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Effects of walkability on physical activity and obesity: a prospective observational study protocol

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ABSTRACT

Introduction The prevalence of overweight and obesity is increasing worldwide, which could lead to a set of chronic and metabolic diseases. Physical activity is a modifiable factor for obesity, which was reported to be correlated with the built environment. However, the effects of the built environment on physical activity are not consistent. Walkability is a convenient way to assess the built environment. We aim to prospectively explore the relationship among walkability, physical activity and obesity in Chinese participants in Chongqing, a hilly city and provide evidence for future urban planning.

Methods and analysis Participants will be recruited from people who receive health examination in the Health Management Centre, the First Affiliated Hospital to Army Medical University. Exposure variables are WalkScores calculated within the areas around workplace and residential addresses of participants. The primary outcomes are body mass index measured through health examination at baseline and follow-ups, and daily walking steps recorded by WeChat mini application for 30 days after every time of health examination. Other health-related data of the participants will also be collected. Multivariate regression analysis will be performed to examine the relationship between exposure variables and outcomes.

Ethics and dissemination The Protocol is approved by the Ethics Committee of the First Affiliated Hospital to Army Medical University (KY201839). The results will be actively disseminated through peer-review journals and conference publications.

Registration number Chinese Clinical Trial Registry (ChiCTR1800017680).

INTRODUCTION

The prevalence of overweight and obesity has doubled worldwide since 1980, which is currently 5% in children and 12% in adults.1 In 2015, the number of children and adults who suffered from obesity was 107.7 million and 603.7 million, respectively.2 High body mass index (BMI), an indicator for obesity, was identified to be a risk factor for various chronic diseases, including cardiovascular disease, diabetes, chronic kidney disease and cancers.3 Chinese Health and Nutrition Survey shown the rate of obesity and overweight in adults increased from 25.1% to 39.6% from 1997 to 2009.3 The updated prevalence of overweight and obesity were reported to be 25.8% and 7.9%, respectively, in 2017.4 It is reported that the obesity rate in Chongqing in Southwestern China is 10.3%.5,6

One of the modifiable risk factors of obesity and chronic diseases is physical inactivity.7,8 Physical activity indicators are correlated with some metabolic indicators.9 Physical inactivity is partly due to insufficient activity during leisure time and an increase in sedentary behaviour during occupational and domestic activities.10 Additionally, an increase in the use of ‘passive’ modes of transport such as taking a car or a bus has also been associated with declining physical activity levels, which means less walking or any human-powered movement in daily life.10 Insufficient physical activity contributes to 6% of the disease burden of coronary heart disease, 7% of that of type 2 diabetes, 10% of that of breast cancer and 10% of that of colon cancer.11 As reported, more than 533000 deaths and more than 1.3 million deaths could be averted annually by reducing the prevalence of physical inactivity by 10% and 25%, respectively.11 Thus, in order to ameliorate physical inactivity, it is crucial to understand its associated factors and determinants. The

Strengths and limitations of this study

- This study innovatively evaluates the effects of walkability on physical activity and obesity in a hilly city prospectively.
- The daily walking steps were recorded using a novel method. WeChat mini application.
- This study combines the data collected from the health examination and cellphones.
- One limitation is that WeChat mini application would fail to record daily walking steps during swimming and other physical activities without cellphones.
- The other limitation is the maximum time for data collection is 30 days after one authorisation.
factors associated with physical activity in high-income countries were reported to be age, sex, health status, self-efficacy, genetic factors and motivation. At the level of population, the factors outside health sectors have been identified to be causally related to physical inactivity, for example, urban planning, transportation system and the built environment.22–24

Walkability is a useful tool in the process of evaluating the effects of the built environment on physical activity. However, the evidence on the associations among the built environment, walkability, physical activity and health is inconsistent. A study published in *Nature* in 2017 with more than 700,000 participants and 68 million days recorded revealed that higher walkability was associated with more daily walking steps, whose effect was stronger for females.15 Porter and colleagues also indicated in a cohort study with 688 participants that as one aspect of the neighbourhood environment, walkability was associated with physical activity among pregnant women.16 Other studies from Japan and North America also supported the positive effects of the built environment on physical activity.17–19 In a middle-size city Bengbu in Eastern China, researchers observed about at least 30% lower risk of cardiovascular diseases were associated with moderate movement and the distance to behavior-related destinations.24–29 Residential housing units are a house, apartment, group of rooms, or a single room for occupancy as a separate living unit, which could predict the population allocation in an area.30 Retail shops are one kind of points of interest, which serve for non-commercial centres, which is characterised by a unique hilly topology with two rivers, Yangtze and Jialing.40 A map and photos with the hilly topography of Chongqing are shown in online supplemental figure 2. Blood samples, clinical data, addresses and related variables are collected prospectively from participants who receive health examination in the Health Management Centre, First Affiliated Hospital to Army Medical University. The daily walking steps of participants are collected by WeChat mini application. The home and workplace addresses and the part of listed variables in *table 1* will be collected by a questionnaire referred to a comprehensive cohort study named China Kadoorie Biobank study.41 Participants will be recruited from October 2019 to 2020 and followed up till 2023. The recruitment period will be extended if necessary. The recruitment process can be referred

The evaluation of the walkability of a community and its effects on physical activity and health status of the residents in China could shed light on urban design, laying a foundation for future urban planning policy and physical activity promotion interventions. Additionally, there is a gap of research on the influences of walkability on physical activity in a hilly city. This protocol is an observational, prospective cohort study of participants who receive health examination in the First Affiliated Hospital to Army Medical University. The aim of this study is to analyse the relationships among walkability, physical activity and obesity in the residents in Chongqing for future urban planning reference. Previous literature shows lower hilliness is associated with enhanced physical health.32 Our research hypothesis is that high WalkScore will be associated with the decrease of BMI under the context of a hilly city. The daily walking steps and metabolic profiles will be the mediators through the effect pathway from WalkScore to BMI.

We illustrate our hypothesis of causal diagram in online supplemental figure 1. Obesity and overweight as well as daily walking steps are the primary outcomes. WalkScore is the exposure variable. Daily walking steps and metabolic profiles are the mediator from WalkScore to obesity.9 33 34 Job and education are possible confoundings between WalkScore and daily walking steps.35 Physical activity is possible confounding between daily walking steps and metabolic profiles.9 30 Online food order habit is possible confounding between WalkScore and metabolic profiles. Eating habit, smoking and alcohol consumption are other factors, which will influence metabolic profiles.37–39

**MATERIALS AND METHODS**

**Study design and setting**

Our protocol is an observational, prospective cohort study. The location of our protocol is Chongqing, a Chinese city, with multi-commercial centres, which is characterised by a unique hilly topology with two rivers, Yangtze and Jialing. A map and photos with the hilly topography of Chongqing are shown in online supplemental figure 2. Blood samples, clinical data, addresses and related variables are collected prospectively from participants who receive health examination in the Health Management Centre, First Affiliated Hospital to Army Medical University, Chongqing. Blood samples are examined by the clinical laboratory of the hospital. Clinical and demographic data are recorded in the hospital’s database. The daily walking steps of participants are collected by WeChat mini application. The home and workplace addresses and the part of listed variables in *table 1* will be collected by a questionnaire referred to a comprehensive cohort study named China Kadoorie Biobank study. Participants will be recruited from October 2019 to 2020 and followed up till 2023. The recruitment period will be extended if necessary. The recruitment process can be referred
Table 1  All measured variables

| Variable category | Name of variable | Normal limits* or categories | Definition of variables† | Sources of data |
|-------------------|------------------|-----------------------------|--------------------------|----------------|
| Primary outcomes  | Body mass index  | 18.5–24 kg/m²               | Outcome                  | Calculate from health examination data (height and weight) |
|                   | Daily walking steps in 1 month |                         | Outcome and mediator | WeChat mini application |
| Secondary outcomes| Fasting blood glucose | 3.6–6.1 (mmol/L) | Outcome | Health examination |
|                   | Total cholesterol | 3.1–5.7 (mmol/L)           | Outcome                  | Health examination |
|                   | Triglyceride      | 0.4–1.73 (mmol/L)          | Outcome                  | Health examination |
|                   | Low density lipoprotein cholesterol | 2.07–3.1 (mmol/L) | Outcome | Health examination |
|                   | High density lipoprotein cholesterol | 0.9–2 (mmol/L) | Outcome | Health examination |
|                   | Body composition  | Mass percentage of fat     | Outcome                  | Health examination |
| Exposure variables| WalkScore corresponding to home address | 0–100                  | Exposure                  | Calculate from questionnaire information |
|                   | WalkScore corresponding to workplace address | 0–100                  | Exposure                  | Calculate from questionnaire information |
| Other variables   | Height            |                             | Health examination       |                            |
|                   | Weight            |                             | Health examination       |                            |
|                   | Age               | 16–65 years old            | Possible confounding      | Questionnaire               |
|                   | Gender            | Male; female               | Possible confounding      | Questionnaire               |
|                   | Job               |                             | Possible confounding      | Questionnaire               |
|                   | Education         | Under primary school; primary school, middle school; bachelor; master and above | Possible confounding | Questionnaire               |
|                   | Smoking status    | Giving up; never; sometimes smoke; frequently smoke | Other factors will influence outcome | Questionnaire               |
|                   | Alcohol consumption | Giving up; never; sometimes drink; frequently drink | Other factors will influence outcome | Questionnaire               |
|                   | Online food order habit | Never; sometimes order; frequently order | Possible confounding | Questionnaire               |
|                   | Eating diet       | Not applicable             | Other factors will influence outcome | Questionnaire               |
|                   | Physical activity | Not applicable             | Possible confounding      | Questionnaire               |

* Normal limits’ means in these limits, the corresponding condition is normal, otherwise, it suggests there may be some health concerns or some errors.
† The definition of variables can be referred to online supplemental figure 1.

to figure 1 and the timeline is shown in online supplemental table 1. Moreover, we will include the participants who decided an examination appointment before health examination day if he/she meets the inclusion/exclusion criteria. We need to require this kind of participants to provide home and workplace addresses on the first visit and fill the questionnaire on the health examination day.

In the baseline, the specific recruitment and data collection procedure are as follows. Stage 1: after participants signed informed consent, we collected demographic data
and home/workplace addresses information in 2019 October. The recruitment time will be extended to 2020 May. Stage 2: Before or on the health examination day in 2020 March–May, we will check the inclusion/exclusion criteria and screen the participants for the first time. Stage 3: collecting questionnaire on the health examination day in 2020 March–May. Stage 4: requesting participants to instal WeChat mini application and endow authorisation on the health examination day in 2020 March–May. Stage 4: health examination including blood sample collection and height/weight measurement will be conducted. Stage 5: daily steps in 30 days will be collected after the day of health examination. Stage 6: the inclusion/exclusion criteria will be checked second after data collection.

In the three times follow-ups in 2021, 2022 and 2023, the data collection procedure is similar to those in the baseline. Stage 1: collecting demographic data and updating home/workplace addresses information. Stage 2: collecting questionnaire. Stage 3: requesting participants to instal WeChat mini application and endow authorisation. Stage 4: health examination including blood sample collection and height/weight measurement will be conducted. Stage 5: daily steps in 30 days will be collected after the day of health examination.

Participants
This is an open cohort study. Participants are eligible for inclusion if they satisfy the following criteria: an age between 16 and 65, using smartphones, habitual residents in the downtown area of Chongqing.

The exclusion criteria will be: (1) participants with the symptoms or signs of cardiovascular and cerebrovascular diseases, such as chest tightness, shortness of breath and even chest pain, especially those whose symptoms get worse when climbing stairs or walking fast; (2) participants with diagnosed heart diseases, such as coronary heart diseases, hypertensive heart diseases, valvular heart diseases and pulmonary heart diseases, who need to exercise based on principles of cardiac rehabilitation; (3) participants with other severe complications of diabetes, such as those with vision severely affected by eye diseases, those with balancing ability affected by peripheral neuropathy, those with diabetic foot and those with renal dysfunction; (4) participants whose movement is affected by musculoskeletal disorders, for example, patients with musculoskeletal disorders and cardiopulmonary dysfunction; (5) participants who refuse to provide corresponding information, or are not able to complete the questionnaire and health examination (this item should also be checked in data cleaning stage); (6) participants who plan to migrate to other areas or leave for a long time (more than 1 year); (7) participants with secondary morbid obesity caused by congenital diseases, metabolic diseases, neurologic diseases and endocrine diseases. After checking the inclusion/exclusion criteria, the participants are planned to be recruited. Participants must be able to sign written informed consent after acknowledging the benefits and risks of this study. Participants information will be checked and the follow-ups will be traced by the health managers and nurses in the Health Management Centre.

The number of the sample size was calculated using the following formula:

\[ n = \frac{z_\alpha \sqrt{2p_0q_0} + z_\beta \sqrt{p_0q_0 + p_1q_1}}{(p_1 - p_0)^2} \]

The parameters used in the calculation are: \( p_0 \) (the obesity prevalence in control group) as 10.3%, \( p_1 \) (the supposed risk ratio (RR) between groups with high WalkScore and low WalkScore as 0.5, \( \alpha = 0.05 \) and \( 1-\beta = 0.9 \). In this formula, \( p_1 = p_0 \times RR = 0.15 \), \( p = (p_0 + p_1)/2 \), \( q = 1 - p \), \( q_0 = 1 - p_0 \) and \( q_1 = 1 - p_1 \). \( Z_\alpha = 1.96 \), and \( Z_\beta = 1.282 \). Based on these parameters, the sample size in exposure group and control group should be 400, respectively. Concerning the possibility of loss of follow-up, we increased the sample size by 10% to 440 participants in each group. The final sample size is 880 in total.

Measures
The questionnaire (full version of the questionnaire is attached in online supplemental file 1) filled by participants under nurses’ guidance includes the questions of participant demographics, exposure and lifestyle factors. The measured variables, primary outcome and secondary outcomes, exposure variables, as well as possible confoundings are listed in table 1. The variables in detail are shown in online supplemental file 2. The relationships among different variables are illustrated in a causal diagram in online supplemental figure 1.

During the process of data collection, the following data were collected by the questionnaire and health examination procedure as well as WeChat mini application:

1. Primary outcomes: BMI, and everyday walking steps are recorded by a WeChat mini application. Every year, the daily walking steps in 30 days will be collected after health examination in the hospital. BMI was calculated by the weight in kilograms divided by the square of the height in metres. Overweight and obesity were defined...
as a BMI of 24–27.9 kg/m² and a BMI≥28 kg/m², respectively.4 The participants will authorise the application in order to allow the researchers in this study to obtain the daily walking steps in 30 days collected by the WeChat mini application. (They only need to record walking steps of 30 days once a year.)

2. Secondary outcomes: metabolic profiles by blood tests; for example, cholesterol levels and blood glucose. Body composition was measured by a machine named Inbody 220, when doing the measurement in which, the participants will stand on the machine without shoes and hold the two poles of the machine for 5 min.

3. Exposure variables: Walkscores, which will be calculated based on the workplace address and residential address of the participants.

4. Participant demographics: age, gender, height, marital status and education.

5. Lifestyle factors: smoking status, alcohol consumption, online food order habit, eating diet and physical activity.

6. Identification of non-communicable diseases: for example, hypertension, coronary artery disease and diabetes.

**Biological samples and assay methods**

The blood samples are collected by nurses in the Health Management Centre in the morning. The participants should be fasting for 12–14 hours before health examination. A sum of 5 mL blood was collected in the yellow tube with inert separating gel for cholesterol and glucose testing. A total of 2 mL blood for blood routine test was stored in a purple tube with EDTA as anticoagulant. The blood samples are analysed by automated biochemical analyser, with the series number of Beckman AU5811. Total cholesterol was tested by the cholesterooxidase enzyme method. Triglyceride was tested by the glycerol phosphate dehydrogenase and peroxidase method.

**Physical examination**

The physical examination included the measurement of height, body weight, blood pressure and body component following the guidelines of the Health Management Centre. The blood pressure was evaluated by electronic sphygmomanometer (Omron, type: B-203RV III C). The machine Inbody 220 was used to analyse body component, including the proportion of water, protein, mineral salt and fat.

**WalkScore**

WalkScore measures pedestrian friendliness by analysing the distance to points of interest and the weights of points of interest. Data sources are from Google, Factual, Great Schools, Open Street Map, the US Census, Localeze and places added by the WalkScore user community.45 The algorithm of WalkScore is not disclosed in its official website. The formula45 of WalkScore illustrated in Tsinghua University is

\[ \sum_{i=1}^{m} \sum_{j=1}^{n} \left( W_i \ast S_{ij} \ast DD_j \right) \ast \left( \frac{100}{15} \right) \]

\[ W_i \] is the weight of one kind of amenity. Table 2 shows the weights of different amenities.

The letter of i stands for different kinds of amenities. The letter of j stands for different walking distance. \( S_{ij} \) stands for service scope of a specific amenity. \( DD_j \) stands for the attenuation coefficient based on distance from the calculated point to an amenity. Table 3 shows the attenuation coefficients based on the distances from the calculated point to an amenity.

The calculation of WalkScore is free, to obtain which we could type the name of calculated point into the official website/cellphone application and wait for the score (www.WalkScore.com). The limit of the score is 0–100. The WalkScore of residential address and workplace address will be calculated separately.

The following table 4 describes the meanings of different WalkScore.

**WeChat mini application**

WeChat is a cellphone application for communication used by more than a billion people.44 The customers of it can send voice, video, photos and text. On the basis of WeChat and its great number of users, the company of WeChat opens the resources to the public of developing different kinds of WeChat mini applications. Users could link its WeChat ID to WeChat mini application without download instalment package and achieve data sharing through WeChat mini application. WeChat could also record daily step data from users’ cellphones after user’s agreement. Through WeChat mini application, we could extract the daily walking steps of WeChat users in 1 month after customer agreement. After we develop the WeChat mini application following the guideline from

**Table 2** Weights of different amenities

| Amenity’s name | Weight | Amenity’s name | Weight | Amenity’s name | Weight |
|----------------|--------|----------------|--------|----------------|--------|
| Convenience store 3 | Café/teahouse 2 | School 1 | Shop 2 | Park 1 | Entertainment places 1 |

**Table 3** Attenuation coefficients based on the distances

| Distances (m) | Attenuation coefficients |
|---------------|--------------------------|
| <400          | 1                        |
| 400–800       | 0.9                      |
| 800–1200      | 0.55                     |
| 1200–1600     | 0.25                     |
| 1600–2400     | 0.08                     |
| >2400         | Out of distance scope, which will not be calculated. |
WeChat and publish it, the participants could open the WeChat mini application in their WeChat and signed a second consent to agree that they are willing to allow us to extract daily steps on the platform of WeChat. Then, the customers’ daily step information will be delivered to our datasets automatically. The obtained data will be consistent with the records in participants’ cell phones.

**Statistical methods**

The data analysis will be conducted after data collection in 2020. The prospective analysis will be implemented in 2023. Stata (V.14.0, Stata Corp., College Station, Texas, USA) and R (V.4.0.2) will be used for data analysis. Descriptive statistics will be performed to analyse the distribution of the data. Missing data will be addressed by deletion or last observation carried forward based on specific case status. Single variable analysis will be implemented to analyse the correlations between exposures, possible confoundings (ie, online food order habits, education, job, physical activity) and outcomes. The participants will be divided into five groups by the categories of the WalkScore with regard to workplace address and residential address, respectively. The lifestyle factors and outcomes will be compared among groups. All the variables in causal diagrams will be compared between baseline and follow-ups. T-test will be used for comparing the difference of the continuous variables in two groups and $\chi^2$ test or analysis of variance will be used for comparing the difference of categorial variables in different groups. Multivariate linear regression will be conducted taken BMI and daily walking steps as dependent variables, respectively, as cross-sectional analyses, after data collection in 2020. Sensitivity analysis will be implemented by bootstrap method. With replacement from the original dataset, the bootstrap method enables estimation of the accuracy of an estimator by random sampling. Further longitudinal analyses with G estimation and inverse probability weight analysis will be conducted after data collection in 2023 in order to take into account the effects of confounders whose conditions may change over time. The first step is to determine the ranges and variations of the independent variables, which are input into our multivariate linear regression. The second step is to generate independent variables based on the Sobol sequence by R package ‘randtoolbox’. The final step is to collect and process the simulation results, which can be used in sensitivity analysis through conducting multivariate linear regression.\(^4^5\)

**PATIENT AND PUBLIC INVOLVEMENT**

Our study is an observational study without intervention on participants. The development of the research question and outcome measures were informed by participants’ priorities, experience and preferences on the basis of informed consents. There is no participants’ involvement in the study design. We recruit participants when conducting the study, but participants would not be the conductor of the study. The results are planned to disseminate to study participants.

**ETHICS AND DISSEMINATION**

The Protocol is approved by the Ethics Committee of the First Affiliated Hospital to Army Medical University (KY201839). All the participants will receive consultation about the benefits and possible risks of the study from health managers and nurses, and endow written informed consent before enrollment. All the participants will be informed that they can withdraw from the study at any time for any reason. The withdrawal cases will be discarded and related information will be deleted from the database of the study.

The sample volume of blood for the study is 11 per participant-visit and maximum 55 for 5years. The blood sampling process is part of the procedure of health examination and this study acquires the data use authority after the recruitment. The participants will be contacted and informed the results of the health examination. The researchers of this study will be responsible for implementing the study adhering to the Declaration of Helsinki.

We plan to analyse and publish study results according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines. Results will be published in international and peer-reviewed scientific journals. Negative, positive, conclusive or inconclusive results will be published.

**STUDY STATUS**

We collected demographic data, home addresses and workplace addresses of participants in October 2019. We plan to check previous data and collect the data of health examination and questionnaire of participants in March–May 2020 and daily walking steps of participants by WeChat mini application in 2020 (in 1 month after health examination). We will continue follow-up in 2021–2023. The follow-up will be sustained by contacting participants and requiring health examination by phone. Currently, the daily walking steps collector of the WeChat mini application has been developed. The study was registered in Chinese clinical trial registration. The date of the
study in a timeline is shown in online supplemental table 1. There will be six waves of data collection.

DISCUSSION AND POTENTIAL LIMITATIONS
This observational and prospective study could innovatively provide evidence of the relationship among walkability, obesity and physical activity in China. It will also provide evidence of the influence of the built environment on physical activity in a hilly city, Chongqing. We hypothesised that the walkability, physical activity and obesity status are strongly associated with each other. The use of WeChat mini application in data collection process has a lot of advantages. Through extracting data from cellphones’ records, the data collection is very convenient and cost-effective, which eliminates the errors of manual typing. The participants will sign informed consents before recruitment and sign an agreement to endow WeChat mini application to collect their daily steps before the use of WeChat, in which way we could ensure the process meets the ethic requirements.

There are some limitations in the collection of physical activity. The WeChat mini application can only record the daily walking steps when the participants walk with their phone. Like other studies, activities without carrying phones such as swimming and ball games will not be recorded in the data collection procedure. Moreover, more than 30 days’ collection needs second authorisation (the maximum data collection time is 30 days after one authorisation) which is less adherent; thus the researchers could only collect the data of 30 days in 1 year for convenience. In order to compensate for this limitation, the participants will be recruited all year round and the researchers will ask for a second authorisation of daily step collection in the follow-up visit. In terms of season, the season when we do the data collection may also influence the number of daily steps. We will consider the season as a confounder in future data analysis.

Moreover, WalkScore is based on an online calculation website which has not opened the algorithm officially. Other walkability evaluation tools such as Pedestrian Environment Quality Index depend on the evaluation of geographic information system, the score process of which is relatively clean; however, the practice is more complex. Thus, we decide to choose WalkScore for the exploratory study. If the results could indicate a strong relationship between walkability and obesity, we could further analyse the specific component factors such as the diversity of points of interests of walkability in the following analysis.

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Questionnaire

Part One: Basic Personal Information

1. Name: ____________

2. Physical Examination Number: ____________

3. Birthplace: City________, Province________

4. Present Address: Number________, Neighborhood Committee/Village________, Township/Street________, District/County________, City________, Province________

5. Work Address: Number________, Neighborhood Committee/Village________, Township/Street________, District/County________, City________, Province________

6. Except for home and office, is there any other place you are frequently present?

□ Yes  □ No  If yes, how long will you spend in this place in one week? ____ hours

7. ID Number: ____________

8. Nationality: □ The Han Nationality □ National Minority: ____________

9. Blood Type: ____________

10. Height: ____________ cm

11. Weight: ____________ kg

12. Education Level:

□ Did not attend school normally □ Primary school or below

□ Junior high school □ High school and secondary technical school

□ Junior college □ Undergraduate college

□ Master degree and above
13. Category of Employment:

- Company employee
- House
- Student
- Active duty soldier
- Freelancer
- Industrial worker
- Self-employed people
- Full-time driver
- Service and sales personnel
- Professional and technical personnel
- Civil servant, personnel of public institutions and state-owned enterprises
- Farmers, herdsmen and fishermen
- Others

14. Are you currently customer of Wechat daily step calculator?

- Yes
- No

15. In the past week, what is your average step recorded by Wechat daily step calculator, or other step recorder? ________steps
Part Two: Family History and Personal Health Status

1. Family History (Choose the diseases which your relatives are / were diagnosed with at present / in the past from those listed below)

Are / were your parents, brothers or sisters currently diagnosed with the following diseases?

(multiple choice, put a √ under the options)

| Diseases                              | Father | Mother | Brother | Sister |
|---------------------------------------|--------|--------|---------|--------|
| Lung cancer                           |        |        |         |        |
| Liver cancer                          |        |        |         |        |
| Gastric cancer                        |        |        |         |        |
| Esophageal cancer                     |        |        |         |        |
| Colorectal cancer                     |        |        |         |        |
| Thyroid cancer                        |        |        |         |        |
| Prostate cancer                       |        |        |         |        |
| Cervical cancer                       |        |        |         |        |
| Endometrial cancer                    |        |        |         |        |
| Ovarian cancer                        |        |        |         |        |
| Breast cancer                         |        |        |         |        |
| Diabetes mellitus                     |        |        |         |        |
| Hypertension                          |        |        |         |        |
| Obesity                               |        |        |         |        |
| Gout (hyperuricemia)                  |        |        |         |        |
| Hyperlipidemia                        |        |        |         |        |
| Asthma                                |        |        |         |        |
| Chronic obstructive pulmonary         |        |        |         |        |
| (chronic bronchitis, emphysema)       |        |        |         |        |
| Stroke                                |        |        |         |        |
| Coronary heart disease or myocardial infarction |        |        |         |        |
| Osteoporosis                          |        |        |         |        |
| Mental disease                        |        |        |         |        |
| Other diseases                        |        |        |         |        |
| None                                  |        |        |         |        |
2. Personal History of Diseases

Whether the following diseases are / were diagnosed? (multiple choice)

- Lung cancer
- Liver cancer
- Gastric cancer
- Esophageal cancer
- Colorectal cancer
- Thyroid cancer
- Prostate cancer
- Cervical cancer
- Endometrial cancer
- Ovarian cancer
- Breast cancer
- Diabetes
- Hypertension
- Hyperlipidemia
- Stroke
- Asthma
- Osteoporosis
- Fracture
- Mental disorders
- Neurasthenia
- Gout (hyperuricemia)
- Thyroid disease (thyroiditis, nodule)
- Chronic cholecystitis and cholelithiasis
- Gastritis or duodenal ulcer
- Coronary heart disease or myocardial infarction
- Prostatic disease (hyperplasia of prostate, hypertrophy)
- Chronic obstructive pulmonary disease (chronic bronchitis, emphysema)
- Chronic liver disease (hepatitis B, hepatitis C, fatty liver, alcoholic liver, liver cirrhosis)
- Chronic glomerulonephritis (nephritis, nephrotic syndrome, chronic renal insufficiency)
- Chronic breast diseases (hyperplasia of mammary glands, nodules, adenosis, cysts, etc.)
- Chronic gynecologic diseases (uterine fibroids, ovarian cysts, inflammations, etc.)
- History of operation: (The operation name: ____)
- Other diseases
- None of the above diseases

3. Medication History

Do you take the following medicines for a long term? (continuous use for above 6 months, and more than once per day on average)

- Hypotensive drugs
- Beta blockers
- Psychotropic drugs
- Antiarrhythmic drugs
- Uric acid-lowering drugs
- Hypoglycemic drugs
- Sedative or hypnotic drugs
- Hormone drugs
- Chinese herbal medicines
- Antipyretic analgesics
- Antiplatelet drugs such as aspirin
- Lipid-modulating drugs (lipid-lowering drugs)
- Angiotensin-converting enzyme inhibitors
- Anti-asthmatic drugs
- Others
- None
Part Three: Eating Habits and Lifestyle

1. Eating Habit

1.1. Generally speaking, how many days during a week will you eat the following food on average? (single choice)

| Food                          | 5 - 7 days | 3 - 4 days | 1 - 2 days | <1 day or never eat |
|-------------------------------|------------|------------|------------|---------------------|
| Rice                          |            |            |            |                     |
| Noodles                       |            |            |            |                     |
| Coarse Cereals                |            |            |            |                     |
| Meat (pigs, cattle, sheep, poultry) |            |            |            |                     |
| Fish or other aquatic products|            |            |            |                     |
| Fresh vegetable and fruit     |            |            |            |                     |
| Milk and dairy products       |            |            |            |                     |
| Eggs and their products       |            |            |            |                     |
| Beans and bean products       |            |            |            |                     |
| Dessert (pastries, candy, etc)|            |            |            |                     |
| Fried food                    |            |            |            |                     |
| Pickled, smoked food          |            |            |            |                     |

1.2. In the past year, did you take the following nutrients for at least one month? (except for ginseng)

- Cod liver oil / fish oil
- Ginseng (at least five times a year)
- Vitamin
- Other health supplements
- Calcium / iron / zinc

1.3. Have you ever experienced severe food shortages in your life?

- Yes
- No

If not, please turn to question 4

1.3.1. In which year did you experience the most severe food shortage? _____

1.3.2. When you were experiencing the most severe food shortage:
1.3.2.1. Did your weight decrease significantly?

☐ Yes  ☐ No  If yes, it dropped by ___ kilograms

1.3.2.2. Did you suffer from edema, severe anemia and other diseases caused by food shortages such as?

☐ Yes  ☐ No

1.4. In the past month, how often did you eat spicy food?

☐ Never / almost never  ☐ 1-2 days a week

☐ A few times, but less than once a week on average

☐ 3-5 days a week  ☐ Every day or almost every day

1.5. How old did you begin to eat spicy food every week? ____ years old

1.6. Do you like slightly spicy food or very spicy food?

☐ Slightly spicy  ☐ Spicy  ☐ Very spicy

1.7. Do you order food online?

☐ Yes  ☐ No

1.8. How often will you order food online in one week? _______ Times

1.9. What are the categories of online-ordered food you select?

☐ Noodles with soup  ☐ Rice  ☐ Fried noodles  ☐ Dumplings

☐ Sweet food, eg. cake  ☐ Drinks  ☐ Others

1.10. How often will you eat outside home (not including online order food)?

______ Times

2. Smoking

Do you smoke?

☐ Yes. Please answer questions 2.1, 2.2, 2.5 and 2.6

☐ No. Please answer questions 2.7-2.8.

☐ Quit smoking. (have quit smoking for more than one month) Please answer questions 2.3-2.6.

2.1. You began to smoke at the age of _____.

2.2. You smoke ____ cigarettes per day on average.

2.3. You quitted smoking at the age of _____.

2.4. Before quitting smoking, you smoked ____ cigarettes per day on average.

2.5. Which type of cigarettes do you smoke at present/or did you smoke before quitting?

☐ Filter cigarette  ☐ Non-filter Cigarettes  ☐ Cigar

☐ Hand-rolled cigarette / tobacco

☐ Tobacco pipe / waterpipe smoking

2.6. Which organ do you suck the smoke into?
3. Alcohol drinking

3.1. Do you drink alcohol? (Make the choice and fill in the blanks based on reality)
☐ Never ☐ In the past (have quit drinking for more than 6 months)

☐ Yes (If yes, please answer questions 3.1.1-3.1.4)

3.1.1 You began to drink alcohol at the age of _____.

3.1.2 How often do you drink? (Single choice)
☐ Twice almost everyday  ☐ Once almost everyday  ☐ 3-4 times a week
☐ 1-2 times a week  ☐ Drink every month, but less than once a week  ☐ Seldom
once a week

3.1.3 How much do you drink each time (only fill in the blanks with the alcohol you drink commonly)?
☐ Beer, ____ bottles/day
☐ Yellow wine / rice wine / fruit wine, ____ grams/day
☐ Wine, ____ grams/day
☐ Liquor with a high alcohol level (≥40°), ____ grams/day
☐ Liquor with a low alcohol level (≤40°), ____ grams/day

4. Sleeping (Make the choice and fill in the blanks based on reality)

4.1. How is the quality of your sleep in the past month?
☐ Very good ☐ Good ☐ Bad ☐ Very bad

4.2. How long did you sleep per day on average in the past month? ____ hours
4.3. Did you need to take medicine to help you fall asleep in the past month? (medicine prescribed by the doctor or purchased by yourself)

□ No □ < Once every week on average
□ Once-twice every week on average □ ≥ 3 times every week on average

5. Physical activity

5.1. In the past year, what is your activity status during work?

□ Sedentary □ Standing □ Activity with medium amount
□ Activity with heavy work load □ Retired or disabled to work

5.2. What is your average working hour in one week? _______ hours

5.3. In the past year, what is your transportation way to go to work?

□ Walking □ Driving □ Taking a bus
□ Riding a bike □ Work at home □ Others
or the place closed to home

5.4. How long is the commuting time of your work? _____ min

5.5. In the past one year, what is your physical activity frequency?

□ Never □ 1-3 times one month □ 1-2 times one week
□ 3-5 times one week □ Almost everyday

5.6. What is the exercise way you did the most frequently?

□ Taichi/Walking □ Fast walking □ Running/or other aerobics
□ Swimming □ Ball game □ Others(such as hiking)

5.7. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, heavy construction, or climbing up stairs as part of your work?

_____ days per week

5.8. How much time did you usually spend on one of those days doing vigorous physical activities as part of your work?

_____ hours per day, _____ minutes per day
5.9. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads as part of your work? Please do not include walking.

_____ days per week

5.10. How much time did you usually spend on one of those days doing moderate physical activities as part of your work?

_____ hours per day, _____ minutes per day

5.11. During the last 7 days, on how many days did you walk for at least 10 minutes at a time as part of your work?

_____ days per week

5.12. How much time did you usually spend on one of those days walking as part of your work?

_____ hours per day, _____ minutes per day

5.13. During the last 7 days, how much time did you usually spend sitting on a weekday?

_____ hours per day, _____ minutes per day

5.14. Did you use sport watch or app for record steps or heart rate?

☐ Yes   ☐ No

If yes, the name of the sport watch is______, the name of the sport app is______

6. Others

6.1. Are you satisfied with your current living conditions?

☐ Cannot be more satisfied   ☐ Basically satisfied

☐ Ordinary                  ☐ Dissatisfied                  ☐ Very dissatisfied

6.2. Did you experience the events that have a significant impact on your life in the past two years, such as those listed below?

☐ Marital separation/divorce   ☐ Serious trauma or car accident

☐ Unemployment / laid-off / retirement   ☐ Death of spouse

☐ Serious family diversity and conflicts   ☐ Violent attacks / rapes

☐ Loss of economic resources / liabilities

☐ Bankruptcy of self-owned business or family economic breakdown

☐ Death or serious diseases of other family members

☐ Serious natural disasters (such as drought, waterlogging, etc.)

☐ None
6.3. In the past year, are you under great mental stress in work and life?
□ No pressure □ Little pressure □ Ordinary
□ Great pressure □ Extremely great pressure
6.4. In the past one year, is any change in your body weight?
□ No □ Add at least 2.5kg □ Lose at least 2.5kg
6.5. In the past one year, do you using drugs or controlling diet intake in order to lose weight?
□ Yes □ No
6.6. Could you remember your body weight when you was at age of 25?
______kg; □ Not applicable
Signature______________________________________
| Variable category | Name of variable                        | Normal limits or categories | Definition of variables                  | Data resources                        |
|------------------|----------------------------------------|-----------------------------|------------------------------------------|---------------------------------------|
| **Primary outcomes** | body mass index                        | 18.5-24kg/m²                | outcome                                  | calculate from health examination information |
|                  | daily steps in one month               |                             | mediator and outcome                     | Wechat mini application               |
| **Secondary outcomes** | fasting blood glucose (GLU)           | 3.6-6.1 (mmol/L)            | outcome                                  | health examination                    |
|                  | total cholesterol (TC)                 | 3.1-5.7 (mmol/L)            | outcome                                  | health examination                    |
|                  | triglyceride (Tg)                      | 0.4-1.73 (mmol/L)           | outcome                                  | health examination                    |
|                  | low density lipoprotein cholesterol (LDL-C) | 2.07-3.1 (mmol/L)              | outcome                                  | health examination                    |
|                  | high density lipoprotein cholesterol (HDL-C) | 0.9-2 (mmol/L)                     | outcome                                  | health examination                    |
|                  | body composition                       | mass percentage of fat      | outcome                                  | health examination                    |
| **Exposure variables** | WalkScore corresponding to home address | 0-100                       | exposure                                  | calculate from questionnaire information |
|                  | WalkScore corresponding to workplace address | 0-100                       | exposure                                  | calculate from questionnaire information |
| **Other variables** | height                                 |                             | health examination                       |                                       |
|                  | weight                                 |                             |                                         |                                       |
|                  | age                                    | 16 - 65 years old           | possible confounding                      | questionnaire                          |
|                  | gender                                 | male; female                | possible confounding                      | questionnaire                          |
|                  | job                                    |                             | possible confounding                      | questionnaire                          |
|                  | education                              | under primary school; primary school; middle school; bachelor; master and above | possible confounding                      | questionnaire                          |
|                  | smoking status                         | giving up; never; sometimes smoke; frequently smoke | other factors will influence outcome | questionnaire |
|                  | alcohol consumption                    | giving up; never; sometimes drink; frequently drink | other factors will influence outcome | questionnaire |
|                  | online food order habit                 | never; sometimes order; frequently order | other factors will influence outcome | questionnaire |
|                  | eating diet                             | more details showed in questionnaire | other factors will influence outcome | questionnaire |
|                  | physical activity                      | more details showed in questionnaire | possible confounding                      | questionnaire |

Supplemental material

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### The name of health examination

| Specific name of items | Normal limits or result categories |
|------------------------|-----------------------------------|
| **Five items of thyroid function** | |
| Free triiodothyronine (FT3) | 2.0-6.6 pmol/L |
| Free thyroxine (FT4) | 10.3-31.0 pmol/L/0.8-2.3ng/dL |
| Thyroid-stimulating hormone (TSH) | 0.3-4.5 uIU/mL |
| Total triiodothyronine (TT3) | 1.8-2.9 nmol/L/115-190ng/dL |
| Total thyroxine (TT4) | 65-155 nmol/L/5.0-12.0μg/dL |
| **12-leads electrocardiogram** | |
| N=Normal; A=abnormal | |
| **Ultrasound (splenorenal major abdominal and portal vein)** | |
| Liver | N=Normal; A=abnormal |
| Gallbladder | N=Normal; A=abnormal |
| Pancreas | N=Normal; A=abnormal |
| Spleen | N=Normal; A=abnormal |
| Bilateral kidneys | N=Normal; A=abnormal |
| Portal vein | N=Normal; A=abnormal |
| **Carcinoembryonic antigen (CEA)** | 0-5 (ng/ml) |
| **Liver function** | 38-51 (g/L) |
| Albumin (Alb) | 1.2-2.5 |
| Gamma-glutamyl transpeptidase (GGT) | 4-50 (IU/L) |
| Alanine amino transferase (ALT) | 0-42 (IU/L) |
| Aspartate amino transferase (AST) | 0-42 (IU/L) |
| Alkaline Phosphatase (ALP) | 34-114 (IU/L) |
| Globulin (G) | 25-38 (g/L) |
| Total protein (TP) | 66-83 (g/L) |
| **Alpha-fetoprotein (AFP)** | 0-20 (ng/ml) |
| **Urine routine** | 4.6-8.0 |
| Potential of hydrogen (PH) | Negative or positive |
| Urine leukocyte (LEU) | 1.003-1.03 |
| Specific gravity (SG) | Negative or positive |
| Bilirubin (BIL) | N=Normal; A=abnormal |
| Urobilinogen (URO) | Negative or positive |
| Urine protein (PRO) | Negative or positive |
| Urine Casts | Negative or positive |
| Urine erythrocyte (ERY) | Negative or positive |
| Urine pus cells | Negative or positive |
| Urine colour | Negative or positive |
| Test                                      | Reference Range           |
|-------------------------------------------|---------------------------|
| Uroepithelial cell (U-Epc)                | Negative or positive      |
| Urine sugar (U-GLU)                       | Negative or positive      |
| Urine ketone (KET)                        | Negative or positive      |
| Urine nitrite (NIT)                       | Negative or positive      |
| Urine transparency                        | Negative or positive      |
| Urinary mucous silk (U-MUCS)              | Negative or positive      |
| Creatinine (CR)                           | 45-84 (μmol/L)            |
| Blood urea nitrogen (UN)                  | 1.7-8.3 (mmol/L)          |
| Uric acid (UN)                            | 155-428 (μmol/L)          |
| Fasting blood glucose (GLU)               | 3.6-6.1 (mmol/L)          |
| Serum cystatin c (Cys-c)                  | 0.5-1.1 (mg/L)            |
| Blood routine                             |                           |
| white blood cell (WBC)                    | 3.5-9.5 (10^9/L)          |
| Percent monocytes (MON%)                  | 3-10 (%)                  |
| Monocytes (MON)                           | 0.1-0.6 (10^9/L)          |
| Red blood cell (RBC)                      | 3.8-5.1 (10^12/L)         |
| Red blood cell distribution width (SD)    | 11-16 (%)                 |
| Red blood cell distribution width (CV)    | 37.54 (fL)                |
| Hematokrit (HCT)                          | 35-45 (%)                 |
| Percent lymphocyte (LYMPH%)               | 20-50 (%)                 |
| Lymphocyte count (LYMPH)                  | 1.1-3.2 (10^9/L)          |
| Mean corpuscular volume (MCV)             | 82-100 (fL)               |
| The average RBC hemoglobin content (MCH)  | 27-34 (pg)                |
| The average RBC hemoglobin concentration (MC) | 115-150                  |
| mean platelet volume (MPV)                | 9-13 (fL)                 |
| Basophilic cell percentage (BAS%)         | 0-1 (%)                   |
| absolute basophil count (BAS)             | 0.00-0.06 (10^9/L)        |
| Acidophilic cell percentage (EOS%)        | 0.4-8 (%)                 |
| Acidophil number (EOS)                    | 0.02-0.52 (10^9/L)        |
| Hemoglobin (HGB)                          | 115-150                   |
| Platelet distribution width (PDW)         | 9-17 (%)                  |
| blood platelet count (PLT)                | 125-350 (10^9/L)          |
| Thrombocytocrit (PCT)                     | N (%)                     |
|                                |                                      |
|--------------------------------|--------------------------------------|
| **Neutrophilic granulocyte percentage (NEU%)** | 40-75 (%)                           |
| **Neutrophilic granulocyte count (NEU)**       | 1.8-6.3 (10^9/L)                     |
| **Blood lipids**                           |                                      |
| **Total cholesterol (TC)**                 | 3.1-5.7 (mmol/L)                     |
| **Triglyceride (Tg)**                      | 0.4-1.73 (mmol/L)                    |
| **Low density lipoprotein cholesterol (LDL-C)** | 2.07-3.1 (mmol/L)                  |
| **High density lipoprotein cholesterol (HDL-C)** | 0.9-2 (mmol/L)                      |
| **Hepatitis B**                            |                                      |
| Hepatitis B e antibody (HBe)               | Negative or positive                 |
| Hepatitis B e antigen (HBeAg)              | Negative or positive                 |
| Hepatitis B surface antibody (HBs)         | Negative or positive                 |
| Hepatitis B surface antigen (HBsAg)        | Negative or positive                 |
| Hepatitis B core antibody (HBe)            | Negative or positive                 |
| **Ultrasound (bilateral mammary gland)**    | N=Normal; A=abnormal                 |
| **Ultrasound (uterus, annex)**             | N=Normal; A=abnormal                 |
| **Vaginal secretion examination**          |                                      |
| Trichomonad                                 | Negative or positive                 |
| Mycete                                      | Negative or positive                 |
| Cleanliness of leucorrhea                  | Negative or positive                 |
| **Thinprep cytology test (TCT)**           | N=Normal; A=abnormal                 |
| **Body composition**                       | Mass percentage of fat, protein, and water |
### Supplementary Table 1. The timeline of study conduction

| Event                                                                 | Date                  |
|----------------------------------------------------------------------|-----------------------|
| Approval of ethic committee                                          | 2018 July 10th        |
| Completion of clinical registration on Chinese Clinical Trial Registry Platform | 2018 August 9th       |
| Date collection of demographic data and home/workplace addresses of participants | 2019 October          |
| Development of Wechat mini App for recording daily steps             | 2020 January          |
| Previous data checking and data collection of questionnaire and health examination of participants | 2020 March-May        |
| Date collection of daily steps of participants by Wechat mini App    | 2020 June             |
| Follow-up: Data collection of questionnaire, health examination of participants, and daily steps in one month | 2020 December – 2021 February |
| Follow-up: Data collection of questionnaire, health examination of participants, and daily steps in one month | 2021 December – 2022 February |
| Follow-up: Data collection of questionnaire, health examination of participants, and daily steps in one month | 2022 December – 2023 February |
Supplementary Figure 1. Causal diagram of measured variables. Obesity and overweight as well as daily walking steps are the primary outcomes. WalkScore is the exposure variable. The participants will be divided into five groups by the categories of the WalkScore with regard to workplace address and residential address, respectively (In this way, we decide the exposure degree). Daily walking steps and metabolic profiles are the mediator from WalkScore to obesity. Job and education are possible confoundings between WalkScore and daily walking steps. Physical activity is possible confounding between daily walking steps and metabolic profiles. Online food order habit is possible confounding between WalkScore and metabolic profiles. Eating habit, smoking, and alcohol consumption are other factors, which will influence metabolic profiles.
Supplementary Figure 2A. Chongqing map. It is the nine main districts of Chongqing extracted from Open Street Map. The black point shows the location of the First Affiliated Hospital to Army Medical University in Shapingba District. Shapingba District is an old town with a lot of renowned high schools and universities.

Supplementary Figure 2B. Chongqing location. It shows the location of Chongqing relative to the other cities (Chengdu, Suining, Zigong, Jianyang, and so on). The topography of Chongqing is more hilly than that of Chengdu.