Associations of environment and lifestyle factors with suboptimal health status: a population-based cross-sectional study in urban China

Yunlian Xue 1,2†, Zhuomin Huang 1,3†, Guihao Liu 2, Zicheng Zhang 1,3, Yefang Feng 1,3, Mengyao Xu 1,3, Lijie Jiang 1,3, Wenyuan Li 4* and Jun Xu 1*

Abstract

Introduction: Suboptimal health status (SHS), an intermediate state between chronic disease and health, is characterized by chronic fatigue, non-specific pain, headaches, dizziness, anxiety, depression, and functional system disorders with a high prevalence worldwide. Although some lifestyle factors (e.g. smoking, alcohol consumption, physical exercise) and environmental factors (e.g. air quality, noise, living conditions) have already been studied, few studies can comprehensively illustrate the associations of lifestyle and environment factors with general, physical, mental, and social SHS.

Methods: A cross-sectional study was conducted among 6750 urban residents aged 14 years or over in five random cities from September 2017 to September 2018 through face-to-face questionnaires. There were 5881 valid questionnaires with a response rate of 87%. A general linear model and structural equation model were developed to quantify the effects of lifestyle behaviors and environment factors on SHS.

Results: The detection rates of general, physical, mental, and social SHS were 66.7, 67.0, 65.5, and 70.0%, respectively. Good lifestyle behaviors and favorable environment factors positively affected SHS ($P < 0.001$). Lifestyle behaviors had the largest effect on physical SHS ($\beta = -0.418$), but the least on social SHS ($\beta = -0.274$). Environment factors had the largest effect on mental SHS ($\beta = 0.286$), but the least on physical SHS ($\beta = 0.225$).

Conclusions: Lifestyle behaviors and environment factors were important influencing factors of SHS. Physical SHS was more associated with lifestyle. Lifestyle and environment were similarly associated with mental and social SHS.

Keywords: Suboptimal health status, Lifestyle behaviors, Environment, Urban residents, China

© The Author(s). 2021. Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated in a credit line to the data.
Introduction
Health was defined by the World Health Organization (WHO) in 1946 as “a state of complete physical, mental, social well-being and not merely the absence of disease or infirmity” [1, 2]. Non-communicable diseases (NCDs), also known as chronic disease, are the opposite side of the spectrum, which is a great challenge to health. It is reported that NCDs accounted for an estimated 80% of total deaths, responsible for 70% of all disability-adjusted life-years (DALYs) in the early twentieth century [3]. The prevalence of NCDs steadily increases with urbanization and aging [4], and more than 88% of total deaths occurred from NCDs during 2019 in China [5]. A study found that NCDs accounted for 18 of the leading 20 causes of age-standardized years lived with disability worldwide [6]. The preclinical status of NCDs and their early detection have become major issues in the promotion of basic health services during health care reform [7].

Some studies have shown that suboptimal health status (SHS) may contribute to the progression or development of chronic disease [8, 9]. SHS is a state between chronic disease and health characterized by chronic fatigue, non-specific pain (e.g., back and chest pain), headaches, dizziness, anxiety, depression, and functional system disorders [8]. In recent decades, China’s urbanization has developed rapidly, with the proportion of the urban population increasing from 17.9% in 1978 to 58.5% in 2017 [10]. The rapid environmental changes accompanied by urbanization have led to the increased prevalence of major risk factors for SHS, including poor dietary habits, work stress, physical inactivity, poor breakfast eating habits, smoking, tobacco use, air pollution, and noise [2, 11, 12]. These risk factors can be categorized into two aspects: lifestyle behaviors and environment factors. Although previous studies have noted the interaction between lifestyle behaviors, environment factors and SHS [8, 9, 11, 13], the associative strengths between the factors with SHS have not been well elucidated.

SHS has a prevalence of higher than 65% in China [13–16] and has become a severe issue in many other countries [17, 18]. Moreover, the prevalence may be severely underestimated since many individuals are not aware that they are suffering from SHS. In an investigation of 6000 Chinese self-reported “healthy people,” 72.8% were in SHS [19] (see Appendix Table 6). Identification of the risk factors is essential to prevention of SHS, and would provide useful information for first-level prevention of NCDs.

This study aimed to examine the associations between lifestyle behaviors and environment factors with general, physical, mental, and social SHS in a large urban population.

Methods
Study design and population
We conducted a multi-city cross-sectional survey using a four-stage stratified sampling method from September 2017 to September 2018. In the first stage, we selected Guangdong Province (Southeast China), Harbin City, Heilongjiang Province (Northeast China), Sichuan Province (Northwest China), Tianjin City (East China), and Lanzhou City, Gansu Province (Southwest China) as representatives of different Chinese regions based on their geographic distribution, economic characteristics, and populational demographics. The second stage included sampling of 3 ~ 5 representative cities in each province based on demographic, economic, and geographic factors of which two cities were randomly selected in the next stage, respectively. In the final stage, 1 ~ 3 streets were randomly selected from each city and the residents were selected using sampling method, who were administrated questionnaires. To ensure representativeness, the participants on each street were stratified by male and female respondents and age (i.e., brackets of 14–24, 25–34, 35–44, 45–54, and 55+). As such, survey participants were representative of the level of SHS in their respective urban areas.

Oral informed consent was obtained from each participant prior to the data collection. This consent was deemed sufficient as participants volunteered participation and were told they still could withdraw. All data were kept strictly confidential. This experiment has obtained approval of the Ethics Committee of Nanfang Hospital (Approval number: NFEC-2019-196).

Survey instrument
This study used an SHS questionnaire to investigate urban Chinese residents. It contained two sections (i.e. both a self-designed and standardized questionnaire) [14]. The self-designed questionnaire asked for general demographic characteristics as well as information on lifestyle and environment. Here, the demographic characteristics included age, gender, and marital status and there were ten lifestyle variables (i.e., smoking, second-hand smoke, alcohol consumption, bad dietary habits, breakfast consumption, sun exposure, physical exercise, early bedtime (before 11 pm), sleep duration, and surfing the internet), and eight environmental variables (i.e., air quality, noise, housing conditions, living conditions, neighborhood harmony, fitness facilities, and supporting facilities). All variables were reported themselves in recent 3 months. The standardized components were based upon the Sub-Health Measurement Scale V1.0 (SHMS V1.0), which were designed by our research group to assess participant health status [20]. Uniform instructions were provided by trained investigators. Each participant was asked to complete the questionnaire in approximately 25 min.
SHS assessment
Health-status assessments were performed in accordance with the SHMS V1.0. Testing procedures revealed that it had high reliability and validity (Cronbach’s α and split-half reliability coefficients of 0.917 and 0.831, respectively) [20]. The SHMS V1.0 consists of 39 items in total. Respondents were asked to answer each of these items according to a 5-point scale (1 to 5, from very bad to very good). The SHMS V1.0 was used to assess general SHS (GS) based on three symptom dimensions, including physical SHS (PS), mental SHS (MS), and social SHS (SS). Of the 39 items, Nos. 4–12, 15, 20–25, 28, and 38–39 were reverse scored (six plus the original score). The original subscale score was the sum of all items: higher scores indicated better health status. We calculated and analyzed transformed scores to further understand and compare the data. Transformed scores were determined using the formula: (original score - theoretically lowest score) / (theoretically highest score - theoretically lowest score) × 100. Following our previous study, SHS prevalence was calculated based on transformed scores [21].

Statistical analysis
Considering that difference provinces may have different rate of sub-health, the generalized linear mixed models (GLMM) were established to analyze the group effect of sampling areas. The intra-class correlation coefficient (ICC) close to 0 and 95% confidence interval (95%CI) indicated no significant group effect and general regression model rather than multilevel model, suggesting that the GLMM model could be used in the association analysis. A general linear model was used to analyze the association of lifestyles (environmental factors) and SHS as adjusted by demographic characteristics and environment factors (lifestyles). Furthermore, a path model of latent variables was constructed based on a hypothesized relationship between items. Structural equation modeling (SEM) was then used to analyze the complexity of associations between lifestyle factors, environment factors, and SHS to estimate model fitness and analyze the direct and indirect effects of the multiple factors used in the hypothesized model [22]. Model fitness was assessed using the five indices commonly applied in SEM analyses (i.e., the relative X² (CMIN/DF), root-mean-square error of approximation (RMSEA), comparative fit index (CFI), goodness-of-fit index (GFI), and adjusted goodness-of-fit index (AGFI)) [23]. The bootstrapping method [22] of repeat sampling (i.e., 2000 times) was applied to verify statistical significance and calculate confidence intervals for the direct, indirect, and total effects ($P < 0.05$). All statistical analyses were conducted using (SPSS Statistics version 20.0, SPSS Inc., Chicago, IL). Two-tailed $p$-values $< 0.05$ were considered statistically significant.

Results

Participant demographic characteristics
This study surveyed 6750 urban Chinese residents aged 14 year old or more who had lived in an area for the preceding over 6 months. A total of 807 participants who had become ill during 1 month of the study period were excluded. As such, 5943 respondents were either healthy or SHS for at least a period of 1 month prior to the study. However, 62 of these surveys had missing values for lifestyle, environment, and/or SHS items, and were thus excluded. Therefore, 5881 urban residents were finally included in the current study (a valid response rate of 87.13%).

Table 1 presents overall baseline, lifestyle, and environmental characteristics. The participants included 2817 males and 3064 females with a mean age of 40.27 ± 15.69 years. Most participants were married (64.50%). Furthermore, 66.7% were in GS, 67.0% were in PS, 65.5% were in MS, and 70.0% were in SS.

Comparison of SHS for different lifestyle and environment factors
The mean standard deviation (SD) transformed scores for GS, PS, MS, and SS were 67.23 (12.03), 71.08 (12.70), 67.04 (14.63), 61.47 (15.65), respectively. The GLMM model analysis found that the group effect of provinces investigated was insignificant in the analysis of overall sub-health (ICC = 0.019, 95%CI: −0.018 - 0.057), physical sub-health (ICC = 0.028, 95%CI: −0.024 - 0.08), psychological sub-health (ICC = 0.011, 95%CI: −0.011 - 0.033) and social sub-health (ICC = 0.016, 95%CI: −0.017 - 0.048). So, the general linear model could be an appropriate measure of the association between lifestyle and environment factors with SHS.

Association between each lifestyle factor and SHS was adjusted by other lifestyle behaviors, demographic characteristics, and environment factors (Table 2). Participants who never smoked, had good dietary habits, consumed breakfast daily, did daily physical exercise, and slept 7–9 h per night had the highest GS, PS, MS, and SS transformed scores. Participants who were not exposed to second-hand smoke and never consumed alcohol had the highest GS, PS, and MS transformed scores. Participants with sufficient sleeping (bedtimes before 11 p.m.) had the highest GS and PS transformed scores. Sun exposure was only associated with PS; the highest PS scores were found in the people with 14 h or more of sun exposure each week. Surfing the internet was only associated with MS; those who surfed less than 3 hours a day had the highest scores.

Table 3 shows the effects of environmental factors after adjusting other environment factors, demographic characteristics, and lifestyle behaviors. Pleasant housing, harmonious neighborhoods, and convenient living conditions were positively associated with GS, PS,
Table 1  Frequency distribution of participant demographic characteristics (n = 5881)

| Characteristic | N   | GS mean (SD) | PS mean (SD) | MS mean (SD) | SS mean (SD) |
|----------------|-----|--------------|--------------|--------------|--------------|
| Gender         |     |              |              |              |              |
| Male           | 2817 (47.9) | 71.24 (12.65) | 68.13 (14.6) | 61.39 (16.03) | 67.64 (12.11) |
| Female         | 3064 (52.1) | 70.93 (12.75) | 66.05 (14.58) | 61.56 (15.3) | 66.85 (11.95) |
| Age            |     |              |              |              |              |
| 14–24          | 1129 (19.2) | 72.65 (12.19) | 65.01 (13.87) | 60.85 (15.82) | 72.65 (12.19) |
| 25–34          | 1167 (19.84) | 72.21 (12.76) | 65.97 (14.93) | 60.92 (15.61) | 72.21 (12.76) |
| 35–44          | 1345 (22.87) | 71.28 (12.96) | 67.3 (14.61) | 61.48 (15.22) | 71.28 (12.96) |
| 45–54          | 1120 (19.04) | 70.05 (12.08) | 68.56 (14.32) | 62.57 (15.9) | 70.05 (12.08) |
| ≥ 55           | 1120 (19.04) | 69.54 (12.92) | 69 (1504) | 61.53 (15.69) | 69.54 (12.92) |
| Marital status |     |              |              |              |              |
| Unmarried      | 1673 (28.45) | 72.25 (12.31) | 64.96 (14.31) | 60.51 (15.64) | 66.73 (11.64) |
| Married        | 3793 (64.9) | 71.03 (12.69) | 68.42 (14.51) | 62.16 (15.38) | 67.85 (11.99) |
| Divorced       | 200 (3.4) | 66.79 (13.15) | 62.7 (14.4) | 58.57 (18.02) | 63.28 (13.11) |
| Widowed        | 183 (3.11) | 66.84 (13.75) | 63.24 (16.18) | 60.17 (17.38) | 63.89 (13.32) |
| Information    |     |              |              |              |              |
| missing        | 32 (0.54) | 67.24 (13.96) | 61.33 (14.22) | 56.34 (16.91) | 62.41 (12.54) |

Note: GS general suboptimal health status, PS physical suboptimal health status, MS mental suboptimal health status, SS social suboptimal health status
| Variables                        | N      | GS mean (SD) | GS P value | PS mean (SD) | PS P value | MS mean (SD) | MS P value | SS mean (SD) | SS P value |
|---------------------------------|--------|--------------|------------|--------------|------------|--------------|------------|--------------|------------|
| **Smoking**                     |        |              |            |              |            |              |            |              |            |
| Never                           | 4079   | 67.67 (11.80)| < 0.001    | 71.70 (12.50)| < 0.001    | 67.15 (14.55)| 0.001      | 62.10 (15.26)| < 0.001    |
| Quit                            | 615    | 64.79 (13.06)|            | 68.37 (13.57)|            | 65.37 (15.11)|            | 58.44 (17.40)|            |
| Yes                             | 1187   | 66.95 (12.12)|            | 70.35 (12.70)|            | 67.53 (14.60)|            | 60.90 (15.86)|            |
| **Second-hand smoking influence**|        |              |            |              |            |              |            |              |            |
| None                            | 1150   | 68.95 (12.73)| < 0.001    | 72.94 (12.99)| < 0.001    | 68.97 (15.61)| 0.001      | 62.72 (16.88)| 0.376      |
| Little                          | 1804   | 67.54 (12.03)|            | 71.68 (12.72)|            | 67.31 (14.29)|            | 61.41 (15.68)|            |
| Some                            | 1702   | 66.60 (11.21)|            | 70.31 (12.32)|            | 66.55 (13.62)|            | 60.92 (14.51)|            |
| Much                            | 1225   | 66.00 (12.25)|            | 69.52 (12.65)|            | 65.53 (15.3)|            | 61.17 (15.90)|            |
| **Alcohol consumption**         |        |              |            |              |            |              |            |              |            |
| Never                           | 2166   | 68.41 (12.26)| < 0.001    | 72.24 (13.14)| < 0.001    | 68.29 (14.81)| < 0.001    | 62.59 (15.92)| 0.177      |
| Occasional                      | 3107   | 66.86 (11.56)|            | 70.87 (12.02)|            | 66.51 (14.22)|            | 61.09 (15.13)|            |
| A little /day                   | 427    | 65.79 (13.10)|            | 69.01 (13.72)|            | 66.32 (15.80)|            | 60.08 (16.64)|            |
| Some /day                       | 106    | 65.13 (11.48)|            | 67.94 (13.05)|            | 65.27 (13.62)|            | 60.59 (14.84)|            |
| Much /day                       | 75     | 59.47 (14.03)|            | 62.57 (15.03)|            | 59.64 (16.30)|            | 54.41 (21.06)|            |
| **Bad dietary habits**          |        |              |            |              |            |              |            |              |            |
| No                              | 3396   | 69.93 (11.63)| < 0.001    | 73.33 (12.54)| < 0.001    | 70.23 (14.21)| < 0.001    | 64.23 (14.86)| < 0.001    |
| Yes                             | 2485   | 63.53 (11.59)|            | 68.00 (12.27)|            | 62.68 (14.06)|            | 57.72 (15.93)|            |
| **Breakfast consumption (days/week)** |        |              |            |              |            |              |            |              |            |
| Everyday                        | 2720   | 69.91 (11.75)| < 0.001    | 73.06 (12.76)| < 0.001    | 70.19 (14.53)| < 0.001    | 64.63 (14.78)| < 0.001    |
| 5–6                             | 1562   | 67.08 (11.39)|            | 71.15 (11.94)|            | 66.41 (14.11)|            | 61.66 (14.72)|            |
| 3–4                             | 848    | 62.97 (11.13)|            | 68.08 (12.05)|            | 61.93 (13.08)|            | 56.43 (15.45)|            |
| 1–2                             | 609    | 62.69 (12.07)|            | 67.04 (12.62)|            | 62.75 (14.21)|            | 55.87 (16.81)|            |
| Never                           | 142    | 62.16 (14.29)|            | 67.58 (15.47)|            | 62.54 (17.10)|            | 53.23 (20.14)|            |
| **Sunshine (hours/week)**       |        |              |            |              |            |              |            |              |            |
| ≥ 14                            | 476    | 68.96 (12.57)| 0.071      | 72.22 (13.32)| 0.008      | 68.71 (15.10)| 0.170      | 64.23 (15.97)| 0.504      |
| < 14                            | 874    | 69.41 (12.12)|            | 73.20 (13.04)|            | 69.58 (14.20)|            | 63.30 (15.74)|            |
| < 7                             | 1695   | 67.26 (12.14)|            | 71.11 (12.88)|            | 67.18 (14.69)|            | 61.37 (15.31)|            |
| < 3                             | 1578   | 66.84 (11.84)|            | 70.80 (12.09)|            | 66.64 (14.47)|            | 60.93 (15.96)|            |
| < 1                             | 1258   | 65.49 (11.54)|            | 69.50 (12.50)|            | 64.96 (14.53)|            | 59.98 (15.32)|            |
| Variables                      | N  | GS mean (SD) | P value | GS mean (SD) | P value | GS mean (SD) | P value | GS mean (SD) | P value |
|-------------------------------|----|--------------|---------|--------------|---------|--------------|---------|--------------|---------|
| Physical exercise (days/week)|    |              |         |              |         |              |         |              |         |
| Everyday                      | 630| 72.14 (11.89)| < 0.001| 74.46 (12.84)| < 0.001| 73.24 (14.82)| < 0.001| 67.07 (15.12)| < 0.001 |
| 5–6                           | 613| 68.96 (12.27)|         | 71.93 (13.02)|         | 68.74 (14.89)|         | 64.63 (15.28)|         |
| 3–4                           | 1412| 67.67 (12.71)|         | 71.57 (13.24)|         | 67.64 (14.63)|         | 61.62 (16.82)|         |
| 1–2                           | 2375| 66.24 (11.17)|         | 70.57 (11.82)|         | 65.60 (14.03)|         | 60.36 (14.57)|         |
| Never                         | 851 | 64.36 (11.82)|         | 68.58 (13.21)|         | 64.25 (14.43)|         | 57.92 (15.78)|         |
| Bedtime before 11 pm (days/week)| | 0.019 |         | 0.003 |         | 0.146 |         | 0.388 |
| Everyday                      | 1119| 70.05 (12.09)|         | 73.00 (13.41)|         | 70.84 (14.86)|         | 64.43 (15.44)|         |
| 5–6                           | 1007| 68.35 (12.10)|         | 71.61 (12.73)|         | 68.44 (14.51)|         | 63.17 (14.79)|         |
| 3–4                           | 1236| 66.23 (12.38)|         | 70.11 (12.87)|         | 65.98 (14.54)|         | 60.52 (16.01)|         |
| 1–2                           | 1549| 66.1 (11.30) |         | 70.48 (11.97)|         | 65.56 (13.79)|         | 59.98 (15.51)|         |
| Never                         | 970 | 65.87 (11.96)|         | 70.52 (12.49)|         | 64.92 (14.95)|         | 59.90 (15.92)|         |
| Sleep duration (hours)        |    |              | < 0.001|              | < 0.001|              | < 0.001|              | < 0.001 |
| ≥ 9                           | 503 | 67.91 (12.95)|         | 71.48 (13.65)|         | 68.26 (15.34)|         | 61.88 (16.59)|         |
| < 9                           | 3792| 68.51 (11.63)|         | 72.57 (12.30)|         | 68.18 (14.41)|         | 62.64 (14.86)|         |
| < 7                           | 1402| 64.85 (11.67)|         | 68.10 (12.40)|         | 64.82 (14.23)|         | 59.85 (15.96)|         |
| < 5                           | 145 | 56.75 (13.13)|         | 62.18 (12.60)|         | 56.71 (14.61)|         | 48.37 (18.90)|         |
| < 3                           | 39  | 57.77 (11.65)|         | 61.77 (13.69)|         | 59.19 (14.40)|         | 49.64 (21.62)|         |
| Surfing the internet (hours)  |    |              | 0.062  |              | 0.154  |              | < 0.001|              | 0.983 |
| < 3                           | 3019| 67.78 (12.60)|         | 71.09 (13.24)|         | 68.39 (15.00)|         | 61.83 (16.37)|         |
| < 5                           | 1739| 67.06 (11.40)|         | 71.17 (12.07)|         | 66.51 (14.00)|         | 61.42 (14.75)|         |
| < 7                           | 720 | 66.49 (10.86)|         | 71.46 (11.59)|         | 64.66 (13.94)|         | 61.18 (14.46)|         |
| ≥ 7                           | 403 | 65.07 (12.05)|         | 69.91 (13.10)|         | 63.53 (14.39)|         | 59.59 (15.91)|         |

Note: GS general suboptimal health status, PS physical suboptimal health status, MS mental suboptimal health status, SS social suboptimal health status

** P value is statistically significant, P<0.01
Table 3 Comparison of SHS with different living environmental factors (mean (SD))

| Variables            | N (%)  | GS mean (SD) | PS mean (SD) | MS mean (SD) | SS mean (SD) | P value |
|----------------------|--------|--------------|--------------|--------------|--------------|---------|
| Greenery             | 0.002  |              |              |              |              |         |
| bad                  | 3105   | 65.65 (11.58)| 69.99 (12.44)| 65.25 (14.17)| 59.42 (15.10)| < 0.001 |
| good                 | 2776   | 68.99 (12.28)| 72.30 (12.88)| 69.04 (14.87)| 63.77 (15.94)|         |
| Air                  | 0.002  |              |              |              |              |         |
| bad                  | 2977   | 65.72 (11.47)| 69.86 (12.24)| 65.21 (14.35)| 59.99 (15.32)| 0.274   |
| fresh                | 2904   | 68.76 (12.39)| 72.34 (13.04)| 68.92 (14.67)| 63.00 (15.85)|         |
| Noiseless            | 0.788  |              |              |              |              |         |
| no                   | 4019   | 66.53 (12.08)| 70.40 (12.69)| 66.35 (14.83)| 60.75 (15.82)| 0.905   |
| yes                  | 1862   | 68.72 (11.79)| 72.54 (12.61)| 68.53 (14.07)| 63.03 (15.19)|         |
| Pleasant housing     | < 0.001|              |              |              |              |         |
| no                   | 824    | 63.54 (11.55)| 68.55 (12.47)| 62.34 (14.12)| 57.36 (15.46)| 0.003   |
| yes                  | 5057   | 67.83 (12.00)| 71.49 (12.69)| 67.81 (14.57)| 62.15 (15.58)|         |
| Spacious rooms       | 0.003  |              |              |              |              |         |
| yes                  | 663    | 63.60 (10.82)| 68.83 (11.92)| 61.61 (13.48)| 58.13 (15.11)| 0.186   |
| no                   | 5218   | 67.69 (12.10)| 71.37 (12.77)| 67.73 (14.62)| 61.90 (15.67)|         |
| Neighbor harmony     | < 0.001|              |              |              |              |         |
| no                   | 3351   | 65.47 (11.67)| 69.76 (12.57)| 65.02 (14.19)| 59.40 (15.50)| < 0.001 |
| yes                  | 2530   | 69.55 (12.11)| 72.84 (12.67)| 69.72 (14.77)| 64.22 (15.44)|         |
| Fitness facility     | 0.001  |              |              |              |              |         |
| few                  | 4766   | 66.40 (11.66)| 70.44 (12.41)| 66.15 (14.31)| 60.46 (15.42)| 0.001   |
| many                 | 1115   | 70.74 (12.92)| 73.81 (13.53)| 70.86 (15.34)| 65.80 (15.90)|         |
| Living convenience   | < 0.001|              |              |              |              |         |
| no                   | 3832   | 65.59 (11.91)| 69.68 (12.62)| 65.41 (14.53)| 59.45 (15.68)| < 0.001 |
| yes                  | 2049   | 70.29 (11.66)| 73.70 (12.44)| 70.09 (14.32)| 65.25 (14.90)|         |

Note: GS general suboptimal health status, PS physical suboptimal health status, MS mental suboptimal health status, SS social suboptimal health status
MS, and SS. Urban green space was positively associated with GS and SS. We also observed positive associations between fresh air and GS, PS, and MS. The presence of many fitness facilities was positively associated with GS and MS. There were no significant associations between noise and SHS. However, people with spacious homes had lower GS and MS scores.

**SEM analysis of lifestyle, environment, and SHS**

The total associations of lifestyle behaviors and environment with SHS were analyzed through SEM (Fig. 1). Although noiseless areas were not independently associated with SHS, the model was not deemed fit without an environmental noise component. The SEM thus included a “noiseless” variable. Except for the CMIN/DF, CFI, and AGFI of Model 1 and the CMIN/DF of Model 2, Table 4 presents information about the fitness measurements for all four models. The associations of lifestyle and environment factors with SHS are listed in Table 5. The data demonstrated that unhealthy lifestyle had significantly negative effects on GS, PS, MS, and SS, while good environment factors had a positive impact ($P < 0.001$). Lifestyle had the largest effect on PS ($\beta = -0.418$) and the least effect on SS ($\beta = -0.274$). On the other hand, environment factors had the largest effect on MS ($\beta = 0.286$) and the least effect on PS ($\beta = 0.225$). As the influencing effects were standardized, GS had a larger association with lifestyle ($\beta = -0.371$), but less with environment ($\beta = -0.282$); physical health was more associated with lifestyle ($\beta = -0.418$), but less associated with environment ($\beta = -0.225$). The associations of lifestyle behaviors and environment were similar for MS and identical for SS.

**Discussion**

This cross-sectional study of nationally representative urban Chinese residents found that lifestyle behaviors and environment factors were significantly associated with SHS. The associations of lifestyle behaviors with GS and PS were larger than those of environment factors. The associations of lifestyle behaviors and environment factors with MS and SS were almost identical.

To the best of our knowledge, our work was the first study on the associations of lifestyle behaviors and environment factors with SHS. The findings in this study were generally in line with those of previous studies on the relationship between lifestyle and PS [24, 25]. Innovative findings in this study were the significant associations of environment factors with MS and SS. However, the association between environment factors and mental health has been elucidated before.

This study used the 39-item SHMS V.1.0 questionnaire to analyze SHS, which includes physical, mental, and social dimensions. Our previous research indicated that SHMS V.1.0 had good internal consistency among southern Chinese medical staff members [21] and urban residents of

![Fig. 1 Structural equation model involving lifestyle, environment, and SHS (A = GS, B = PS, C = MS, and D = SS)](image-url)
three districts in China [26]. The detection rate of GS in Chinese urban residents was 66.7%, slightly higher than in southern China (65.1%) [16] and Tianjin (66.37%) [17].

This study found that bad lifestyle habits such as smoking, alcohol consumption, second-hand smoke exposure, poor dietary habits, and surfing the internet correlated to low SHS scores. On the other hand, healthy lifestyle habits such as breakfast eating habits, adequate sun exposure and exercise, and sufficient sleeping with a consistent bedtime before 11 pm were associated with non-SHS. A study among Chinese university students similarly depicted the correlation between a sleep duration of less than 6 hours per day and poor self-reported health problem [27]. Breakfast skipping is reported to raise risk of mortality from cardiovascular disease [28]. Furthermore, an English study reported that poor health outcomes were more common among ex-smokers and current smokers than those who had never smoked [29]. Black men with alcohol consumption and short sleep duration are more prone to poor health in the United States [30].

Accumulating evidence has indicated that exercise, physical activity, and physical-activity interventions are beneficial for physical and mental-health outcomes. Sufficient fresh air and sun exposure are also good for promoting public health [31]. In conclusion, these studies and our findings emphasize the importance of maintaining good lifestyle habits, which is a simple way to prevent SHS and improve overall well-being.

This study further found that environment factors such as sufficient greenery, fresh air, pleasant housing, less spacious rooms, harmonious neighborhoods, the presence of many fitness facilities, and convenient living conditions were associated with high SHS scores. It is well-known that positive environments (especially natural outdoor areas) are good for human health [32]. Contrary to our general expectations, however, we found that people who lived in spacious rooms were more vulnerable to both MS and GS. This may be due to feelings of emptiness in one's surroundings. As indicated by a systematic review, living alone may be associated with low levels of positive mental health [33].

Study strengths

This population-based study examined a sample of urban residents (5881 respondents), thus facilitating overall generalizability to the entire urban population in suboptimal health prevention in China. Furthermore, we illustrated the relative strengths of lifestyle behaviors and environment factors on the associations with SHS. We firstly illustrated the important association between environment factors and MS and SS, which had almost the same association with lifestyle behaviors. Furthermore, associated factors were examined comprehensively, including ten lifestyle behaviors and eight environment factors, which can be intervention targets and would be helpful for preventing SHS and NCDs.

Limitations

First, because of the cross-sectional design it was not possible to confirm causal relationships of SHS with lifestyle behaviors and environment factors. Second, lifestyle factors and environmental variables were self-reported in this study, which may have potential bias and affect the accuracy of the measurement. Third, environment factors included in this study were all life-related, and other environment factors hadn't been included. What's more, although we have considered as many factors as possible, bias would inevitably occur because of certain factors not being included.

Conclusions

This large-scale cross-sectional study of Chinese urban residents or more demonstrates that good lifestyle behaviors and positive environment are both associated with low rates of SHS (i.e., high SHS scores). Lifestyle behaviors are more associated with PS and GS. However, the associations of environment factors and MS and SS are greater than that with PS, which are similar with lifestyle behaviors.
## Appendix

Table 6 This scale consists of 39 questions, including physical, mental and social health conditions

| Sub-health measurement scale (SHMS V1.0) |
|------------------------------------------|
| 1. How is your appetite? | □ very bad | □ worse | □ average | □ better | □ very good |
| 2. How is your sleep? | □ very bad | □ worse | □ average | □ better | □ very good |
| 3. Are you satisfied with your hair growth? (e.g. premature graying, yellowing or hair loss) | □ very dissatisfied | □ less satisfied | □ average | □ more satisfied | □ very satisfied |
| 4. Do you feel bitter or dry mouth? | □ never | □ few | □ sometimes | □ often | □ always |
| 5. Do you have gastrointestinal discomfort? (e.g. acid reflux, belching, nausea, abdominal pain, bloating, diarrhea, constipation, etc.) | □ none | □ rarely | □ sometimes | □ often | □ always |
| 6. Do you have abnormal urine symptoms? (e.g. yellow urine, painful urination, oliguria, frequent urination, excessive nocturia, etc.) | □ none | □ rarely | □ sometimes | □ often | □ always |
| 7. Do you have head discomfort? (e.g. dizziness, headache, heavy head, head swelling, head numbness, etc.) | □ none | □ rarely | □ sometimes | □ often | □ always |
| 8. Do you feel discomfort of your auditory system? (e.g. tinnitus, hearing loss, ear pain, etc.) | □ none | □ rarely | □ sometimes | □ often | □ always |
| 9. Do you feel discomfort of your visual system? (e.g. eye discomfort, blurred, easily fatigued, polycythemia, etc.) | □ very bad | □ worse | □ average | □ better | □ very good |
| 10. Do you have difficulty bending and flexing your knees? | □ very bad | □ worse | □ average | □ better | □ very good |
| 11. Do you have difficulty climbing 3 to 5 floors normally? | □ very bad | □ worse | □ average | □ better | □ very good |
| 12. Do you have difficulty walking 1500 m? | □ very bad | □ worse | □ average | □ better | □ very good |
| 13. Can your fatigue be relieved after rest? | □ very bad | □ worse | □ average | □ better | □ very good |
| 14. Do you have enough energy to cope with daily life, work and study? | □ very bad | □ worse | □ average | □ better | □ very good |
| 15. What state do you think your physical (somatic) health is in? | □ very bad | □ worse | □ average | □ better | □ very good |
| 16. Do you have confidence in yourself? | □ very bad | □ worse | □ average | □ better | □ very good |
| 17. Are you satisfied with your current living condition? | □ very bad | □ worse | □ average | □ better | □ very good |
| 18. Are you optimistic about the future? | □ very bad | □ worse | □ average | □ better | □ very good |
| 19. Do you feel happy? | □ very bad | □ worse | □ average | □ better | □ very good |
| 20. Do you feel nervous mentally? | □ very bad | □ worse | □ average | □ better | □ very good |
| 21. Do you feel bad or depressed? | □ very bad | □ worse | □ average | □ better | □ very good |
| 22. Do you feel insecure? | □ very bad | □ worse | □ average | □ better | □ very good |
| 23. Do you feel scared for no reason? | □ very bad | □ worse | □ average | □ better | □ very good |
| 24. Do you feel lonely? | □ very bad | □ worse | □ average | □ better | □ very good |
| 25. Are you sensitive and suspicious? | □ very bad | □ worse | □ average | □ better | □ very good |
| 26. How is your memory? | □ very bad | □ worse | □ average | □ better | □ very good |
| 27. How is your ability to think about or deal with problems? | □ very bad | □ worse | □ average | □ better | □ very good |
| 28. What state do you think your mental health (such as emotion, cognitive ability, etc.) is in? | □ very bad | □ worse | □ average | □ better | □ very good |
| 29. Can you properly deal with the unpleasant things happen in your life? | □ very bad | □ worse | □ average | □ better | □ very good |
Table 6 This scale consists of 39 questions, including physical, mental and social health conditions (Continued)

| Life, work and study? | □ very dissatisfied | □ less dissatisfied | □ average | □ more satisfied | □ very satisfied |
|-----------------------|---------------------|---------------------|-----------|------------------|------------------|
| 30. Are you satisfied with your interpersonal relationship in the society? | □ never | □ rarely | □ sometimes | □ mostly can | □ absolutely |
| 31. Are you satisfied with your performance in life, work and study? | □ never | □ rarely | □ sometimes | □ often | □ more often |
| 32. Can you adapt quickly to your new life, work and study? | □ never | □ rarely | □ sometimes | □ often | □ more often |
| 33. Do you keep in touch with your friends and relatives frequently (such as visiting each other, telephone greetings, correspondence, etc.)? | □ never | □ rarely | □ sometimes | □ often | □ more often |
| 34. Do you have friends you can share your happiness and sorrow with? | □ never | □ rarely | □ sometimes | □ often | □ more often |
| 35. Are there any colleagues, classmates, neighbors, relatives or friends with whom you are close to? | □ never | □ rarely | □ sometimes | □ often | □ always |
| 36. When you need help, will your family, colleagues or friends give you material or emotional support or help? | □ never | □ rarely | □ sometimes | □ often | □ always |
| 37. When you encounter difficulties, will you proactively seek support and help of others? | □ health | □ mild suboptimal health | □ average suboptimal health | □ severe suboptimal health | □ disease |
| 38. What state do you think your "social health" is in (e.g. interpersonal relationship, social interaction, etc.)? | □ health | □ mild suboptimal health | □ average suboptimal health | □ severe suboptimal health | □ disease |
| 39. What do you think your general health (including physical, mental and social health) is in? | □ health | □ mild suboptimal health | □ average suboptimal health | □ severe suboptimal health | □ disease |

Abbreviations
SHS: Suboptimal health status; GS: General suboptimal health status; PS: Physical suboptimal health status; MS: Mental suboptimal health status; SS: Social suboptimal health status; SEM: Structural equation model; CMIN/DF: relative X²; RMSEA: root mean-square error of approximation; CFI: Comparative fit index; GFI: Goodness-of-fit index; AGFI: Adjusted goodness-of-fit index; NCDs: Noncommunicable chronic diseases

Acknowledgments
The authors thank all study participants. We also thank the investigators and students for their assistance in this research.

Authors’ contributions
YL X and ZM H did the analysis and interpretation of data, and wrote the manuscript. J X initiated and designed the survey. WY L provided supporting for the survey. ZM H, GH L, ZC Z, YF F, LJ J, and MY X contributed to the national survey. ZM H, J X and WY L revised the manuscript. All authors read and approved the final manuscript.

Funding
This research was supported by the National Natural Science Fund, National Natural Science Foundation of China (No: 71673126), the Science and Technology Planning Project of Guangzhou City of China (No: 201803010089). Funders were not involved in the design of the study nor the collection, analysis, interpretation of data or writing of this manuscript.

Availability of data and materials
Data used in this study were obtained under the support of Nanfang Hospital, Southern Medical University. Researchers who meet the criteria for access to confidential data can contact Jun Xu (drugstat@163.com) at Nanfang Hospital, Southern Medical University to request the data.

Declarations
Ethics approval and consent to participate
The study protocol was approved by Medical Ethics committee of Nanfang Hospital of Southern Medical University (NFEC-2019-196). All participants gave oral informed consent in Chinese.

Consent for publication
Not applicable.

Competing interests
None declared.

Author details
1Department of Operation Management, Nanfang Hospital, Southern Medical University, 1023 Shatai South Road, Baiyun District, Guangzhou GD 20, Guangdong Province, China. 2Guangdong Provincial People’s Hospital (Guangdong Academy of Medical Sciences), Guangzhou, Guangdong Province, China. 3School of Health Services Management, Southern Medical University, Guangzhou, Guangdong Province, China. 4Department of Hospital Administrative Office, Nanfang Hospital, Southern Medical University, 1023 Shatai South Road, Baiyun District, Guangzhou GD 20, Guangdong Province, China.

Received: 15 January 2021 Accepted: 5 July 2021
Published online: 28 July 2021

References
1. Grad FP. The preamble of the constitution of the World Health Organization. Bull World Health Organ. 2002;80(12):981–4.
2. Bi JL, Ying H, Ya X, Cheng JR, Fei L, Tian W, et al. Association of lifestyle factors and suboptimal health status: a cross-sectional study of Chinese students. BMJ Open. 2014;4(6):e005156.
3. Strong K, Mathers C, Leeder S, Beaglehole R. Preventing chronic diseases: how many lives can we save? Lancet. 2005;366(9496):1578–82. https://doi.org/10.1016/S0140-6736(05)67341-2.

4. Wang L, Kong LZ, Wu F, Bai YM, Burton R. Preventing chronic diseases in China. Lancet. 2005;366(9499):1821–4. https://doi.org/10.1016/0140-6736(05)67344-8.

5. Transcript of press conference of the office of Health China action Promotion Committee on July 31, 2019. http://www.nhc.gov.cn/xcs/2017747/201707/fd959ae49f4810aad45a9a1e9f7367.shtml.

6. GBD 2015 Mortality and Causes of Death Collaborators. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet. 2016;388(10053):165–220.

7. 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;14:391–302.

8. Yan YX, Dong J, Liu YQ, Zhang J, Song MS, He Y, et al. Association of suboptimal health status with psychosocial stress, plasma cortisol and mRNA expression of glucocorticoid receptor α and β in lymphocyte. Stress. 2015;18(1):29–34. https://doi.org/10.3109/10253890.2014.999233.

9. Yan Y, Dong J, Liu Y, Yang X, Li M, Shia G, et al. Association of suboptimal health status and cardiovascular risk factors in urban Chinese workers. J Urban Health. 2012;89(2):329–38. https://doi.org/10.1111/j.1541-0264.2012.06936.x.

10. Jia RX. China’s 40 years of urbanization: from high speed to high quality. China Dev Watch. 2016;32:76–80. https://doi.org/10.1016/j.puhe.2019.03.003.

11. Chen JY, Cheng JR, Liu YY, Tang Y, Sun XM, Wang T, et al. Associations between breakfast eating habits and health-promoting lifestyle, suboptimal health status in Southern China: a population based, cross sectional study. J Transl Med. 2012;11(1):348.

12. Ma N, Liu M. Research progress on the epidemiology of sub-health state. China Prev Med. 2012;55:56–65.

13. Xue YL, Xu J, Liu GH, Feng Y, Xu M, Xie J, et al. Study of association between personality and sub-health status among urban residents aged more than 14 years old in 4 cities in China. J Southern Med Univ. 2019;39(4):443–9.

14. Xue YL, Xu J, Liu GH, Feng Y, Xu M, Xie J, et al. The mediating effect of adversity quotient on the correlation between stressful life events and sub-health status. Mod Prevent Med. 2019;46(1):82–85,90.

15. Sun X, Wei M, Zhu C, Wang XL, Zhao XS, Luo R. The epidemiological investigation of sub-health status in Guangdong, Shandong Med J. 2008;48:59–60.

16. Xie J, Luo HB, Zhu H, Chang WJ, Xu J. Prevalence and influence factors of sub-health status among urban residents in Tianjin. Chin J Public Health. 2016;32:76–80.

17. Sou J, Goldenberg SM, Duff P, Nguyen P, Shoveller J, Shannon K. Recent im/migration to Canada linked to unmet health needs among sex workers in Vancouver, Canada: findings of a longitudinal study. Issues Health Care Women. 2017;38(3):492–506. https://doi.org/10.1080/07399332.2017.1296842.

18. Dunstan RH, Sparks DL, Roberts TK, Crompton MJ, Gottfried J, Dascombe BJ. Development of a complex amino acid supplement, fatigue reviva, for oral ingestion: initial evaluations of product concept and impact on symptoms of suboptimal health in a group of males. Nutr J. 2013;12(1):115. https://doi.org/10.1186/s12903-013-0107-6.

19. Liu Z, Li M. The third state and psychosomatic medicine research. Med Philos. 2001;22(1):36–8.

20. Xu J, Feng LY, Luo R, Qiu JC, Zhang JH, Zhao XS, et al. Assessment of the reliability and validity of the sub-health status measurement scale Version1. 0. J Southern Med Univ. 2011;31(1):33–8.

21. Xu J, Xue YL, Liu GH, Feng Y, Xu M, Xie J, et al. Establishment of the norms of sub-health status measurement scale version 1.0 for Chinese urban residents. J South Med Univ. 2019;29(3):271–8.

22. Bucy EP, Holbert RL. Sourcebook for political communication research: methods, measures, and analytical techniques. New York: Routledge; 2014. https://doi.org/10.4324/9781315782713.

23. Yamaga E, Sato Y, Minakuchi S. A structural equation model to test a conceptual framework of oral health in Japanese edentulous patients with an item weighting method using factor score weights: a cross-sectional study. BMC Oral Health. 2018;18(1):7–9. https://doi.org/10.1186/s12903-018-0527-1.

24. Minich DM, Bland JS. Personalized lifestyle medicine: relevance for nutrition and lifestyle recommendations. Sci World J. 2013;12:9941.