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Perceived Stress and Sleep Quality Among the Non-diseased General Public in China During the 2019 Coronavirus Disease: A Moderated Mediation Model

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1   **Perceived Stress and Sleep Quality Among the Non-diseased General Public in China**

2   **During the 2019 Coronavirus Disease: A Moderated Mediation Model**

3

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1   **Abstract**

2   **Background**: The 2019 coronavirus disease (COVID-19) has spread worldwide, and its

3   associated stressors have resulted in decreased sleep quality among front-line workers.

4   However, in China, the general public displayed more psychological problems than the

5   front-line workers during the pandemic. Therefore, we investigated the influence of perceived

6   stress on the sleep quality of the non-diseased general public and developed a moderated

7   mediation model to explain said relationship.

8   **Methods**: Questionnaire-based surveys were conducted online from February 18–25, 2020

9   with 1,630 Chinese participants (aged 18–68 years).

10   **Results**: Around one-third (36.38%) of participants were poor sleepers during the COVID-19

11   pandemic. Moreover, higher perceived stress was significantly associated with higher anxiety

12   levels, which, in turn, was associated with lower sleep quality. Self-esteem moderated the

13   indirect effect of perceived stress on sleep quality through its moderation of the effect of

14   perceived stress on anxiety. This indicated that the mediation effect of anxiety was stronger in

15   those with low levels of self-esteem than in those with high levels of self-esteem.

16   **Conclusions**: These findings suggest that both the sleep quality and perceived stress levels of

17   the non-diseased general public required attention during the COVID-19 pandemic. Our

18   findings also identify personality characteristics related to better sleep quality, demonstrating

19   the important role of self-esteem in environmental adaptation.

20   **Keywords:** COVID-19, perceived stress, sleep quality, anxiety, self-esteem

1 Introduction

Since December 2019, the outbreak of the novel coronavirus disease (COVID-19) has

infected more than 80,000 individuals in China, and it has since been declared a global

pandemic [1]. According to the World Health Organization's report, by April 30, 2020,

3,090,445 confirmed cases and 217,769 deaths had been reported worldwide. As COVID-19

is highly contagious and no vaccine is currently available, it has become an uncontrollable

stressor for many individuals [2].

Exposure to uncontrollable or unpredictable stressors (eg, hurricanes, earthquakes,

tsunamis, etc.) can alter individuals' sleep; (eg, leading to lower sleep quality, longer sleep

latency, increased awareness during the night, and more sleep complaints) [3-5]. Previous

studies showed that perceived stress is a major obstacle to sleep and eroded sleep quality

[6,7]. Specifically, the higher the perceived stress, the worse the sleep quality [8-13], and the

reduction in perceived stress predicted an improvement in sleep quality [7]. Notably,

researchers revealed that front-line workers (eg, medical staff) had poor sleep quality during

COVID-19 in China [2]; however, a recent study investigated the vicarious traumatization in

the general public and front-line medical staff and found the general public displayed more

vicarious traumatization than did front-line medical staff during the pandemic [14]. Therefore,

we investigated the influence of perceived stress on the sleep quality of the non-diseased

general public during the COVID-19 pandemic in China.

Anxiety is defined as an emotional state that includes worry, nervousness, apprehension,

and physical arousal [15]. According to the cognitive theory of emotion, cognitive appraisal

1 is a key factor in determining one's emotional state [16-18]. Anxiety may occur when one's

2 life is appraised as threatening or stressful. Some evidence shows that anxiety levels increase

3 after exposure to stressful events (eg, war, earthquakes, violence, etc. [19-21]) and higher

4 perceived stress is significantly associated with increased anxiety [22-25]. In contrast, it is

5 increasingly clear that anxiety is negatively related to sleep quality. For example, higher

6 anxiety is an important predictor of poor sleep quality, more insomnia symptoms, and longer

7 sleep onset time [26,27]. Importantly, higher anxiety predicted lower sleep quality among

8 individuals during the COVID-19 [2]. Thus, we posit that anxiety mediates the influence of

9 perceived stress on sleep quality.

10   Self-esteem is conceptualized as an individual's sense of self-worth [28-30]. Individuals

11 with high (vs. low) self-esteem can better respond to threats and frustrations and display

12 stronger subjective well-being, meaning in life, positive emotions, and life satisfaction

13 [31,32,29,33,34]. Importantly, researchers who utilized Terror Management Theory (TMT)

14 believe that high self-esteem is the result of an individual's adaptation to the environment and

15 serves to buffer against potential anxiety [35,36]. Consistent with TMT theory, a

16 meta-analysis of longitudinal studies showed that higher self-esteem significantly predicted

17 lower anxiety levels [37]. Further, when manipulating self-esteem through personality

18 feedback, researchers found that participants in the high self-esteem condition had lower

19 anxiety levels when facing the stressful stimuli (eg, a video about death) than did participants

20 in the low self-esteem condition [38]. Taken together, self-esteem may moderate the

21 relationship between perceived stress and anxiety; further, it may moderate the indirect effect

1   of perceived stress on sleep quality through anxiety.

2   Moreover, self-esteem may be a protective factor for sleep. For example, higher

3   self-esteem was related to fewer insomnia symptoms in a large community-based sample of

4   adults aged 30 to 84 years [39]. Lemola et al. [39], also found that short (< 6 h) and long (> 9

5   h) sleep duration that were harmful to health (eg, increasing mortality hazard [40]) were

6   correlated with low self-esteem. Even when dealing with stressful events (ie, hospitalization),

7   self-esteem was positively correlated with children's sleep efficiency [41]. Therefore, it is

8   logical to speculate that people with low self-esteem will have lower sleep quality than

9   people with high self-esteem, especially when facing stressful events. That is, the direct effect

10   of perceived stress on sleep may be moderated by self-esteem.

11   Considering the above, we investigated the influence of perceived stress on sleep quality

12   among the non-diseased general public during COVID-19 in China. We hypothesized that

13   perceived would be an important predictor of sleep quality. Moreover, we posited that

14   perceived stress would predict increased anxiety levels, which, in turn, would be associated

15   with decreased sleep quality. Finally, we hypothesized that individuals' self-esteem would

16   moderate both the relationship between perceived stress and anxiety and the relationship

17   between perceived stress and sleep quality. In other words, higher perceived stress and lower

18   self-esteem would be correlated with higher anxiety levels which, in turn, would be

19   associated with lower sleep quality. The moderated mediation model is shown in Figure 1.
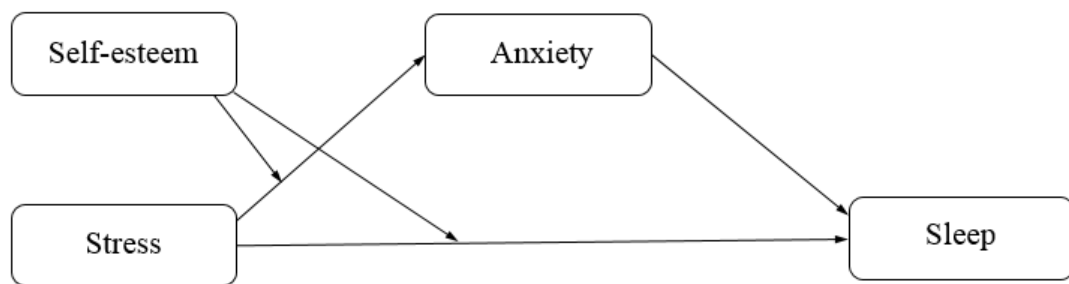
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2   Figure 1. The proposed moderated mediation model

3   **2 Materials and Methods**

4   2.1 Participants

5   A total of 1,722 people from 32 provinces or political areas in China were recruited to

6   complete a questionnaire survey. Participants were asked to report both their current health

7   status (non-diseased individuals/individuals with pandemic-related symptoms (eg,

8   fever/suspected patients/confirmed patients/cured cases of COVID-19) and their identity

9   (front-line workers (eg, medical staff)/general public). Among them, 92 participants (13

10   participants with pandemic-related symptoms, one cured case of COVID-19, and 78

11   front-line workers) were excluded, resulting in a final sample of 1,630 non-diseased members

12   of the general public (mean age = 29.17 ± 10.58 years, age range = 18–68 years). Most

13   participants (83.43%, n = 1,360) had at least a college degree. Only 13.19% (n = 215) of

14   participants had left the house to work. In addition, 71.84% (n = 1,171) of the participants

15   paid great attention to COVID-19.

16   2.2 Materials

17   2.2.1 Perceived Stress Scale (PSS)

18   Perceived stress levels over the past month were assessed with the Chinese version of the

1   10-item PSS, which was based on Cohen et al., [42]. This version of the PSS was reliable

2   (Cronbach's α = 0.75) and had satisfactory construct validities in a study of 9,507 Chinese

3   individuals (aged ≥ 18 years; education ≥ junior high school; [43]). PSS assesses the extent

4   that individuals believe their lives are overloaded, unpredictable, and uncontrollable (eg, in

5   the last month, how often have you found that you could not cope with all the things that you

6   had to do?). Participants rated the items on a 5-point Likert scale (0 = *never*, 4 = *very often*),

7   with higher scores indicating higher perceived stress. Cronbach's α was 0.82 in this study.

8   2.2.2 Pittsburgh Sleep Quality Index (PSQI)

9   Global sleep quality over the past month was assessed with the Chinese version of the

10 19-item PSQI, which was based on Buysse et al., [44]. The Chinese version of the PSQI has

11 good validity and internal consistency (Cronbach's αs = 0.75–0.85 [45-47] and test-retest

12 reliability (0.85 over 14- and 21-day intervals [46]). The seven subscale scores (subjective

13 sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use

14 of sleep medication, and daytime dysfunction) were summed to calculate a global score.

15 Scores on the PSQI ranged from 0 to 21, with higher scores indicating poorer sleep quality.

16 People with a PSQI score greater than five were defined as "poor sleepers" [44]. Cronbach's

17 α was 0.81 in this study.

18 2.2.3 Self-Rating Anxiety Scale (SAS)

19 Anxiety levels during the previous seven days were measured with the Chinese version of the

20 20-item SAS, which was based on Zung [48]. This version of the SAS is valid and reliable

21 (Cronbach's α = 0.93 [49]. All responses were made using a 4-point Likert scale (1 = *never*, 4

1　= *very often*). Higher scores indicated higher anxiety levels. Cronbach's α was 0.79 in this

2　study.

3　2.2.4 Rosenberg Self-Esteem Scale (RSE)

4　The Chinese revision of the RSE scale, based on Rosenberg [30], was used to measure

5　overall self-esteem. Previous studies showed this version of the RSE to have good internal

6　consistency (Cronbach's α = 0.82; [50]) and test-retest reliability (0.78 over a 14-day interval;

7　[51]). The Chinese version of the RSE consists of six positive items (items 1, 2, 4, 6, 7, and 8)

8　and four negative items (items 3, 5, 9, and 10). Participants were asked to answer the items

9　using a 4-point Likert scale (1 = *strongly agree*, 4 = *strongly disagree*). Higher scores

10　indicated higher levels of self-esteem. Cronbach's α was 0.87 in this study.

11　2.3 Procedures

12　This study was approved by the review board of the Faculty of Psychology of Southwest

13　University (no. IRB20200218). Anonymous questionnaires were conducted via an online

14　survey platform—"SurveyStar"—from February 18–25, 2020. It took about 15 minutes for

15　participants to complete all questionnaires. Upon completion, participants were paid five

16　yuan as gratitude (approximately $0.70 US).

17　2.4 Statistical analyses

18　All data were analyzed using IBM SPSS Statistics 22.0. We used Model 4 of the Hayes [52]

19　PROCESS macro to examine the mediation effect of anxiety. Moreover, Model 8 of the

20　PROCESS macro was used to test whether self-esteem moderated the mediation process.

21　Bootstrapping (5,000 bootstrap samples) with 95% confidence intervals (CIs) was conducted

1   to test the significance of indirect effects [52]. The 95% CIs did not include zero, indicating a

2   significant effect.

3   **3 Results**

4   3.1 Preliminary analyses

5   3.1.1 National epidemic trend of COVID-19 in China

6   Figure 2 shows the national epidemic trend of COVID-19 in China from February 4 to March

7   10, 2020, with a peak (n = 58,016) in the number of existing confirmed cases on February 17,

8   2020. According to Figure 2, the epidemic (the number of existing confirmed cases ranged

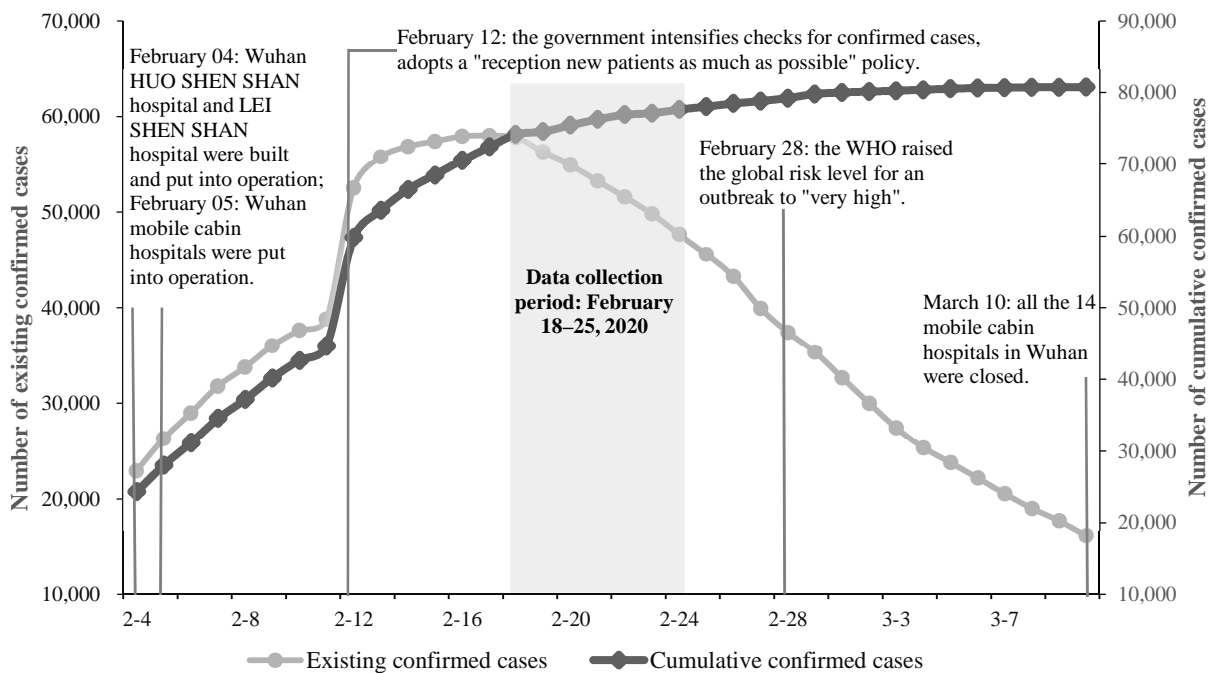9   from 45,604 to 57,805) remained severe during the questionnaire collection period.

10

11   Figure 2. The national pandemic trend of the 2019 coronavirus disease (COVID-19) in China

12   from February 4 to March 10, 2020; existing confirmed cases = cumulative confirmed cases -

13   cured cases - death cases.

1   3.1.2 Descriptive statistics for sleep quality

2   The distribution of PSQI scores is presented in Figure 3. We also calculated the mean scores

3   of the seven subscales: subjective sleep quality (mean = 0.94, SD = 0.76), sleep latency

4   (mean = 1.24, SD = 0.96), sleep duration (mean = 0.13, SD = 0.44), habitual sleep efficiency

5   (mean = 0.53, SD = 0.83), sleep disturbances (mean = 0.99, SD = 0.53), use of sleep

6   medication (mean = 0.04, SD = 0.31), and daytime dysfunction (mean = 1.02, SD = 0.96).

7   Among the 1,630 participants, there were 1,037 (63.62%) good sleepers and 593 (36.38%)
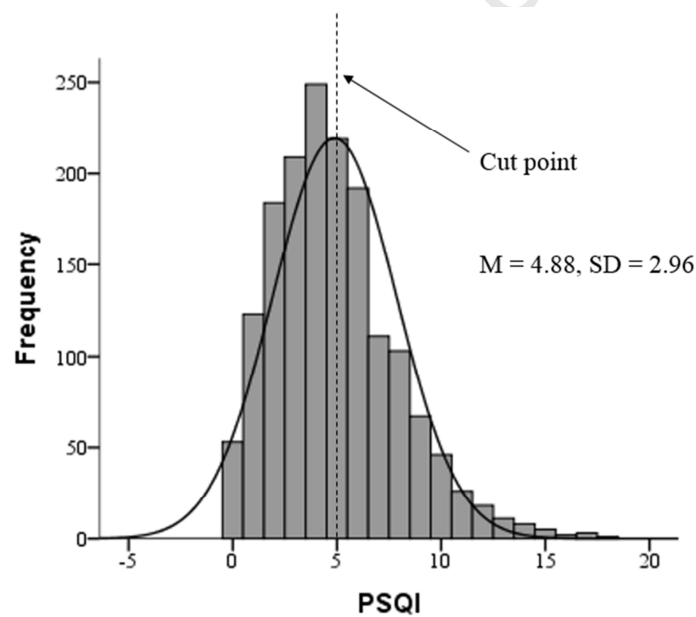
8   poor sleepers.

10   Figure 3. Distribution of Pittsburgh Sleep Quality Index (PSQI) scores. People with scores

11   greater than five were defined as "poor sleepers."

12   3.1.3 Correlations for all variables

13   The results of Pearson's correlations are presented in Table 1. As expected, higher perceived

14   stress was correlated with lower sleep quality. Higher anxiety was related to higher perceived

15   stress and lower sleep quality. Moreover, higher self-esteem was associated with lower

1   anxiety and better sleep quality.

Table 1. Correlations between all variables

	Mean	SD	PSS	PSQI	SAS	RSE
PSS	15.82	5.56	1.00			
PSQI	4.88	2.96	0.35***	1.00		
SAS	39.96	8.34	0.52***	0.53***	1.00	
RSE	29.35	4.27	-0.43***	-0.27***	-0.36***	1.00

2   Note. N = 1,630. SD = standard deviation; PSQI = Pittsburgh Sleep Quality Index; PSS =

3   Perceived Stress Scale; SAS = Self-Rating Anxiety Scale; RSE = Rosenberg Self-Esteem

4   Scale; ***$P < .001$.

5   3.2 Mediation Analysis

6   Controlling for age, education, working or not (ie, whether they left the house to work), and

7   attention to COVID-19, the mediation effect of anxiety was examined. Results showed that a

8   higher level of perceived stress significantly predicted lower sleep quality (see Model 1 of

9   Table 2). Higher perceived stress was also a predictor of higher anxiety (see Model 2 of Table

10   2). When controlling for perceived stress, higher anxiety significantly predicted lower sleep

11   quality (see Model 3 of Table 2). Moreover, bootstrapping indicated that the mediation effect

12   of anxiety was significant (ab = 0.13, Boot SE = 0.01, Boot 95% CI = [0.11, 0.15]), and it

13   accounted for 66.29% of the total effect. Taken together, anxiety mediated the relationship

14   between perceived stress and sleep quality.

15   Table 2. Testing the mediation effect of perceived stress on sleep quality

	Model 1 (PSQI)		Model 2 (SAS)		Model 3 (PSQI)	
Predictor	B	t	B	t	B	t
Age	0.03	3.65[***]	-0.05	-2.88[**]	0.04	5.46[***]
Education	0.04	0.57	-0.99	-6.01[***]	0.21	3.55[***]
Work or not	0.02	0.09	-0.56	-1.08	0.12	0.64
Attention to COVID-19	0.07	0.74	0.26	1.11	0.02	0.28
PSS	0.20	15.52[***]	0.75	23.38[***]	0.07	5.04[***]
SAS					0.17	19.76[***]
R^2	0.13		0.29		0.30	
F	49.01[***]		131.08[***]		115.69[***]	

1   Note. N = 1,630. PSQI = Pittsburgh Sleep Quality Index; PSS = Perceived Stress Scale; SAS

2   = Self-Rating Anxiety Scale; [***]$P < .001$; [**]$P < .01$.

3   3.3 Moderated mediation analysis

4   Controlling for age, education, working or not, and attention to COVID-19, we conducted the

5   moderated mediation analysis. As Table 3 shows, the interaction (Model 1) between

6   perceived stress and self-esteem significantly predicted anxiety, suggesting that self-esteem

7   moderated the effect of perceived stress on anxiety. Simple slope tests suggested that, for

8   individuals with high (Mean + SD; $B_{simple} = 0.59$, $t = 13.06$, $p < .001$) and low (Mean - SD;

9    $B_{simple} = 0.73$, $t = 16.80$, $p < .001$) self-esteem, higher perceived stress predicted higher

10   anxiety (Figure 4a). Nevertheless, the slope for individuals with low self-esteem was larger

1   than that for individuals with high self-esteem. Further, self-esteem significantly moderated

2   the effect of perceived stress on sleep through anxiety. There was a significant indirect effect

3   at each level of self-esteem (Table 4); however, the indirect effect of perceived stress on sleep

4   quality through anxiety was stronger at low levels of self-esteem.

5   Table 3 also shows the interaction (Model 2) between perceived stress and self-esteem,

6   which significantly predicted sleep quality. This suggests that self-esteem moderated the

7   direct effect of perceived stress on sleep quality. Simple slope tests (Figure 4b) showed that,

8   for individuals with low self-esteem, higher perceived stress predicted lower sleep quality

9   ($B_{simple} = 0.76$, $t = 4.53$, $p < .001$); however, for individuals with high self-esteem, perceived

10   stress was not related to sleep quality ($B_{simple} = 0.03$, $t = 1.56$, $p = .12$).

11   Table 3. Testing the moderated mediation effect of perceived stress on sleep quality

Predictors	Model 1 (SAS)		Model 2 (PSQI)	
	B	t	B	t
Age	-0.05	-2.58[**]	0.04	5.65[***]
Education	-0.85	-5.18[***]	0.22	3.78[***]
Work or not	-0.52	-1.01	0.12	0.65
Attention to COVID-19	0.39	1.67	0.06	0.68
PSS	1.14	6.10[***]	0.22	3.28[**]
RSE	-0.03	-0.28	0.03	0.83
SAS			0.17	18.82[***]
PSS x RSE	-0.02	-2.61[**]	-0.01	-2.57[**]

R^2	0.31	0.31
F	103.43[***]	90.25[***]

1   Note. N = 1,630. PSQI = Pittsburgh Sleep Quality Index; PSS = Perceived Stress Scale; SAS

2   = Self-Rating Anxiety Scale; RSE = Rosenberg Self-Esteem Scale; [***]$P < .001$; [**]$P < .01$.

3   Table 4. Bootstrap results for the moderated mediation effect

	RSE	Effect	Boot SE	Boot 95% CI	
				Low	High
	Low RSE	0.12	0.01	0.10	0.14
	Medium RSE	0.11	0.01	0.09	0.13
Conditional indirect effects	High RSE	0.10	0.01	0.08	0.12

4   Note. N = 1,630. RSE = Rosenberg Self-Esteem Scale; Medium RSE = Mean of RSE; Low

5   RSE = Mean -1 SD; High RSE = Mean +1 SD; SD = standard deviation; CI = confidence

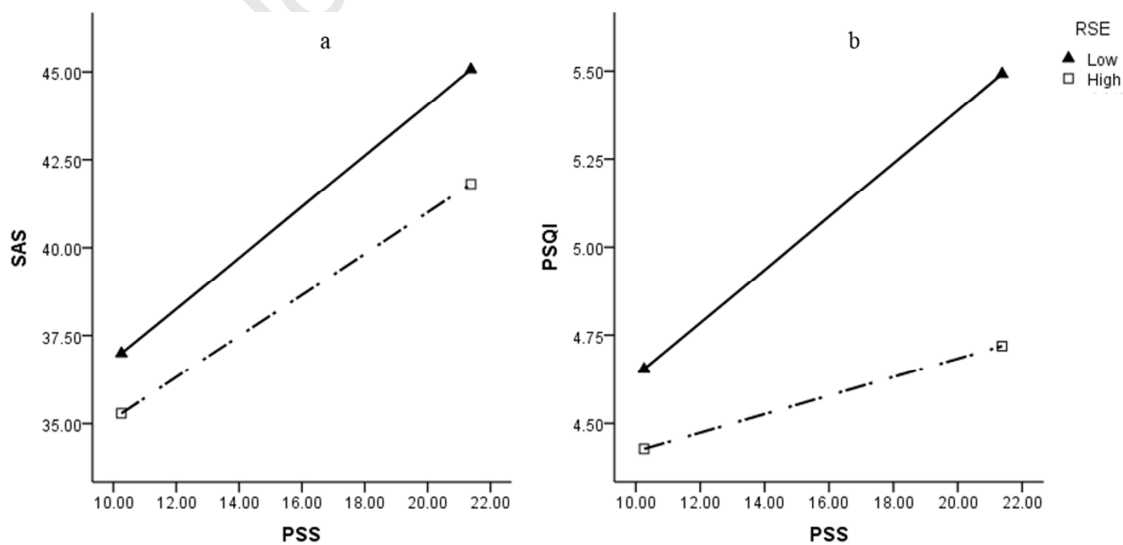6   interval.

8   Figure 4. The moderation effect of self-esteem. (a) self-esteem moderated the relationship

9   between perceived stress and anxiety. (b) self-esteem moderated the relationship between

14

1   perceived stress and sleep quality. PSQI = Pittsburgh Sleep Quality Index; PSS = Perceived

2   Stress Scale; SAS = Self-Rating Anxiety Scale; RSE = Rosenberg Self-Esteem Scale; Low

3   RSE = Mean -1 SD; High RSE = Mean +1 SD; SD = standard deviation.

4

5   **4 Discussion**

6   The current study investigated the influence of perceived stress on sleep quality in the

7   non-diseased general public during the COVID-19 pandemic in China and the mediating

8   effect of anxiety and moderating mechanisms of self-esteem. Results showed that about

9   one-third of participants were poor sleepers during the pandemic. Moreover, people's anxiety

10   significantly mediated the relationship between perceived stress and sleep quality. Further,

11   people's self-esteem moderated the indirect effect of perceived stress on sleep quality through

12   its moderation of the effect of perceived stress on anxiety, indicating the mediation effect of

13   anxiety was stronger at low levels of self-esteem than at high levels of self-esteem. The direct

14   effect of perceived stress on sleep quality was moderated by self-esteem.

15   The number of poor sleepers in the current study was much higher than the proportion

16   reported in previous Chinese studies, which were not related to COVID-19. For example,

17   Zhang et al. [53], surveyed the sleep quality of 27,912 Chinese rural individuals aged 18–79

18   years and found that 21.80% of participants were getting poor sleep [53]. Ning et al. [54],

19   found that 24.10% of 1,469 HIV-infected Chinese adults (aged 18–80 years) and 19.90% of

20   2,938 HIV-uninfected participants had poor sleep quality [54]. Jiang et al. [55], calculated the

21   global PSQI score only based on six subscale scores (subjective sleep quality, sleep latency,

1   habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime

2   dysfunction), and found that 27.44% of 28,202 Chinese rural participants aged 18–79 years

3   were poor sleepers [55]. The current results thus suggest that the sleep quality of the

4   non-diseased general public during COVID-19 was worse than usual. This study was

5   conducted when the pandemic was severe, which may explain the decline in participants'

6   sleep quality. In line with this notion, previous studies showed that exposure to stressors (eg,

7   hurricanes) leads to lower sleep quality, longer sleep latency, increased awareness during the

8   night, and more sleep complaints [3-5].However, our results suggested that, during

9   COVID-19, the sleep quality of the non-diseased general public (mean PSQI = 4.88) was

10 better than that of the front-line medical staff (mean PSQI = 8.58; [2]). We cautiously

11 speculate that the countermeasures for COVID-19 may reduce the impact of the pandemic on

12 the sleep quality of the general public. On one hand, to cut-off the transmission of the virus,

13 the general public was encouraged to practice home-isolation and wear masks, which

14 effectively reduced the risk of infection. On the other hand, during the period of

15 home-isolation, the state has implemented many measures to ensure that the daily lives of the

16 general public are as normal as possible; for example, college students can take classes online

17 at home.

18   We found that higher levels of perceived stress predicted lower sleep quality, which is

19 consistent with previous studies [8-13]. Moreover, perceived stress affected sleep quality

20 through anxiety, indicating that perceived stress increased feelings of anxiety, which, in turn,

21 decreased sleep quality. These results were consistent with Stress and Coping Theory, which

1   proposes that stress occurs when individuals perceive that the demands of environmental

2   stimuli exceed or tax their resources, which results in a changed emotional state (eg, anxiety)

3   that, in turn, affects one's health [56-59,18]. Since perceived stress was measured by the

4   degree of unpredictability, uncontrollability, and overload [42]. in the current study,

5   participants with higher stress perceived lower control over their lives. Accumulating

6   evidence has demonstrated that lower perceived control is associated with higher anxiety

7   levels and more anxiety symptoms [60-64]; therefore, our results were consistent with these

8   models of anxiety, which suggests that control over life plays an important role in anxiety

9   development [65]. In addition, we found that higher anxiety levels predicted worse sleep

10   quality. In line with this study, previous studies have consistently found that higher anxiety

11   levels were associated with worse self-reported health, decreased well-being, higher levels of

12   depression, increased disability, and cognitive impairment [66-72].

13   Our results showed that self-esteem moderated the relationship between perceived stress

14   and anxiety, which, in turn, moderated the indirect effect of perceived stress on sleep quality

15   through anxiety. Specifically, the effect of perceived stress on anxiety was stronger in those

16   with low self-esteem vs. high self-esteem. These findings are consistent with TMT theory,

17   which suggests that high self-esteem helps buffer against anxiety [35,36]. Accordingly, faced

18   with the stressors induced by COVID-19, participants with low self-esteem were more likely

19   to experience anxiety than were participants with high self-esteem. Individuals with high

20   self-esteem typically hold more positive beliefs (eg, intelligent, popular, attractive, etc.) about

21   themselves relative to those with low self-esteem [73-75]. Similarly, compared with

1   individuals with low self-esteem, those with high self-esteem are more confident in their

2   ability and more optimistic about their performance on future tasks, even following a failure

3   [76]. Further, participants with high self-esteem display more self-protection and attribute

4   failure more to external factors than participants with low self-esteem [74,77]. These

5   characteristics of high self-esteem may help reduce anxieties related to threats. In addition,

6   we also found that self-esteem moderated the relationship between perceived stress and sleep

7   quality, indicating that higher perceived stress predicted lower sleep quality in those with low

8   self-esteem, but not in those with high self-esteem. These findings are consistent with

9   previous studies, suggesting that self-esteem is a protective factor for sleep [39,41].

10   Several limitations deserve mentioning. Previous studies showed that, compared with

11   women, men have shorter sleep quantity and lower sleep quality [78,79]. Results also suggest

12   that sleep problems are more common among women, especially those with depression

13   [78,79]. However, owing to data collection problems, 795 participants did not report their sex,

14   which prevents analyzing any possible sex differences. To control for the potential influence

15   of sex on the current results, we only analyzed the data with sex information (n = 835, 254

16   men and 581 women). The results indicated that the mediation effect of anxiety (ab = 0.137,

17   Boot SE = 0.02, Boot 95% CI = [0.11, 0.17]) and the moderated mediation analysis of

18   self-esteem (the effect of the interaction between perceived stress and self-esteem on anxiety:

19   B = -0.02, t = -2.00, $p < 0.05$) were both stable. Second, we did not have data from front-line

20   workers, which prevents directly analyzing the difference in sleep quality between front-line

21   workers and the non-diseased general public. Third, the measure of sleep was based on

1   individuals' subjective sleep reports. Previous studies showed that subjective sleep reports

2   could underestimate or overestimate sleep quality compared to objective sleep assessments

3   owing to psychological factors, such as mood [80-82]. Thus, future studies should try to

4   objectively measure sleep (eg, polysomnography or actigraphy). Finally, this study employed

5   a cross-sectional design; thus, we cannot infer causality. Further research should adopt

6   experimental or longitudinal designs to explore the causal implications of this study.

7   **5 Conclusion**

8   In sum, this study suggests that, owing to the increase in perceived stress during the 2019

9   COVID-19 pandemic, the sleep quality in the non-diseased general public deteriorated.

10 Moreover, high levels of anxiety may be an explanation for the higher levels of stress

11 associated with worse sleep quality. Further, high self-esteem helped reduce people's anxiety

12 induced by perceived stress and lead to better sleep quality. These findings suggest that both

13 the sleep quality and the perceived stress levels of the non-diseased general public required

14 attention during the COVID-19 pandemic. We also identified personality characteristics

15 related to better sleep quality, demonstrating the important role of self-esteem in

16 environmental adaptation.

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3   **Declarations of Interest**

4   None

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Highlights

- One-third of the 1,630 healthy participants were poor sleepers during the COVID-19 pandemic.

- Higher perceived stress was related to lower sleep quality.

- Anxiety significantly mediated the relationship between perceived stress and sleep quality.

- Anxiety as a mediator was stronger in those with low (vs. high) self-esteem.

Credit Author Statement

Xiaolin Zhao: Conceptualization, Methodology, Formal analysis, Investigation, Writing-Original draft preparation, Writing - Review & Editing. Mengxue Lan: Conceptualization, Investigation, Formal analysis. Huixiang Li: Investigation, Formal analysis. Juan Yang: Conceptualization, Writing - Review & Editing, Supervision, Funding acquisition.