The mediating effect of perceived stress on the relationship between big five personality traits and suboptimal health status: A national cross-sectional survey in China

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Research Article

Keywords: Predictive, preventive and personalized medicine (PPPM/3PM), Big five personality traits, Perceived stress, Suboptimal health status (SHS), Cross-sectional study, China

Posted Date: September 18th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3319115/v1

Version of Record: A version of this preprint was published at EPMA Journal on December 11th, 2023. See the published version at https://doi.org/10.1007/s13167-023-00349-x.

Abstract

Background

Psychological factor plays a crucial role in the development of suboptimal health status (SHS), however the mechanism behind the complex relationship between big five personality traits and SHS is unclear. Identification of the individuals with specific personality trait that is susceptible to SHS will contribute to improving quality of life and decreasing the burdens of chronic diseases in the framework of predictive, preventive and personalized medicine (PPPM/3PM). This study aimed to investigate the relationship between personality traits and SHS, and whether perceived stress plays a mediating effect in the development of SHS.

Method

A nationwide cross-sectional survey based on multistage random sampling was conducted in 148 cities of China from June 20 to August 31, 2022. The personality traits, perceived stress and SHS were measured with Big Five Inventory-10 (BFI-10), Perceived Stress Scale-4 items (PSS-4), and Short-Form Suboptimal Health Status Questionnaire (SHSQ-SF), respectively. Pearson's correlation analysis was employed to examine the associations between personality traits, perceived stress, and SHS. Structural equation model (SEM) was applied to explore the mediating role played by perceived stress in the relationship between personality traits and SHS.

Result

A total of 22,897 participants were enrolled in this study, among whom the prevalence of SHS was 52.88%. SHS was negatively correlated with three dimensions of personality traits (*i.e.*, extraversion, agreeableness, and conscientiousness), and positively correlated with neuroticism. Meanwhile, stress was negatively correlated with extraversion, agreeableness, conscientiousness, and openness, whereas in positive association with neuroticism. The SEM analysis showed that, adjusted for the covariables (*i.e.*, gender, age, BMI, educational level, current residence, marital status, and occupational status), agreeableness (β = -0.049, P < 0.001) and conscientiousness (β = -0.103, P < 0.001) caused a lower prevalence of SHS, while neuroticism (β = 0.130, P < 0.001) and openness (β = 0.026, P < 0.001) induced a higher prevalence of SHS. Perceived stress played a partial mediating role in the relationship between personality traits and SHS, contributing to 41.3%, 35.9% and 32.5% of the total effects of agreeableness, conscientiousness and neuroticism on SHS, respectively. Moreover, the mediating effect of perceived stress was significant even though extraversion had no direct effect on SHS.

Conclusion

This study revealed a high prevalence of SHS in Chinese residents. Personality traits of individuals have significant effects on the occurrence of SHS, which can be mediated by their perceived stress. From a PPPM/3PM perspective, early screening and targeted intervention for persons with neuroticism trait, as well as stress alleviation, might contribute to health improvement and chronic diseases prevention.

Introduction

Suboptimal health status (SHS) is an intermediate condition between optimal health and illness, characterized by perception of health complaints, general weakness and low energy, without clear disease in clinical diagnosis [1]. Even though SHS cannot be diagnosed as any of specific diseases, it is predominantly associated with the development of chronic diseases among multiple populations, including in Eastern Asians, Africans, and Australians [2, 3]. Epidemiological surveys released that approximately half of population experience SHS in China [4, 5].

SHS has been identified preceding the occurrence of chronic diseases, including type 2 diabetes mellitus (T2DM) [6, 7] and cardiovascular diseases (CVD) [4, 8], acting as a biomarker of subclinical stage of chronic diseases. Early identification of SHS and its relevant determinants will contribute to targeted prevention and personalized treatment of chronic diseases from the perspective of predictive, preventive, and personalized medicine (PPPM/3PM) [9]. Adverse psychological factors have been widely described in the development of SHS [10], but it is not yet clear whether personality traits play a part. Studies have presented that personality is one of important predictors of healthy behavior patterns (*e.g.*, reaction pattern, and movement), closely associated with health conditions [11]. The Big Five personality model explains personality traits in five dimensions: extraversion, agreeableness, conscientiousness, neuroticism, and openness [12]. The diverse strength of each personality trait can cause complex effects on the human body in a variety of aspects [13], enabling personality traits measurements of potential roles in predicting health outcomes [14]. Extraversion [15–18], agreeableness [19, 20], conscientiousness [21], and openness [22] are positively associated with healthy condition, while neuroticism leads to unhealthy outcomes [23].

Recently published studies have shown that personality traits are also associated with perceived stress, which has intensive impact on health [24]. In particular, neuroticism is positively associated with stress; whereas extraversion, agreeableness, conscientiousness, and openness are negatively linked to stress. Furthermore, stress is well understood in its relationship with higher risk of SHS [25, 26]. These findings suggest a complex relationship of personality traits and stress with SHS.

Working hypothesis in the framework of PPPM/3PM

As a reversible borderline condition between optimal health and illness, SHS has been recognized as one of major determinants of non-communicable diseases (NCDs) [4, 7]. Screening of SHS and its relevant factors provides a window of opportunity for early prevention and targeted intervention of NCDs in the context of PPPM/3PM. Adverse psychological condition, one of key aspects of SHS, is a target for identification of persons at high risk of chronic diseases. On the basis of framework of PPPM/3PM, identification of SHS-related personality trait will contribute to decreasing the burdens of such diseases. However, the relationship between personality traits and SHS is not yet clear. Hereby, we conducted a nation-wide survey to seek the effect of personality traits on SHS, and to examine the mediating role played by perceived stress in the relationship between personality traits and SHS.

Methods

Study design and study participants

This study was a nation-wide cross-sectional survey conducted in 148 cities of China [27]. A multistage random sampling method was applied to recruit participants: 1) probability sampling at the provincial, municipal, district/county, and community/village levels, and 2) quota sampling from community/village to individual level. The sampling ratios were established in 23 provinces, 5 autonomous areas, and 4 municipalities based on the population proportion provided by the Seventh National Census Data of China. The research protocol was approved by the Shaanxi Health Culture Research Center ethics review board and is currently registered in the Chinese Clinical Trial Registry (registration number ChiCTR2200061046).

Participants who met the following criteria were included in this study: 1) age ≥ 16 years old; 2) permanent residents with Chinese nationality; and 3) possessed the necessary skills to read and comprehend the questionnaires. The exclusion criteria were: 1) individuals with somatic diseases currently; 2) individuals with psychiatric abnormalities or cognitive impairment currently; and 3) individuals participating in other clinical investigations at present.

Parameter measurement

Investigators who participated in face-to-face interview were publicly recruited from local university in each city. All the investigators participated in training courses in quality control, research tools, and sampling techniques, and then were tested in accordance with the predefined training protocol. Written informed consents were obtained from all the participants.

Demographic characteristics

The demographic characteristics of the participants, including gender, age, BMI, educational level, current residence (urban/rural), marital status and occupational status, were collected by a face-to-face interview.

Big Five Inventory-10 items (BFI-10)

BFI-10, a 5-point Likert self-reported questionnaire, was applied to measure the personality traits of the respondents. This scale included 10 items that represent 5 dimensions of personality traits, *i.e.*, extraversion, agreeableness, conscientiousness, neuroticism, and openness. The higher are the score of a domain of personality traits, the more significant the personality belongs to. BFI-10 has shown good reliability and validity in our investigation across China [28].

Perceived Stress Scale-4 items (PSS-4)

PSS-4 was adopted to measure the level of perceived stress of the respondents. This simplified 5-point Likert-type scale consists of 4 items of 2 dimensions. The total score is between 4 to 20, and a higher score indicated a higher level of perceived stress. This scale has been proved to show good validity and reliability in previous studies [29].

Short-Form Suboptimal Health Status Questionnaire (SHSQ-SF)

SHSQ-SF, a 5-point Likert scale with 9 items, was applied to measure the health status of the respondents. Each item is scored on scale ranging from 0 (almost none) to 4 (almost always), and a total score ≥ 11 indicates SHS, otherwise optimal health condition was confirmed.

Pilot study

A total of 400 participants were enrolled in this study's three rounds of pre-investigation, which were conducted from June 5 to 8, June 10 to 13, and June 15 to 18 in 2022. The advice and comments provided by the respondents and researchers during the pilot study were promptly gathered and compiled. The final questionnaire was revised after three rounds of pre-investigation.

Statistical analysis

Descriptive statistics was used to elucidate the sociodemographic characteristics of the participants. Pearson's correlation was applied to examine correlations between personality traits, stress, and SHS. The reliability and validity of the measurements of personality traits, stress, and SHS were identified using Cronbach's α and confirmatory factor analysis (CFA). The CFA results of the hypothesized model showed good overall model fit indices: root mean square error of approximation = 0.039 < 0.080, comparative fit index = 0.991 > 0.950, and Tucker-Lewis index = 0.954 > 0.950. The mediation analysis and structural equation modelling (SEM) were carried out to explore the mediating effects of stress on the relationship between personality traits and SHS.

In the SEM model of SHS, the five dimensions of personality traits were independent variables, stress were predefined as mediator. In addition, the effects of covariates (*i.e.*, gender, age, BMI, educational level, current residence, marital status, and occupational status) were controlled in the SEM analysis. The maximum-likelihood method was applied for the asymptotically unbiased, consistent, and efficient estimators. The significance of paths was verified by bias-corrected bootstrapping analysis with 5,000 replicates. Data analyses were performed using IBM SPSS Statistics (version 26.0, Armonk, NY, USA) and MPLUS (version 8.3, Linda, Bengt, LA). All statistical tests were two-sided and the $P < 0.05$ was considered statistical significance.

Results

Recruitment of respondents and characteristics of participants

A total of 30,505 respondents were recruited in this survey, among whom 7,608 were excluded due to the following reasons: 1) 1,182 with chronic diseases, 2) 4,352 with unavailable SHS data, and 3) 2,074 under 16 years of age or over 60 years old. Finally, 22,897 participants were enrolled in this analysis. The flowchart of participants recruitment was shown in Fig. 1, and the regional distribution of the participants was shown in Fig. 2.

Regarding to characteristics of participants, 9,841 (42.98%) were men and 13,056 (57.02%) were women. Among them, 10,827 (47.29%) were under 24 years of age, and 4,667 (20.38%) were over 45 years old. In addition, 5,662 (24.73%) participants were recruited from rural areas, and 17,235 (75.27%) were from urban areas. The details of participants characteristics were listed in Table 1.

Table 1
Characteristics of participants

Variables		N	Health (N = 10789)	SHS (N = 12108)	χ^2	*P*
Gender	Male	9841	4971 (50.51)	4870 (49.49)	79.762	< 0.001
	Female	13056	5818 (44.56)	7238 (55.44)		
Age (years)	≤ 24	10827	4613 (42.61)	6214 (57.39)	173.470	< 0.001
	25~	4046	2037 (50.35)	2009 (49.65)		
	35~	3357	1688 (50.28)	1669 (49.72)		
	≥ 45	4667	2451 (52.52)	2216 (47.48)		
BMI categories	Thin	3763	1578 (41.93)	2185 (58.07)	55.823	< 0.001
	Normal	14090	6805 (48.30)	7285 (51.70)		
	Overweight	4020	1945 (48.38)	2075 (51.62)		
	Obese	1024	461 (45.02)	563 (54.98)		
Educational level	Middle school and below	3493	1972 (56.46)	1521 (43.54)	159.789	< 0.001
	Senior high school	5816	2764 (47.52)	3052 (52.48)		
	College	12673	5630 (44.43)	7043 (55.57)		
	Master and above	915	423 (46.23)	492 (53.77)		
Marital status	Single	12823	5531 (43.13)	7292 (56.87)	208.477	< 0.001
	Married	9651	5085 (52.69)	4566 (47.31)		
	Divorced or widowed	423	173 (40.90)	250 (59.10)		
Occupational status	Student	10244	4361 (40.42)	5883 (48.59)	159.947	< 0.001
	Employed	10877	5511 (51.08)	5366 (44.32)		
	Retired	474	223 (2.07)	251 (2.07)		
	Unemployment	1302	694 (6.43)	608 (5.02)		
Place of residence	Rural	5662	2654 (46.87)	3008 (53.13)	0.182	0.669
	Urban	17235	8135 (47.20)	9100 (52.80)		

SHS, suboptimal health status

The prevalence of SHS

As shown in Table 1, the prevalence of SHS was 52.88% (12,108/22,897). The prevalence was significantly higher among women (55.44%; 7,238/13,056) than men (49.49%; 4,870/9,841). Compared with participants aged over 45 years old (47.48%; 2,216/4,667), those under 24 years of age had a higher prevalence (57.39%; 6,214/10,827). In terms of marital status, divorced or widowed participants were more susceptible to SHS (59.10%; 3250/423) than married participants (47.31%; 4,566/9,651). Participants who attained college education had a relatively high prevalence of 55.57% (7,043/12,673). The participants were classified into four groups in accordance with the Chinese criteria of body mass index (BMI) [30]: thin (BMI < 18.5), normal (18.5 ≤ BMI < 24), overweight (24 ≤ BMI < 28) and obese ones (BM ≥ 28). The prevalence of SHS was the highest among underweight participants (58.07%; 2,185/3,763). No significant differences were observed between rural and urban participants.

Personality traits of the participants

The standardized scores of five dimensions of personality traits were calculated, including extraversion, agreeableness, conscientiousness, neuroticism and openness. As shown in Fig. 3, the score of neuroticism of SHS participants was significantly higher than those in the healthy group, while the scores of extraversion, agreeableness, and conscientiousness were lower in the SHS ones. With regard to the score of openness, there was no significant difference between the SHS and healthy groups.

Perceived stress of the participants

As shown in Table 2, the score of PSS-4 among SHS men was 11.40 ± 2.12, which was significantly higher than the healthy men (9.83 ± 2.58). Similarly, among women, the PSS-4 score was significantly high for SHS participants. These results indicated that SHS participants suffered higher perceived stress than healthy ones.

Table 2
Stratified analysis of PSS-4 scores among men and women

Groups		n	PSS-4
Men	Health	4971	9.83 ± 2.58
	SHS	4870	11.40 ± 2.12*
Women	Health	5818	9.86 ± 2.52
	SHS	7238	11.40 ± 2.34*
Total	22897	10.67 ± 2.52	

PSS-4, Perceived Stress Scale-4 items; SHS, suboptimal health status; Data of continuous variables were expressed as mean ± standard deviation; *, P < 0.001 compared with healthy group

Correlation analyses

As listed in Table 3, three dimensions of personality traits (*i.e.*, extraversion, agreeableness, and conscientiousness) were negatively correlated with SHS, whereas neuroticism was positively correlated with SHS. Extraversion, agreeableness, conscientiousness and openness were negatively associated with perceived stress, while neuroticism was positively associated with stress. A significant positive relationship was also observed between perceived stress and SHS.

Table 3
Means, standard deviations, ranges, and inter-correlations of study variables

Variables	M	SD	Range	Skewness (SE)	Kurtosis (SE)	1	2	3	4	5	6	7
1.BFI-10-Ext	6.25	1.67	2–10	0.102(0.016)	0.112(0.032)	1						
2.BFI-10-Agr	6.98	1.48	2–10	0.035(0.016)	-0.122(0.032)	0.003	1					
3.BFI-10-Con	6.59	1.65	2–10	0.211(0.016)	-0.156(0.032)	0.189**	0.260**	1				
4.BFI-10-Neu	5.85	1.57	2–10	-0.093(0.016)	0.436(0.032)	-0.189**	-0.234**	-0.219**	1			
5.BFI-10-Ope	6.64	1.56	2–10	0.169(0.016)	0.002(0.032)	0.204**	0.078**	0.024**	-0.009	1		
6.PSS-4	10.67	2.52	4–20	-0.385(0.016)	0.422(0.032)	-0.226**	-0.268**	-0.348**	0.348**	-0.096**	1	
7.SHSQ-SF	11.60	7.52	0–36	0.619(0.016)	0.378(0.032)	-0.107**	-0.172**	-0.233**	0.253**	-0.008	0.345**	1

BFI-10-Agr, Big Five Inventory-10-Agreeableness; BFI-10-Com, Big Five Inventory-10- Conscientiousness; BFI-10-Ext, Big Five Inventory-10-Extraversion; BFI-10-Neu, Big Five Inventory-10-Neuroticism; BFI-10-Ope, Big Five Inventory-10-Openness; M, mean; PSS-4, Perceived Stress Scale-4 items; SD, standard deviation; SHSQ-SF, Short-Form Suboptimal Health Status Questionnaire; *, P < 0.05; **, P < 0.01 (two-tailed)

Mediation analyses of stress on personality traits and SHS

As shown in Table 4, extraversion had a direct effect on stress (β = -0.126), meanwhile stress had a direct effect on SHS (β = 0.250). Moreover, there was no significant direct effect of extraversion on SHS, suggesting that stress played a total mediation effect on the relationship between extraversion and SHS.

Table 4
SEM pathways of big five personality traits, stress and SHS

Model pathways		Crude coefficient	95%CI	*P*	Adjust coefficient	95%CI	*P*
Extraversion							
Direct effects	Ext → SHS	-0.011	[-0.023, 0.001]	0.068	-0.011	[-0.023, 0.001]	0.080
Indirect effects	Ext → Stress	-0.126	[-0.140, -0.113]	< 0.001	-0.126	[-0.140, -0.113]	< 0.001
	Stress → SHS	0.250	[0.237, 0.262]	< 0.001	0.252	[0.239, 0.266]	< 0.001
	Indirect effect/total effect	1			1		
Agreeableness							
Direct effects	Agr → SHS	-0.049	[-0.063, -0.037]	< 0.001	-0.052	[-0.065, -0.040]	< 0.001
Indirect effects	Agr → Stress	-0.147	[-0.160, -0.133]	< 0.001	-0.145	[-0.158, -0.131]	< 0.001
	Stress → SHS	0.250	[0.237, 0.262]	< 0.001	0.252	[0.239, 0.266]	< 0.001
	Indirect effect/total effect	0.429			0.413		
Conscientiousness							
Direct effects	Con → SHS	-0.103	[-0.117, -0.091]	< 0.001	-0.098	[-0.112, -0.084]	< 0.001
Indirect effects	Con → Stress	-0.233	[-0.246, -0.219]	< 0.001	-0.218	[-0.232, -0.204]	< 0.001
	Stress → SHS	0.250	[0.237, 0.262]	< 0.001	0.252	[0.239, 0.266]	< 0.001
	Indirect effect/total effect	0.361			0.359		
Neuroticism							
Direct effects	Neu → SHS	0.130	[0.117, 0.143]	< 0.001	0.123	[0.111, 0.136]	< 0.001
Indirect effects	Neu → Stress	0.239	[0.225, 0.253]	< 0.001	0.235	[0.222, 0.249]	< 0.001
	Stress → SHS	0.250	[0.237, 0.262]	< 0.001	0.252	[0.239, 0.266]	< 0.001
	Indirect effect/total effect	0.315			0.325		
Openness							
Direct effects	Ope → SHS	0.026	[0.015, 0.038]	< 0.001	0.014	[0.001, 0.026]	0.030
Indirect effects	Ope → Stress	-0.051	[-0.064, -0.037]	< 0.001	-0.056	[-0.069, -0.044]	< 0.001
	Stress → SHS	0.250	[0.237, 0.262]	< 0.001	0.252	[0.239, 0.266]	< 0.001
	Indirect effect/total effect	-			-		

Agr, Agreeableness; Con, Conscientiousness; CI, confidence interval; Ext, Extraversion; Neu, Neuroticism; Ope, Openness; SHS, suboptimal health status

Similarly, agreeableness had a direct effect on stress (β = -0.147), meanwhile stress had a direct effect on SHS (β = 0.250). And agreeableness had a significant direct effect on SHS (β = -0.049). Approximately 42.9% of the total effect of agreeableness on SHS was mediated by stress.

Furthermore, conscientiousness had a direct effect on SHS (β = -0.103), and the significant mediation effect of stress accounted for 36.1% of the total effects of conscientiousness on SHS.

For neuroticism, there was significant direct effect on SHS (β = 0.130), and the mediation analyses showed that 31.5% of the total effect of neuroticism on SHS was mediated by stress.

With regard to openness, it had a direct effect on SHS (β = 0.026), and the indirect effect of openness on SHS was significant (β = -0.013), which meant that stress alleviated or masked the direct impact of openness on SHS. That is, people high in openness were less likely to perceive stress, thereby reducing the risk of SHS. The detailed results are presented in Fig. 4.

Covariate analysis

After adjusting for the effects of sociodemographic covariates, the SEM confirmed the robustness of the adjusted mediation model. As shown in Table 4, five dimensions of personality traits had significant direct effects on stress, and stress had a significant influence on SHS. In addition, four dimensions of the personality traits had significant direct effects on SHS in the model of agreeableness (β = -0.052), conscientiousness (β = -0.098), neuroticism (β = 0.123), and openness (β = 0.014). Moreover, the personality traits had indirectly effects on SHS *via* perceived stress, contributing to 100.0%, 41.3%, 35.9%, and 32.5% of the total effect of extraversion, agreeableness, conscientiousness, and neuroticism on SHS, respectively.

The covariate analysis indicated that age group was one of the determinants of both stress and SHS. Compared with participants aged > 45 years, other age groups had a higher level of stress (β = 0.037 ~ 0.081, P < 0.001), and less SHS (β = -0.059~ -0.026, P < 0.001). In terms of BMI, normal BMI reduced the degree of stress (β = -0.020, P = 0.016) and had preventive effects from SHS (β = -0.045, P < 0.001). Moreover, divorced or widowed persons were found to be negatively related to higher level of both SHS (β = 0.018, P = 0.013) and stress (β = 0.015, P = 0.017) (Table 5).

Table 5
SEM results of covariates on the SHS model

Covariates	SHS			Stress		
	β	95%CI	*P*	β	95%CI	*P*
Gender (reference: Male)	0.029	[0.017, 0.042]	< 0.001	0.004	[-0.007, 0.016]	0.475
Age (reference: ≥45)						
≤ 24	-0.058	[-0.092, -0.023]	0.001	0.081	[0.052, 0.110]	< 0.001
25~	-0.059	[-0.076, -0.042]	< 0.001	0.064	[0.047, 0.081]	< 0.001
35~	-0.026	[-0.041, -0.013]	< 0.001	0.037	[0.023, 0.052]	< 0.001
BMI categories (reference: Thin)						
Normal	-0.045	[-0.064, -0.027]	< 0.001	-0.020	[-0.038, -0.004]	0.016
Overweight	-0.021	[-0.038, -0.004]	0.020	-0.016	[-0.032, 0.001]	0.062
Obese	0.001	[-0.013, 0.015]	0.860	-0.004	[-0.018, 0.010]	0.602
Educational level (reference: Middle school and below)						
Senior high school	0.040	[0.021, 0.056]	< 0.001	0.017	[-0.001, 0.033]	0.054
College	0.096	[0.077, 0.115]	< 0.001	-0.001	[-0.019, 0.018]	0.924
Master and above	0.062	[0.048, 0.077]	< 0.001	-0.022	[-0.035, -0.009]	0.001
Place of residence (reference: Rural)	-0.010	[-0.023, 0.003]	0.116	-0.033	[-0.044, -0.022]	< 0.001
Marital status (reference: Single)						
Married	-0.037	[-0.063, -0.011]	0.006	-0.017	[-0.039, 0.005]	0.133
Divorced/Widowed	0.018	[0.004, 0.032]	0.013	0.015	[0.003, 0.027]	0.017
Occupational status (reference: Retired)						
Student	-0.046	[-0.099, 0.007]	0.085	-0.040	[-0.084, 0.008]	0.090
Employed	-0.043	[-0.089, 0.003]	0.067	-0.005	[-0.046, 0.036]	0.813
Unemployment	-0.039	[-0.063, -0.015]	0.002	0.012	[-0.009, 0.034]	0.295

CI, confidence interval; SHS, suboptimal health status

Discussion

This nation-wide cross-sectional study illustrated that approximately 52.88% participants reported complaint of SHS among 22,897 Chinese people. Two dimensions of personality traits, *i.e.*, agreeableness and conscientiousness, might protect individuals against SHS. Persons with neuroticism trait had a higher likelihood of developing SHS. Moreover, perceived stress played a key role in mediating the relationship between personality traits and SHS.

Studies on SHS prevalence commonly presented inconsistent results due to the heterogeneities of respondents and SHS measurements. There are more than five SHS scales that have been reported in China investigations, such as the Suboptimal Health Status Questionnaire-25 (SHSQ-25), the Multidimensional Sub-health Questionnaire of Adolescents (MSQA), the Sub-health Measurement Scale Version 1.0 (SHMS V1.0), the Chinese Sub-health State Evaluation Scale (CSHES), and the Sub-Health Self-Rating Scale (SSS) [31–33]. Of these scales, SHSQ-25 is the most widely used worldwide, including Eastern Asian, African, Oceanian, and European.

Two studies conducted with SHSQ-25 scale reported a lower level of SHS in college students (20.98%) and a higher one in general adult population (69.46%) in China [34, 35]. In the current study, we observed a prevalence of 52.88% across 148 cities of China. It is need to be noted that we used a simplified form of SHSQ-25. This may introduce heterogeneity of methodology across these studies even though SHSQ-SF has been validated in both northern and southern populations in China. Moreover, this study included a large number of younger participants and college students, which might lead to an underestimation compared to the measurements within middle-aged and elderly population [35].

Psychological factors play a crucial role in the development of SHS, and psychological symptom is always one of the key dimensions of SHS measurement [10]. Studies have identified the impact of depression and anxiety on the health issues of college students [34]. Personality is also one of the important contributors to quality of life and health conditions [36]. With regard to the direct effects of personality traits on SHS, the current results suggested that participants with higher levels of agreeableness and conscientiousness are more likely to experience optimal health. This finding is consistent with a previous survey in a diverse sample, which found that agreeableness and conscientiousness were the best predictors of health behavior [37].

It has been shown that agreeableness is negatively related to risk-taking behavior [37]. Given that agreeableness has an inverse association with hostility [38], the finding was in line with earlier researches that linked hostility to negative health habits [37, 39]. Negative patterns of lifestyles increased the risk of somatic diseases among individuals with hostility trait, supporting that positive patterns of habits decrease the risk of SHS among persons with higher agreeableness. In addition, the personality of conscientiousness improves health status through healthy behavior management, *i.e.*, maintaining healthy behavior patterns, and avoiding the harmful ones [40].

Our results demonstrated that participants with personality of neuroticism were more likely to develop SHS, supporting the previous findings that emotional stability is a strong contributor to perceived health condition [36, 41]. Individuals with a tendency of neuroticism (*i.e.*, low emotional stability) experience more negative affections and poorer emotional functions [42], which lead to perceived unhealthy symptoms and adverse outcomes [36]. Furthermore, these persons tend to adaptive dysfunction when confronted with perceived stress [36], making them more vulnerable to poor health condition.

We did not find the direct effect of extraversion on SHS. Although some studies demonstrated a significant relationship between extraversion and quality of life in adult population [43], the others conducted in pediatric samples reported either non-significant or weak results [41, 44]. Persons with openness have a propensity to think and behave in nonconforming ways, which may create diversity in their response to health issues. Although the relationship between openness and perceived health condition has not been confirmed [45, 46], we observed that individuals with openness personality had a higher prevalence of SHS.

An individual's susceptibility to psychological and physical disorders associated with chronic stress exposure, *e.g.*, cardiovascular and infectious diseases, could be predicted by their reactivity to psychosocial stressor. Personality is one of important psychological factors associated with both stress resilience and health outcomes. An understanding of how personality traits influence responses to stress may shed light upon individual differences in susceptibility to chronic stress-linked diseases. Previous studies have suggested that personality traits can modulate responses to perceived stress due to the different effects of distinct traits on the separate components of stress response [47–49]. Stress exposure activates the production of hormonal, as well as cardiovascular and emotional responses [48]. Positive personality traits (*e.g.*, extraversion, agreeableness, conscientiousness, and openness) largely protect against hormonal responses to stress, whereas negative traits (*e.g.*, neuroticism) inversely predict cardiovascular responses [49]. In other words, individuals with high extraversion or openness may be more resilient to negative environmental stimuli and stress-related symptoms. For agreeableness and conscientiousness, the tendency to closely interpersonal and social relationships may protect against excessive stress responses. In addition, combined with the current finding that perceived stress can positively predict the occurrence of SHS, high level of neuroticism may identify individuals at elevated risk for chronic stress-related diseases.

Notably, we identified the mediating effect of perceived stress on the relationship between personality traits and SHS. The mature personality (*i.e.*, extraversion, agreeableness, conscientiousness, or openness) can function as an internal resource which helps people in dealing with various stressors and other psychological distress, thereby playing favorably into their health status. Conversely, the personality of neuroticism may expose people to poor stress adjustment and emotional functioning, thus adversely affecting health conditions.

It is understood that women are more likely to experience psychological distress and neuropsychiatric disorders [26, 50]. Our stratified analysis also revealed a higher level of SHS among women, indicating that women are more prone to both mental problems and SHS due to the differences in physiological and psychological characteristics [51]. Furthermore, the differences in lifestyles between men and women, as well as their pursuit of physical activities, are closely relevant to their mental and physical well-being [52, 53].

Regarding the effects of the covariates, our finding demonstrated that age was one of the important determinants of SHS and perceived stress, in which older participants experienced more SHS and less stress than the younger ones. Consistent with the research conducted within another Chinese resident sample [54], the key factor is a gradual decrease in physical fitness and energy in elderly people. In term of marriage status, being divorced or widowed was significant contributor to SHS and stress. This evidenced the findings that poor marital status was statistically associated with psychological distress and poor health status [55]. With regard to the BMI classifications, our study also showed that the risk of SHS and stress among normal participants is lower than that among thin participants. It has been shown that an underweight status is associated with psychiatric disorders and higher health risks[56, 57], which supports the speculation that reasonable eating habits contribute to alleviation of health issues.

Limitations

This study had several limitations that commonly exist in population-based cross-sectional survey. Firstly, we could not demonstrate the causal relationship between personality traits, stress, and SHS due to the lack of chronological evidence. Secondly, all the data were collected by self-reported questionnaires, which might lead to potential information bias. Thirdly, although the levels of stress and SHS were assessed by standardized questionnaires, these measurements were not equal to clinical diagnoses.

To the best of our knowledge, this study is the first investigation on the relationship between personality traits, perceived stress, and SHS among representative Chinese populations, by covering a broad age range and including different minorities and regions using data from a large-scale cross-sectional survey.

Conclusion and expert recommendations

Approximately 52.88% of participants experience SHS in China. Perceived stress plays a mediating effect on the relationship of personality traits on SHS. Personality traits and perceived stress can be employed as potential intervening targets to cope with health problems. From a PPPM/3PM perspective, early screening and targeted intervention for persons with neuroticism trait, as well as stress alleviation, might contribute to health improvement and chronic diseases prevention.

Predictive approach

Early screening of individuals at high-risk of SHS has been considered one of important approaches to improve health conditions in the advanced paradigm of PPPM/3PM [58]. The present study clarified the relationship between personality traits and SHS, and evaluated the mediating effect of perceived stress on the development of SHS that was attributed to personality traits.

Targeted prevention

As a subclinical stage in advance of NCDs, early detection of SHS is conducive to the timely prevention of chronic diseases. Our major findings that perceived stress plays a partial mediating role in the relationship between agreeableness, conscientiousness and neuroticism traits and SHS suggest sufficient approaches to preventing SHS among individuals with such personality traits, especially those with neuroticism trait.

Personalization of medicine services

Interventions should be tailored to one's unique risk profile. Early and personalized intervention can minimize the adverse outcomes of NCDs. For persons diagnosed with SHS, targeted intervention may reverse the disease progression since SHS is a reversable condition between optimal health and diseases. As individuals with SHS has no pathological syndromes, early and effective diagnosis always plays a crucial role, and contributes to application of personalized intervention and establishment of strategies from a PPPM/3PM perspective. This course of action will hopefully reduce delayed intervention, untargeted prevention, and ineffective treatment.

Paradigm shifts from reactive medicine to PPPM/3PM and moving beyond the state of the art

NCDs are usually treated after disease onset, which is a relatively delayed management. As SHS is a preclinical and reversible stage preceding the onset of NCDs, early identification of SHS among persons with high-risk personality traits opens a window in the targeted prevention and personalized treatment of NCDs from the viewpoint of PPPM/3PM [9]. In order to shift from reactive medicine to PPPM/3PM, exploring the determinants closely associated with SHS and developing new strategy models are urgently needed.

Abbreviations

Agr: Agreeableness; BFI-10: Big Five Inventory-10; BFI-10-Ext: Big Five Inventory-10-Extraversion; BFI-10-Agr: Big Five Inventory-10-Agreeableness; BFI-10-Com: Big Five Inventory-10-Conscientiousness; BFI-10-Neu: Big Five Inventory-10-Neuroticism; BFI-10-Ope: Big Five Inventory-10-Openness; BMI: body mass index; Con: Conscientiousness; CI: confidence interval; CVD: cardiovascular diseases; CFA: confirmatory factor analysis; CSHES: Chinese Sub-health State Evaluation Scale; Ext: Extraversion; M: mean; MSQA: Multidimensional Sub-health Questionnaire of Adolescents; Neu: Neuroticism; NCDs: non-communicable diseases; Ope: Openness; PPPM/3PM: predictive, preventive and personalized medicine; PSS-4: Perceived Stress Scale-4 items; SHS: suboptimal health status; SHSQ-SF, Short-Form Suboptimal Health Status Questionnaire;

SD: standard deviation; SEM: structural equation model; SHSQ-25: Suboptimal Health Status Questionnaire-25; SHMS V1.0: Sub-health Measurement Scale Version 1.0; SSS: Sub-Health Self-Rating Scale; T2DM: type 2 diabetes mellitus.

Declarations

Funding This work was supported by Natural Science Foundation of Shandong

Province (ZR2022MH082).

Competing interests The authors declare no competing interests.

Ethics approval The current study was approved by the Ethics Research Committee (JKWH-2022-02).

Consent to participate The study was conducted in accordance with the Declaration of Helsinki of the World Medical Association and written informed consent was obtained from all the participants.

Consent for publication All authors have given consent for publication.

Data availability The data are available from the corresponding authors on a reasonable request.

Code availability Not applicable.

Author contribution Haifeng Hou conceived the study and guided the development of research and the preparation of manuscripts. Qihua Guan, Hualei Dong, Zhihui Zhang, Zheng Guo, Zi Lin, and Hui Niu performed the material preparation and data collection. Qihua Guan, Hualei Dong and Zhihui Zhang researched data, performed the statistical analyses, and wrote the manuscript. Haifeng Hou provided critical expert advice or critical review of the current manuscript. All authors read and approved the final manuscript.

Acknowledgements We would like to thank the participants who participated in the study for their consent and involvement for this investigation.

References

1. Wang W, Russell A, Yan Y. Traditional Chinese medicine and new concepts of predictive, preventive and personalized medicine in diagnosis and treatment of suboptimal health. The EPMA journal. 2014;5(1):4.http://doi.org/10.1186/1878-5085-5-4.
2. Adua E, Memarian E, Russell A, Trbojević-Akmačić I, Gudelj I, Jurić J *,et al.* Utilization of N-glycosylation profiles as risk stratification biomarkers for suboptimal health status and metabolic syndrome in a Ghanaian population. Biomarkers in medicine. 2019;13(15):1273-1287.http://doi.org/10.2217/bmm-2019-0005.
3. Anto EO, Roberts P, Coall DA, Adua E, Turpin CA, Tawiah A *,et al.* Suboptimal health pregnant women are associated with increased oxidative stress and unbalanced pro- and antiangiogenic growth mediators: a cross-sectional study in a Ghanaian population. Free radical research. 2020;54(1):27-42.http://doi.org/10.1080/10715762.2019.1685668.
4. Wang Y, Liu X, Qiu J, Wang H, Liu D, Zhao Z *,et al.* Association between Ideal Cardiovascular Health Metrics and Suboptimal Health Status in Chinese Population. Scientific reports. 2017;7(1):14975.http://doi.org/10.1038/s41598-017-15101-5.
5. Liu Y, Wan C, Xi X. Measurement properties of the EQ-5D-5L in sub-health: evidence based on primary health care workers in China. Health and quality of life outcomes. 2023;21(1):22.http://doi.org/10.1186/s12955-023-02105-1.
6. Adua E, Roberts P, Wang W. Incorporation of suboptimal health status as a potential risk assessment for type II diabetes mellitus: a case-control study in a Ghanaian population. The EPMA journal. 2017;8(4):345-355.http://doi.org/10.1007/s13167-017-0119-1.
7. Ge S, Xu X, Zhang J, Hou H, Wang H, Liu D *,et al.* Suboptimal health status as an independent risk factor for type 2 diabetes mellitus in a community-based cohort: the China suboptimal health cohort study. EPMA J. 2019;10(1):65-72.http://doi.org/10.1007/s13167-019-0159-9.
8. Yan YX, Dong J, Liu YQ, Yang XH, Li M, Shia G *,et al.* Association of suboptimal health status and cardiovascular risk factors in urban Chinese workers. Journal of urban health : bulletin of the New York Academy of Medicine. 2012;89(2):329-338.http://doi.org/10.1007/s11524-011-9636-8.
9. Wang W, Yan Y. Suboptimal health: a new health dimension for translational medicine. Clinical and translational medicine. 2012;1(1):28.http://doi.org/10.1186/2001-1326-1-28.
10. Zhu J, Ying W, Zhang L, Peng G, Chen W, Anto EO *,et al.* Psychological symptoms in Chinese nurses may be associated with predisposition to chronic disease: a cross-sectional study of suboptimal health status. The EPMA journal. 2020;11(4):551-563.http://doi.org/10.1007/s13167-020-00225-y.

11. Friedman HS. Long-term relations of personality and health: dynamisms, mechanisms, tropisms. Journal of personality. 2000;68(6):1089-1107.http://doi.org/10.1111/1467-6494.00127.
12. Heine SJ, Buchtel EE. Personality: the universal and the culturally specific. Annual review of psychology. 2009;60:369-394.http://doi.org/10.1146/annurev.psych.60.110707.163655.
13. Sutin AR, Zonderman AB, Ferrucci L, Terracciano A. Personality traits and chronic disease: implications for adult personality development. The journals of gerontology Series B, Psychological sciences and social sciences. 2013;68(6):912-920.http://doi.org/10.1093/geronb/gbt036.
14. Yao Y, Xu Y, Zhao J, Ma Y, Su K, Yuan W *,et al.* Detection of Significant Association Between Variants in Cannabinoid Receptor 1 Gene (CNR1) and Personality in African-American Population. Frontiers in genetics. 2018;9:199.http://doi.org/10.3389/fgene.2018.00199.
15. Goodwin R, Engstrom G. Personality and the perception of health in the general population. Psychol Med. 2002;32(2):325-332.http://doi.org/10.1017/s0033291701005104.
16. Masthoff ED, Trompenaars FJ, Van Heck GL, Hodiamont PP, De Vries J. The relationship between dimensional personality models and quality of life in psychiatric outpatients. Psychiatry research. 2007;149(1-3):81-88.http://doi.org/10.1016/j.psychres.2006.01.004.
17. Poppe C, Crombez G, Hanoulle I, Vogelaers D, Petrovic M. Improving quality of life in patients with chronic kidney disease: influence of acceptance and personality. Nephrology, dialysis, transplantation : official publication of the European Dialysis and Transplant Association - European Renal Association. 2013;28(1):116-121.http://doi.org/10.1093/ndt/gfs151.
18. Ibrahim N, Teo SS, Che Din N, Abdul Gafor AH, Ismail R. The Role of Personality and Social Support in Health-Related Quality of Life in Chronic Kidney Disease Patients. PloS one. 2015;10(7):e0129015.http://doi.org/10.1371/journal.pone.0129015.
19. Rassart J, Luyckx K, Goossens E, Apers S, Klimstra TA, Moons P. Personality traits, quality of life and perceived health in adolescents with congenital heart disease. Psychology & health. 2013;28(3):319-335.http://doi.org/10.1080/08870446.2012.729836.
20. de la Fuente J, Paoloni P, Kauffman D, Yilmaz Soylu M, Sander P, Zapata L. Big Five, Self-Regulation, and Coping Strategies as Predictors of Achievement Emotions in Undergraduate Students. International journal of environmental research and public health. 2020;17(10).http://doi.org/10.3390/ijerph17103602.
21. Warrian KJ, Spaeth GL, Lankaranian D, Lopes JF, Steinmann WC. The effect of personality on measures of quality of life related to vision in glaucoma patients. British Journal of Ophthalmology. 2009;93(3):310-315.http://doi.org/10.1136/bjo.2008.139592.
22. Goodwin R, Engstrom G. Personality and the perception of health in the general population. Psychological Medicine. 2002;32(2):325-332.http://doi.org/10.1017/s0033291701005104.
23. Gao LF, Zhai SM, Xie HP, Liu QQ, Niu GF, Zhou ZK. Big five personality traits and problematic mobile phone use: A meta-analytic review. Current Psychology. 2022;41(5):3093-3110.http://doi.org/10.1007/s12144-020-00817-x.
24. Luo J, Zhang B, Cao M, Roberts BW. The Stressful Personality: A Meta-Analytical Review of the Relation Between Personality and Stress. Pers Soc Psychol Rev. 2023;27(2):128-194.http://doi.org/10.1177/10888683221104002.
25. Wu S, Xuan Z, Li F, Xiao W, Fu X, Jiang P *,et al.* Work-Recreation Balance, Health-Promoting Lifestyles and Suboptimal Health Status in Southern China: A Cross-Sectional Study. International journal of environmental research and public health. 2016;13(3).http://doi.org/10.3390/ijerph13030339.
26. Bi J, Huang Y, Xiao Y, Cheng J, Li F, Wang T *,et al.* Association of lifestyle factors and suboptimal health status: a cross-sectional study of Chinese students. BMJ Open. 2014;4(6):e005156.http://doi.org/10.1136/bmjopen-2014-005156.
27. Wang Y, Kaierdebieke A, Fan S, Zhang R, Huang M, Li H *,et al.* Study protocol: A cross-sectional study on psychology and behavior investigation of Chinese residents, PBICR. Psychosom Med Res. 2022;4(3):13–19.http://doi.org/10.53388/202219.
28. Rammstedt B, John OP. Measuring personality in one minute or less: A 10-item short version of the Big Five Inventory in English and German. Journal of Research in Personality. 2007;41(1):203-212.http://doi.org/10.1016/j.jrp.2006.02.001.
29. Vallejo MA, Vallejo-Slocker L, Fernández-Abascal EG, Mañanes G. Determining Factors for Stress Perception Assessed with the Perceived Stress Scale (PSS-4) in Spanish and Other European Samples. Frontiers in psychology. 2018;9:37.http://doi.org/10.3389/fpsyg.2018.00037.
30. Chen C, Lu FC. The guidelines for prevention and control of overweight and obesity in Chinese adults. Biomedical and environmental sciences : BES. 2004;17 Suppl:1-36
31. Yan YX, Liu YQ, Li M, Hu PF, Guo AM, Yang XH *,et al.* Development and evaluation of a questionnaire for measuring suboptimal health status in urban Chinese. J Epidemiol. 2009;19(6):333-341.http://doi.org/10.2188/jea.je20080086.
32. Cao H, Sun Y, Wan Y, Hao J, Tao F. Problematic Internet use in Chinese adolescents and its relation to psychosomatic symptoms and life satisfaction. BMC public health. 2011;11:802.http://doi.org/10.1186/1471-2458-11-802.
33. Miao J, Liu J, Wang Y, Zhang Y, Yuan H. Reliability and validity of SHMS v1.0 for suboptimal health status assessment of Tianjin residents and factors affecting sub-health: A cross-sectional study. Medicine (Baltimore).

2021;100(17):e25401.http://doi.org/10.1097/MD.0000000000025401.

34. Hou H, Feng X, Li Y, Meng Z, Guo D, Wang F *,et al.* Suboptimal health status and psychological symptoms among Chinese college students: a perspective of predictive, preventive and personalised health. EPMA J. 2018;9(4):367-377.http://doi.org/10.1007/s13167-018-0148-4.
35. Xu T, Zhu G, Han S. Prevalence of Suboptimal Health Status and the Relationships between Suboptimal Health Status and Lifestyle Factors among Chinese Adults Using a Multi-Level Generalized Estimating Equation Model. International journal of environmental research and public health. 2020;17(3).http://doi.org/10.3390/ijerph17030763.
36. Van De Ven MO, Engels RC. Quality of life of adolescents with asthma: the role of personality, coping strategies, and symptom reporting. J Psychosom Res. 2011;71(3):166-173.http://doi.org/10.1016/j.jpsychores.2011.03.002.
37. Goktan AJ, Weston SJ, Luo J, Graham EK, Mroczek DK. Personality traits and mental health care utilization: Longitudinal findings from the MIDUS. J Res Pers. 2022;99.http://doi.org/10.1016/j.jrp.2022.104260.
38. Zajenkowski M. Hostile and energetic: Anger is predicted by low agreeableness and high energetic arousal. PloS one. 2017;12(9):e0184919.http://doi.org/10.1371/journal.pone.0184919.
39. Turiano NA, Pitzer L, Armour C, Karlamangla A, Ryff CD, Mroczek DK. Personality trait level and change as predictors of health outcomes: findings from a national study of Americans (MIDUS). The journals of gerontology Series B, Psychological sciences and social sciences. 2012;67(1):4-12.http://doi.org/10.1093/geronb/gbr072.
40. Bogg T, Roberts BW. Conscientiousness and health-related behaviors: a meta-analysis of the leading behavioral contributors to mortality. Psychol Bull. 2004;130(6):887-919.http://doi.org/10.1037/0033-2909.130.6.887.
41. De Clercq B, De Fruyt F, Koot HM, Benoit Y. Quality of life in children surviving cancer: a personality and multi-informant perspective. Journal of pediatric psychology. 2004;29(8):579-590.http://doi.org/10.1093/jpepsy/jsh060.
42. Caspi A, Roberts BW, Shiner RL. Personality development: stability and change. Annual review of psychology. 2005;56:453-484.http://doi.org/10.1146/annurev.psych.55.090902.141913.
43. Wang L, Shi Z, Li H. Neuroticism, extraversion, emotion regulation, negative affect and positive affect: The mediating roles of reappraisal and suppression. Social Behavior and Personality. 2009;37(2):193-194
44. Vollrath M, Landolt MA. Personality predicts quality of life in pediatric patients with unintentional injuries: a 1-year follow-up study. Journal of pediatric psychology. 2005;30(6):481-491.http://doi.org/10.1093/jpepsy/jsi073.
45. Cai L, He J, Wu Y, Jia X. The relationship between big five personality and quality of life of people with disabilities: The mediating effect of social support. Frontiers in psychology. 2022;13:1061455.http://doi.org/10.3389/fpsyg.2022.1061455.
46. Crestani Calegaro V, Canova Mosele PH, Lorenzi Negretto B, Zatti C, Miralha da Cunha AB, Machado Freitas LH. The role of personality in posttraumatic stress disorder, trait resilience, and quality of life in people exposed to the Kiss nightclub fire. PloS one. 2019;14(7):e0220472.http://doi.org/10.1371/journal.pone.0220472.
47. Takahashi T, Ikeda K, Ishikawa M, Kitamura N, Tsukasaki T, Nakama D *,et al.* Anxiety, reactivity, and social stress-induced cortisol elevation in humans. Neuro endocrinology letters. 2005;26(4):351-354
48. Schommer NC, Hellhammer DH, Kirschbaum C. Dissociation between reactivity of the hypothalamus-pituitary-adrenal axis and the sympathetic-adrenal-medullary system to repeated psychosocial stress. Psychosomatic medicine. 2003;65(3):450-460.http://doi.org/10.1097/01.psy.0000035721.12441.17.
49. Chida Y, Hamer M. Chronic psychosocial factors and acute physiological responses to laboratory-induced stress in healthy populations: a quantitative review of 30 years of investigations. Psychol Bull. 2008;134(6):829-885.http://doi.org/10.1037/a0013342.
50. Romero-Acosta K, Canals J, Hernández-Martínez C, Penelo E, Zolog TC, Domènech-Llaberia E. Age and gender differences of somatic symptoms in children and adolescents*. Journal of mental health (Abingdon, England). 2013;22(1):33-41.http://doi.org/10.3109/09638237.2012.734655.
51. Hsu SH, Chen DR, Cheng Y, Su TC. Association of Psychosocial Work Hazards With Depression and Suboptimal Health in Executive Employees. Journal of occupational and environmental medicine. 2016;58(7):728-736.http://doi.org/10.1097/jom.0000000000000760.
52. Xu J, Wei Y. Social support as a moderator of the relationship between anxiety and depression: an empirical study with adult survivors of Wenchuan earthquake. PloS one. 2013;8(10):e79045.http://doi.org/10.1371/journal.pone.0079045.
53. Adams TB, Moore MT, Dye J. The relationship between physical activity and mental health in a national sample of college females. Women & health. 2007;45(1):69-85.http://doi.org/10.1300/J013v45n01_05.
54. Wang Y, Ge S, Yan Y, Wang A, Zhao Z, Yu X *,et al.* China suboptimal health cohort study: rationale, design and baseline characteristics. J Transl Med. 2016;14(1):291.http://doi.org/10.1186/s12967-016-1046-y.
55. Ji Z, Yan E. Psycho-Social Factors Associated with Intimacy Needs in Divorced and Widowed Older Chinese Women. International journal of environmental research and public health. 2022;19(19).http://doi.org/10.3390/ijerph191912360.

56. Mak KK, Tan SH. Underweight problems in Asian children and adolescents. European journal of pediatrics. 2012;171(5):779-785.http://doi.org/10.1007/s00431-012-1685-9.
57. Boddy LM, Hackett AF, Stratton G. The prevalence of underweight in 9-10-year-old schoolchildren in Liverpool: 1998-2006. Public health nutrition. 2009;12(7):953-956.http://doi.org/10.1017/s136898000800311x.
58. Gerner C, Costigliola V, Golubnitschaja O. MULTIOMIC PATTERNS IN BODY FLUIDS: TECHNOLOGICAL CHALLENGE WITH A GREAT POTENTIAL TO IMPLEMENT THE ADVANCED PARADIGM OF 3P MEDICINE. Mass spectrometry reviews. 2020;39(5-6):442-451.http://doi.org/10.1002/mas.21612.

Figures

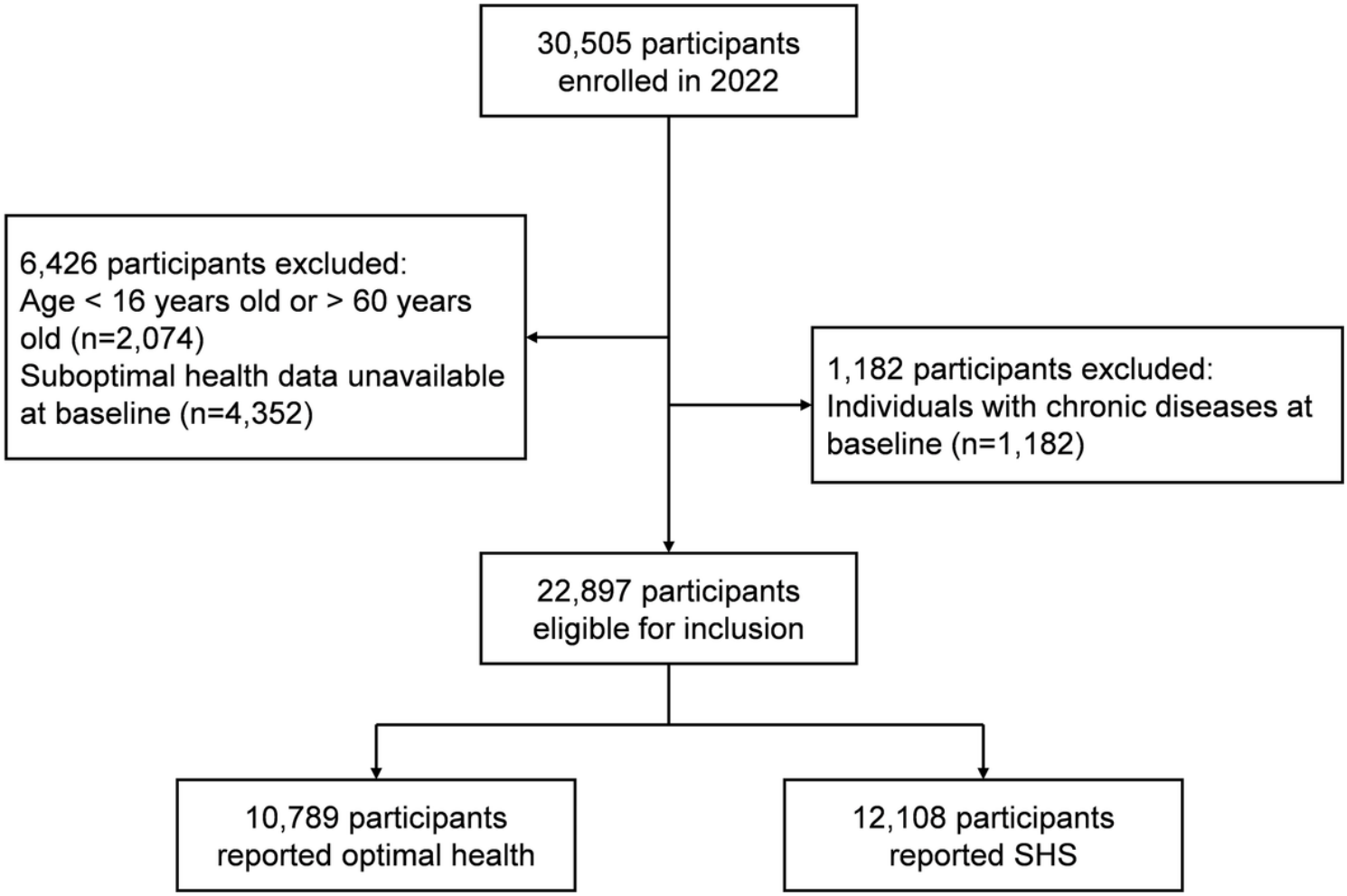

Figure 1

Flowchart of participants recruitments

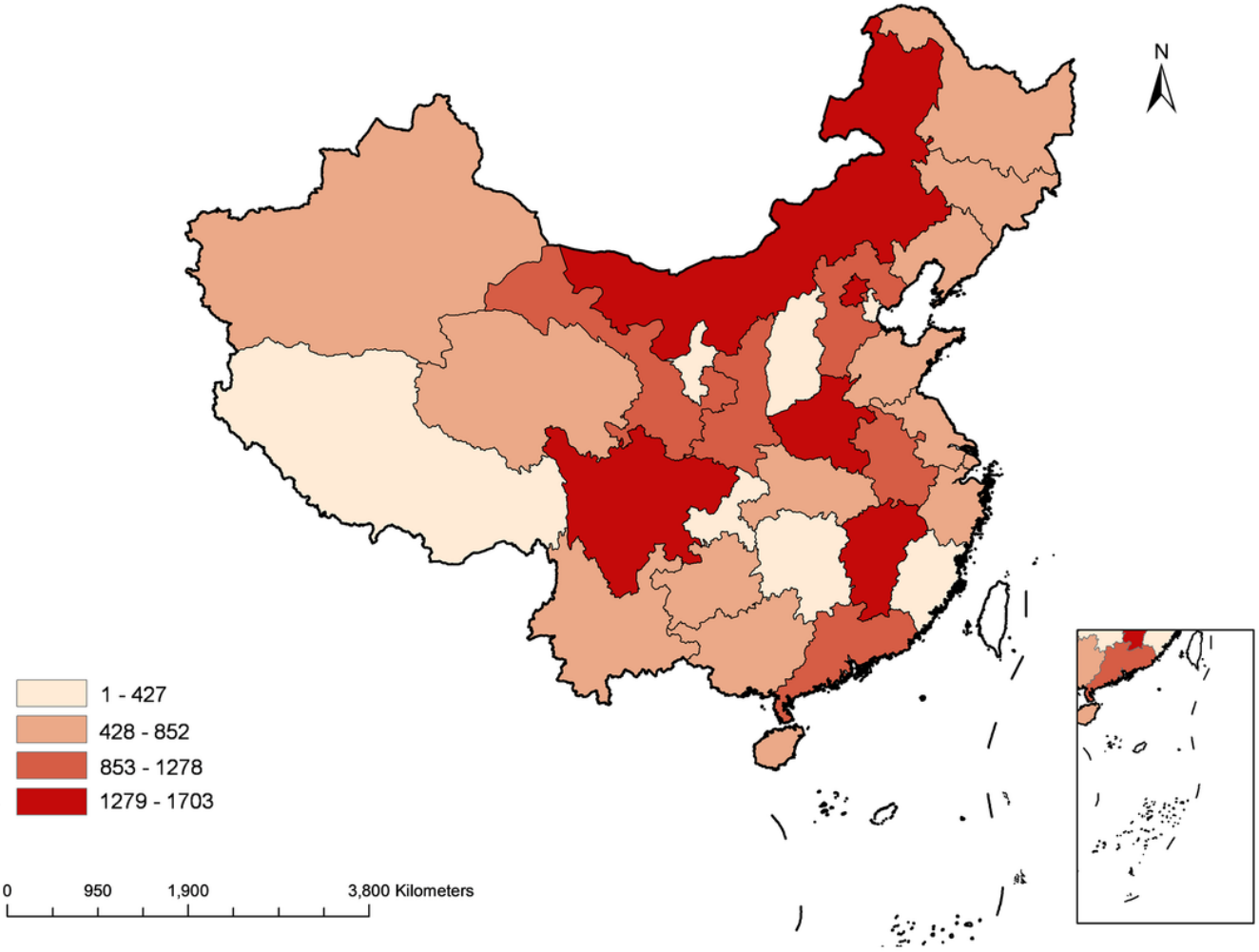

Figure 2

Regional distribution of study participants

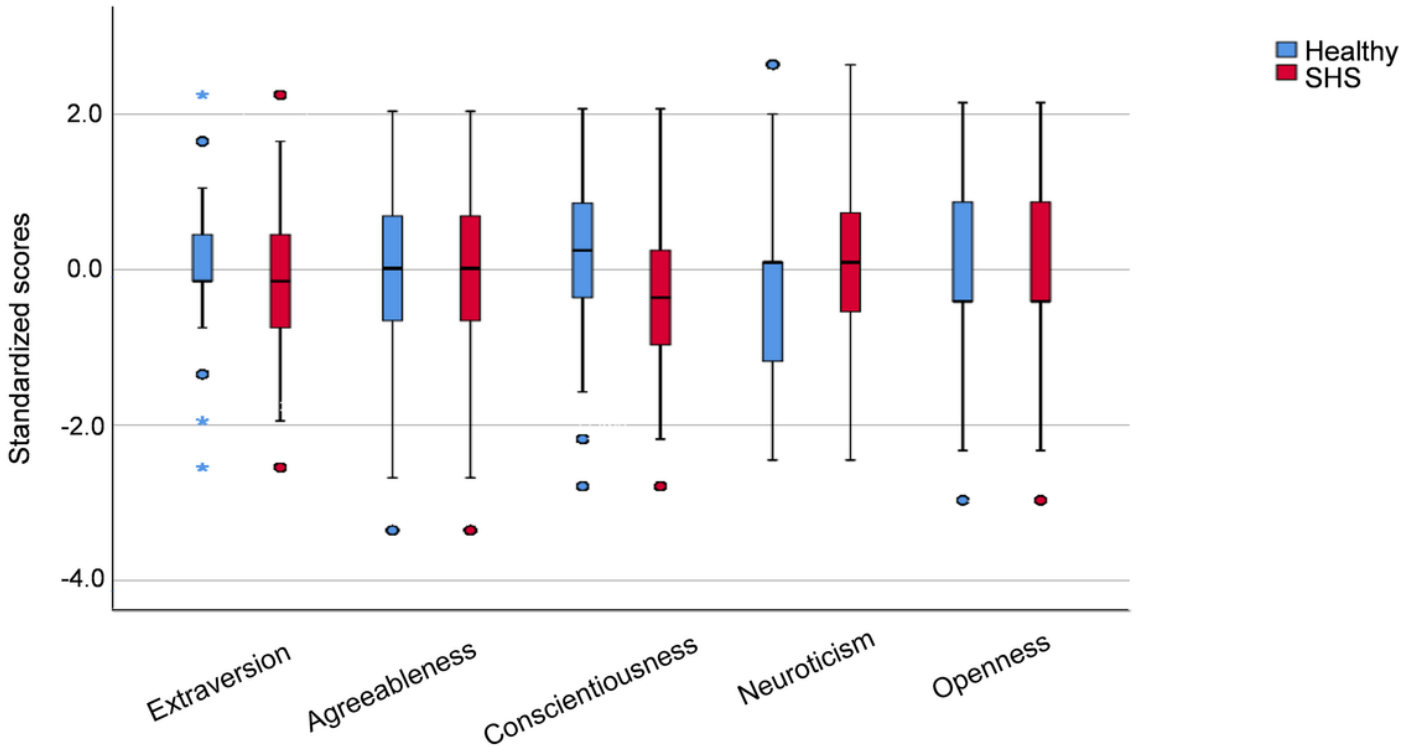

Figure 3

Box plot of BFI-10 scores of healthy and SHS participants

The data were expressed as minimum, P25, median, P75, and maximum. BFI-10, Big Five Inventory-10 items; SHS, Suboptimal Health Status

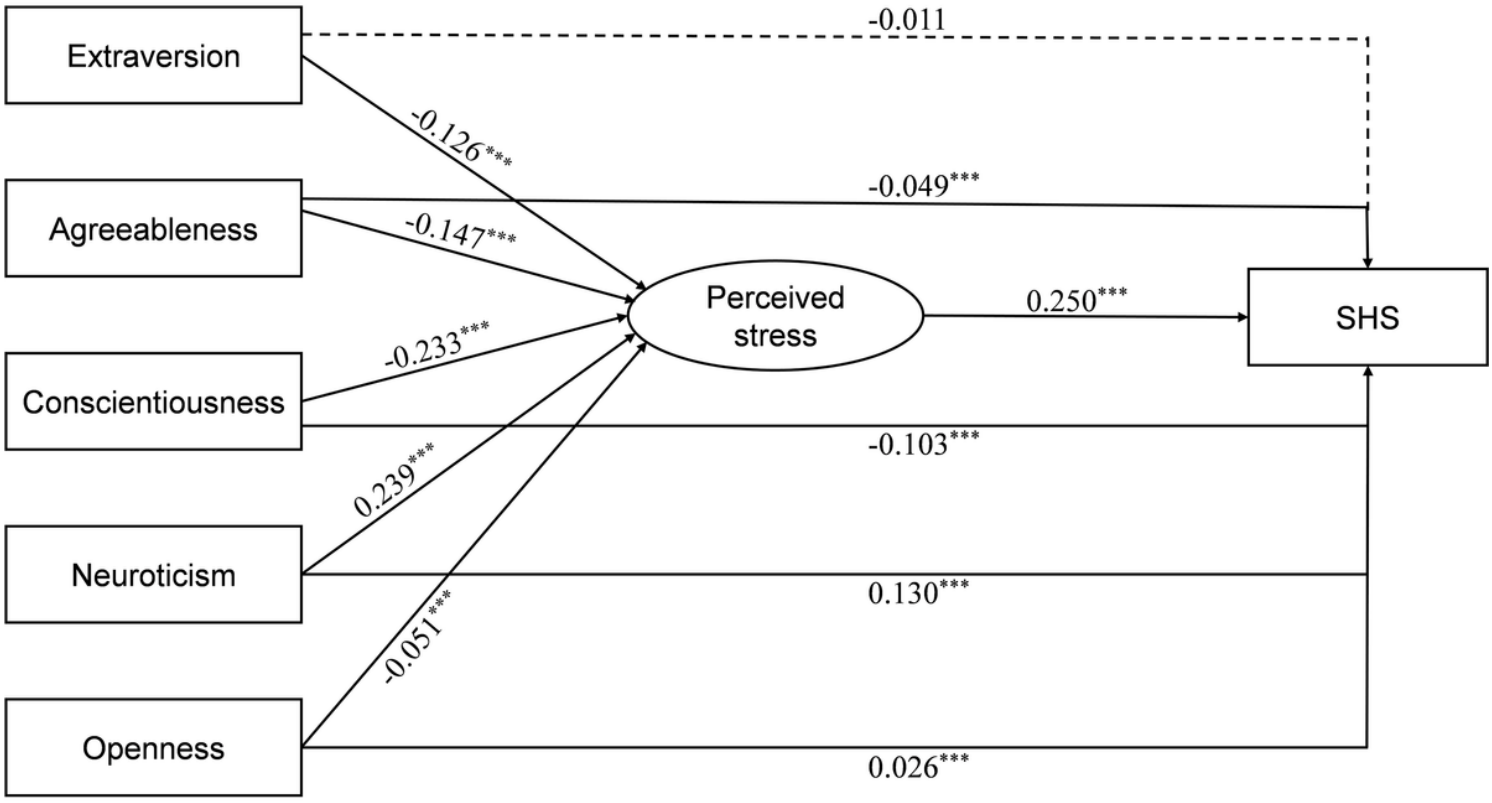

Figure 4

The mediating analysis of perceived stress on the relationship between personality traits and SHS

The effects of covariates (*i.e.,* gender, age, BMI, educational level, current residence, marital status, and occupational status) were controlled in the SEM analysis. All the coefficients in the figure were standardized. Model fit indices: RMSEA = 0.039, CFI = 0.991, TLI = 0.954. CFI, comparative fit index; RMSEA, root mean square error of approximation; SHS, Suboptimal Health Status; TLI, Tucker-Lewis index; $^{***}P<0.001$