No. R01AG023627), and the United Nations Population Fund. The work was supported by the 512 Talent Training Project of Bengbu Medical College (BY51201203).

References

[1] D. Regier, "Interview with Darrel A. Regier. The developmental process for the diagnostic and statistical manual of mental disorders, fifth edition. Interview by Norman Sussman," *CNS Spectrums*, vol. 13, no. 2, pp. 120–124, 2008.

[2] A. T. Beekman, J. R. Copeland, and M. J. Prince, "Review of community prevalence of depression in later life," *The British Journal of Psychiatry*, vol. 174, no. 4, pp. 307–311, 1999.

[3] C. Li, Y. Zhou, and L. Ding, "Effects of long-term household air pollution exposure from solid fuel use on depression: evidence from national longitudinal surveys from 2011 to 2018," *Environmental Pollution*, vol. 283, article 117350, 2021.

[4] L. K. Chen, J. Woo, P. Assantachai et al., "Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment," *Journal of the American Medical Directors Association*, vol. 21, no. 3, pp. 300–307.e2, 2020.

[5] S. Cohen, J. A. Nathan, and A. L. Goldberg, "Muscle wasting in disease: molecular mechanisms and promising therapies," *Nature Reviews. Drug Discovery*, vol. 14, no. 1, pp. 58–74, 2015.

[6] GBD 2017 Disease and Injury Incidence and Prevalence Collaborators, "Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017," *Lancet*, vol. 392, no. 10159, pp. 1789–1858, 2018.

[7] J. V. Olthuis, M. C. Watt, K. Bailey, J. A. Hayden, and S. H. Stewart, "Therapist-supported Internet cognitive behavioural therapy for anxiety disorders in adults," *Cochrane Database of Systematic Reviews*, vol. 3, no. 3, article CD011565, 2016.

[8] O. Remes, C. Brayne, R. van der Linde, and L. Lafortune, "A systematic review of reviews on the prevalence of anxiety disorders in adult populations," *Brain and Behavior: A Cognitive Neuroscience Perspective*, vol. 6, no. 7, article e00497, 2016.

[9] W. Q. Xu, L. H. Lin, K. R. Ding et al., "The role of depression and anxiety in the relationship between poor sleep quality and subjective cognitive decline in Chinese elderly: exploring parallel, serial, and moderated mediation," *Journal of Affective Disorders*, vol. 294, pp. 464–471, 2021.

[10] H. M. Lai, M. Cleary, T. Sitharthan, and G. E. Hunt, "Prevalence of comorbid substance use, anxiety and mood disorders in epidemiological surveys, 1990-2014: a systematic review and meta-analysis," *Drug and Alcohol Dependence*, vol. 154, pp. 1–13, 2015.

[11] X. Du, X. Li, P. Qian, and H. Wu, "Indoor air pollution from solid fuels use, inflammation, depression and cognitive function in middle-aged and older Chinese adults," *Journal of Affective Disorders*, vol. 319, pp. 370–376, 2022.

[12] L. Smith, N. Veronese, G. F. López Sánchez et al., "The association of cooking fuels with depression and anxiety symptoms among adults aged ≥65 years from low- and middle-income countries," *Journal of Affective Disorders*, vol. 311, pp. 494–499, 2022.

[13] C. G. Zundel, P. Ryan, C. Brokamp et al., "Air pollution, depressive and anxiety disorders, and brain effects: a systematic review," *Neurotoxicology*, vol. 93, pp. 272–300, 2022.

[14] S. Y. Kim, M. Bang, J. H. Wee et al., "Short- and long-term exposure to air pollution and lack of sunlight are associated with an increased risk of depression: a nested case-control study using meteorological data and national sample cohort data," *Science of the Total Environment*, vol. 757, article 143960, 2021.

[15] B. Chen, W. Ma, Y. Pan, W. Guo, and Y. Chen, "PM2.5 exposure and anxiety in China: evidence from the prefectures," *BMC Public Health*, vol. 21, no. 1, p. 429, 2021.

[16] P. W. Francisco, D. E. Jacobs, L. Targos et al., "Ventilation, indoor air quality, and health in homes undergoing weatherization," *Indoor Air*, vol. 27, no. 2, pp. 463–477, 2017.

[17] M. Bentayeb, D. Norback, M. Bednarek et al., "Indoor air quality, ventilation and respiratory health in elderly residents living in nursing homes in Europe," *The European Respiratory Journal*, vol. 45, no. 5, pp. 1228–1238, 2015.

[18] W. Wang, J. Chen, X. Jin, Y. Ping, and C. Wu, "Association between indoor ventilation frequency and cognitive function among community-dwelling older adults in China: results from the Chinese longitudinal healthy longevity survey," *BMC Geriatrics*, vol. 22, no. 1, p. 106, 2022.

[19] Y. Zeng, Q. Feng, D. Gu, and J. W. Vaupel, "Demographics, phenotypic health characteristics and genetic analysis of centenarians in China," *Mechanisms of Ageing and Development*, vol. 165, no. Part B, pp. 86–97, 2017.

[20] Y. Liu, X. Chen, and Z. Yan, "Depression in the house: the effects of household air pollution from solid fuel use among the middle-aged and older population in China," *Science of the Total Environment*, vol. 703, article 134706, 2020.

[21] E. M. Andresen, J. A. Malmgren, W. B. Carter, and D. L. Patrick, "Screening for depression in well older adults: evaluation of a short form of the CES-D," *American Journal of Preventive Medicine*, vol. 10, no. 2, pp. 77–84, 1994.

[22] R. L. Spitzer, K. Kroenke, J. B. Williams, and B. Löwe, "A brief measure for assessing generalized anxiety disorder," *Archives of Internal Medicine*, vol. 166, no. 10, pp. 1092–1097, 2006.

[23] Z. Ren, Y. Zhou, and Y. Liu, "The psychological burden experienced by Chinese citizens during the COVID-19 outbreak: prevalence and determinants," *BMC Public Health*, vol. 20, no. 1, p. 1617, 2020.

[24] L. Niu, Y. Qiu, D. Luo et al., "Cross-culture validation of the HIV/AIDS stress scale: the development of a revised Chinese version," *PLoS One*, vol. 11, no. 4, article e0152990, 2016.

[25] K. Kisielinski, S. Wagner, O. Hirsch, B. Klosterhalfen, and A. Prescher, "Possible toxicity of chronic carbon dioxide exposure associated with face mask use, particularly in pregnant women, children and adolescents - a scoping review," *Heliyon*, vol. 9, no. 4, article e14117, 2023.

[26] A. Czerwińska and T. Pawłowski, "Cognitive dysfunctions in depression - significance, description and treatment prospects," *Psychiatria Polska*, vol. 54, no. 3, pp. 453–466, 2020.

[27] E. D. Shenassa, C. Daskalakis, A. Liebhaber, M. Braubach, and M. Brown, "Dampness and mold in the home and depression: an examination of mold-related illness and perceived control of one's home as possible depression pathways," *American Journal of Public Health*, vol. 97, no. 10, pp. 1893–1899, 2007.

[28] N. Li, Q. Song, W. Su et al., "Exposure to indoor air pollution from solid fuel and its effect on depression: a systematic review and meta-analysis," *Environmental Science and Pollution Research International*, vol. 29, no. 33, pp. 49553–49567, 2022.

[29] Y. Deng, H. Zhao, Y. Liu et al., "Association of using biomass fuel for cooking with depression and anxiety symptoms in older Chinese adults," *Science of the Total Environment*, vol. 811, article 152256, 2022.

[30] W. W. Nazaroff, "Indoor bioaerosol dynamics," *Indoor Air*, vol. 26, no. 1, pp. 61–78, 2016.

[31] S. Goel and R. Gupta, "Experimental assessment of natural ventilation as a mitigation measure for indoor air pollution problem," in *Recent Advancements In Civil Engineering: Select Proceedings of ACE 2020*, pp. 517–525, Springer, Singapore, 2022.

[32] A. Tamuro, R. Kuwahara, and H. Kim, "Effects of outdoor air pollutants on indoor environment due to natural ventilation," *Atmosphere*, vol. 13, no. 11, p. 1917, 2022.

[33] K. Takagaki, Y. Okamoto, R. Jinnin et al., "Behavioral characteristics of subthreshold depression," *Journal of Affective Disorders*, vol. 168, pp. 472–475, 2014.

[34] L. Glodzik, C. Randall, H. Rusinek, and M. J. de Leon, "Cerebrovascular reactivity to carbon dioxide in Alzheimer's disease," *Journal of Alzheimer's Disease*, vol. 35, no. 3, pp. 427–440, 2013.

[35] OECD, *Executive Summary*, OECD, 2018.

[36] N. Bruce, R. Perez-Padilla, and R. Albalak, "Indoor air pollution in developing countries: a major environmental and public health challenge," *Bulletin of the World Health Organization*, vol. 78, no. 9, pp. 1078–1092, 2000.

[37] K. Huang, R. Wang, G. Feng, J. Wang, M. Yu, and N. He, "Ventilation status of the residential kitchens in severe cold region and improvement based on simulation: a case of Shenyang, China," *Journal of the Air & Waste Management Association*, vol. 72, no. 9, pp. 935–950, 2022.

[38] K. M. Kiely, B. Brady, and J. Byles, "Gender, mental health and ageing," *Maturitas*, vol. 129, pp. 76–84, 2019.

[39] J. McHenry, N. Carrier, E. Hull, and M. Kabbaj, "Sex differences in anxiety and depression: role of testosterone," *Frontiers in Neuroendocrinology*, vol. 35, no. 1, pp. 42–57, 2014.

[40] M. O. Chaiton, J. E. Cohen, J. O'Loughlin, and J. Rehm, "A systematic review of longitudinal studies on the association between depression and smoking in adolescents," *BMC Public Health*, vol. 9, no. 1, p. 356, 2009.

[41] J. M. Boden, D. M. Fergusson, and L. J. Horwood, "Cigarette smoking and depression: tests of causal linkages using a longitudinal birth cohort," *The British Journal of Psychiatry*, vol. 196, no. 6, pp. 440–446, 2010.

[42] M. C. Ivan, A. B. Amspoker, M. R. Nadorff et al., "Alcohol use, anxiety, and insomnia in older adults with generalized anxiety disorder," *The American Journal of Geriatric Psychiatry*, vol. 22, no. 9, pp. 875–883, 2014.

[43] P. J. Carek, S. E. Laibstain, and S. M. Carek, "Exercise for the treatment of depression and anxiety," *International Journal of Psychiatry in Medicine*, vol. 41, no. 1, pp. 15–28, 2011.

[44] F. Durand, B. Bonnefoy, D. Marchand, and T. Meyer, "Psychological antecedents of the intention to open the windows at home and exposure to a ventilation recommendation," *Frontiers in Psychology*, vol. 13, article 872626, 2022.

[45] J. Velten, A. Bieda, S. Scholten, A. Wannemüller, and J. Margraf, "Lifestyle choices and mental health: a longitudinal survey with German and Chinese students," *BMC Public Health*, vol. 18, no. 1, p. 632, 2018.

[46] X. Gao, T. Geng, M. Jiang et al., "Accelerated biological aging and risk of depression and anxiety: evidence from 424,299 UK Biobank participants," *Nature Communications*, vol. 14, no. 1, p. 2277, 2023.

[47] G. S. Alexopoulos, "Depression in the elderly," *Lancet*, vol. 365, no. 9475, pp. 1961–1970, 2005.

[48] M. Rantakokko, M. Mänty, S. Iwarsson et al., "Fear of moving outdoors and development of outdoor walking difficulty in older people," *Journal of the American Geriatrics Society*, vol. 57, no. 4, pp. 634–640, 2009.

[49] J. Yin, Q. Zhan, M. Tayyab, and A. Zahra, "The ventilation efficiency of urban built intensity and ventilation path identification: a case study of Wuhan," *International Journal of Environmental Research and Public Health*, vol. 18, no. 21, article 11684, 2021.

[50] C. R. Siah, E. H. Kua, and Y. S. Goh, "The impact of restorative green environment on mental health of big cities and the role of mental health professionals," *Current Opinion in Psychiatry*, vol. 35, no. 3, pp. 186–191, 2022.

[51] S. J. Fan, J. Heinrich, M. S. Bloom et al., "Ambient air pollution and depression: a systematic review with meta-analysis up to 2019," *Science of the Total Environment*, vol. 701, article 134721, 2020.

[52] M. W. Bari, S. Saleem, M. Bashir, and B. Ahmad, "Impact of ambient air pollution on outdoor employees' performance: mediating role of anxiety," *Frontiers in Psychology*, vol. 13, article 926534, 2022.