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ORIGINAL RESEARCH

Complex Association Among Diet Styles, Sleep Patterns, and Obesity in Patients with Diabetes

Yi Zhang[1,2], Yanlei Wang[1,*], Shengwu Zhang[1,*], Yulin Zhang[3], Qiu Zhang[1]

On behalf of the China National Diabetic Chronic Complications Study Group

[1]Department of Endocrinology, The First Affiliated Hospital of Anhui Medical University, Hefei, Anhui, 230032, People's Republic of China; [2]Department of Maternal, Child and Adolescent Health, School of Public Health, Anhui Medical University, Hefei, Anhui, 230032, People's Republic of China; [3]The Second Clinical Medical College, Anhui Medical University, Hefei, Anhui, 230032, People's Republic of China

*These authors contributed equally to this work

Correspondence: Qiu Zhang, Department of Endocrinology, The First Affiliated Hospital of Anhui Medical University, Hefei, Anhui, 230022, People's Republic of China, Email zhangqiu@ahmu.edu.cn

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Background: Health risk factors (HRFs), including the adjustment of disturbed sleep patterns (including disorders and duration) and improvement of dietary intake, have become relatively novel and critical strategies to prevent the development of diabesity and treat diabetic complications.

Objective: We aimed to explore 1) whether there was an association between diet styles (including healthy and unhealthy diets) and diabesity; 2) whether sleep patterns could moderate this relationship; and 3) whether there was a complex interaction association between sleep patterns, diet styles, and diabesity.

Methods: The study was based on a national survey conducted by the China National Diabetic Chronic Complications Study Group, this study extracted data from some cities in Anhui Province and obtained basic and lifestyle information using a detailed questionnaire for analysis. The primary exposure was diet styles, and the outcomes were body mass index (BMI) and waist circumference (WC), while HbA1c and FBG and sleep patterns were moderators. Data were pooled using logistic regression and moderation analysis.

Results: The overall response rate was 92.0%. This study ultimately included 1765 participants. The mean age was 57.10 ± 10.0 years. Sociographically, participants with lower educational levels were more likely to have lower levels of WC (χ^2 = 2.73) and BMI (χ^2 = 3.47), were female (t=6.54), were more likely to have lower educational levels (F=13.78) and were older (F=23.75), were more likely to have higher detection rates of sleep disorders and were more likely to have other HRFs (walking, SSBs, HbA1c and TG). Additionally, diet styles were also significantly associated with BMI and WC. In the moderation analysis, SES (socioeconomic status) also affected the correlation between healthy diet style, sleep disorders and WC (β=0.20), neither in BMI nor unhealthy diet style in BMI and WC; the combination effect between diet styles, sleep patterns and HbA1c was associated with WC and BMI.

Conclusion: Complex associations and interactions were found between diet styles, sleep patterns, HbA1c, and diabesity. Therefore, it is necessary to understand the dietary pattern and other HRFS that cause diabesity, so as to strengthen further preventive measures. These results can provide some theoretical basis for the treatment of diabesity in the public health field.

Keywords: diabesity, BMI, waist circumference, diet styles, diabetes

Introduction

Around one in every eleven adults worldwide has diabetes mellitus (The vast majority of people have type 2 diabetes [T2DM] (nearly 90%).[1,2] Diabetes prevalence has been increasing annually, according to previous survey results.[2] The International Diabetes Federation (IDF) forecasted in its 2021 report that the number of persons with diabetes will rise annually, reaching a record high of 597 million this year, and in 2045, this number will reach 783 million. In addition, 3 out of 4 diabetics reside in low- and middle-income nations; the IDF Diabetes Atlas 10th edition shows an ongoing rise in diabetes prevalence worldwide, proving that the disease poses a serious threat to the health and well-being of people,

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families, and society.[3] The severity of the diabetes epidemic is highlighted by the current global estimations and predictions of T2DM. Over time, this number will keep rising. Over time, this number will keep rising. Diabetes itself is harmful, and its far-reaching effects should not be ignored. For example, people with T2DM are also at a higher risk of adverse complications, such as cardiovascular disease (CVD), which may be greater than not having diabetes at all, and cardiometabolic syndrome itself is associated with an increased risk of diabetes.[4] Furthermore, studies evaluating the risk of CVD in diabetic patients have identified diabetic dyslipidemia and obesity as important indicators.[2]

To reduce the lives of patients who die as a result of the progression and death of atherosclerotic cardiovascular disease, early detection of diabetes-related risk factors and aggressive treatment for subsequent diagnosis of diabetes, such as dyslipidemia and prevention of obesity, are critical . One of them is obesity, especially diabetes combined with obesity, also known as diabesity, which refers to the combined detrimental effects of obesity and T2DM on one's health,[5] and the global-dependent obesity and T2DM epidemic is a critical public health concern.[6] The negative effect of diabesity among older adults also has an essential role. As a result, "diabesity" is increasingly used to describe the combined harmful health effects of obesity and diabetes. In addition, the increase in diabetes and obesity is parallel, so a high body mass index (BMI) in diabetic patients is independently associated with an increased coronary plaque burden, providing evidence for the notion that diabesity is a dangerous mix of obesity and T2DM.[7]

Given its increasing prevalence, a proper diet is essential for diabetes management, and it is particularly important to emphasize diet as one of the five drivers in guidelines for glycemic control of diabetes. Increased consumption of poor diets with a high concentration of red meat and processed meat, refined grains and sugar-sweetened beverages (SSB) is one of the main reasons contributing to the global T2DM epidemic diet management.[2] Among them, SSB consumption is positively associated with obesity, and weight gain has long been associated with CVD, which has also been confirmed by relevant studies. According to epidemiological studies, SSB consumption is a significant source of sugar consumed outside of the context of a typical diet and a significant portion of total dietary intake and is associated with metabolic syndrome, hypertension, and weight gain.[8] Additionally, many estimated deaths were caused by diabetes (72.3%), followed by CVD (24.2%) and BMI-related cancers (3.5%), according to country-level data.[9] The researchers estimated based on global data that the four modifiable risk factors that meet the GBD criteria (high body mass index, high fasting blood glucose, high SSBs diet and smoking) likely account for 22.3% (11.8%-35.1%) of the total number of Alzheimer's disease DALYs globally in 2016,[9] and other studies also brought up this phenomenon.[10] The proportion of deaths caused by excessive consumption of carbon-containing beverages increased from 0.34% in 1990 to 0.46% in 2019, an increase of 35%.[11] Furthermore, a series of meta-analyses have further confirmed adverse outcomes associated with SSBs, with a positive association between intake and diabetes and CVD.[12,13] In addition, other factors, such as vegetables and fruits, also have benefits on diabetes.[14,15] Some authoritative follow-up studies have demonstrated that these biomarkers are objective indicators of fruit and vegetable consumption and suggest that diets rich in even modestly higher fruit and vegetable consumption could help to prevent the development of T2DM.[16] Major clinical trials have also demonstrated that diet and lifestyle modifications are effective in preventing T2DM in high-risk individuals.[2] Previous articles have reviewed the factors influencing the underlying biological processes leading to diabesity and their clinical implications.[12,13] Furthermore, T2DM is associated with a characteristic pattern of dyslipidemia, often termed diabetic dyslipidemia. People with T2DM typically present with low levels of HDL and high levels of low-density LDL particles, accompanied by elevated triglyceride levels.[17] Therefore, it is important to understand the impact of dietary patterns on the management of diabetes and its complications.

Although many studies have concentrated on the detrimental consequences of a poor diet, it appears that additional factors play a role in the onset and progression of diabesity, and these risk factors may interact with each other. In other words, the interaction between risk factors may play a more important role. Interestingly, sleep disturbances were associated with a positive energy balance, possibly due to increased food intake, as a relatively novel risk factor related to metabolism.[18] The sleep/wake cycle is linked to circadian rhythms, the internal clock that regulates metabolic processes, and it has been reported that some exposures that occur during sleep may affect functions such as insulin resistance, cellular function, and glycemic control.[19] Circadian dysregulation, in which sleep occurs during atypical circadian phases, such as sleep disturbances and difficulty falling asleep, can also adversely affect insulin sensitivity. Sleep disorders may predict worse outcomes in those with existing diabetes. For example, Antza et al reported that restricted sleep is linked to modifications in energy homeostasis, insulin resistance and β-cell function. Epidemiological cohort studies established short sleep duration as a risk factor for developing obesity and T2DM.[20] Furthermore, van Cauter et al demonstrated that poor sleep patterns, such as sleep disorders and misalignment of the sleep-wake cycle and melatonin rhythm, may promote insulin resistance through regulation of the endocrine system, peripheral clock genes, and mitochondrial respiratory function.[21]

In general, it is interesting that improving dietary patterns can reduce the risk of obesity and related diseases such as T2DM, and the correlation between dietary patterns and diabetes has attracted considerable attention. Regarding the interaction between these factors, no system of study has been proven to prevent T2DM. Weight control is the major factor, and all programs for preventing diabetes and obesity and changing one's lifestyle must include exercise.[22] The influence of dietary factors, such as decreased SSB consumption, increased fruit and vegetable intake,[13,23] poor sleep habits and sleep disorders,[19] also plays an important role. In addition, these studies on HRF, such as dietary patterns and sleep disorders, can contribute to the construction and evolution formation and development of diabetes management strategies and provide indirect evidence for the subsequent formulation of interventions. Similarly, HRF itself and research based on HRF elements require a comprehensive theoretical model, such as a moderation model. Therefore, the co-occurrence and clustering of obesity in middle-aged and elderly patients with diabetes (diabesity) should be considered comprehensively, including exploring the co-occurrence pattern of behaviors and regulating diet and sleep rhythm, to bring about the intended effect.

However, to our knowledge, few studies have looked at whether eating habits in different regions are related to disability, and whether the sleep patterns of people with diabetes play a role in this relationship. In addition, no population-based epidemiological studies on diabetes-related complications and comorbidities have been reported. Moreover, understanding the association between diet styles (including healthy and unhealthy diets) and sleep disorders in participants with diabesity in different regions and observing these relationships through blood glucose monitoring are essential to inform public health policy and tailor interventions. Therefore, we propose the following hypotheses: 1) diet styles and other HRFs were correlated with diabesity in China's community; 2) sleep patterns could moderate this relationship; and 3) there was a complex association between sleep patterns, HbA1c, diet styles, and diabesity (Figure 1). Additionally, to address this critical issue, we extracted some data for analysis according to the results of the previous research design in China; detailed steps are shown in a previous study.[24] In this study, we aimed to explore the correlation between sleep disorders, HbA1c, diet styles, BMI, waist circumference (WC), and other metabolic indices.

Materials and Methods

Sampling Setting and Collection

To investigate the epidemiological characteristics and related factors of multiple chronic complications and diabetes comorbidities (retinopathy, nephropathy, peripheral neuropathy, peripheral arterial disease, peripheral arterial disease (PAD) and cardiovascular disease (CVD)). The China National Diabetic Chronic Complications Study also evaluated the rate of achieving metabolic goals and the implementation of standardized diagnosis and treatment in Chinese adults with diabetes from March 2018 to January 2020.[24] Using a comprehensive questionnaire, this study extracted data from some cities in Anhui Province and obtained basic and lifestyle information using a detailed questionnaire for analysis. Furthermore, multistage stratified random sampling was employed for the respondent selection. Detailed sampling

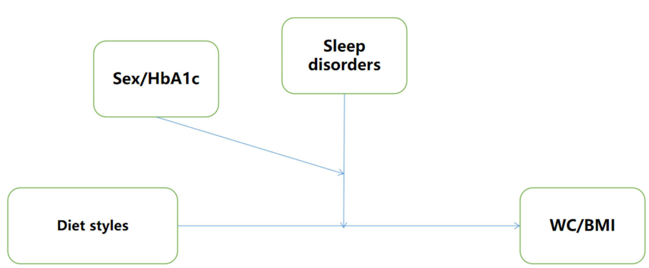

Figure 1 Hypothesis model.

techniques are provided in a previous study. This study was designed and reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist. The study met the standards for the ethical treatment of participants and was approved by the Ethics Committee of Anhui Medical University.

Sample Size Estimation

Based on previous studies, diabetes prevalence was 11.2%, corresponding to the trends in obesity and overweight, with a relative precision of 15% (ε), $\alpha = 0.05$, $Z_{1\text{-}\alpha/2} = 1.96$. Therefore, applying the following formula, the minimum sample size was determined to be 690. Through the preliminary study,[24] combined with the geographical distribution of the region and given a multicenter design with different ages and regions, analysis, and future follow-up needs, this minimum requirement was used for grade sampling in all regions to ensure that the analysis was performed at multiple stratification levels in each community. Finally, 1400 participants were surveyed.

$$n = \frac{(1-p)Z_{1-\alpha/2}}{\varepsilon^2 p}$$

Inclusion Criteria

Participants: 1) had patients' informed consent, 2) were 18 years of age and older and had lived in the survey area for at least 6 months during the 12 months before the survey, and 3) were diagnosed with diabetes.

Exclusion Criteria

Participants: 1) informed consent was not obtained; 2) pregnant women and those with mental illness were excluded; 3) failure to submit a questionnaire; 4) congenital or acquired immunodeficiency; and 5) incomplete medical examination. The study's flowchart is shown in Figure 2.

Investigation Contents and Methods

Questionnaire Survey

After drawing blood on an empty stomach in the morning, the participants waited in a room dedicated to the questionnaire, and then a uniformly trained investigator used a tablet computer to conduct face-to-face personal interviews with the participants. The investigator completed the personal questionnaire, which the respondents could not fill out. The questionnaire included sociodemographic characteristics and some HRFs, such as smoking, drinking, diet styles, physical activity, screen time, sleep duration (sleep disorders and sleep duration) and sedentary behavior.[24] Three HRFs, including diet styles, sleep disorders and sleep duration, were obtained in this study. When the mentioned questions are difficult to answer, they should be answered by a family member most familiar with the situation. In our study, diet styles included soybean products, fresh vegetables, fresh fruits, nuts, coffee and tea, tubers, SSBs and fruit juices. Diet styles were measured as follows:[24] "Please recall whether you regularly consumed any of the following foods in the previous 12 months and estimate the frequency and amount consumed." Participants answered, "Whether or not to eat, the frequency of consumption, and the amount of each consumption." The consumption of each soybean product, fresh vegetables, fresh fruits, nuts, coffee and tea, tubers, SSBs and fruit juices was employed in the study's analysis.

Furthermore, use the following criteria to assess sleep disorders: Have you had the following sleep complications at least 3 days weekly in the past 30 days?" including snoring, choking, or suffocating; difficulty falling asleep (more than 30 minutes); more awakening twice (including twice); waking up early, and difficulty sleeping again; have you taken sleeping pills (Western medicine or traditional Chinese medicine) for at least 1 day in the past 30 days to help you sleep. The participants answered yes or no. Subsequently, we summed these answers into a total score and further manipulated other analyses. In this study, we also asked participants how much they slept at night.

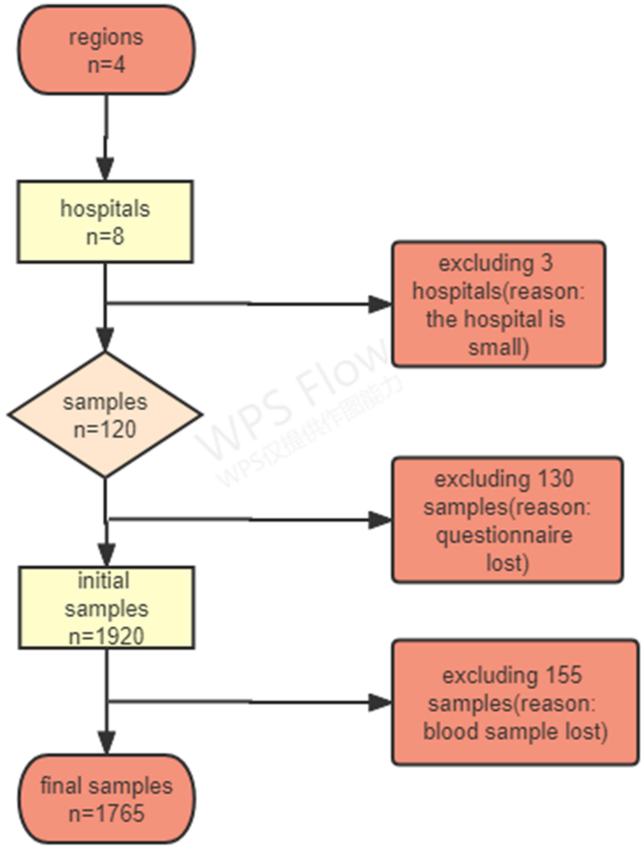

Figure 2 Flow chart of participants in study.

Body Measurement

Body measurements included height, weight, WC, blood pressure, and heart rate (HR). Height was measured as tide gauge zero (TGZ) height with a maximum scale of 2.0 m and precision of 0.1 cm; weight was measured using a TANITA HD-390 body weight scale with a minimum unit of 0.1 kg; WC was measured with 1.5 Meter soft retractable measuring tape a maximum scale of 1.5 m, 1 cm width, and precision of 0.1 cm; blood pressure and HR measurements were performed using the Omron blood pressure monitor.[24] In this study, we extracted data on waist circumference and BMI.

Laboratory Testing

At the investigation site, a fasting venous blood sample (5 mL) was drawn from each recruited subject by a professional nurse and divided into standard tubes. All direct biochemical measurements were performed using automated chemical analyzers and off-The-shelf reagent kits in accordance with the manufacturer's standardized protocols. Detection measures included fasting glucose (glucose oxidase or hexokinase method), FPG measured by the local laboratory with a unified quality control plan), glycosylated hemoglobin (HbA1c) (high-performance liquid chromatography), lipids (serum TC and serum TG, etc.), and blood glucose was measured by the local laboratory through the survey website (enzymatic method). Other blood and urine samples were then centrifuged and packaged at the investigation site, stored as required before being collected, frozen, and transported to the medical examination institutions designated by the National Project Working Group for testing and storage.

Covariates

Gender, age, educational level, residential area, overall annual household income, marital status, and ethnicity were covariates in this study.

Statistical Analysis

The mean ± standard deviation (SD) were used to characterize continuous and categorical variables and were analyzed by the chi-square test. The *t*-test and/or ANOVA were used to observe the correlation between sociodemographic factors, BMI and WC. Then, linear regression was used to evaluate the relationship between diet styles (including healthy and unhealthy diet), sleep disorders and HRFs with BMI and WC. A step-modulated analysis was then performed using a process-modulated procedure to assess the outcomes of associations between dietary styles, sleep disorders and HRFs, BMI, and WC. Finally, we tested the correlation between HRFs, sleep duration, BMI, and WC.[25,26] Finally, we adjusted for the impacts of sociodemographic correlates in the moderation model. The missing data were processed using SPSS version 23.0 after preliminary data sorting. Generally, the missing data rate in this study was minimal, and that for each item was < 1%. Therefore, a multiple imputation method is adopted in SPSS version 23.0 to analyze the missing data at the project level.[26] The moderating effect was considered significant when the 95% confidence interval (CI) did not contain zero. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 23.0.

Sensitivity analysis was used to test the robustness of the model: (1) Model 1 did not control for covariables, and Model 2 controlled for covariates. (2) We also examined the association between different HRFs and diabesity, such as physical activity (moderate), sedentary behavior, walking, alcohol drinking, smoking, sleep duration and BMI and WC. (3) We also explored the relationship between FBG, diet styles, sleep disorders, BMI, and WC. The China DiaChronic Study was approved by the Ethical Review Committee (Approval No: 2018–010) and was registered in the Chinese Clinical Trial registry (ChiCTR1800014432).[24]

Results

The General Demographic Characteristics of Waist Circumference (WC) and BMI

In this study, 1920 participants were included, of which those who did not complete the questionnaire were excluded, leaving 1765 participants. The mean age was 59.10 ± 10.0 years old, 49.5% of participants were male, the frequency of more than 3 types of healthy diet styles, 2 types healthy diet styles and 1 type healthy diet styles and none was 46.1%, 32.4%, 19.0% and 2.6%, respectively, and the frequency of more than 3 types of unhealthy diet styles, 2 types unhealthy diet styles and 1 type unhealthy diet styles and none was 1.5%, 6.5%, 68.1% and 24.0%, respectively. Additionally, the BMI detection rates were 34.8% (obese), 36.7% (overweight), 1.0% (underweight), and 27.5% (normal weight), and the average WC was 89.71 ± 9.89 cm. Furthermore, the results of the relationship between general sociodemographic indicators and WC showed that a higher educational level was more likely to result in a lower level of WC (Table 1).

Sex (χ^2=31.24), age (χ^2=13.87), and total annual household income (χ^2=21.91) were correlated with sleep disorders; sex (t=0.50), age (F=5.96), SES (socioeconomic status) (F=4.12) and educational level (F=3.47) were correlated with BMI; sex (t= −6.54), age (F=23.75), SES (F= 29.67) and total annual household income (F=13.78) were also correlated with sleep disorders (Table 2).

Multilevel Linear Regression Between Dependent Health Risk Factors (HRFs) and WC and BMI

Table 3 shows the correlation between health risk factors, BMI and waist circumference. After adjusting for covariates, some HRFs were positively correlated with BMI levels, and sedentary behavior, walking, sleep disorders, SSBs, glycosylated hemoglobin, and TG levels were dose-responsive to waist circumference. In addition, there was no correlation between moderate physical activity, dietary patterns, smoking, sleep duration, and waist circumference.[27] In addition, after controlling for covariates, sedentary behavior, walking behavior, sleep disturbances, SSBs, FBG, and TG were also dose-dependent with BMI. However, there was no correlation between moderate PA, smoking, diet, HBA1c level, sleep duration and BMI.

The Moderation Analysis Between SES, Diet Styles, Sleep Disorders, BMI, and WC

An unhealthy diet included tuber crops, SSBs, and juice. Accordingly, moderation analyses were performed controlling for educational level, marital status, ethnicity, and age. Based on sociodemographic indicators, we put SES into the

Table 1 The Characteristics of WC

Variables	Total N(%)	≤p25	P25-p50	p50-p75	≥p75	χ^2 /F value
Age						13.87*
≤43y	194	59(30.4)	40(20.6)	40(20.6)	55(28.4)	
44–59y	823	206(25.0)	193(23.5)	230(27.9)	194(23.6)	
≥60y	748	178(23.8)	208(27.8)	175(23.4)	187(25.0)	
Sex						31.24**
Male	873	179(20.5)	210(24.1)	227(26.0)	257(29.4)	
Female	892	264(29.6)	231(25.9)	218(24.4)	179(20.1)	
Ethnic						0.44
Han	1745	439(25.2)	436(25.0)	440(25.2)	430(24.6)	
Nonhan	20	4(20.0)	5(25.0)	5(25.0)	6(30.0)	
Married						0.39
No	30	9(30.0)	7(23.3)	7(23.3)	7(23.3)	
Yes	1735	434(25.0)	434(25.0)	438(25.2)	429(24.7)	
Education level						6.34
Primary below	800	208(26.0)	199(24.9)	207(25.9)	186(23.3)	
Primary	262	64(24.4)	68(26.0)	61(23.3)	69(26.3)	
Junior college	472	108(22.9)	113(23.9)	120(25.4)	131(27.8)	
Senior high or above	231	63(27.3)	61(26.4)	57(24.7)	50(21.6)	
Total annual household income (yuan)						21.91**
≤18,000	354	101(28.5)	70(19.8)	83(23.4)	100(28.2)	
18,000–40,000	749	165(22.0)	185(24.7)	206(27.5)	193(25.8)	
40,000–70,000	346	84(24.3)	97(28.0)	84(24.3)	81(23.4)	
>70,000	316	93(29.4)	89(28.2)	72(22.8)	62(19.6)	
Very good						
Occupation status						2.54
No	653	161(24.7)	177(27.1)	160(24.5)	155(23.7)	
Yes	1112	282(25.4)	264(23.7)	285(25.6)	281(25.3)	
Social economic status						7.22
Low	835	219(26.2)	200(24.0)	208(24.9)	208(24.9)	
Medium	461	102(22.1)	111(24.1)	123(26.7)	125(27.1)	
High	469	122(26.0)	130(27.7)	114(24.3)	103(22.0)	

Note: *P<0.05, **P<0.01.
Abbreviation: WC, waist circumference.

Table 2 The General Demographic Characteristics of BMI and Sleep Disorders

Variables	BMI (kg/m^2)				Sleep Disorders			
	N (%)	Average	Standard Deviation	*t*/*F* value	N (%)	Average	Standard Deviation	*t*/*F* value
Gender				0.50*				−6.54**
Male	874	25.97	3.59		873	6.85	1.21	
Female	891	26.07	3.72		892	7.25	1.31	
Married status				−1.13				−1.09
Unmarried	30	25.27	3.90		30	6.80	1.19	
Married	1735	26.04	3.65		1735	7.06	1.28	
Ethnic				0.22				0.54
Han	1745	26.02	3.65		1745	7.05	1.28	
Non-Han	20	25.84	4.15		20	6.90	1.25	

(*Continued*)

Table 2 (Continued).

Variables	BMI (kg/m^2)				Sleep Disorders			
	N (%)	Average	Standard Deviation	*t/F* value	N (%)	Average	Standard Deviation	*t/F* value
Educational level				3.47*				
Under primary	800	26.16	3.61		800	7.33	1.27	
Primary	262	25.79	3.55		262	6.99	1.22	
Junior high	472	26.23	3.90		472	6.82	1.27	
Senior high above	231	25.40	3.34		231	6.65	1.18	
Total annual household income (yuan)				1.19				13.78**
≤18,000	354	26.0	4.14		354	7.38	0.066	
18,000–40,000	749	26.17	3.48		749	7.06	0.046	
40,000–70,000	346	26.02	3.41		346	6.94	0.072	
>70,000	316	25.71	3.75		316	6.78	0.067	
SES				4.12*				29.67**
Low	835	25.99	3.67		835	7.16	1.24	
Medium	461	26.39	3.78		461	7.25	1.33	
High	469	25.71	3.48		469	6.67	1.22	
Age (years)				5.96*				23.75**
≤43	194	26.540	4.4100		194	6.55	1.25	
44–59	823	26.084	3.6472		823	7.0	1.27	
≥60	748	25.821	3.4360		748	7.24	1.26	

Note: *P<0.05, **P<0.01.

Table 3 The Multilevel Linear Regression Between Dependent Health Risk Factors and WC and BMI

Variables	WC(cm)			BMI(kg/m^2)		
	R^2	P	β (95% CI)	R^2	P	β (95% CI)
Physical activity (moderate)	0.02	>0.05	−0.29(−0.99, 0.71)	0.01	>0.05	0.21(−0.29, 0.71)
Sedentary behavior	0.02	<0.05*	0.15(−0.03, 0.33)	0.01	<0.05*	0.42(0.06, 0.78)
Walking	0.02	<0.05*	−0.12(−0.24, −0.01)	0.01	<0.05*	−0.004(−0.01, −0.001)
Sleep (dichotomy)	0.02	>0.05	−0.55(−0.12, 1.76)	0.01	>0.05	0.14(−0.21, 0.49)
Alcohol drinking	0.02	>0.05	0.97(−0.12, 2.07)	0.01	>0.05	−0.32(−0.68, 0.04)
Smoking	0.02	>0.05	0.24(−1.01, 1.49)	0.01	>0.05	−0.19(−1.10, 0.72)
SSBs	0.03	<0.01**	2.97(1.09, 4.84)	0.02	<0.01**	1.29(0.59, 1.99)
Sleep disorders	0.03	<0.01**	0.87(0.50, 1.24)	0.02	<0.01**	0.33(0.19, 0.47)
Sleep duration	0.02	>0.05	−0.14(−0.40, 0.13)	0.01	>0.05	−0.01(−0.11, 0.09)
HbA1c	0.03	<0.05*	0.28(0.01, 0.54)	0.01	>0.05	−0.03(−0.12, 0.07)
FBG	0.02	>0.05	0.02(−0.13, 0.16)	0.01	<0.05*	−0.06(−0.11, −0.002)
TG	0.04	<0.01**	0.55(0.38, 0.72)	0.03	<0.01**	0.21(0.15, 0.28)
TC	0.02	>0.05	0.11(−0.27, 0.50)	0.01	>0.05	−0.03(−0.18, 0.11)

Note: Controlled for educational level, total annual household income, marital status, ethnic, gender and age. *P<0.05, **P<0.01.
Abbreviations: BMI, body mass index; WC, waist circumference.

moderation model to evaluate diabesity, and the results are shown in Table 4 and Table 5. There was no significant effect between unhealthy diet and SES on BMI and WC, and there was also no significant effect between sleep disorders and unhealthy diet on BMI and WC. However, the effects of a healthy diet (including cereals, multigrains, legumes, vegetables, fruits, nuts, coffee and tea) on BMI and WC were significant, as shown in Table 6 and Table 7.

Table 4 The Moderation Analysis Between Diet (Unhealthy), Sleep Disorders, SES and BMI

Variables	BMI					
	Coeff	**se**	**t**	**P**	**LLCI**	**ULCI**
Diet (unhealthy)	3.72	3.88	0.96	>0.05	−3.90	11.33
Sleep disorders	2.24	2.75	0.81	>0.05	−3.16	7.64
SES	1.79	2.33	0.77	>0.05	−2.78	6.36
Int_1	−0.42	0.53	−0.80	>0.05	−1.47	0.62
Int_2	−0.40	0.45	−0.88	>0.05	−1.29	0.49
Int_3	−0.19	0.32	0.58	>0.05	−0.82	0.45
Int_4	0.04	0.06	0.68	>0.05	−0.08	0.17

Note: Int 1: diet × sleep disorders; Int 2: diet × HbA1c; Int 3: HbA1c × sleep disorders; Int 4: diet × sleep disorders × HbA1c.
Abbreviations: BMI, body mass index; WC, waist circumferenc.

Table 5 The Moderation Analysis Between Diet (Unhealthy), Sleep Disorders, SES and BMI

Variables	WC					
	Coeff	**se**	**t**	**P**	**LLCI**	**ULCI**
Diet (unhealthy)	4.46	10.53	0.43	>0.05	−16.19	25.11
Sleep disorders	1.71	7.46	0.23	>0.05	−12.92	16.34
SES	1.40	6.32	0.22	>0.05	−11.0	13.79
Int_1	−0.35	1.44	−0.24	>0.05	−3.17	2.48
Int_2	−0.39	1.23	−0.32	>0.05	−2.80	2.01
Int_3	−0.02	0.88	−0.02	>0.05	−1.74	1.71
Int_4	0.02	0.17	0.14	>0.05	−0.31	0.36

Notes: Int 1: diet × sleep disorders; Int 2: diet × HbA1c; Int 3: HbA1c × sleep disorders; Int 4: diet × sleep disorders × HbA1c.
Abbreviations: BMI, body mass index; WC, waist circumference.

Table 6 The Moderation Analysis Between Diet (Healthy), Sleep Disorders, SES and BMI

Variables	WC					
	Coeff	**se**	**t**	**P**	**LLCI**	**ULCI**
Diet (healthy)	8.52	5.30	1.61	>0.05	−1.88	18.92
Sleep disorders	14.39	7.69	1.87	<0.05	−0.70	29.48
SES	12.43	6.69	1.86	>0.05	−0.70	25.56
Int_1	−1.40	0.73	−1.93	>0.05	−2.82	0.03
Int_2	−1.28	0.64	−1.99	<0.05	−2.55	−0.02
Int_3	−1.98	0.94	−2.12	0.05	−3.82	−0.15
Int_4	0.20	0.09	2.26	<0.05	0.03	0.38

Notes: Int 1: diet × sleep disorders; Int 2: diet × SES; Int 3: SES × sleep disorders; Int 4: diet × sleep disorders × SES.
Abbreviations: BMI, body mass index; WC, waist circumference.

The Moderation Analysis Between HbA1c, Diet Styles, Sleep Disorders, BMI, and WC

An unhealthy diet included tuber crops, SSBs, and juice. Accordingly, moderation analyses were performed using educational level, marital status, ethnicity, gender, and age as the control variables. To further explore the influence of blood glucose management on diabesity, we also included HbA1c in the model. Table 8 and Table 9 show the results. Notably, unhealthy diet was not significantly associated with BMI or WC level combined with HbA1c. Furthermore, sleep disorders were significantly linked to WC combined with HbA1c but not to BMI, whereas there was a three-way interaction effect between unhealthy diet, sleep disorders HbA1c and BMI and WC.

Table 7 The Moderation Analysis Between Diet (Healthy), Sleep Disorders, SES and BMI

Variables	BMI					
	Coeff	**se**	**t**	**P**	**LLCI**	**ULCI**
Diet (healthy)	2.48	1.96	1.27	>0.05	−1.36	6.32
Sleep disorders	4.44	2.84	1.56	>0.05	−1.13	10.01
SES	3.55	2.47	1.44	>0.05	−1.29	8.40
Int_1	−0.42	0.27	−1.57	>0.05	−0.95	0.10
Int_2	−0.37	0.24	−1.57	>0.05	−0.84	0.09
Int_3	−0.59	0.35	−1.70	>0.05	−1.27	0.09
Int_4	0.06	0.03	1.82	0.069	−0.005	0.13

Notes: Int 1: diet × sleep disorders; Int 2: diet × HbA1c; Int 3: HbA1c × sleep disorders; Int 4: diet × sleep disorders × HbA1c.
Abbreviations: BMI, body mass index; WC, waist circumference.

Table 8 The Moderation Analysis Between Diet, Sleep Disorders, HbA1c and WC

Variables	WC					
	Coeff	**se**	**t**	**P**	**LLCI**	**ULCI**
Diet (unhealthy)	−0.72	0.70	−1.03	>0.05	−7.64	0.50
Sleep disorders	−3.57	2.07	−1.72	>0.05	−0.95	0.50
HbA1c	−0.63	0.44	−1.42	>0.05	−1.50	0.64
Int_1	0.68	0.41	1.69	>0.05	−0.11	1.48
Int_2	0.12	0.09	1.41	>0.05	−0.05	0.29
Int_3	0.56	0.26	2.15	<0.05	0.048	1.07
Int_4	−0.10	0.05	−2.05	<0.05	−0.20	−0.005

Notes: Int 1: diet × sleep disorders; Int 2: diet × HbA1c; Int 3: HbA1c × sleep disorders; Int 4: diet × sleep disorders × HbA1c.
Abbreviations: BMI, body mass index; WC, waist circumference.

Table 9 The Moderation Analysis Between SSBs, Sleep Disorders, HbA1c and WC

Variables	BMI					
	Coeff	**se**	**t**	**P**	**LLCI**	**ULCI**
Diet (unhealthy)	0.89	0.74	1.19	>0.05	−0.57	2.34
Sleep disorders	3.68	2.21	1.67	>0.05	−0.65	8.02
HbA1c	0.62	0.47	1.32	>0.05	−0.30	1.55
Int_1	−0.77	0.43	−1.79	>0.05	−1.62	0.07
Int_2	−0.12	0.09	−1.35	>0.05	−0.30	0.06
Int_3	−2.54	0.28	−1.94	>0.05	−1.08	0.01
Int_4	0.11	0.054	1.97	<0.05	0.0004	0.21

Notes: Int 1: diet × sleep disorders; Int 2: diet × HbA1c; Int 3: HbA1c × sleep disorders; Int 4: diet × sleep disorders × HbA1c.
Abbreviations: BMI, body mass index; WC, waist circumference.

The Mediated Moderation Analysis Between FBG, Diet Styles, Sleep Disorders, BMI, and WC

We also performed moderated mediation analyses, as shown in Tables 10–13. The results demonstrated that HbA1c levels significantly moderated the effects of diet styles on BMI and WC. Remarkably, the mediation of sleep disorders on BMI and WC was significantly moderated by the HbA1c level.

Table 10 Model Characteristics for the Conditional Process Analysis (Diet [Unhealthy], FBG, Sleep Disorders and BMI)

Variables	Sleep Disorders			BMI		
	B	t value	*P* value	B	t value	*P* value
Diet (unhealthy)	−0.06	−0.40	>0.05	0.12	0.28	>0.05
FBG	−0.08	−0.97	>0.05	−0.30	−1.18	<0.01
Diet*FBG	0.01	0.72	>0.05	−0.02	−0.54	>0.05
Sleep disorders				−0.20	−0.97	>0.05
Sleep disorders*FBG				0.06	−2.65	>0.05
R^2	0.003			0.02		
F	1.92			6.48		

Notes: Mediate variables: sleep disorders, moderated variables: HbA1c, independent variables: diet, dependent variables: WC. The model was uncontrolled covariates.
Abbreviations: BMI, body mass index; WC, waist circumference.

Table 11 Bootstrapped Conditional Direct and Indirect Effects (Diet [Unhealthy], FBG, Sleep Disorders and BMI

			BMI		
Direct effect			Effect	SE	(LL,UL)
	Predictor	BMI			
	Moderator (FBG)	Low	6.17	−0.02	−0.43, 0.40
		Medium	9.43	−0.09	−0.38, 0.20
		High	12.69	−0.17	−0.56, 0.22
Indirect effect			Effect	SE	(LL,UL)
	Predictor	BMI			
	Mediator (sleep disorders)	Low	6.17	0.0006	−0.02.0.03
		Medium	9.43	0.01	−0.02, 0.05
		High	12.69	0.04	−0.03, 0.11

Table 12 Model Characteristics for the Conditional Process Analysis (Diet [Unhealthy], FBG, Sleep Disorders and WC

Variables	Sleep Disorders			WC		
	B	t value	*P* value	B	t value	*P* value
Diet (unhealthy)	−0.06	−0.40	>0.05	0.68	0.57	>0.05
FBG	−0.08	−0.97	>0.05	−0.63	−0.90	>0.05
Diet*Sleep disorders	0.01	0.72	>0.05	−0.07	−0.60	>0.05
Sleep disorders				−0.70	−1.24	>0.05
FBG *Sleep disorders				0.15	2.66	<0.05
R^2	0.003			0.01		
F	1.92			4.64		

Notes: Mediate variables: sleep disorders, moderated variables: HbA1c, independent variables: diet, dependent variables: WC. The model was uncontrolled covariates.
Abbreviations: BMI, body mass index; WC, waist circumference.

The Mediated Moderation Analysis Between HbA1c, Diet Styles, Sleep Duration, BMI, and WC

We also performed moderated mediation analyses, as shown in Tables 14–17. The results demonstrated that HbA1c levels significantly moderated the effects of diet styles on BMI and WC. Remarkably, the mediation of sleep duration on BMI and WC was significantly moderated by the HbA1c level.

Table 13 Bootstrapped Conditional Direct and Indirect Effects (Diet [Unhealthy], FBG, Sleep Disorders and WC

			WC		
Direct effect			Effect	SE	(LL,UL)
	Predictor	WC			
	Moderator (FBG)	Low	6.17	0.57	−0.87, 1.37
		Medium	9.43	0.40	−0.77, 0.81
		High	12.69	0.54	−1.26, 0.84
Indirect effect			Effect	SE	(LL,UL)
	Predictor	WC			
	Mediator (sleep disorders)	Low	6.17	0.001	−0.05, 0.08
		Medium	9.43	0.03	−0.04, 0.11
		High	12.69	0.09	−0.060.28

Table 14 Model Characteristics for the Conditional Process Analysis (Diet [Healthy], FBG, Sleep Disorders and BMI)

Variables	**Sleep Duration**			**WC**		
	B	**t value**	***P* value**	**B**	**t value**	***P* value**
Diet (healthy)	−0.08	−0.52	>0.05	−1.16	−1.38	>0.05
HbA1c	−0.19	−0.95	>0.05	0.69	0.59	>0.05
Diet*Sleep duration	0.02	0.02	>0.05	0.13	1.21	>0.05
Sleep duration				1.77	3.02	<0.01
HbA1c *Sleep duration				−0.25	−3.32	<0.01
R^2	0.01			0.01		
F	5.40			3.96		

Notes: Mediate variables: sleep duration, moderated variables: HbA1c, independent variables: diet, dependent variables: WC. The model was uncontrolled covariates.
Abbreviations: BMI, body mass index; WC, waist circumference.

Table 15 Model Characteristics for the Conditional Process Analysis (Diet [Healthy], FBG, Sleep Disorders and BMI)

			WC		
Direct effect			Effect	SE	(LL,UL)
	Predictor	WC			
	Moderator (HbA1c)	Low	5.83	−0.40	−0.93, 0.13
		Medium	7.58	−0.17	−0.55, 0.21
		High	9.33	0.27	−0.47, 0.58
Indirect effect			Effect	SE	(LL,UL)
	Predictor	WC			
	Mediator (sleep duration)	Low	5.83	0.02	−0.005, 0.09
		Medium	7.58	−0.01	−0.05, 0.02
		High	9.33	0.05	−0.19, −0.02

Sensitivity Analysis

In the sensitivity analysis, we found a significant moderation effect between FBG, diet styles, sleep disorders, BMI and WC, and the results are shown in Table 18 and Table 19.

Table 16 Model Characteristics for the Conditional Process Analysis (Diet [Healthy], FBG, Sleep Disorders and WC

Variables	Sleep Duration			WC		
	B	t value	*P* value	B	t value	*P* value
Diet (unhealthy)	0.49	0.30	>0.05	2.14	1.25	>0.05
HbA1c	0.23	0.20	>0.05	3.31	2.78	>0.05
Diet*Sleep duration	−0.03	0.04	>0.05	−0.27	−1.25	>0.05
Sleep duration				1.62	2.78	<0.01
HbA1c *Sleep duration				−0.23	−3.10	<0.01
R^2	0.01			0.01		
F	5.51			3.83		

Notes: Mediate variables: sleep duration, moderated variables: HbA1c, independent variables: diet, dependent variables: WC. The model was uncontrolled covariates.
Abbreviations: BMI, body mass index; WC, waist circumference.

Table 17 Model Characteristics for the Conditional Process Analysis (Diet [Healthy], FBG, Sleep Disorders and WC)

			WC		
Direct effect			Effect	SE	(LL,UL)
	Predictor	WC			
	Moderator (HbA1c)	Low	5.83	0.57	−0.55, 1.67
		Medium	7.58	0.40	−0.71, 0.88
		High	9.33	−0.39	−1.45, 0.67
Indirect effect			Effect	SE	(LL,UL)
	Predictor	WC			
	Mediator (sleep duration)	Low	5.83	0.08	−0.01, 0.26
		Medium	7.58	−0.03	−0.12, 0.03
		High	9.33	−0.09	−0.26, 0.002

Table 18 The Moderation Analysis Between Diet Styles, Sleep Disorders, FBG and WC

Variables	WC					
	Coeff	se	t	P	LLCI	ULCI
Diet (healthy)	−9.02	0.74	−1.73	>0.05	−19.21	1.18
Sleep disorders	−3.09	1.45	−2.13	<0.05	−5.92	−0.25
FBG	−3.05	1.02	−3.01	<0.01	−5.05	−1.07
Int_1	1.37	0.74	1.85	>0.05	−0.08	2.82
Int_2	1.17	0.52	2.27	<0.05	0.16	2.19
Int_3	0.45	0.14	3.12	<0.01	0.17	0.73
Int_4	−0.17	0.07	−2.30	<0.05	−0.32	−0.03

Notes: Int 1: diet × sleep disorders; Int 2: diet × FBG; Int 3: FBG× sleep disorders; Int 4: diet × sleep disorders × FBG.
Abbreviations: BMI, body mass index; WC, waist circumference.

Discussion

Principal Findings

Here, the frequencies of more than 3 types of healthy diet styles, 2 types of healthy diet styles and 1 type of healthy diet styles and none were 46.1%, 32.4%, 19.0% and 2.6%, respectively; the frequencies of more than 3 types of unhealthy

Table 19 The Moderation Analysis Between Diet Styles, Sleep Disorders, FBG and BMI

Variables	BMI					
	Coeff	se	t	P	LLCI	ULCI
Diet (healthy)	−3.46	1.92	−1.80	>0.05	−7.22	0.31
Sleep disorders	−1.11	0.53	−2.08	<0.05	−2.16	−0.06
FBG	−1.13	0.37	−3.02	<0.01	−1.87	−0.40
Int_1	0.52	0.27	1.90	>0.05	−0.02	1.05
Int_2	0.40	0.19	2.10	<0.05	0.03	0.77
Int_3	0.16	0.05	2.98	<0.01	0.05	0.26
Int_4	−0.06	0.03	−2.14	<0.05	−0.11	−0.01

Notes: Int 1: diet × sleep disorders; Int 2: diet × FBG; Int 3: FBG× sleep disorders; Int 4: diet × sleep disorders × FBG.
Abbreviations: BMI, body mass index; WC, waist circumference.

diet styles, 2 types of unhealthy diet styles and 1 type of unhealthy diet styles and none were 1.5%, 6.5%, 68.1% and 24.0%, respectively. The overall detection rate of obesity and overweight was 71.5% among participants, which was similar to a previous study.[28] The average sleep disorder score was 7.05 ± 1.28, and the average sleep duration was 6.90 ± 1.74 hours/day. An association between diet styles, sleep patterns, HbA1c and diabesity was also observed. Sensitivity analysis verified the robustness of the results.

The Correlation Between Diet Styles and Diabesity

First, in our results, we listed some possible influencing factors based on previous studies. There are behavioral indicators, and there are also biological indicators.[28] Obesity itself is a complex disease as is diabetes combined with obesity, which is influenced by a variety of factors, including but not limited to genetics, lifestyles (diet and food environment, physical activity, metabolism), psychosocial influences and other environmental factors,[2,29,30] whereas abdominal adiposity assessment waist circumference or waist-to-hip ratio predicted T2DM risk independently of BMI.[31] Therefore, in this study, we listed two indicators to evaluate obesity, BMI and WC. Second, although T2DM has been known for a long time and its biological mechanisms have been studied, little has been done about the factors involved and potential moderation mechanisms when considered from an epidemic perspective. Zheng et al reviewed as is diabetes combined with obesity, which is influenced by a variety of factors, regular consumption of sugary beverages and red meats and low consumption of whole grains and other fiber-rich foods. Some studies have also mentioned the pathological process of diabetes. Insulin resistance and β-cell function play an important role, and their critical importance has been verified.[2] Clinical practice guidelines recommend dietary and lifestyle changes as the basis of treatment to prevent diabetes and complications.[32] Third, another mechanism, such as the dietary inflammation index (DII) and DII, was positively correlated with body weight, BMI, waist-hip ratio and body fat percentage, supporting an inflammatory diet as a risk factor for obesity.[33] A positive dose–response gradient was observed for the difference in GL and HbA1c.[34] We looked at the relationship between diet styles, sleep disorders and sex differences in obesity since gender differences affect the development of obesity in a significant way. These results provide the basic theoretical basis for our study. Finally, we examined the correlation between diet styles, sleep disorders, glucose management (HbA1c and FBG monitoring) and WC and BMI. Our sensitivity analysis also explored the relationship between dietary behaviors (including SSBs, juice, and tuber crops), sleep duration, WC, and BMI. In addition, sleep patterns and diet styles have also been identified as appropriate targets for public health interventions because of their strong association with obesity, with poor sleep patterns and unhealthy diet habits providing circadian disturbances and "empty" calories, the latter of which have little nutritional value. In addition, unhealthy lifestyle choices, characterized by dietary imbalances and sleep deprivation, can lead to metabolic changes that contribute to the development of noncommunicable diseases (NCDs).[35,36] Modification of lifestyle, including weight loss, increasing physical activity and adopting a healthy diet, remains one of the first-line strategies for the management of T2DM.[2,37] A high-carb diet also promotes the body's accumulation of fatty acids and triglycerides, increasing the risk of CVD by triggering high postprandial insulin levels (the carbohydrate-insulin model).[38]

Previous RCTs and cohort studies found a strong link between diet styles and T2DM, which is basically consistent in epidemiological studies,[39] such as red meat, processed meat, and SSB, in the linear dose–response meta-analysis, which showed a significant relation with the risk of T2D. In our study, we also studied at the relationship between two aspects of diet, healthy and unhealthy patterns, with diet styles having a significant effect on BMI and WC and T2DM; moreover, better BMI management had a more pronounced effect on diet styles and T2DM, which corresponds with our results. Additionally, BMI itself is an important influencing factor, reflecting the complex interaction between diet styles and caloric intake in obesity and T2DM progression. They also looked at the availability of dietary interventions;[40] this trend also provides a theoretical basis for our results, which show that diet styles correlate with obesity and T2DM. Furthermore, a large number of studies have shown that in patients with T2DM and obesity, more stringent dietary energy restriction management and intake of a very low calorie diet can significantly reduce HbA1c and fasting blood glucose levels and maintain sustained remission of diabetes[41,42] and effectiveness of lipid management for at least 2 years.[43] Therefore, given the potential importance of lifestyle and glycemic management, we examined the associations and possible mechanisms among the influencing factors contributing to the development of diabetes. In this study, we found a three-way interaction of HbA1c, sleep disturbance (sleep duration), and diet style on BMI and WC. In addition, the effects of FBG, sleep disorders and dietary patterns on BMI and WC were treated in the sensitivity analysis. The above results indicate that diabesity may be the result of the interaction of multiple factors and provide a reliable theoretical basis for further intervention in diabesity.

The Results of the Conditional Process Model

The association of single risk factors with diabetes and its complications has been noted in previous and other studies. Because of the interaction between various factors, it is worth investigating whether there is an additional additive effect between these risk factors and diabetes. In previous studies, different dietary patterns have been found to be associated with both T2DM and CVD risk, in part because they may be mediated through both weight gain and insulin resistance.[44] However, this effect could also be due to the large amount of carbohydrates that can be absorbed quickly, such as any form of unhealthy food (including SSBs and fried foods). Furthermore, consumption of SSBs alone can lead to rapid and significant increases in blood glucose and insulin concentrations, which, when consumed frequently and in large quantities, can lead to a higher dietary glycemic load (GL);[45] meanwhile, several cross-sectional observations provide evidence that food glycemic index (GI) or GL is correlated with body weight.[46] These results further verified the significant correlation between diet lifestyles and obesity, which also provided some evidence to build our diabesity study. Moreover, among other things, studies have shown that patients with high SSB consumption had an odds ratio (OR) (without adjusting for obesity) of 2.56 for T2DM.[40] Changes in diet toward unhealthy eating behaviors play an important role,[39] and dietary limits like SSB intake are examples of lifestyle modifications for people with diabetes, with the advantage of SSB restriction achieved through BMI management.[12]

Combined with previous studies, it is suggested that obesity itself is affected by many factors, so obesity in diabetic patients also does not occur overnight. We tried to summarize previous studies and found that sleep also plays an important role in this, and insufficient sleep traits have become more prevalent in recent years.[47] Poor sleep quality's impact on insulin sensitivity is one such pathway.[19] Therefore, it is advantageous to discover new risk factors for obesity that may suggest straightforward and low-cost interventions with fewer potential iatrogenic effects.[48] Therefore, since it is generally known that sleep/wakefulness regulation is connected to circadian rhythms, which are the body's internal clock that regulates metabolic processes, we also looked at sleep disorders related to diabetes in our study.[19] In regard to sleep and diet, the relation between diet and sleep is an emerging area of inquiry. Two meta-analyses demonstrated the effects of quantity, quality and periodization of carbohydrate consumption on sleep,[48,49] while the findings are not always consistent; they generally shed light on some issues that high-GI diets may increase the chance of developing insomnia.[49] Among them, higher intakes of dietary added sugars, starch, and nonwhole/refined grains were each associated with higher odds of incident insomnia. Therefore, we included sleep disorders in the analysis of diet and diabesity. In addition, the pathway to T2DM linked to obesity may be affected by disturbed sleep, and a preclinical investigation found that sleep deprivation increased nocturnal catecholamine levels.[19,20,50] Here is substantial evidence that short sleep duration leads to the secretion of obesity-related hormones,[51] which may be a risk factor for obesity. Corella et al also found an association between shorter sleep duration and higher regular soft drink intake.[52] In addition, there is increasing evidence that sleep deprivation (short) and/or poor quality of sleep and obesity and other harmful health outcomes and the main mechanism between sleep and weight gain result in increased food intake, especially high-energy food intake. In addition, it is important to consider the relationship between obesity and metabolic indicators and sleep from the perspective of patients with diabetes.[53] Therefore, screening for habitual sleep patterns in diabesity patients, including sleep quality and degree of sleep disturbance, is also critical. Earlier, Morselli et al concluded that there is a relationship between shorter sleep duration and the incidence of diabetes and/or obesity and that insufficient sleep also increases food intake. The need of identifying people with diabetes who have habitual sleep patterns is further demonstrated by this review.[54]

By assessing the relationship between correlated variables along these pathways and conducting formal moderation analyses, we enable observational studies to better understand the function and relative significance of the putative biological pathways that link unhealthy eating behaviors to chronic disease.[55] Therefore, the constructive study also provides a reliable basis for our research. We will use previous research methods to analyze the possible factors, which will promote us to identify potential causal pathways and potential mechanisms of scientific knowledge. Combining statistical methods with clinical data will also help to identify potential intervention targets, especially considering the limitations of conducting long-term randomized controlled trials.[56] A systematic review reviewed some studies showing that social determinants influence glycemic control, LDL, and blood pressure to a greater or lesser extent.[57] A number of studies have noted that increases in the incidence, prevalence and burden of chronic diseases are associated with increases in poverty and hunger and decreases in income, education and socioeconomic status.[57,58] Previous studies have paid attention to the influence of SES on chronic diseases,[58] but the interaction between SES and other factors has not been well confirmed. Social determinants, such as SES, have an impact on people with T2DM, however research on this topic has primarily focused on the prevention or risk of developing diabetes. Therefore, this study proposes that SES is involved in the process of diabesity and complements diet and sleep disorders. As IDF reported, 3 in 4 people with diabetes live in low- and middle-income countries.[3] This implies that social determinants of health have an impact on how T2DM develops.[57]

Conclusion

This study found that sleep disorders and unhealthy eating habits can lead to the occurrence and development of diabesity. Reasonable management of these two ways is an important modifiable risk factor in the prevention and treatment of diabetes and other metabolic diseases. In the process of blood glucose management, increasing the above factors that may affect diabetes has a good effect on the effective control of diabesity and other complications.

At present, in most health surveys and disease screening, waist circumference itself has a good correlation with total body fat and can be a good indicator of body fat distribution, thus showing good applicability in some studies.[59] Therefore, WC and BMI were used as outcome variables in this study. Through previous studies, it was found that factors acting on obesity itself can also lead to diabetes combined with obesity (diabesity) because WC and BMI can serve as predictive indications of the severity of diabetes according to several research.[51,60]

Strengths and Limitations

This study has certain advantages: the study used the correlation between diet style and sleep pattern to study metabolic indicators, which can provide a solid theoretical basis for the subsequent combined treatment of sleep intervention and diet intervention in diabetic patients. This research group will conduct additional studies in the future to further explore the predictive value of these HRFs for clinical outcomes and ultimately as a potential surrogate value for the growing cohort of diabetic patients worldwide. In addition, this study adopted a multicenter and multilevel design and included participants from 4 regions, which was representative to a certain extent.

This study also had some limitations. First, although the face-to-face interview method was adopted in this study, the overall sleep patterns and eating habits of the participants were mainly measured by self-report, which had certain imprecision and recall bias, and the ability of accurate assessment was also limited. Second, as a cross-sectional study, it is difficult to observe the causal relationship between HbA1c, sleep patterns, diet styles, BMI and WC, and its generalizability needs to be further confirmed by cohort studies. Finally, sleep duration was measured using a questionnaire, and follow-up studies will assess patients with accelerometers or sleep monitoring.

Data Sharing Statement

The datasets generated for this study are available on request to the corresponding author.

Ethics Approval and Consent

The study met the standards for the ethical treatment of participants and was approved by the ethnic community of Anhui Medical University, and this study complies with the Declaration of Helsinki. The China DiaChronic Study was approved by the Ethical Review Committee (Approval No: 2018-010) and was registered in the Chinese Clinical Trial Registry (ChiCTR1800014432), and all subjects signed informed consent forms.

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Author Contributions

All authors made a significant contribution to the work reported, whether in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work. The work presented here has not been published previously and is not being considered for publication elsewhere. The author(s) read and approved the final manuscript. All authors have read and approved the manuscript.

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