Suboptimal health status as an independent risk factor for type 2 diabetes mellitus in a community-based cohort: the China suboptimal health cohort study

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Received: 3 September 2018 / Accepted: 11 January 2019 / Published online: 24 January 2019

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Abstract

Background The prevalence of diabetes, constituted chiefly by type 2 diabetes mellitus (T2DM), is a global public health threat. Suboptimal health status (SHS), a physical state between health and disease, might contribute to the progression or development of T2DM.

Methods We conducted a prospective cohort study, based on the China Suboptimal Health Cohort Study (COACS), to understand the impact of SHS on the progress of T2DM. We examined associations between SHS and T2DM outcomes using multivariable logistic regression models and constructed predictive models for T2DM onset based on SHS.

Results A total of 61 participants developed T2DM after an average of 3.1 years of follow-up. Participants with higher SHS scores had more T2DM outcomes ($p = 0.036$). Moreover, compared with the lowest quartile of SHS scores, participants with fourth, third, and second quartile SHS scores were found to be associated with a 1.7-fold, 1.6-fold, and 1.5-fold risk of developing T2DM, respectively. The predictive model constructed with SHS had higher discriminatory power ($AUC = 0.848$) than the model without SHS ($AUC = 0.795$).

Conclusions The present study suggests that a higher SHS score is associated with a higher incidence of T2DM. SHS is a new independent risk factor for T2DM and has the capability to act as a predictive tool for T2DM onset. The evaluation of SHS combined with the analysis of modifiable risk factors for SHS allows the risk stratification of T2DM, which may consequently contribute to the prevention of T2DM development. These findings might require further validation in a longer-term follow-up study.

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s13167-019-0159-9>) contains supplementary material, which is available to authorized users.

Keywords Suboptimal health status · Type 2 diabetes mellitus · Risk factor · Predictive preventive personalized medicine

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Introduction

The prevalence of diabetes, constituted chiefly by type 2 diabetes mellitus (T2DM), is a global public health threat [1]. In the past two decades, the prevalence in urban areas has increased remarkably in China [2]. The association of diabetes mellitus, especially T2DM, with increased cardiovascular risk is well known [3]. Hence, the preclinical status of T2DM and its early detection will become increasingly important, and the availability of reliable instruments for these diseases will be essential. An economical and valid instrument is necessary as a screening technique. Among the new methods of questionnaire screening, the estimate of suboptimal health status (SHS) deserves special attention [4, 5].

SHS is a physical state between health and disease, characterized (1) by the perception of health complaints, general weakness, chronic fatigue, and low energy levels within a period of 3 months and (2) as a subclinical, reversible stage of chronic disease [5]. We therefore established a robust screening tool (suboptimal health status questionnaire-25, SHSQ-25) for investigating SHS [4]. SHSQ-25 accounts for the multidimensionality of SHS by encompassing the following domains: (1) fatigue, (2) the cardiovascular system, (3) the digestive tract, (4) the immune system, and (5) mental status [4].

Previous studies have revealed that SHS is associated with T2DM-related risk factors. In a case–control study conducted in Ghana, we found that higher fasting plasma glucose (FPG), HbA1c and blood pressure levels were significantly correlated with higher SHS [6]. In a cross-sectional study conducted in urban Beijing, we found correlations between SHS and fasting plasma glucose, blood pressure, and serum lipids among men and women [7]. Work–recreation balance performance and unhealthy lifestyle behaviors, including lack of physical exercise, smoking, and irregular breakfast eating habits, were found to be related to the risk of SHS in southern China [8–11]. From a community-based cross-sectional study conducted in Russia, we identified a correlation between endothelial dysfunction and high SHS [12]. The most recent study conducted in northern China suggested that ideal cardiovascular health metrics are associated with a lower prevalence of SHS, and the combined evaluation of SHS and cardiovascular health metrics allows the risk classification of cardiovascular disease or T2DM as well [13]. Moreover, we investigated the association between SHS and short relative telomere length and found that the SHS score was negatively correlated with relative telomere length, indicating that SHS could be used as a screening tool for measuring biological aging [14]. SHS is also significantly associated with psychological symptoms in Chinese college students [15]. Taken together, these studies have indicated that SHS may contribute to the progression or development of noncommunicable chronic diseases (NCD), especially T2DM.

Although case–control studies may be sufficient for the investigation of the potential relationship between SHS and the risk factors of T2DM, the relevance between SHS and the incidence of T2DM is still poorly understood without a large community-based prospective cohort study. However, no such study has been conducted before.

We conducted the China Suboptimal Health Cohort Study (COACS), a longitudinal study initiated in 2013, to understand the impact of SHS on the progress of T2DM [16]. The aims of this study were (1) to assess the correlation between baseline suboptimal health status and the incidence of T2DM and (2) to build a SHS-based prediction instrument for T2DM onset.

Methods

Study population and design

This study is a prospective cohort study, based on the COACS, which has been described previously [16]. A total of 4313 participants were included in the COACS study after excluding those currently suffering from diabetes, hypertension, hyperlipidemia, and cardiovascular or cerebrovascular conditions (including atrial fibrillation, atrial flutter, heart failure, myocardial infarction, transient ischemic attack, and stroke), any type of cancer and gout. During 3.1 years of follow-up, 678 subjects (15.7%) were lost to follow-up and excluded from the study. Finally, we included 3635 participants (53.8% women, aged from 18 to 65 years) in the final investigation (Fig. 1). The characteristics of the included and excluded participants are summarized in Table S1.

Baseline evaluation

From 2013 to 2014, all participants provided a medical history and underwent a standardized physical examination and laboratory assessment of T2DM risk factors as described [16]. Briefly, we measured body mass index (BMI), blood pressure (mean of two auscultatory values obtained by a physician using a mercury column sphygmomanometer on the left arm of the seated participants), fasting glucose level, total cholesterol (TC), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) concentrations. We defined blood pressure as the mean of two readings. Participants underwent assessments of physical activity cigarette smoking and alcohol intake, using questionnaires with the assistance of a well-trained research assistant. Smoking status was classified as never (never or quit-smoking > 12 months), former (former smoking ≤ 12 months), or current (currently smoking). Drinking status was classified as never (no drinks), moderate (1–2 standard drinks per day), or heavy (> 2 standard drinks per day) according to the 2015–2020 Dietary Guidelines for Americans [17, 18]. Physical activity was assessed using the short form of the International Physical Activity Questionnaire (IPAQ) and classified as very active (≥ 150 min/week of moderate intensity or ≥ 75 min/week of vigorous intensity), moderately (1–149 min/week of moderate intensity or 1–74 min/week of vigorous intensity), or inactive (none) [19].

Determination of SHS

The SHS score was measured using the SHS questionnaire, SHSQ-25 (supplementary figure), a self-reported survey tool validated in various populations [20]. SHSQ-25 accounts for the multidimensionality of SHS by containing five systemic domains: fatigue, cardiovascular system, digestive tract,

Fig. 1 Flowchart of study participants. T2DM, type 2 diabetes mellitus

immune system, and mental status [20]. A score ≥ 35 represents SHS, and < 35 represents ideal health. To assess the hierarchical association between SHS and T2DM, we transformed the SHS score into quartiles (Q1, Q2, Q3, and Q4) of SHS.

Follow-up and T2DM outcomes

T2DM outcomes were followed up yearly from 2013 to 2017. The last time point for T2DM outcome information collection was December 2017. We obtained medical records for all hospitalizations and physician visits related to T2DM during follow-up, which were reviewed by an adjudication panel consisting of three investigators. Type 2 diabetes mellitus (ICD-10: E11) was defined as the presence of any of the following criteria: (1) fasting plasma glucose value of ≥ 126 mg/dL (7.0 mmol/L) on two occasions or symptoms of diabetes and a casual plasma glucose value of ≥ 200 mg/dL (11.1 mmol/L) or both, (2) current use of insulin or oral hypoglycemic agents, or (3) a positive response to the question: “Has a doctor ever told you that you have diabetes?”

Statistical analysis

Normality distributions of continuous variables were analyzed by the Kolmogorov–Smirnov test. Continuous variables underlying normal distribution were described as the means $\pm$ standard deviation (SD) and compared using ANOVA,

otherwise using nonparametric methods. Categorical variables were described with percentages and compared using the chi-squared test. We examined associations between SHS and T2DM outcomes by calculating relative risk (RR) using multivariable logistic regression, adjusting for age, gender, and other T2DM-related risk factors. We then fitted two logistic regression models using T2DM-related risk factors with or without SHS to predict T2DM onset and generated receiver operating characteristic (ROC) curves to assess the performance of the models. Cox regression was not used for the difficulties in identifying the precise time for the onset of T2DM in the follow-up.

All analyses were performed with SPSS Version 24.0 (IBM Corp, NY, USA) and R language 3.4.3 (R Core Team 2017, Vienna, Austria). We considered a two-sided $p < 0.05$ to be statistically significant.

Results

Baseline characteristics

During follow-up (median, 3.1 years), a total of 61 participants developed T2DM, and 3574 participants remained healthy. The overall cumulative incidence rate was 1.7%. Men had a significantly higher cumulative incidence rate (2.2%) than women (1.2%). An increasing incidence rate was observed with aging (p for trend $<$

0.001). Compared with healthy controls, participants with higher SHS scores had more T2DM outcomes (p for trend = 0.036). The characteristics of the participants ($n = 3635$; 53.8% women; mean age 37.3, 18–65 years) at baseline are presented in Table 1. Differences were found in gender, age, SHS, smoking habits, BMI, systolic blood pressure (SBP), diastolic blood pressure (DBP),

TC, TG, LDL-C, and HDL-C (all p values < 0.05) between patients with T2DM and healthy controls. Age, SHS, BMI, SBP, DBP, TC, TG, LDL-C, and HDL-C showed significant differences between the two groups in both male and female participants, whereas differences in physical activity were observed only in male participants (Table S2).

Table 1 Baseline demographic characteristics of study population

Characteristic	Overall ($n = 3635$)	Healthy controls ($n = 3574$)	T2DM Incidents ($n = 61$)	t or χ^2	p value
Male (%)	1681 (46.2%)	1644 (46.0%)	37 (60.7%)	5.183	0.023*
Age (years)	37.3 $\pm$ 10.6	37.2 $\pm$ 10.5	45.5 $\pm$ 12.2	6.151	$< 0.001^*$
~ 35	1947 (53.6%)	1932 (54.1%)	15 (24.6%)	38.366	$< 0.001^*$
35~45	824 (22.7%)	810 (22.7%)	14 (23.0%)		
45~55	512 (14.1%)	498 (13.9%)	14 (23.0%)		
55~	352 (9.7%)	334 (9.3%)	18 (29.5%)		
SHS group				0.368	0.544
Ideal health ($n = 3299$)	3299 (90.8%)	3245 (90.8%)	54 (88.5%)		
SHS ($n = 336$)	336 (9.2%)	329 (9.2%)	7 (11.5%)		
SHS quartiles				7.575	0.008*
Quartile 1	884 (24.4%)	877 (24.5%)	9 (14.7%)		
Quartile 2	892 (24.5%)	876 (24.5%)	16 (26.3%)		
Quartile 3	924 (25.4%)	906 (25.3%)	18 (29.5%)		
Quartile 4	933 (25.7%)	915 (25.6%)	18 (29.5%)		
Smoking				7.128	0.028*
Never	2764 (76.0%)	2726 (76.3%)	38 (62.3%)		
Former or current	871 (24.0%)	848 (23.7%)	23 (37.7%)		
Drinking				0.886	0.642
Never	2531 (69.6%)	2490 (69.7%)	41 (67.2%)		
Moderate	401 (11.0%)	392 (11.0%)	9 (14.8%)		
Heavy	703 (19.3%)	692 (19.3%)	11 (18.0%)		
Physical activity				3.114	0.211
Inactive	1206 (33.2%)	1185 (33.2%)	21 (34.4%)		
Moderately	519 (14.3%)	515 (14.4%)	4 (6.6%)		
Very active	1910 (52.5%)	1874 (52.4%)	36 (59%)		
BMI (kg/m^2)				49.973	$< 0.001^*$
< 24.0	2056 (56.6%)	2043 (59.9%)	13 (21.7%)		
24.0~27.9	1102 (30.3%)	1073 (31.5%)	29 (48.3%)		
> 28.0	311 (8.6%)	293 (8.6%)	18 (30.0%)		
SBP (mmHg)	116.9 $\pm$ 10.7	116.8 $\pm$ 10.7	123.3 $\pm$ 7.6	4.677	$< 0.001^*$
DBP (mmHg)	74.5 $\pm$ 8.2	74.4 $\pm$ 8.17	78.8 $\pm$ 7.1	4.131	$< 0.001^*$
TC (mmol/L)	4.3 $\pm$ 0.8	4.3 $\pm$ 0.8	4.8 $\pm$ 0.9	4.760	$< 0.001^*$
TG (mmol/L)	1.3 $\pm$ 1.0	1.3 $\pm$ 0.9	2.4 $\pm$ 2.9	8.596	0.005*
LDL-C (mmol/L)	2.4 $\pm$ 0.6	2.3 $\pm$ 0.6	2.7 $\pm$ 0.6	5.010	$< 0.001^*$
HDL-C (mmol/L)	1.2 $\pm$ 0.3	1.2 $\pm$ 0.3	1.1 $\pm$ 0.2	-4.176	$< 0.001^*$

T2DM type 2 diabetes mellitus, SHS suboptimal health status, BMI body mass index, SBP systolic blood pressure, DBP diastolic blood pressure, FPG fasting plasma glucose, TC total cholesterol, TG triglyceride, LDL-C low-density lipoprotein cholesterol, HDL-C high-density lipoprotein cholesterol

* $p < 0.05$ indicates a significant difference between T2DM incident and healthy controls

Relative risks of SHS for T2DM onset

The SHS score was entered in the logistic regression model as quartiles, with the lowest quartile as the reference. Individuals with higher levels of SHS (Q4, Q3, and Q2) had considerably higher risks of T2DM, with relative risks (RRs) of 1.93 (95% CI 1.29–2.88), 1.98 (95% CI 1.33–2.96), and 1.89 (95% CI 1.2–2.72), respectively. After adjusting for age and gender, RRs of 1.83 (95% CI 1.17–2.66), 1.71 (95% CI 1.13–2.56), and 1.61 (95% CI 1.08–2.48) were observed for Q4, Q3, and Q2 of SHS, respectively, with Q1 of SHS as the reference. After further adjusting for T2DM-related factors including heavy or moderate drinking, inactive physical activity, lower SBP, and lower HDL-C, Q4 and Q3 of SHS still presented higher risks of T2DM, with RRs of 1.71 (95% CI 1.11–2.61) and 1.62 (95% CI 1.02–2.41), respectively. We also performed stratified analysis according to gender. In males, participants with higher SHS (Q4, Q3, and Q2) showed higher risks of T2DM (RRs = 1.73, 1.72, and 1.72, respectively), whereas in females, participants with only Q4 of SHS had a higher risk of T2DM onset (RR = 1.93, 1.02–3.65) (Table 2).

Predictive model with SHS for T2DM

Forward selection logistic regression analyses revealed that age, SHS, BMI, SBP, TG, LDL-C, and HDL-C were significantly associated with T2DM onset, and these factors were finally aggregated into the predictive models. The model with SHS as an independent variable had a higher AUC value than the model without SHS among all participants, with statistical significance ($\Delta\text{AUC} = 0.053$, $p = 0.016$) (Fig. 2). From the stratification analyses, we observed a significantly higher AUC value for the model with SHS than the model without SHS in males ($\Delta\text{AUC} = 0.075$, $p = 0.001$), whereas no significant differences in AUC values between models with SHS

and without SHS were found in females ($\Delta\text{AUC} = 0.023$, $p = 0.411$) (Fig. 2).

Association between T2DM-related risk factors and SHS

We observed that female sex, heavy or moderate drinking, inactive physical activity, lower SBP, and lower HDL-C were cross-sectionally associated with SHS (Table 3). Age, smoking status, BMI, blood pressure, FPG, total cholesterol, triglyceride, and low-density lipoprotein cholesterol were not retained. Comparable results were returned with statistically significant interactions between gender and heavy or moderate drinking, inactive physical activity, lower SBP, and lower HDL-C in the gender-stratified analysis (Table S3).

Discussion

In the present study, we applied SHSQ-25 in a cohort of 3635 participants to assess their SHS score at baseline. After follow-up for 3.1 years on average, we compared the difference in cumulative incidence between different SHS groups and investigated the relation between SHS levels and risk of T2DM onset. The main result of our study was that participants with higher levels of SHS had a considerably higher risk of T2DM. Those in the highest quartile of SHS showed a 1.7-fold risk of developing T2DM compared to those in the lowest quartile. This association is independent of the known confounding factors, i.e., age, gender, heavy or moderate drinking, inactive physical activity, lower SBP, and lower HDL-C, suggesting that a high SHS score is a new independent risk factor for T2DM and can be applied as a monitoring parameter to further address the biological characteristics of T2DM. Moreover, compared with the lowest level of SHS (Q1), the Q4, Q3,

Table 2 Relative risk for T2DM incidents by quartile groups of SHS

Models	RRs of SHS (95% CI)			
	Q1 (SHS < 8)	Q2 (SHS = 8–14)	Q3 (SHS = 14–24)	Q4 (SHS ≥ 24)
Model 1	1.00 (ref)	<i>1.80 (1.20–2.72)</i>	<i>1.98 (1.33–2.96)</i>	<i>1.93 (1.29–2.88)</i>
Model 2	1.00 (ref)	<i>1.61 (1.08–2.48)</i>	<i>1.71 (1.13–2.56)</i>	<i>1.80 (1.17–2.66)</i>
Model 3	1.00 (ref)	1.54 (0.95–2.29)	<i>1.62 (1.02–2.41)</i>	<i>1.71 (1.11–2.61)</i>
Stratified analysis				
Model in male	1.00 (ref)	<i>1.72 (1.02–2.92)</i>	<i>1.72 (1.02–2.91)</i>	<i>1.73 (1.01–2.98)</i>
Model in female	1.00 (ref)	1.69 (0.86–3.34)	1.90 (0.99–3.64)	<i>1.93 (1.02–3.65)</i>

Model 1, crude model; model 2, adjusting for age and gender; model 3, model 2 + age, gender, smoking status, BMI, SBP, DBP, TC, TG, LDL-C, and HDL-C; model in male, model 2 + age, BMI, physical activity SBP, DBP, TC, TG, LDL-C, and HDL-C; model in female, model 2 + age, BMI, SBP, DBP, TC, TG, LDL-C, and HDL-C. Statistically significant RRs are presented in italics

RR relative risk, SHS suboptimal health status

Fig. 2 ROC curves of the different T2DM predictive models. **a** Model that constructed with SHS had a significant higher discriminate power (AUC = 0.848) than the model without SHS (AUC = 0.795) among all participants. **b** Model that constructed with SHS had a significant higher discriminate power (AUC = 0.850) than the model without SHS (AUC = 0.775) among male participants. **c** Model that constructed with SHS had a higher discriminate power (AUC = 0.841) than the model without SHS (AUC = 0.818) among female participants, but with no significance

and Q2 of SHS were found to be associated with 1.7-, 1.6-, and 1.5-fold risks of developing T2DM, respectively. This finding indicated that the risk will increase with the increasing SHS performance of an individual. These results provide the potential application of SHS as dynamic monitoring index for the development of T2DM.

In male participants, we observed stationary 1.7-fold risks of T2DM for Q2, Q3, and Q4, compared with Q1 of SHS with significant differences, indicating that any quartile increase in SHS will increase the risk of developing T2DM for males. However, in female participants, only Q4 of SHS was found to be significantly associated with a 2.0-fold risk of T2DM. These results may reflect the preexisting difference in SHS between males and females, which we have described here and reported previously [7]. Females suffer from a relatively worse suboptimal health status than males across different age groups in different regions of China [9, 10]. Combined with

our current results, we hypothesize that females may be more accustomed to a health status with a higher SHS score, where a moderate increase in SHS will not cause an observable risk of T2DM onset. Moreover, male participants have relatively lower SHS scores in previous and present studies [7], which may result in more sensitive reactions towards any increase in SHS compared with female participants.

We also established an SHS-based predictive model for T2DM onset. Age, BMI, SBP, TG, LDL-C, and HDL-C have been previously identified as T2DM-related factors and applied in many risk assessment tools for T2DM onset across different studies [21, 22]. Here, for the first time, we found that SHS could predict the risk of developing T2DM, and the SHS-based predictive model presented a higher discriminatory power than the model without SHS. This finding indicates that SHS is not only related to the current health status of individuals but might also have the capability to predict the possible occurrence of T2DM. As a short and simple to complete questionnaire, the SHSQ-25 could be used as a risk assessment and stratification tool for T2DM in both large-scale studies of the general population and routine health surveys [20].

The present study is also one of the largest studies to investigate the health- and T2DM-related risk factors for suboptimal health status, where female, moderate or heavy drinking habits, inactive physical activity, low SBP level, and low HDL-C level were independent risk factors for SHS. We found that the level of SBP was decreased in the participants (OR = 0.981) with a higher SHS score, which is inconsistent with our previous study [7]. Another cross-sectional study conducted in Russia showed that blood pressure is not correlated with SHS ($\beta = 0.069$, $p = 0.199$, and $\beta = -0.040$, $p =$

Table 3 Associations of SHS and T2DM-related risk factors

Risk factors		ORs for SHS (95% CI)	<i>p</i> value
Female sex		2.15 (1.57–2.95)	< 0.001
Drinking	Never	1.00 (ref)	
	Moderate	2.00 (1.35–2.94)	< 0.001
	Heavy	1.90 (1.34–2.69)	< 0.001
Physical activity	Inactive	1.00 (ref)	
	Moderately	0.83 (0.60–1.15)	0.257
	Very active	0.62 (0.49–0.78)	< 0.001
SBP		0.98 (0.97–0.99)	< 0.001
HDL-C		0.44 (0.28–0.70)	< 0.001

OR odds ratio, CI confidence interval, SHS suboptimal health status, SBP systolic blood pressure, HDL-C high-density lipoprotein cholesterol

0.416, for SBP and DBP, respectively) [12]. This inconsistency may be due to the exclusion of subjects with hypertension at baseline, which might lead to lower measures of blood pressure in subjects with SHS than in those with ideal health [16]. Moreover, we observed two lifestyle parameters that significantly influence the level of SHS, drinking habits, and physical activity. Participants who drink regularly are associated with a 2-fold risk, and those who are physically inactive are associated with a 1.6-fold risk of SHS, regardless of gender. Several recent studies have reported that chronic diseases may be preventable by targeting modifiable risk factors [23–25]. This finding suggests that unhealthy drinking habits and physically inactive are independent risk factors of SHS and that the modification of these two factors will help improve SHS and further prevent or slow the development towards T2DM.

Previous studies have demonstrated that SHS is associated with cardiovascular risk factors and chronic psychosocial stress [7, 12]; however, little is known as to whether SHS contributes independently to the incidence and development of NCD, such as T2DM, which now affects 11.6% of the Chinese population (114 million) with threatening complications [26]. From our community-based longitudinal cohort, we observed a higher cumulative incidence of T2DM in participants with higher SHS, indicating the potential of SHS as an independent biomarker for T2DM. Moreover, our novel SHSQ-25, along with objective measurements of biomarkers, provided a potential approach for the early detection of the preclinical status of T2DM from perspectives of predictive, preventive, and personalized medicine [6, 16].

Although our study includes a large sample size and adjustments for a variety of potential confounders, some limitations should be noted. First, the participants were only followed for 3.1 years on average, which may be insufficient for the onset of diabetes, especially for a young cohort (mean age 37.3, 18–65 years) resulting in fewer patients developing T2DM. Second, the exclusion criteria of this study were relatively strict compared to those of other studies potentially leading to missing important information, such as the interaction between SHS and history of hypertension or hyperlipidemia in the development of T2DM, as blood pressure and lipid levels were reported to be risk factors for T2DM previously [27].

Conclusion

SHS is a novel predictive factor for T2DM onset, and a higher SHS score is associated with a higher incidence of T2DM. The evaluation of SHS combined with the analysis of modifiable risk factors for SHS allows the risk stratification of T2DM, which might consequently contribute to the prevention of T2DM.

Authors' contributions YW, YZ, and WW conceived the study. SG, XX, JZ, and MS performed the investigation and collected the data. SG, HW, DL, and XZ performed the statistical analysis. SG, XX, HH, and YZ wrote the paper. All authors read and approved the final manuscript.

Funding information This work was supported by grants from the National Natural Science Foundation of China (NSFC) (81673247, 81872682, and 81773527), the Joint Project of the Australian National Health & Medical Research Council (NHMRC), and the NSFC (NHMRC APP1112767, NSFC 81561128020), Beijing Nova Program (Z141107001814058), and China Scholarship Council (CSC-2017).

Compliance with ethical standards

Competing interests The authors declare that they have no competing interests.

Consent for publication Not applicable.

Ethical approval and consent to participate The study was conducted according to the guidelines of Helsinki Declaration. Approvals have been obtained from Ethical Committees of the Staff Hospital of *Jidong* Oil-field of Chinese National Petroleum, and Capital Medical University. Written informed consent has also been obtained from each of the participants.

Abbreviations SHS, suboptimal health status; SHSQ-25, Suboptimal Health Status Questionnaire-25; T2DM, type 2 diabetes mellitus; COACS, China Suboptimal Health Cohort Study; NCD, noncommunicable chronic diseases; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; TC, total cholesterol; TG, triglyceride; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; RR, relative risk; OR, odds ratio; CI, confidence interval; ANOVA, analysis of variance; ROC, receiver operating characteristic; AUC, area under the ROC curve

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