BMJ Open

# Anemia and associated factors among the elderly in an urban district in China: a large-scale cross-sectional study



| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID | bmjopen-2021-056100 |
| Article Type: | Original research |
| Date Submitted by the Author: | 03-Aug-2021 |
| Complete List of Authors: | Ni, Wenqing; Shenzhen Center for Chronic Disease Control<br>Yuan, Xueli; Shenzhen Center for Chronic Disease Control<br>Sun, Yuanying<br>Zhang, Hong<br>Zhang, Yan<br>Xu, Jian; Shenzhen Nanshan Center for Chronic Disease Control |
| Keywords: | NUTRITION & DIETETICS, Anaemia < HAEMATOLOGY, EPIDEMIOLOGY |
| | |

*I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.*

*The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.*

*Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.*

# Anemia and associated factors among the elderly in an urban district in China: a large-scale cross-sectional study

Wenqing Ni[1#], Xueli Yuan[1#], Yuanying Sun[1], Hongmin Zhang[1], Yan Zhang[1], Jian Xu[1]

[1]Department of Elderly Health Management, Shenzhen Center for Chronic Disease Control, Shenzhen, Guangdong, 518020, China

# These authors contributed equally to this work.

*Corresponding author :
Jian Xu, Ph.D.
Shenzhen Center for Chronic Disease Control
No.2021, Buxin Rd. Shenzhen, Guangdong 518020, P.R. China

Tel: 86-755-25506942
Fax: 86-755-25506942
E-mail: anniexu73@126.com

Tel: 86-755-25506942
Fax: 86-755-25506942
E-mail: 1498384005@qq.com

## Abstract

**Objective**: Anemia leads to poor health outcomes in the elderly; however, most current research in China has focused on younger adults. The present study aimed to investigate the prevalence of anemia and its associated risk factors in elderly individuals in an urban district in China.

**Design**: A cross-sectional study.

**Setting**: A urbanization region, Shenzhen of China.

**Participants**: A total of 121,981 participants aged ≥ 65 years were recruited at local community health service centers in Shenzhen from January to December 2018.

**Primary outcomes**: Their hemoglobin (Hb) levels and the prevalence of anemia were analyzed and potential associated factors were evaluated.

**Results**: The mean Hb level was13.64 ± 1.67g/dL and the prevalence of anemia was 15.43%. Anemia was positively associated with older age, being underweight (odds ratio (*OR*): 2.06, 95% confidence interval (*CI*): 1.93–2.20), diabetes (*OR*: 1.23, 95% *CI*: 1.19–1.28), and chronic kidney disease (*OR*: 1.41, 95% *CI*: 1.36–1.46), and inversely with higher education level, current-smoker (*OR*: 0.84, 95% *CI*: 0.78–0.89), non-habitual drinker (*OR*: 0.86, 95% *CI*: 0.81–0.92), habitual drinker (*OR*: 0.81, 95% *CI*: 0.75–0.87), overweight (*OR*: 0.67, 95% *CI*: 0.64–0.70), obesity (*OR*: 0.57, 95% *CI*: 0.53–0.61), central obesity (*OR*: 0.86, 95% *CI*: 0.82–0.89), hypertension (*OR*: 0.86, 95% *CI*: 0.83–0.89), and dyslipidemia (*OR*: 0.81, 95% *CI*: 0.78–0.84).

**Conclusion**: Anemia is prevalent among people aged 65 years and older in China. Prevention, screening of key populations, and treatment of senile anemia should be a top priority in Shenzhen, and should be listed as important public health intervention measures for implementation.


**Keywords**: elderly, anemia, epidemiologic study, risk factor

## Strengths and limitations of this study

■This is the first large-scale cross-sectional study to assess the prevalence of anemia and its factors in an urban district in China.

■ This study had a sufficient sample size to detect statistical significance in the prevalence of anemia among elderly.

■Convenience sampling was used to enroll the population sample.

■The data set used in this study did not provide information on dietary behaviour of the participants.

# 1. Introduction

Anemia, characterized by decreased hemoglobin (Hb) levels, occurs when low numbers of red blood cells reduce the ability of the blood to carry oxygen to meet the body's physiological needs. Although anemia may occur at any stage of life, older people are particularly vulnerable,[1, 2] and anemia in the elderly is a risk factor for a variety of adverse health outcomes, such as hospitalization, disability, and death.[1, 3-5] Anemia is also an independent risk factor for declining physical performance, and has a negative impact on quality of life, physical function, and muscle strength in older people.[6-8]

Globally, 11.0% of men and 10.2% of women aged ≥ 65 years are anemic [9]. Ruan et al. revealed that the prevalence of anemia among middle-aged and elderly residents in China was 31.0%,[10] while Qin et al. reported a prevalence of 12.86% among similar populations from 2011 to 2012.[11] Although China has seen a significant reduction in anemia among middle-aged and elderly residents in the past decade, its occurrence among the elderly cannot be neglected.

A total of 150 million Chinese were aged 65 years or above in 2016, accounting for 10.8% of the population.[12] Improving anemia in the elderly thus has important public health implications. Previous studies have investigated the prevalence of anemia in middle-aged and elderly people, but there is a lack of large-scale studies on anemia in the urban elderly population.[10, 11, 13] The current study therefore aimed to assess the prevalence of anemia and associated factors among elderly people in an urban district in China.

# 2. Materials and methods

## a) Study population

We used convenience sampling to select our population sample by recruiting people aged 65 years and older from the lists of all residents registered at local community health centers in Shenzhen, China, from January 2018 through December 2018. Recruitment activities include pasting posters or placing foldings in local community health centers and other public places. Electronic posters also be distributed via all the open WeChat groups of local community health centers' staff, to make the survey available to the close contacts easily. Moreover, the staff of the local community health centers recruited the elderly adults in their service community to participate in the survey by telephone. The eligibility criteria were as follows: (1) having lived in Shenzhen for more than 6 months; and (2) able to participate in the study and give informed consent. A total of 141,684 individuals were recruited in this study, accounting for 36.9% (141,684/383,700) of the resident elderly population in Shenzhen according to the 2015 population census. Data were collected at examination centers in local community health centers in the participants' residential areas. Participants were asked to complete a questionnaire, provide a fasting blood sample, and undergo physical examinations. A total of 19,703 respondents were excluded because of failure to fulfil one or all of these requirements. Finally, 121,981 participants (86.09%) were included in the final data analysis.

## 2.2 Questionnaire survey

Prior to the study, all investigators completed a training course to understand the methodology and process of the study. Working manuals containing questionnaire techniques, blood pressure measurement, anthropometric measurements, biological sample collection, and processing information were distributed to all the investigators.

Data were recorded by face-to-face interview 1 hour after blood collection. All participants completed a standardized questionnaire including questions on sociodemographic status (e.g., date of birth, sex, education level, marital status), past medical history (e.g., history of previous disease, operation history, history of trauma), family health history (e.g., hypertension, diabetes, coronary heart disease, malignant tumor, stroke), lifestyle (e.g., smoking, physical activity, alcohol consumption), and medication use, under the supervision of trained general practitioners and nurses. Educational level was categorized into three groups according to the number of years of education: illiterate, no education; primary education, 1–6 years of education; and junior high school education and above, seven or more years of education. Regarding drinking habits, participants were classified as habitual drinkers (drink at least once a day), non-habitual drinkers (six times a week to once a month), or non-drinker (almost never).[14] Based on a previous study, we divided participants into current smokers, ex-smokers, and never-smokers.[15]

## 2.3 Physical examination

Anthropometric examinations were carried out in the morning after overnight fasting, and body measurements were taken by trained examiners based on a standardized protocol. The physical examination methods were described as previous study.[12] Height and weight were measured with the participants wearing light clothing without shoes, using analogue scales. Waist circumference (WC) was measured at the end of normal expiration at the midpoint level of the mid-axillary line between the 12th rib head and the superior anterior iliac spine. Body mass index (BMI) was calculated by dividing body weight (in kilograms) by height squared (in meters). Blood pressure were measured in both arms and recorded the higher one. Calibrated electronic sphygmomanometers were used to measure blood pressure on the arm supported at heart level with sitting position, carried out twice. The average of the two measurements was used for the statistical analysis. To obtain accurate readings, the participants were asked to rest for at least 5 min before the measurement, or, if having engaged in excessive exercise prior to the visit, for at least 30 min before the measurement.

## 2.4 Blood sample collection and biochemical analyses

Venous blood samples were taken after overnight fasting for at least 8 hours. All blood samples were analyzed in clinical laboratories at the grade 2 hospitals to which the community health centers were directly affiliated. All the laboratories had successfully completed a standardization and competency program. Fasting venous blood was used to measure levels of Hb, plasma glucose, creatinine, total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) using an automatic biochemistry analyzer. Biochemical analysis of fresh blood samples was completed within 4 hours.

Serum creatinine was used to calculate the estimated glomerular filtration rate (eGFR) using the full age spectrum equation.[16]

**2.5 Definitions**

Anemia was defined as a Hb concentration < 13 g/dL in men and < 12 g/dL in women, according to World Health Organization standards.[17] Chronic kidney disease (CKD) was defined as eGFR < 60 mL/min/1.73 $m^2$.[18] A diagnosis of hypertension was considered when three consecutive high readings ( ⩾140 systolic and/or ⩾90 mm Hg diastolic) with 2-week intervals were registered or treatment with antihypertensive medication within the previous 2 weeks was self-reported.[19, 20] Participants who met one of the following three criteria were diagnosed with diabetes: (1) previously diagnosed by professional doctors, (2) fasting plasma glucose (FBG) ≥ 7.0 mmol/L, and (3) 2-hour plasma glucose level ≥ 11.1 mmol/L.[21] High TC, high TG, high LDL-C, and low HDL-C were diagnosed according to the 2016 Chinese Guidelines for the Management of Dyslipidemia in Adults.[22] In this study, we defined dyslipidemia as an abnormal concentration of one or more lipid components or the use of anti-dyslipidemia medications in the past 2 weeks.

Participants were divided into four groups based on the adult weight criteria published by the Ministry of Health of China (WS/T 428-2013): BMI < 18.5 kg/$m^2$ (low weight), BMI ≥ 18.5 kg/$m^2$ and <24.0 kg/$m^2$ (normal weight), BMI ≥ 24.0 kg/$m^2$ and < 28.0 kg/$m^2$ (overweight), and BMI ≥ 28.0 kg/$m^2$ (obesity). A WC ≥ 90 cm for men and ≥85 cm for women was defined as central obesity.

**2.6 Statistical analyses**

Descriptive statistics, including means and standard deviations, were used to compute continuous variables. Numerical data were expressed as percentages and compared by $\chi^2$ tests. Multivariate logistic regression analysis was performed to explore the association between prevalence of amemia and associated risk factors. In the multivariate logistic regression model, the prevalence of anemia was defined as the dependent variable, and gender, education level, age group, smoking status, drinking habit, BMI, central obesity, diabetes, hypertension, dyslipidemia and CKD were defined as the independent variables. Data analysis was carried out using SAS 9.4 (Institute, Cary, NC, USA). A two-sided value of $P < 0.05$ was considered to be statistically significant.

**2.7 Participants and public involvement**

Neither the study participants nor the public were involved in the design, recruitment or conduct of the study. All the participants had the option of receiving a health check and biochemical results when they visited the local community health centers.

**2.8 Ethical Approval Statement**

The study received ethnicity approval from the Center for Chronic Disease Control in Shenzhen(Grant No: SZCCC-201802, SZCCC-2020-018-01-PJ). The study complies with the guidelines of the Declaration of Helsinki. Written informed consent was received by all participants before the collection of data and conducting of the research. Where participants were illiterate, we obtained written informed consent from their proxies.

# 3. Results

## 3.1 Characteristics of participants

The characteristics of the study participants are shown in Table 1. The mean age was 71.28 ± 5.58 years (range 65–103 years). There were 54,649 men and 69,358 women, and > 50% of participants had a minimum of a junior school education. Among the study population, 8.22% were current smokers and 6.35% were habitual drinkers. The mean Hb, BMI, SBP, DBP, WC, FBG, TC, TG, LDL-C, HDL-C, and eGFR values among all 121,981 participants were 13.64 ± 1.67 g/dL, 23.83 ± 3.17 kg/m$^2$, 134.71 ± 17.69 mmHg, 77.23 ± 10.31 mmHg, 85.10 ± 8.82 cm, 5.96 ± 1.90 mmol/L, 5.21 ± 2.00 mmol/L, 1.57 ± 1.14 mmol/L, 3.09 ± 1.05 mmol/L, 1.39 ± 1.05 mmol/L, and 68.74 ± 16.70 mL/min/1.73m$^2$, respectively. A total of 100,762 participants (82.60%) had at least one chronic disease, with hypertension (55.61%), dyslipidemia (44.73%), CKD (31.09%), and diabetes (22.31%) being the most prevalent (data not shown).

## 3.2 Prevalence of anemia in different subgroups

The overall prevalence anemia was 15.43%. The prevalence of anemia among subpopulations is shown in Table 2. Anemia was significantly more prevalent in women than in men and generally increased with age. The prevalence was lower among individuals with at least primary-level education, and lower in current smokers and habitual drinkers compared with their counterparts. The prevalence of anemia was higher in participants with low weight and lower in those with overweight, obesity, central obesity, hypertension, or dyslipidemia. Individuals with diabetes or CKD had a higher prevalence of anemia than those without these conditions.

## 3.3 Association between anemia and related variables

Binary logistic regression analysis was carried out with presence or absence of anemia as the dependent variable, and factors in univariate analysis as independent variables to determine the factors influencing anemia. Higher education level, current-smoker, drinker, overweight, obesity, central obesity, hypertension, and dyslipidemia were independently associated with lower odds for the presence of anemia (Fig. 1), while older age, underweight, diabetes, and CKD were independently associated with greater odds (Fig. 1). However, there was no significant difference in the risk of anemia in relation to sex.

# 4. Discussion

In this study, the prevalence of anemia among elderly individuals in an urban district in China was 15.43%. This was higher than the 12.86% reported in previous national studies in China,[11] but lower than the 18.90% prevalence reported in the 2009 national survey in China.[23] The difference in prevalence rates among these studies may have been caused by differences in study design, sample size, and/or the age of the study participants.

The current study found a significant negative correlation between anemia prevalence and educational level. This was consistent with studies conducted in Nepal

and Pakistan, which confirmed that a low educational level was a risk factor for anemia.[24] This relationship probably occurs because higher levels of education enable people to earn more and thus escape from the poverty trap. Multivariate analysis also identified older age as an independent risk factor for anemia, consistent with the findings of other related studies.[9, 25] The prevalence of anemia increased with age, with a two-to-three-fold increase (26.89% vs. 12.72%) in people aged > 80 years, suggesting the need for routine screening for anemia in this high-risk subgroup.

Current smokers had a lower risk of anemia than never smokers, and habitual drinking was also associated with a decreased risk of anemia (odds ratio: 0.81). However, these findings were not consistent with an Indian study.[26] Considering the potential risks to human health from alcohol or tobacco use, we do not recommend that alcohol or tobacco should be used as protective factors against anemia.

We also found a negative association between increased BMI and anemia prevalence, in accord with other studies conducted in China, the United States, Nepal, and Pakistan.[24, 27] The reasons for being underweight may include poor distribution of inadequate food within the family, food insecurity, poverty, and micronutrient deficiencies, which tend to coexist with other macronutrient deficiencies. The underlying mechanism accounting for the significant negative association between overweight or obesity and anemia risk is unclear; however there are several possible explanations. First, obese participants are less likely to be malnourished, because excess calorie intake leads to obesity,[28] and overnutrition in obese participants may thus be associated with a significant reduction in anemia risk. Second, obese participants may have a variety of other diseases that could increase Hb levels, such as obstructive sleep apnea and other obesity-related breathing disorders, which lead to chronic tissue hypoxia and increased red blood cells.[29]

We found that older people with diabetes had higher rates of anemia than non-diabetics, consistent with previous studies.[30] Evidence indicates that the incidence and prevalence of anemia in diabetic patients is often associated with erythropoietin deficiency caused by diabetic kidney damage.[31] Other researchers have also shown a link between anemia and hypertension, as shown in our current study.[18]

This study showed that the prevalence of anemia was low among individuals with dyslipidemia. A study by Zaribaf et al. found a significant positive correlation between Hb levels and dyslipidemia.[32] However, this study differed from our study in that it assessed the relationship between anemia and lipids in premenopausal women, whereas our study focused on older adults (aged 65–113 years).[32] In contrast, a study conducted by other researchers in women of childbearing age found no significant association between serum LDL and anemia.[32] The reasons for the different results in terms of the relationship between dyslipidemia and anemia deserve further investigation. Patients with CKD have defects in renal endocrine function, resulting in decreased erythropoietin secretion by the kidney, leading to nephrogenic anemia.[33] Nearly half of all patients with CKD have anemia.[33] The current study found the similar results.

This study had some limitations. First, it was a cross-sectional study and could only infer correlation, not causation. Second, we adopted a convenient sampling method to

recruit elderly participants. This is a major factor preventing true extrapolation of the results to the general population. Finally, renal disease was assessed based on a one-time GFR measurement, possibly leading to overestimation of the actual prevalence of CKD. However, these limitations do not affect the significance of the results, which provide the first evidence of the prevalence and risk factors of anemia among elderly individuals in urban China.

## 5. Conclusion

In conclusion, anemia is prevalent among the elderly population in China, with older age, underweight, diabetes, CKD, and anemia being positively associated with anemia, and higher education level, current-smoker, drinker, overweight, obesity, central obesity, hypertension, and dyslipidemia being negatively associated. The prevention, screening of key populations, and treatment of senile anemia should be a top priority in Shenzhen, and should be listed as important public health intervention measures for implementation.

**Acknowledgments**

We are grateful to all the volunteers for participating in the present study, and to all the investigators for their support and hard work during this survey.

**Author Contributions**

WN, XY, and JX: study conception and design. WN, XY, JZ, PL, HZ, YZ, and JX: performance of research. XY and JZ: data analysis and interpretation. WN and XY: writing the original draft. WN and JX: Writing the review and editing. All authors have read and agreed to the published version of the manuscript.

**Funding**

This study was supported by the Science and Technology Planning Project of Shenzhen City, Guangdong Province, China (Grant No. JCYJ20180703145202065); Shenzhen medical key discipline construction fund, and Sanming Project of Medicine in Shenzhen (Grant No. SZSM201811093).

**Conflicts of Interest**

The authors declare no conflict of interest.

**Patient consent for publication**

Not required.

**Ethics approval**

This study was approved by the ethical review committee of the Center for Chronic Disease Control of Shenzhen.

## Data sharing statement

All data generated or analysed during this study are included in this published article. No additional data are available.

## References


1. Working Group on "Expert Consensus on nutrition Prevention and Treatment of Iron deficiency Anemia" of Chinese Nutrition Society. Expert consensus on nutrition prevention and treatment of iron deficiency anemia. *Acta Nutrimenta Sinica* **2019**; 41,417-426.
2. Stevens GA, Finucane MM, De-Regil LM, *et al*. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: a systematic analysis of population-representative data. *Lancet Glob Health* **2013**; 1, e16-25.
3. Wu WC, Rathore SS, Wang Y, et al. Blood transfusion in elderly patients with acute myocardial infarction. *N Engl J Med* **2001**; 345, 1230-1236.
4. Groenveld HF, Januzzi JL, Damman K, *et al*. Anemia and mortality in heart failure patients a systematic review and meta-analysis. *J Am Coll Cardiol* **2008**, 52, 818-827.
5. Ezekowitz JA MF, Armstrong PW. Anemia is common in heart failure and is associated with poor outcomes: insights from a cohort of 12065 patients with new-onset heart failure. *Circulation* **2003**; 107, 223-225.
6. Penninx BW, Guralnik JM, Onder G, *et al*. Anemia and decline in physical performance among older persons. *Am J Med* **2003**; 115, 104-110.
7. Penninx BW, Pahor M, Cesari M, *et al*. Anemia is associated with disability and decreased physical performance and muscle strength in the elderly. *J Am Geriatrics Soc* **2004**; 52, 719-724.
8. Cesari M, Penninx BW, Lauretani F, *et al*. Hemoglobin levels and skeletal muscle: results from the InCHIANTI study. *J Gerontol A Biol Sci Med Sci* **2004**;59(3):249-254.
9. Bianchi VE. Role of nutrition on anemia in elderly. *Clin Nutr ESPEN* **2016**; 11, e1-e11.
10. Ruan Y, Guo Y, Kowal P, *et al*. Association between anemia and frailty in 13,175 community-dwelling adults aged 50 years and older in China. *BMC Geriatr* **2019**; 19, 327.
11. Qin T, Yan M, Fu Z, *et al*. Association between anemia and cognitive decline among Chinese middle-aged and elderly: evidence from the China health and retirement longitudinal study. *BMC Geriatr* **2019**; 19, 305.
12. Ni W, Weng R, Yuan X, *et al*. Clustering of cardiovascular disease biological risk factors among older adults in Shenzhen City, China: a cross-sectional study. *BMJ Open* **2019**; 9, e024336.
13. Zhang Q, Qin G, Liu Z, *et al*. Dietary Balance Index-07 and the Risk of

Anemia in Middle Aged and Elderly People in Southwest China: A Cross Sectional Study. *Nutrients* **2018**; 10, 162.

14. Zhang L, Wang F, Wang L, *et al*. Prevalence of chronic kidney disease in China: a cross-sectional survey. *Lancet* **2012**; 379, 815-822.
15. Zhang M, Liu S, Yang L, *et al*. Prevalence of smoking and knowledge about the smoking hazards among 170,000 Chinese adults: a nationally representative survey in 2013-2014. *Nicotine Tob Res* **2019**; 21, 1644-1651.
16. Pottel H, Hoste L, Dubourg L, Ebert N, *et al*. An estimated glomerular filtration rate equation for the full age spectrum. *Nephrol Dial Transplant* **2016**; 31,798-806.
17. World Health Organization. Haemoglobin Concentrations for the Diagnosis of Anaemia and Assessment of Severity. https://apps.who.int/iris/bitstream/handle/10665/85839/WHO_NMH_NHD_MNM_11.1_eng.pdf?ua=1. Accessed July 21 **2021**.
18. Lee YG, Chang Y, Kang J, *et al*. Risk factors for incident anemia of chronic diseases: A cohort study. PLoS One **2019**; 14, e0216062.
19. Writing Group of 2018 Chinese Guidelines for the Management of Hypertension, Chinese Hypertension League, Chinese Society of Cardiology, Chinese Medical Doctor Association Hypertension Committee, Hypertension Branch of China International Exchange and Promotive Association for Medical and Health Care, Hypertension Branch of Chinese Geriatric Medical Association. 2018 Chinese guidelines for the management of hypertension. *Chin J Cardiovasc Med* **2019**; 24, 24-56.
20. Qaseem A, Wilt TJ, Rich R, *et al*. Pharmacologic Treatment of Hypertension in Adults Aged 60 Years or Older to Higher Versus Lower Blood Pressure Targets: A Clinical Practice Guideline From the American College of Physicians and the American Academy of Family Physicians. *Ann Intern Med* **2017**; 166, 430-437.
21. Wang Q, Zhang X, Fang L, *et al*. Prevalence, awareness, treatment and control of diabetes mellitus among middle-aged and elderly people in a rural Chinese population: A cross-sectional study. *PLoS One* **2018**; 13, e0198343.
22. Joint committee for guideline revision. 2016 Chinese guidelines for the management of dyslipidemia in adults. *J Geriatr Cardiol* **2018**; 15, 1-29.
23. Xu X, Hall J, Byles J, *et al*. Dietary pattern, serum magnesium, ferritin, C-reactive protein and anaemia among older people. *Clin Nutr* **2017**; 36, 444-451.
24. Harding KL, Aguayo VM, Namirembe G, *et al*. Determinants of anemia among women and children in Nepal and Pakistan: An analysis of recent national survey data. *Matern Child Nutr* **2018**; Suppl 4, e12478.
25. Fiseha T, Adamu A, Tesfaye M, *et al*. Prevalence of anemia in diabetic adult outpatients in Northeast Ethiopia. *PLoS One* **2019**; 14, e0222111.
26. Didzun O, De Neve JW, Awasthi A, *et al*. Anaemia among men in India: a nationally representative cross-sectional study. *Lancet Glob Health* **2019**; 7, e1685-e1694.

27. Qin Y, Melse-Boonstra A, Pan X, *et al*. Anemia in relation to body mass index and waist circumference among Chinese women. *Nutr J* **2013**. doi: 10.1186/1475-2891-1112-1110.
28. Dandona P, Aljada A, Chaudhuri A, et al. Metabolic syndrome: a comprehensive perspective based on interactions between obesity, diabetes, and inflammation. *Circulation* **2005**;111,1448-1454.
29. Schwartz AR, Patil SP, Laffan AM, *et a*l. Obesity and obstructive sleep apnea: pathogenic mechanisms and therapeutic approaches. *Proc Am Thorac Soc* **2008**; 5, 185-192.
30. Gauci R, Hunter M, Bruce DG, *et al*. Anemia complicating type 2 diabetes: Prevalence, risk factors and prognosis. *J Diabetes Complication*s **2017**; 31, 1169-1174.
31. Thomas MC. The High Prevalence of Anemia in Diabetes Is Linked to Functional Erythropoietin Deficiency. *Semin Nephrol* **2006**; 26, 275-282.
32. Zaribaf F, Entezari MH, Hassanzadeh A, *et al*. Association between dietary iron, iron stores, and serum lipid profile in reproductive age women. *J Educ Health Promot* **2014**; 3: DOI: 10.4103/2277-9531.127586.
33. Ryu SR, Park SK, Jung JY, *et al*. The Prevalence and Management of Anemia in Chronic Kidney Disease Patients: Result from the KoreaN Cohort Study for Outcomes in Patients With Chronic Kidney Disease (KNOW-CKD). *J Korean Med Sci* **2017**; 32, 249-256.

# Tables

**Table 1** Sociodemographic and other characteristics of older adults living in Shenzhen community ($N$ =121981 )

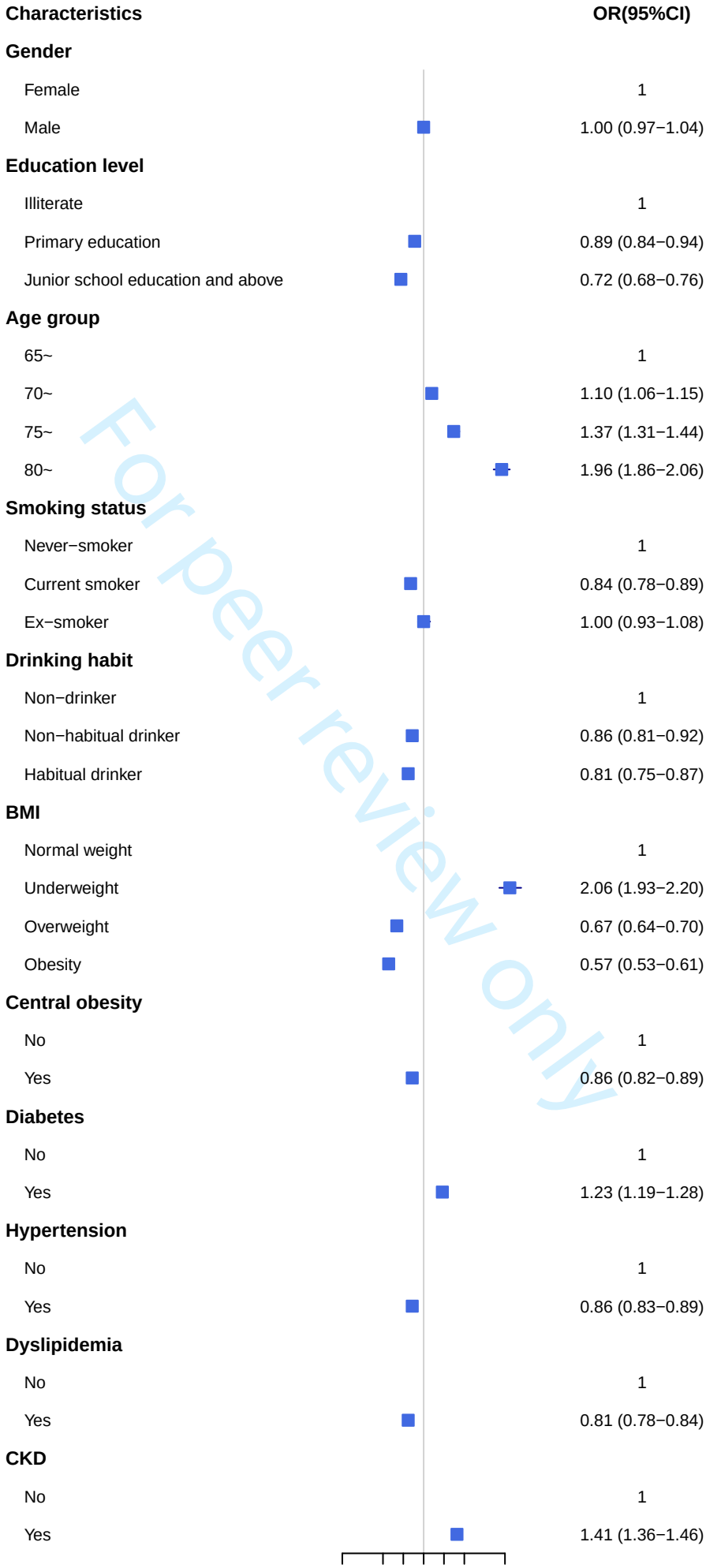
| Characteristics | General |
|---|---|
| Age (years) | 71.28 ± 5.58 |
| Hb(g/dL) | 13.64 ± 1.67 |
| BMI (Kg/m2) | 23.83 ± 3.17 |
| SBP (mm Hg) | 134.71 ± 17.69 |
| DBP (mm Hg) | 77.23 ± 10.31 |
| WC (cm) | 85.1 ± 8.82 |
| FBG (mmol/L) | 5.96 ± 1.9 |
| TC(mmol/L) | 5.21 ± 2 |
| TG(mmol/L) | 1.57 ± 1.14 |
| LDL-C(mmol/L) | 3.09 ± 1.05 |
| HDL-C(mmol/L) | 1.39 ± 0.51 |
| eGFR | 68.74 ± 16.7 |
| Gender, n(%) | |
| Male | 54649 (44.07%) |
| Female | 69358 (55.93%) |
| Education level, n(%) | |
| Illiterate | 9888 (8.11%) |
| Primary education | 43441 (35.61%) |
| Junior school education and above | 68652 (56.28%) |
| Smoking status, n (%) | |
| Current smoker | 10023 (8.22%) |
| Ex-smoker | 7546 (6.19%) |
| Never-smoker | 104412 (85.6%) |
| Drinking habit, n (%) | |
| Non-drinker | 101661 (83.34%) |
| Non-habitual drinker | 12571 (10.31%) |
| Habitual drinker | 7749 (6.35%) |

Table 2 Prevalence of anemia in older adults living in Shenzhen community, according to sociodemographic and other characteristics

| Characteristics | Total | N | % | $\chi^2$ Value | *P* Value |
|---|---|---|---|---|---|
| Total | 121981 | 18820 | 15.43 | | |
| Gender | | | | 22.36 | <0.001 |
| Male | 53743 | 7946 | 14.79 | | |
| Female | 68238 | 10874 | 15.94 | | |
| Education level | | | | 263.21 | <0.001 |
| Illiterate | 9888 | 2027 | 20.50 | | |
| Primary education | 43441 | 7240 | 16.67 | | |
| Junior school education and above | 68652 | 9553 | 13.92 | | |
| Age group | | | | 1201.99 | <0.001 |
| 65～ | 60043 | 7635 | 12.72 | | |
| 70～ | 32750 | 4730 | 14.44 | | |
| 75～ | 16599 | 3070 | 18.50 | | |
| 80～ | 12589 | 3385 | 26.89 | | |
| Smoking status | | | | 68.89 | <0.001 |
| Current smoker | 10023 | 1253 | 12.50 | | |
| Ex-smoker | 7546 | 1047 | 13.87 | | |
| Never-smoker | 104412 | 16520 | 15.82 | | |
| Drinking habit | | | | 130.24 | <0.001 |
| Non-drinker | 101661 | 16302 | 16.04 | | |
| Non-habitual drinker | 12571 | 1589 | 12.64 | | |
| Habitual drinker | 7749 | 929 | 11.99 | | |
| BMI | | | | 1522.11 | <0.001 |
| Low weight | 4496 | 1504 | 33.45 | | |
| Normal weight | 61532 | 11041 | 17.94 | | |
| Overweight | 44644 | 5175 | 11.59 | | |
| Obesity | 11309 | 1100 | 9.73 | | |
| Central obesity | | | | 540.10 | <0.001 |
| Yes | 49051 | 5897 | 12.02 | | |
| No | 72930 | 12923 | 17.72 | | |
| Diabetes | | | | 27.05 | <0.001 |
| Yes | 27220 | 4520 | 16.61 | | |
| No | 94761 | 14300 | 15.09 | | |
| Hypertension | | | | 63.27 | <0.001 |
| Yes | 67835 | 9883 | 14.57 | | |
| No | 54146 | 8937 | 16.51 | | |
| Dyslipidemia | | | | 211.72 | <0.001 |
| Yes | 54564 | 7354 | 13.48 | | |
| No | 67417 | 11466 | 17.01 | | |
| CKD | | | | 624.34 | <0.001 |
| Yes | 37927 | 7574 | 19.97 | | |
| No | 84054 | 11246 | 13.38 | | |

# Figure legends

Fig 1 Risk factors analyses on the prevalence of anemia in older adults living in Shenzhen community



**STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies***

| Section/Topic | Item # | Recommendation | Reported on page # |
|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | Page 1 |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | Page 2 |
| **Introduction** | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | Page 4 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | Page 4 |
| **Methods** | | | |
| Study design | 4 | Present key elements of study design early in the paper | Page 4 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Page 4 |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants | Page 4 |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Page 5-6 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Page 5-6 |
| Bias | 9 | Describe any efforts to address potential sources of bias | Page 6 |
| Study size | 10 | Explain how the study size was arrived at | Page 4 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Not applicable |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | Page 6 |
| | | (*b*) Describe any methods used to examine subgroups and interactions | Not applicable |
| | | (*c*) Explain how missing data were addressed | Not applicable |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy | Not applicable |
| | | (*e*) Describe any sensitivity analyses | Not applicable |
| **Results** | | | |

| | | | |
|---|---|---|---|
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Page 4 |
| | | (b) Give reasons for non-participation at each stage | Not applicable |
| | | (c) Consider use of a flow diagram | Not applicable |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | Page7 |
| | | (b) Indicate number of participants with missing data for each variable of interest | Not applicable |
| Outcome data | 15* | Report numbers of outcome events or summary measures | Page 7 |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | Page 7 |
| | | (*b*) Report category boundaries when continuous variables were categorized | Page 7 |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | Page 7 |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | Not applicable |
| **Discussion** | | | |
| Key results | 18 | Summarise key results with reference to study objectives | Page 7-8 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | Page 8-9 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | Page 7-9 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | Page 9 |
| **Other information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | Page 9 |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

# Anemia and associated factors among older adults in an urban district in China: a large-scale cross-sectional study



| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID | bmjopen-2021-056100.R1 |
| Article Type: | Original research |
| Date Submitted by the Author: | 02-Oct-2021 |
| Complete List of Authors: | Ni, Wenqing; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Yuan, Xueli; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Sun, Yuanying; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Zhang, Hong; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Zhang, Yan; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Xu, Jian; Shenzhen Nanshan Center for Chronic Disease Control, Department of Elderly Health Management |
| Primary Subject Heading: | Epidemiology |
| Secondary Subject Heading: | Epidemiology, Public health |
| Keywords: | Anaemia < HAEMATOLOGY, EPIDEMIOLOGY, Risk management < HEALTH SERVICES ADMINISTRATION & MANAGEMENT |
| | |

*I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.*

*The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.*

*Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.*

# Anemia and associated factors among older adults in an urban district in China: a large-scale cross-sectional study

Wenqing Ni[1#], Xueli Yuan[1#], Yuanying Sun[1], Hongmin Zhang[1], Yan Zhang[1], Jian Xu[1]

[1]Department of Elderly Health Management, Shenzhen Center for Chronic Disease Control, Shenzhen, Guangdong, 518020, China

# These authors contributed equally to this work.

*Corresponding author :
Jian Xu, Ph.D.
Shenzhen Center for Chronic Disease Control
No.2021, Buxin Rd. Shenzhen, Guangdong 518020, P.R. China

Tel: 86-755-25506942
Fax: 86-755-25506942
E-mail: anniexu73@126.com

## Abstract

**Objective**: Anemia leads to poor health outcomes in older adults; however, most current research in China has focused on younger adults. The present study aimed to investigate the prevalence of anemia and its associated factors in older adults in an urban district in China.

**Design**: A cross-sectional study.

**Setting**: A urbanized region, Shenzhen, China.

**Participants**: A total of 121,981 participants aged ≥ 65 years were recruited at local community health service centers in Shenzhen from January to December 2018.

**Primary outcomes**: The prevalence of anemia was analyzed and potential associated factors were evaluated.

**Results**: The mean Hemoglobin level was13.64 ± 1.67g/dL and the prevalence of anemia was 15.43%. Prevalence of mild, moderate and severe anemia were 12.24%, 2.94% and 0.25% respectively. Anemia was positively associated with older age, being underweight (adjusted odds ratio (*AOR*): 2.06, 95% confidence interval (*CI*): 1.93–2.20), diabetes (*AOR*: 1.23, 95% *CI*: 1.19–1.28), and chronic kidney disease (*AOR*: 1.41, 95% *CI*: 1.36–1.46), and inversely with higher education level, current-smoker (*AOR*: 0.84, 95% *CI*: 0.78–0.89), non-habitual drinker (*AOR*: 0.86, 95% *CI*: 0.81–0.92), habitual drinker (*AOR*: 0.81, 95% *CI*: 0.75–0.87), overweight (*AOR*: 0.67, 95% *CI*: 0.64–0.70), obesity (*AOR*: 0.57, 95% *CI*: 0.53–0.61), central obesity (*AOR*: 0.86, 95% *CI*: 0.82–0.89), hypertension (*AOR*: 0.86, 95% *CI*: 0.83–0.89), and dyslipidemia (*AOR*: 0.81, 95% *CI*: 0.78–0.84).

**Conclusion**: Anemia is prevalent among people aged 65 years and older in China. Screening of high-risk populations, and treatment of senile anemia should be a top priority in Shenzhen, and should be listed as important public health intervention measures for implementation.


**Keywords**: older adults, anemia, epidemiologic study, risk factor

## Strengths and limitations of this study

■ This was the first large-scale cross-sectional study to assess the prevalence of anemia and its factors in an urban district in China.

■ This study had a sufficiently large sample size to detect significant differences in the prevalence of anemia among older adults.

■ Convenience sampling was used to enroll the population sample.

■ The dataset used in this study did not provide information on the dietary behavior of the participants.

# 1. Introduction

Anemia results from an inadequate number of erythrocytes which leads to a decreased ability to carry oxygen to meet the body's physiological demands. It is characterized by reduced levels of hemoglobin (Hb) in the blood in affected individuals. Anemia may occur at all stages of life, however, older people are among the most vulnerable.[1,2] Globally, 11.0% of men and 10.2% of women aged 65 years and older are anemic.[3] Anemia is a risk factor for a variety of adverse outcomes in the older population, including hospitalization, disability and mortality.[1] Previous studies found higher mortality rates in people aged 65 years and older hospitalized for myocardial infarction, patients with systolic and diastolic chronic heart failure (CHF), and in older CHF patients with anemia.[4-6] Anemia is also an independent risk factor for decline in physical performance and has a negative impact on quality of life, physical functioning, and muscle strength in older individuals.[7-9] Early identification and treatment of anemia is therefore an important strategy to improve the quality of life of older adults with anemia.

In China, 13.5% of the total population (approximately 190.64 million people) were aged 65 years or older in 2020,[10] and increasing life expectancy and declining fertility rates mean that China is experiencing an ongoing aging process. In line with the aging of the population, anemia has become an important public health problem in China. The China Health and Retirement Longitudinal Study showed a prevalence of anemia in middle-aged and older Chinese residents of 12.86% from 2011 to 2012,[11] and the 2010–2012 China National Nutrition and Health Survey found a prevalence of anemia in older Chinese people of 12.6%.[12] Preventing anemia and improving the health of older adults in China are thus urgent issues. However, the only previous trial for preventing anemia examined the use of iron-fortified soy sauce in some cities in China, which aimed to reduce the prevalence of iron-deficiency anemia among women of reproductive age.[13] The prevention of anemia in older adults thus still presents a challenge, and limited measures have been taken to address this public health problem.

Identifying the factors affecting the occurrence of anemia would help to determine effective interventional targets. Economic development and living standards are important factors affecting anemia.[14] Most previous studies focused on the prevalence of anemia among middle-aged and older adults in urban and rural districts of China, but there is a lack of large-sample studies of anemia among older adults in urban districts.[11,12,15,16] This study therefore aimed to examine the prevalence of anemia and its related factors among people aged 65 or older in an urban district of China, to help develop strategies for future interventions and the prevention of anemia in older adults living in urban districts in China.

# 2. Materials and methods

## 2.1Study population

We used convenience sampling to select our study population by recruiting people aged 65 years and older from the lists of all residents registered at local community

health centers in Shenzhen, China, from January 2018 to December 2018. Recruitment activities include pasting posters or placing leaflets in local community health centers and other public places. Electronic posters were also distributed via all the open WeChat groups of local community health center staff, to make the survey easily available to close contacts . The staff of the local community health centers also recruitedolder adults adults in their community to participate in the survey by telephone. The eligibility criteria were as follows: (1) lived in Shenzhen for more than 6 months; (2) able to participate in the study and give informed consent; and (3) conscious and able to cooperate to complete the face-to-face interview, medical examinations and biomedical tests. We excluded residents living in prisons. A total of 141,684 individuals were recruited in this study, accounting for 36.9% (141,684/383,700) of the resident older adult population in Shenzhen according to the 2015 population census. Data were collected at examination centers in local community health centers in the participants' residential areas. Participants were asked to complete a questionnaire, provide a fasting blood sample, and undergo physical examinations. A total of 19,703 respondents were excluded because of failure to fulfil one or all of these requirements. Finally, 121,981 participants (86.09%) were included in the final data analysis.

**2.2 Questionnaire survey**

Prior to the study, all investigators completed a training course to understand the methodology and process of the study. Working manuals containing questionnaire techniques, blood pressure measurement, anthropometric measurements, biological sample collection, and processing information were distributed to all the investigators.

Data were recorded by face-to-face interview 1 hour after blood collection. All participants completed a standardized questionnaire including questions on sociodemographic status (e.g., date of birth, sex, education level, marital status), past medical history (e.g., history of previous disease, operation history, history of trauma), family health history (e.g., hypertension, diabetes, coronary heart disease, malignant tumor, stroke), lifestyle (e.g., smoking, physical activity, alcohol consumption), and medication use, under the supervision of trained general practitioners and nurses. Educational level was categorized into three groups according to the number of years of education: not educated; primary education(1–6 years of education); and junior high school education and above(⩾7 years of educatio). Regarding drinking habits, participants were classified as habitual drinkers (drink at least once a day), non-habitual drinkers (six times a week to once a month), or non-drinker (almost never).[17] Based on a previous study, we divided participants into current smokers, ex-smokers, and never-smokers.[18]

**2.3 Physical examination**

Anthropometric examinations were carried out in the morning after overnight fasting, and body measurements were taken by trained examiners based on a standardized protocol. Height and weight were measured with the participants wearing light clothing without shoes, using analogue scales. Waist circumference (WC) was measured at the end of normal expiration at the midpoint level of the mid-axillary line between the 12th rib head and the superior anterior iliac spine. Body

mass index (BMI) was calculated by dividing body weight (in kilograms) by height squared (in meters). Blood pressure was measured twice in both arms supported at heart level with the participants in a sitting position, using a calibrated electronic sphygmomanometer and the higher level was recorded and used for statistical analysis. To obtain accurate readings, the participants were asked to rest for at least 5 min before the measurement, or if they had engaged in excessive exercise prior to the visit, to rest for at least 30 min before the measurement.

**2.4 Blood sample collection and biochemical analyses**

Venous blood samples were taken after overnight fasting for at least 8 hours. All blood samples were analyzed in clinical laboratories at the grade 2 hospitals to which the community health centers were directly affiliated. All the laboratories had successfully completed a standardization and competency program. Fasting venous blood was used to measure levels of Hb, plasma glucose, creatinine, total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) using an automatic biochemistry analyzer. Biochemical analysis of fresh blood samples was completed within 4 hours. Serum creatinine was used to calculate the estimated glomerular filtration rate (eGFR) using the full age spectrum equation.[19]

**2.5 Operational definitions/measurements**

Anemia was defined as a Hb concentration < 13 g/dL in men and < 12 g/dL in women, according to World Health Organization standards.[20] The severity of anemia was classified as mild (11–11.9 g/dL (women), 11–12.9 g/dL (men)), moderate (8–10.9 g/dL), and severe (<8 g/dL).[20] Chronic kidney disease (CKD) was defined as eGFR < 60 mL/min/1.73 $m^2$.[21] A diagnosis of hypertension was considered in participants with three consecutive high readings (⩾140 systolic and/or ⩾90 mm Hg diastolic) with 2-week intervals or treatment with antihypertensive medication within the previous 2 weeks was self-reported.[22, 23] Participants who met one of the following three criteria were diagnosed with diabetes: (1) previously diagnosed by professional doctors, (2) fasting plasma glucose (FBG) ≥ 7.0 mmol/L, and (3) 2-hour plasma glucose level ≥ 11.1 mmol/L.[24] High TC, high TG, high LDL-C, and low HDL-C were diagnosed according to the 2016 Chinese Guidelines for the Management of Dyslipidemia in Adults.[25] In this study, we defined dyslipidemia as an abnormal concentration of one or more lipid components or the use of anti-dyslipidemia medications in the past 2 weeks.

Participants were divided into four groups based on the adult weight criteria published by the Ministry of Health of China (WS/T 428-2013): BMI < 18.5 kg/$m^2$ (low weight), BMI ≥ 18.5 kg/$m^2$ and <24.0 kg/$m^2$ (normal weight), BMI ≥ 24.0 kg/$m^2$ and < 28.0 kg/$m^2$ (overweight), and BMI ≥ 28.0 kg/$m^2$ (obesity). A WC ≥ 90 cm for men and ≥85 cm for women was defined as central obesity.[26]

**2.6 Statistical analyses**

Descriptive statistics, including means and standard deviations, were used to compute continuous variables. Numerical data were expressed as percentages and compared by $\chi^2$ tests. Multivariate logistic regression analysis was performed to explore the associations between the prevalence of anemia and associated risk factors.

In the multivariate logistic regression model, the prevalence of anemia was defined as the dependent variable, and sex, education level, age group, smoking status, drinking habit, BMI, central obesity, diabetes, hypertension, dyslipidemia and CKD were defined as the independent variables. Data analysis was carried out using SAS 9.4 (Institute, Cary, NC, USA). A two-sided value of $P < 0.05$ was considered to be statistically significant.

### 2.7 Participants and public involvement

Neither the study participants nor the public were involved in the design, recruitment or conduct of the study. All the participants had the option of receiving a health check and biochemical results when they visited the local community health centers.

### 2.8 Ethical Approval Statement

The study received ethical approval from the Center for Chronic Disease Control in Shenzhen(Grant No: SZCCC-201802, SZCCC-2020-018-01-PJ). The study complied with the guidelines of the Declaration of Helsinki. Written informed consent was obtained from all participants before the collection of data and conducting of the research. If the participants were not educated, we obtained written informed consent from their proxies (son, daughter, daughter-in-law, son-in-law, etc).

## 3. Results

### 3.1 Characteristics of participants

The characteristics of the study participants are shown in Table 1. The mean age was 71.28 ± 5.58 years (range 65–103 years). There were 54,649 men and 69,358 women, and > 50% of participants had a minimum of a junior school education. Among the study population, 8.22% were current smokers and 6.35% were habitual drinkers. The mean Hb, BMI, SBP, DBP, WC, FBG, TC, TG, LDL-C, HDL-C, and eGFR values among all 121,981 participants were 13.64 ± 1.67 g/dL, 23.83 ± 3.17 kg/m$^2$, 134.71 ± 17.69 mmHg, 77.23 ± 10.31 mmHg, 85.10 ± 8.82 cm, 5.96 ± 1.90 mmol/L, 5.21 ± 2.00 mmol/L, 1.57 ± 1.14 mmol/L, 3.09 ± 1.05 mmol/L, 1.39 ± 1.05 mmol/L, and 68.74 ± 16.70 mL/min/1.73m$^2$, respectively. A total of 100,762 participants (82.60%) had at least one chronic disease, with hypertension (55.61%), dyslipidemia (44.73%), CKD (31.09%), and diabetes (22.31%) being the most prevalent (data not shown).

### 3.2 Prevalence of anemia in different subgroups

The overall prevalence anemia was 15.43% and the prevalence (95% confidence intervals(*CI*)) of mild, moderate and severe anemia were 12.24% (12.05-12.42), 2.94% (2.84-3.03) and 0.25% (0.23-0.28) respectively. The prevalence of anemia among subpopulations is shown in Table 2. Anemia was significantly more prevalent in women than in men and generally increased with age. The prevalence was lower among individuals with at least primary-level education, and lower in current smokers and habitual drinkers compared with their counterparts. The prevalence of anemia was higher in participants with low weight and lower in those with overweight, obesity, central obesity, hypertension, or dyslipidemia. Individuals with diabetes or CKD had a higher prevalence of anemia than those without these conditions.

### 3.3 Association between anemia and related variables

Binary logistic regression analysis was carried out with presence or absence of anemia as the dependent variable, and factors in univariate analysis as independent variables to determine the factors influencing anemia. Primary education(adjusted odds ratio (*AOR*)=0.89, 95%*CI*:0.84-0.94), junior school education and above (*AOR*=0.72, 95%*CI*:0.68-0.76) current-smoker (*AOR*=0.84, 95%*CI*:0.78-0.89), non-habitual drinker (*AOR*=0.86, 95%*CI*:0.81-0.92), habitual drinker (*AOR*=0.81, 95%*CI*:0.75-0.87), overweight (*AOR*=0.67, 95%*CI*:0.64-0.70), obesity(*AOR*=0.57, 95%*CI*:0.53-0.61), central obesity (*AOR*=0.86, 95%*CI*:0.82-0.89), hypertension (*AOR*=0.86, 95%*CI*:0.83-0.89), and dyslipidemia (*AOR*=0.81, 95%*CI*:0.78-0.84) were independently associated with lower odds for the presence of anemia (Fig. 1), while age 70-74 years (*AOR*=1.10, 95%*CI*:1.06-1.15) , age 75-79 years (*AOR*=1.37, 95%*CI*:1.31-1.44), age ⩾ 80 years (*AOR*=1.96, 95%*CI*:1.86-2.06), underweight (*AOR*=2.06, 95%*CI*:1.93-2.20), diabetes (*AOR*=1.23, 95%*CI*:1.19-1.28), and CKD (*AOR*=1.41, 95%*CI*:1.36-1.46) were independently associated with greater odds (Fig. 1). However, there was no significant difference in the risk of anemia in relation to sex.

## 4. Discussion

This was the first large-scale cross-sectional survey to report the prevalence of anemia in older adults (aged 65 years or older) living in an urban district of China. This study demonstrated that the prevalence of anemia was relatively high, representing a public health problem in Shenzhen. After controlling for the confounding factors we found that the prevalence of anemia varied with education level, age group, smoking status, drinking habit, BMI, central obesity, and some non-communicable diseases.

The prevalence of anemia among older adults in an urban district in China in current study was 15.43%, which was higher than the 12.86% reported in previous national studies in China,[11] but lower than the 18.90% reported in the 2009 national survey in China.[13] The difference in prevalence rates among these studies may have been caused by differences in study design, sample size, and/or the age of the study participants.

The current study found a significant negative correlation between anemia prevalence and educational level. This was consistent with studies conducted in Nepal and Pakistan, which confirmed that a low educational level was a risk factor for anemia.[27] This relationship probably occurs because higher levels of education enable people to earn more and thus escape from the poverty trap. Multivariate analysis also identified older age as an independent risk factor for anemia, consistent with the findings of other related studies.[3, 28] The prevalence of anemia increased with age, with a two-to-three-fold increase (26.89% vs. 12.72%) in people aged > 80 years, suggesting the need for routine screening for anemia in this high-risk subgroup.

Current smokers had a lower risk of anemia than never smokers. Similarly, previous studies showed that smoking was negatively correlated with the risk of anemia.[29,30] A multiple logistic regression analysis of the health check-up database of

St. Luke's International Hospital in Tokyo between April 2016 and March 2017 revealed that Japanese women (35–49 years) who were current smokers had a 25% lower risk of anemia compared with non-smokers, after adjusting for the covariates.[30] Increased Hb levels in smokers were associated with elevated carboxyhemoglobin (HbCO), a stable complex of Hb and carbon monoxide (CO), because of the exposure to excess CO caused by smoking.[31] The form of HbCO decreases oxygen delivery, and smokers had compensatory elevated Hb to increase erythropoiesis and maintain oxygen transportation.[32] This might explain why adaptation to excess CO during smoking was reflected by increases in Hb and RBC mass.[33] Habitual drinking was also associated with a decreased risk of anemia, with a corresponding OR of 0.81, consistent with a Korean study.[29] However, the direct causality of this negative correlation between alcohol drinking and anemia is still unclear.[29] Given the potential risks of alcohol and tobacco consumption to human health, we do not recommend increasing alcohol consumption or smoking to protect against anemia.

We also found a negative association between increased BMI and anemia prevalence, in accord with other studies conducted in China, the United States, Nepal, and Pakistan.[27, 34] The reasons for being underweight may include poor distribution of inadequate food within the family, food insecurity, poverty, and micronutrient deficiencies, which tend to coexist with other macronutrient deficiencies. The underlying mechanism accounting for the significant negative association between overweight or obesity and anemia risk is unclear; however there are several possible explanations. First, obese participants are less likely to be malnourished, because excess calorie intake leads to obesity,[35] and overnutrition in obese participants may thus be associated with a significant reduction in anemia risk. Second, obese participants may have a variety of other diseases that could increase Hb levels, such as obstructive sleep apnea and other obesity-related breathing disorders, which lead to chronic tissue hypoxia and increased red blood cells.[36]

We found that older people with diabetes had higher rates of anemia than non-diabetics, consistent with previous studies.[37] Evidence indicates that the incidence and prevalence of anemia in diabetic patients is often associated with erythropoietin deficiency caused by diabetic kidney damage.[38] Other researchers have also shown a link between anemia and hypertension, as shown in our current study.[21]

This study showed that the prevalence of anemia was low among individuals with dyslipidemia. A study by Zaribaf et al. found a significant positive correlation between Hb levels and dyslipidemia.[39] However, this study differed from our study in that it assessed the relationship between anemia and lipids in premenopausal women, whereas our study focused on older adults (aged 65–113 years).[39] In contrast, a study conducted by other researchers in women of childbearing age found no significant association between serum LDL and anemia.[39] The reasons for the different results in terms of the relationship between dyslipidemia and anemia deserve further investigation. Patients with CKD have defects in renal endocrine function, resulting in decreased erythropoietin secretion by the kidney, leading to nephrogenic anemia.[40] Nearly half of all patients with CKD have anemia.[40] The current study found the similar results.

This study had some limitations. First, it was a cross-sectional study and could only infer correlation, not causation. Second, randomized sampling would represent the best design for testing the prevalence of anemia and its associated factors among older adults; however, large random sampling was not practically feasible and we therefore adopted a convenient sampling method to recruit older adult participants. This was a major factor preventing the extrapolation of the results to the general population. Finally, renal disease was assessed based on a one-time GFR measurement, possibly leading to overestimation of the actual prevalence of CKD. However, these limitations do not affect the significance of the results, which provide the first evidence of the prevalence and risk factors of anemia among older adults in urban China.

## 5. Conclusion

In conclusion, anemia is prevalent among the older adult population in China, with older age, underweight, diabetes, CKD, and anemia being positively associated with anemia, and higher education level, current-smoker, drinker, overweight, obesity, central obesity, hypertension, and dyslipidemia being negatively associated. Screening of high risk populations, and treatment of senile anemia should be top priorities in Shenzhen, and should be listed as important public health intervention measures for implementation.

**Acknowledgments**

We are grateful to all the volunteers for their participation in the present study, and to all the investigators for their support and hard work during this survey.

**Author Contributions**

WN, XY, and JX: study conception and design. WN, XY, YS, HZ, YZ, and JX: performance of research. XY and YS: data analysis and interpretation. WN and XY: writing the original draft. WN and JX: Writing the review and editing. All authors have read and agreed to the published version of the manuscript.

**Funding**

This study was supported by the Science and Technology Planning Project of Shenzhen City, Guangdong Province, China (Grant No. JCYJ20180703145202065)，the Science and Technology Planning Project of Shenzhen City, Guangdong Province, China(Grant No. KCXFZ20201221173600001) Shenzhen medical key discipline construction fund, and Sanming Project of Medicine in Shenzhen (Grant No. SZSM201811093).

**Conflicts of Interest**

The authors declare no conflict of interest.

## Patient consent for publication

Not required.

## Ethics approval

This study was approved by the ethical review committee of the Center for Chronic Disease Control of Shenzhen.

## Data sharing statement

All data generated or analyzed during this study are included in this published article. No additional data are available.

## References


1. Working Group on "Expert Consensus on nutrition Prevention and Treatment of Iron deficiency Anemia" of Chinese Nutrition Society. Expert consensus on nutrition prevention and treatment of iron deficiency anemia. *Acta Nutrimenta Sinica* **2019**; 41,417-426.
2. Stevens GA, Finucane MM, De-Regil LM, *et al*. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: a systematic analysis of population-representative data. *Lancet Glob Health* **2013**; 1, e16-25.
3. Bianchi VE. Role of nutrition on anemia in elderly. *Clin Nutr ESPEN* **2016**; 11, e1-e11.
4. Wu WC, Rathore SS, Wang Y, et al. Blood transfusion in elderly patients with acute myocardial infarction. *N Engl J Med* **2001**; 345, 1230-1236.
5. Groenveld HF, Januzzi JL, Damman K, *et al*. Anemia and mortality in heart failure patients a systematic review and meta-analysis. *J Am Coll Cardiol* **2008**, 52, 818-827.
6. Ezekowitz JA MF, Armstrong PW. Anemia is common in heart failure and is associated with poor outcomes: insights from a cohort of 12065 patients with new-onset heart failure. *Circulation* **2003**; 107, 223-225.
7. Penninx BW, Guralnik JM, Onder G, *et al*. Anemia and decline in physical performance among older persons. *Am J Med* **2003**; 115, 104-110.
8. Penninx BW, Pahor M, Cesari M, *et al*. Anemia is associated with disability and decreased physical performance and muscle strength in the elderly. *J Am Geriatrics Soc* **2004**; 52, 719-724.
9. Cesari M, Penninx BW, Lauretani F, *et al*. Hemoglobin levels and skeletal muscle: results from the InCHIANTI study. *J Gerontol A Biol Sci Med Sci* **2004**;59:249-254.
10. National Bureau of Statistics. Bulletin of the Seventh National Population Census (No. 5). http://www.stats.gov.cn/tjsj/tjgb/rkpcgb/qgrkpcgb/202106/t20210628_181882

4.html. Accessed September 26 **2021**

11. Qin T, Yan M, Fu Z, *et al*. Association between anemia and cognitive decline among Chinese middle-aged and elderly: evidence from the China health and retirement longitudinal study. *BMC Geriatr* **2019**; 19, 305.
10. Ruan Y, Guo Y, Kowal P, *et al*. Association between anemia and frailty in 13,175 community-dwelling adults aged 50 years and older in China. *BMC Geriatr* **2019**; 19, 327.
12. Chang J, Wang Y. Reports of China Nutrition and Health Survey (2010–2013). Peking University Medical Press Co. LTD, Beijing, **2016**.
13. Xu X, Hall J, Byles J, *et al*. Dietary pattern, serum magnesium, ferritin, C-reactive protein and anaemia among older people. *Clin Nutr* **2017**; 36, 444-451.
14. Wu Y, Ye H, Liu J, *et al*. Prevalence of anemia and sociodemographic characteristics among pregnant and non-pregnant women in southwest China: a longitudinal observational study. *BMC Pregnancy Childbirth* **2020**; 20, 535.
15. Ruan Y, Guo Y, Kowal P, *et al*. Association between anemia and frailty in 13,175 community-dwelling adults aged 50 years and older in China. *BMC Geriatr* **2019**; 19:327.
16. Zhang Q, Qin G, Liu Z, *et al*. Dietary Balance Index-07 and the Risk of Anemia in Middle Aged and Elderly People in Southwest China: A Cross Sectional Study. *Nutrients* **2018**; 10, 162.
17. Zhang L, Wang F, Wang L, *et al*. Prevalence of chronic kidney disease in China: a cross-sectional survey. *Lancet* **2012**; 379, 815-822.
18. Zhang M, Liu S, Yang L, *et al*. Prevalence of smoking and knowledge about the smoking hazards among 170,000 Chinese adults: a nationally representative survey in 2013-2014. *Nicotine Tob Res* **2019**; 21, 1644-1651.
19. Pottel H, Hoste L, Dubourg L, Ebert N, *et al*. An estimated glomerular filtration rate equation for the full age spectrum. *Nephrol Dial Transplant* **2016**; 31,798-806.
20. World Health Organization. Haemoglobin Concentrations for the Diagnosis of Anaemia and Assessment of Severity. https://apps.who.int/iris/bitstream/handle/10665/85839/WHO_NMH_NHD_MNM_11.1_eng.pdf?ua=1. Accessed July 21 **2021**.
21. Lee YG, Chang Y, Kang J, *et al*. Risk factors for incident anemia of chronic diseases: A cohort study. PLoS One **2019**; 14, e0216062.
22. Writing Group of 2018 Chinese Guidelines for the Management of Hypertension, Chinese Hypertension League, Chinese Society of Cardiology, Chinese Medical Doctor Association Hypertension Committee, Hypertension Branch of China International Exchange and Promotive Association for Medical and Health Care, Hypertension Branch of Chinese Geriatric Medical Association. 2018 Chinese guidelines for the management of hypertension. *Chin J Cardiovasc Med* **2019**; 24, 24-56.
23. Qaseem A, Wilt TJ, Rich R, *et al*. Pharmacologic Treatment of Hypertension

in Adults Aged 60 Years or Older to Higher Versus Lower Blood Pressure Targets: A Clinical Practice Guideline From the American College of Physicians and the American Academy of Family Physicians. *Ann Intern Med* **2017**; 166, 430-437.

24. Wang Q, Zhang X, Fang L, *et al*. Prevalence, awareness, treatment and control of diabetes mellitus among middle-aged and elderly people in a rural Chinese population: A cross-sectional study. *PLoS One* **2018**; 13, e0198343.
25. Joint committee for guideline revision. 2016 Chinese guidelines for the management of dyslipidemia in adults. *J Geriatr Cardiol* **2018**; 15, 1-29.
26. National Health Commission of the People´s Republic of China. Criteria of Weight for Adults. http://www.nhc.gov.cn/ewebeditor/uploadfile/2013/08/20130808135715967.pdf. Accessed September 26 **2021**
27. Harding KL, Aguayo VM, Namirembe G, *et al*. Determinants of anemia among women and children in Nepal and Pakistan: An analysis of recent national survey data. *Matern Child Nutr* **2018**; Suppl 4, e12478.
28. Fiseha T, Adamu A, Tesfaye M, *et al*. Prevalence of anemia in diabetic adult outpatients in Northeast Ethiopia. *PLoS One* **2019**; 14, e0222111.
29. Chun MY, Kim JH, Kang JS. Relationship between Self-Reported Sleep Duration and Risk of Anemia: Data from the Korea National Health and Nutrition Examination Survey 2016-2017. *Int J Environ Res Public Health* **2021**; 18:4721.
30. Hisa K, Haruna M, Hikita N, *et al*. Prevalence of and factors related to anemia among Japanese adult women: Secondary data analysis using health check-up database. *Sci Rep* **2019**;9:17048.
31. Nordenberg D, Yip R, Binkin NJ. The effect of cigarette smoking on hemoglobin levels and anemia screening. *JAMA* **1990**;264:1556-1559.
32. Sharma AJ, Addo OY, Mei Z, *et al*. Reexamination of hemoglobin adjustments to define anemia: altitude and smoking. *Ann N Y Acad Sci* **2019**;1450:190-203.
33. Pollini G, Maugeri U, Bernardo A, *et al*. Erythrocytes parameters due to aging, smoking, alcohol consumption and occupational activity in a working population of petrochemical industry. The Pavia Study. *G Ital Med Lav* **1989**;11:237-240.
34. Qin Y, Melse-Boonstra A, Pan X, *et al*. Anemia in relation to body mass index and waist circumference among Chinese women. *Nutr J* **2013**. doi: 10.1186/1475-2891-1112-1110.
35. Dandona P, Aljada A, Chaudhuri A, et al. Metabolic syndrome: a comprehensive perspective based on interactions between obesity, diabetes, and inflammation. *Circulation* **2005**;111,1448-1454.
36. Schwartz AR, Patil SP, Laffan AM, *et a*l. Obesity and obstructive sleep apnea: pathogenic mechanisms and therapeutic approaches. *Proc Am Thorac Soc* **2008**; 5, 185-192.
37. Gauci R, Hunter M, Bruce DG, *et al*. Anemia complicating type 2 diabetes: Prevalence, risk factors and prognosis. *J Diabetes Complication*s **2017**; 31,

1169-1174.

38. Thomas MC. The High Prevalence of Anemia in Diabetes Is Linked to Functional Erythropoietin Deficiency. *Semin Nephrol* **2006**; 26, 275-282.

39. Zaribaf F, Entezari MH, Hassanzadeh A, *et al*. Association between dietary iron, iron stores, and serum lipid profile in reproductive age women. *J Educ Health Promot* **2014**; 3: DOI: 10.4103/2277-9531.127586.

40. Ryu SR, Park SK, Jung JY, *et al*. The Prevalence and Management of Anemia in Chronic Kidney Disease Patients: Result from the KoreaN Cohort Study for Outcomes in Patients With Chronic Kidney Disease (KNOW-CKD). *J Korean Med Sci* **2017**; 32, 249-256.

## Tables

**Table 1** Sociodemographic and other characteristics of older adults living in Shenzhen community (*N* =121, 981 )

| Characteristics | Total | 95%*CI* |
|---|---|---|
| Age (years) | 71.28 ± 5.58 | 71.25-71.31 |
| Hb(g/dL) | 13.64 ± 1.67 | 13.63-13.65 |
| BMI (Kg/m2) | 23.83 ± 3.17 | 23.81-23.85 |
| SBP (mm Hg) | 134.71 ± 17.69 | 134.61-134.81 |
| DBP (mm Hg) | 77.23 ± 10.31 | 77.18-77.29 |
| WC (cm) | 85.1 ± 8.82 | 85.05-85.15 |
| FBG (mmol/L) | 5.96 ± 1.9 | 5.95-5.97 |
| TC(mmol/L) | 5.21 ± 2 | 5.20-5.23 |
| TG(mmol/L) | 1.57 ± 1.14 | 1.57-1.58 |
| LDL-C(mmol/L) | 3.09 ± 1.05 | 3.08-3.09 |
| HDL-C(mmol/L) | 1.39 ± 0.51 | 1.39-1.39 |
| eGFR | 68.74 ± 16.7 | 68.65-68.83 |
| Sex, n(%) | | |
| Male | 54649 (44.07%) | 43.78-44.34 |
| Female | 69358 (55.93%) | 55.66-56.22 |
| Education level, n(%) | | |
| Not educated | 9888 (8.11%) | 7.95-8.26 |
| Primary education | 43441 (35.61%) | 35.34-35.88 |
| Junior school education and above | 68652 (56.28%) | 56.00-56.56 |
| Smoking status, n (%) | | |
| Current smoker | 10023 (8.22%) | 8.06-8.37 |
| Ex-smoker | 7546 (6.19%) | 6.05-6.32 |
| Never-smoker | 104412 (85.59%) | 85.40-85.79 |
| Drinking habit, n (%) | | |
| Non-drinker | 101661 (83.34%) | 83.13-83.55 |
| Non-habitual drinker | 12571 (10.31%) | 10.14-10.48 |
| Habitual drinker | 7749 (6.35%) | 6.22-6.49 |

Table 2 Prevalence of anemia in older adults living in Shenzhen community, according to sociodemographic and other characteristics

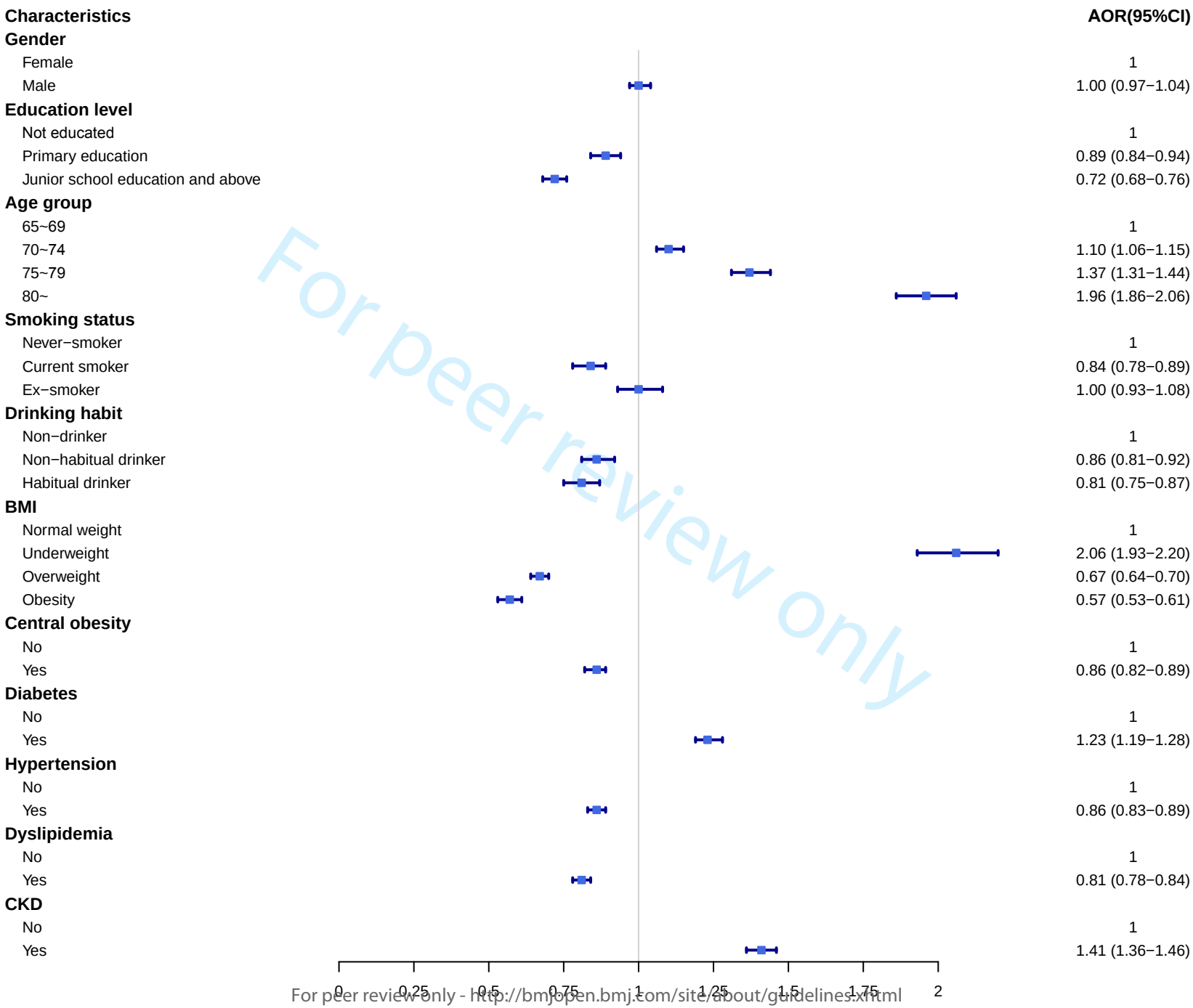
| Characteristics | Total | N | % | 95%*CI* | $\chi^2$ Value | *P* Value |
|---|---|---|---|---|---|---|
| Total | 121981 | 18820 | 15.43 | 15.23-15.63 | | |
| Sex | | | | | 22.36 | <0.001 |
| Male | 53743 | 7946 | 14.79 | 14.49-15.09 | | |
| Female | 68238 | 10874 | 15.94 | 15.66-16.21 | | |
| Education level | | | | | 263.21 | <0.001 |
| Not educated | 9888 | 2027 | 20.50 | 19.70-21.30 | | |
| Primary education | 43441 | 7240 | 16.67 | 16.32-17.02 | | |
| Junior school education and above | 68652 | 9553 | 13.92 | 13.66-14.17 | | |
| Age group | | | | | 1201.99 | <0.001 |
| 65～69 | 60043 | 7635 | 12.72 | 12.45-12.98 | | |
| 70～74 | 32750 | 4730 | 14.44 | 14.06-14.82 | | |
| 75～79 | 16599 | 3070 | 18.50 | 17.90-19.09 | | |
| 80～ | 12589 | 3385 | 26.89 | 26.11-27.66 | | |
| Smoking status | | | | | 68.89 | <0.001 |
| Current smoker | 10023 | 1253 | 12.50 | 11.85-13.15 | | |
| Ex-smoker | 7546 | 1047 | 13.87 | 13.09-14.65 | | |
| Never-smoker | 104412 | 16520 | 15.82 | 15.60-16.04 | | |
| Drinking habit | | | | | 130.24 | <0.001 |
| Non-drinker | 101661 | 16302 | 16.04 | 15.81-16.26 | | |
| Non-habitual drinker | 12571 | 1589 | 12.64 | 12.06-13.22 | | |
| Habitual drinker | 7749 | 929 | 11.99 | 11.27-12.71 | | |
| BMI | | | | | 1522.11 | <0.001 |
| Low weight | 4496 | 1504 | 33.45 | 32.07-34.83 | | |
| Normal weight | 61532 | 11041 | 17.94 | 17.64-18.25 | | |
| Overweight | 44644 | 5175 | 11.59 | 11.29-11.89 | | |
| Obesity | 11309 | 1100 | 9.73 | 9.18-10.27 | | |
| Central obesity | | | | | 540.10 | <0.001 |
| Yes | 49051 | 5897 | 12.02 | 11.73-12.31 | | |
| No | 72930 | 12923 | 17.72 | 17.44-18.00 | | |
| Diabetes | | | | | 27.05 | <0.001 |
| Yes | 27220 | 4520 | 16.61 | 16.16-17.05 | | |
| No | 94761 | 14300 | 15.09 | 14.86-15.32 | | |
| Hypertension | | | | | 63.27 | <0.001 |
| Yes | 67835 | 9883 | 14.57 | 14.30-14.83 | | |
| No | 54146 | 8937 | 16.51 | 16.19-16.82 | | |
| Dyslipidemia | | | | | 211.72 | <0.001 |
| Yes | 54564 | 7354 | 13.48 | 13.19-13.76 | | |
| No | 67417 | 11466 | 17.01 | 16.72-17.29 | | |
| CKD | | | | | 624.34 | <0.001 |

| | | | | |
|---|---|---|---|---|
| Yes | 37927 | 7574 | 19.97 | 19.57-20.37 |
| No | 84054 | 11246 | 13.38 | 13.15-13.61 |

A two-sided value of $P < 0.05$ was considered to be statistically significant.

## Figure legends

Fig 1 Risk factor analyses of the prevalence of anemia in older adults living in Shenzhen community



**STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies***

| Section/Topic | Item # | Recommendation | Reported on page # |
|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | Page 1 |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | Page 2 |
| **Introduction** | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | Page 4 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | Page 4 |
| **Methods** | | | |
| Study design | 4 | Present key elements of study design early in the paper | Page 4 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Page 4 |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants | Page 4 |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Page 5-6 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Page 5-6 |
| Bias | 9 | Describe any efforts to address potential sources of bias | Page 6 |
| Study size | 10 | Explain how the study size was arrived at | Page 4 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Not applicable |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | Page 6 |
| | | (*b*) Describe any methods used to examine subgroups and interactions | Not applicable |
| | | (*c*) Explain how missing data were addressed | Not applicable |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy | Not applicable |
| | | (*e*) Describe any sensitivity analyses | Not applicable |
| **Results** | | | |

| | | | |
|---|---|---|---|
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Page 4 |
| | | (b) Give reasons for non-participation at each stage | Not applicable |
| | | (c) Consider use of a flow diagram | Not applicable |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | Page7 |
| | | (b) Indicate number of participants with missing data for each variable of interest | Not applicable |
| Outcome data | 15* | Report numbers of outcome events or summary measures | Page 7 |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | Page 7 |
| | | (*b*) Report category boundaries when continuous variables were categorized | Page 7 |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | Page 7 |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | Not applicable |
| **Discussion** | | | |
| Key results | 18 | Summarise key results with reference to study objectives | Page 7-8 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | Page 8-9 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | Page 7-9 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | Page 9 |
| **Other information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | Page 9 |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

# Anemia and associated factors among older adults in an urban district in China: a large-scale cross-sectional study



| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID | bmjopen-2021-056100.R2 |
| Article Type: | Original research |
| Date Submitted by the Author: | 30-Nov-2021 |
| Complete List of Authors: | Ni, Wenqing; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Yuan, Xueli; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Sun, Yuanying; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Zhang, Hong; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Zhang, Yan; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Xu, Jian; Shenzhen Nanshan Center for Chronic Disease Control, Department of Elderly Health Management |
| Primary Subject Heading: | Epidemiology |
| Secondary Subject Heading: | Epidemiology, Public health |
| Keywords: | Anaemia < HAEMATOLOGY, EPIDEMIOLOGY, Risk management < HEALTH SERVICES ADMINISTRATION & MANAGEMENT |
| | |

*I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.*

*The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.*

*Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.*

# Anemia and associated factors among older adults in an urban district in China: a large-scale cross-sectional study

Wenqing Ni[1#], Xueli Yuan[1#], Yuanying Sun[1], Hongmin Zhang[1], Yan Zhang[1], Jian Xu[1]

[1]Department of Elderly Health Management, Shenzhen Center for Chronic Disease Control, Shenzhen, Guangdong, 518020, China

# These authors contributed equally to this work.

*Corresponding author :
Jian Xu, Ph.D.
Shenzhen Center for Chronic Disease Control
No.2021, Buxin Rd. Shenzhen, Guangdong 518020, P.R. China

Tel: 86-755-25506942
Fax: 86-755-25506942
E-mail: anniexu73@126.com

## Abstract

**Objective**: Anemia leads to poor health outcomes in older adults; however, most current research in China has focused on younger adults. The present study aimed to investigate the prevalence of anemia and its associated factors in older adults in an urban district in China.

**Design**: A cross-sectional study.

**Setting**: An urbanized region, Shenzhen, China.

**Participants**: A total of 121,981 participants aged ≥ 65 years were recruited at local community health service centers in Shenzhen from January to December 2018.

**Primary outcomes**: The prevalence of anemia was analyzed and potential associated factors were evaluated.

**Results**: The mean hemoglobin level was13.64 ± 1.67g/dL and the prevalence of anemia was 15.43%. The prevalences of mild, moderate, and severe anemia were 12.24%, 2.94%, and 0.25% respectively. Anemia was positively associated with older age, being underweight (adjusted odds ratio (*AOR*): 2.06, 95% confidence interval (*CI*): 1.93–2.20), diabetes (*AOR*: 1.23, 95% *CI*: 1.19–1.28), and chronic kidney disease (*AOR*: 1.41, 95% *CI*: 1.36–1.46), and inversely with higher education level, current-smoker (*AOR*: 0.84, 95% *CI*: 0.78–0.89), non-habitual drinker (*AOR*: 0.86, 95% *CI*: 0.81–0.92), habitual drinker (*AOR*: 0.81, 95% *CI*: 0.75–0.87), overweight (*AOR*: 0.67, 95% *CI*: 0.64–0.70), obesity (*AOR*: 0.57, 95% *CI*: 0.53–0.61), central obesity (*AOR*: 0.86, 95% *CI*: 0.82–0.89), hypertension (*AOR*: 0.86, 95% *CI*: 0.83–0.89), and dyslipidemia (*AOR*: 0.81, 95% *CI*: 0.78–0.84).

**Conclusion**: Anemia is prevalent among people aged 65 years and older in China. Screening of high-risk populations and treatment of senile anemia should be a top priority in Shenzhen, and should be listed as important public health intervention measures for implementation.


**Keywords**: older adults, anemia, epidemiologic study, risk factor

## Strengths and limitations of this study

■ This was the first large-scale cross-sectional study to assess the prevalence of anemia and its factors in an urban district in China.

■ This study had a sufficiently large sample size to detect significant differences in the prevalence of anemia among older adults.

■ Convenience sampling was used to enroll the population sample.

■ The dataset used in this study did not provide information on the dietary behavior of the participants.

# 1. Introduction

Anemia results from an inadequate number of erythrocytes which leads to a decreased ability to carry oxygen to meet the body's physiological demands. It is characterized by reduced levels of hemoglobin (Hb) in the blood in affected individuals. Anemia may occur at all stages of life, however, older people are among the most vulnerable.[1,2] Globally, 11.0% of men and 10.2% of women aged 65 years and older are anemic.[3] Anemia is a risk factor for a variety of adverse outcomes in the older population, including hospitalization, disability and mortality.[1] Previous studies found higher mortality rates in people aged 65 years and older hospitalized for myocardial infarction, patients with systolic and diastolic chronic heart failure (CHF), and in older CHF patients with anemia.[4-6] Anemia is also an independent risk factor for decline in physical performance and has a negative impact on quality of life, physical functioning, and muscle strength in older individuals.[7-9] Early identification and treatment of anemia is therefore an important strategy to improve the quality of life of older adults with anemia.

In China, 13.5% of the total population (approximately 190.64 million people) were aged 65 years or older in 2020,[10] and increasing life expectancy and declining fertility rates mean that China is experiencing an ongoing aging process. In line with the aging of the population, anemia has become an important public health problem in China. The China Health and Retirement Longitudinal Study showed a prevalence of anemia in middle-aged and older Chinese residents of 12.86% from 2011 to 2012,[11] and the 2010–2012 China National Nutrition and Health Survey found a prevalence of anemia in older Chinese people of 12.6%.[12] Preventing anemia and improving the health of older adults in China are thus urgent issues. However, the only previous trial for preventing anemia examined the use of iron-fortified soy sauce in some cities in China, which aimed to reduce the prevalence of iron-deficiency anemia among women of reproductive age.[13] The prevention of anemia in older adults thus still presents a challenge, and limited measures have been taken to address this public health problem.

Clarifying the risk factors of anemia in the older adults will help to identify the population at risk of anemia, and promote the development of targeted screening and intervention measures. Economic development and living standards are important factors affecting anemia.[14] Most previous studies focused on the prevalence of anemia among middle-aged and older adults in urban and rural districts of China, but there is a lack of large-sample studies of anemia among older adults in urban districts.[11,12,15,16] This study therefore aimed to examine the prevalence of anemia and its related factors among people aged 65 or older in an urban district of China, to help develop strategies for future interventions and the prevention of anemia in older adults living in urban districts in China.

# 2. Materials and methods

## 2.1 Study population

We used convenience sampling to select our study population by recruiting people

aged 65 years and older from the lists of all residents registered at local community health centers in Shenzhen, China, from January 2018 to December 2018. Recruitment activities include pasting posters or placing leaflets in local community health centers and other public places. Electronic posters were also distributed via all the open WeChat groups of local community health center staff, to make the survey easily available to close contacts. The staff of the local community health centers also recruited older adults in their community to participate in the survey by telephone. The eligibility criteria were as follows: (1) lived in Shenzhen for more than 6 months; (2) able to participate in the study and give informed consent; and (3) conscious and able to cooperate to complete the face-to-face interview, medical examinations and biomedical tests. Prisoners are not free to visit community health centres, and we excluded residents living in prisons. A total of 141,684 individuals were recruited in this study, accounting for 36.9% (141,684/383,700) of the resident older adult population in Shenzhen according to the 2015 population census. Data were collected at examination centers in local community health centers in the participants' residential areas. Participants were asked to complete a questionnaire, provide a fasting blood sample, and undergo physical examinations. A total of 19,703 respondents were excluded because of failure to fulfil one or all of these requirements. Finally, 121,981 participants (86.09%) were included in the final data analysis.

**2.2 Questionnaire survey**

Prior to the study, all investigators completed a training course to understand the methodology and process of the study. Working manuals containing questionnaire techniques, blood pressure measurement, anthropometric measurements, biological sample collection, and processing information were distributed to all the investigators.

Data were recorded by face-to-face interview 1 hour after blood collection. All participants completed a standardized questionnaire including questions on sociodemographic status (e.g., date of birth, sex, education level, marital status), past medical history (e.g., history of previous disease, operation history, history of trauma), family health history (e.g., hypertension, diabetes, coronary heart disease, malignant tumor, stroke), lifestyle (e.g., smoking, physical activity, alcohol consumption), and medication use, under the supervision of trained general practitioners and nurses. Educational level was categorized into three groups according to the number of years of education: not educated; primary education(1–6 years of education); and junior high school education and above( $\geqslant$ 7 years of education). Regarding drinking habits, participants were classified as habitual drinkers (drink at least once a day), non-habitual drinkers (six times a week to once a month), or non-drinker (almost never).[17] Based on a previous study, we divided participants into current smokers, ex-smokers, and never-smokers.[18]

**2.3 Physical examination**

Anthropometric examinations were carried out in the morning after overnight fasting, and body measurements were taken by trained examiners based on a standardized protocol. Height and weight were measured with the participants wearing light clothing without shoes, using analogue scales. Waist circumference (WC) was measured at the end of normal expiration at the midpoint level of the

mid-axillary line between the 12th rib head and the superior anterior iliac spine. Body mass index (BMI) was calculated by dividing body weight (in kilograms) by height squared (in meters). Blood pressure was measured twice in both arms supported at heart level with the participants in a sitting position, using a calibrated electronic sphygmomanometer and the higher level was recorded and used for statistical analysis. To obtain accurate readings, the participants were asked to rest for at least 5 min before the measurement, or if they had engaged in excessive exercise prior to the visit, to rest for at least 30 min before the measurement.

**2.4 Blood sample collection and biochemical analyses**

Venous blood samples were taken after overnight fasting for at least 8 hours. All blood samples were analyzed in clinical laboratories at the grade 2 hospitals to which the community health centers were directly affiliated. All the laboratories had successfully completed a standardization and competency program. Fasting venous blood was used to measure levels of Hb, plasma glucose, creatinine, total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) using an automatic biochemistry analyzer. Biochemical analysis of fresh blood samples was completed within 4 hours. Serum creatinine was used to calculate the estimated glomerular filtration rate (eGFR) using the full age spectrum equation.[19]

**2.5 Operational definitions/measurements**

Anemia was defined as a Hb concentration < 13 g/dL in men and < 12 g/dL in women, according to World Health Organization standards.[20] The severity of anemia was classified as mild (11–11.9 g/dL (women), 11–12.9 g/dL (men)), moderate (8–10.9 g/dL), and severe (<8 g/dL).[20] Chronic kidney disease (CKD) was defined as eGFR < 60 mL/min/1.73 $m^2$.[21] A diagnosis of hypertension was considered in participants with three consecutive high readings (⩾140 systolic and/or ⩾90 mm Hg diastolic) with 2-week intervals or self-reported treatment with antihypertensive medication within the previous 2 weeks.[22, 23] Participants who met one of the following three criteria were diagnosed with diabetes: (1) previously diagnosed by professional doctors, (2) fasting plasma glucose (FBG) ≥ 7.0 mmol/L, and (3) 2-hour plasma glucose level ≥ 11.1 mmol/L.[24] High TC, high TG, high LDL-C, and low HDL-C were diagnosed according to the 2016 Chinese Guidelines for the Management of Dyslipidemia in Adults.[25] In this study, we defined dyslipidemia as an abnormal concentration of one or more lipid components or the use of anti-dyslipidemia medications in the past 2 weeks.

Participants were divided into four groups based on the adult weight criteria published by the Ministry of Health of China (WS/T 428-2013): BMI < 18.5 kg/$m^2$ (low weight), BMI ≥ 18.5 kg/$m^2$ and <24.0 kg/$m^2$ (normal weight), BMI ≥ 24.0 kg/$m^2$ and < 28.0 kg/$m^2$ (overweight), and BMI ≥ 28.0 kg/$m^2$ (obesity). A WC ≥ 90 cm for men and ≥85 cm for women was defined as central obesity.[26]

**2.6 Statistical analyses**

Descriptive statistics, including means and standard deviations, were used to compute continuous variables. Numerical data were expressed as percentages and compared by $\chi^2$ tests. Multivariate logistic regression analysis was performed to

explore the associations between the prevalence of anemia and associated risk factors. In the multivariate logistic regression model, the prevalence of anemia was defined as the dependent variable, and sex, education level, age group, smoking status, drinking habit, BMI, central obesity, diabetes, hypertension, dyslipidemia and CKD were defined as the independent variables. Data analysis was carried out using SAS 9.4 (Institute, Cary, NC, USA). A two-sided value of $P < 0.05$ was considered to be statistically significant.

### 2.7 Participants and public involvement

Neither the study participants nor the public were involved in the design, recruitment or conduct of the study. All the participants had the option of receiving a health check and biochemical results when they visited the local community health centers.

### 2.8 Ethical Approval Statement

The study received ethical approval from the Center for Chronic Disease Control in Shenzhen(Grant No: SZCCC-201802, SZCCC-2020-018-01-PJ). The study complied with the guidelines of the Declaration of Helsinki. Written informed consent was obtained from uneducated participants before the collection of data and conducting of the study. For participants who were not educated, the participants and a proxy (family member) who accompanied the participant in the survey were informed orally (participant) and in writing (proxy) about the purpose, process, methods, benefits, and health risks of the study. During the informed consent process, uneducated older adults and their proxies were able to consult the investigators with questions at any time. After explaining the concept of informed consent, uneducated older adults provided verbal agreement, and written informed consent to participate in the study was provided by their proxy. The consent processes were approved by the committee of the Center for Chronic Disease Control of Shenzhen.

## 3. Results

### 3.1 Characteristics of participants

The characteristics of the study participants are shown in Table 1. The mean age was 71.28 ± 5.58 years (range 65–103 years). There were 54,649 men and 69,358 women, and > 50% of participants had a minimum of a junior school education. Among the study population, 8.22% were current smokers and 6.35% were habitual drinkers. The mean Hb, BMI, SBP, DBP, WC, FBG, TC, TG, LDL-C, HDL-C, and eGFR values among all 121,981 participants were 13.64 ± 1.67 g/dL, 23.83 ± 3.17 kg/m$^2$, 134.71 ± 17.69 mmHg, 77.23 ± 10.31 mmHg, 85.10 ± 8.82 cm, 5.96 ± 1.90 mmol/L, 5.21 ± 2.00 mmol/L, 1.57 ± 1.14 mmol/L, 3.09 ± 1.05 mmol/L, 1.39 ± 1.05 mmol/L, and 68.74 ± 16.70 mL/min/1.73m$^2$, respectively. A total of 100,762 participants (82.60%) had at least one chronic disease, with hypertension (55.61%), dyslipidemia (44.73%), CKD (31.09%), and diabetes (22.31%) being the most prevalent (data not shown).

### 3.2 Prevalence of anemia in different subgroups

The overall prevalence anemia was 15.43% and the prevalences (95% confidence intervals(*CI*)) of mild, moderate and severe anemia were 12.24% (12.05-12.42),

2.94% (2.84-3.03) and 0.25% (0.23-0.28) respectively. The prevalence of anemia among subpopulations is shown in Table 2. Anemia was significantly more prevalent in women than in men and generally increased with age. The prevalence was lower among individuals with at least primary-level education, and lower in current smokers and habitual drinkers compared with their counterparts. The prevalence of anemia was higher in participants with low weight and lower in those with overweight, obesity, central obesity, hypertension, or dyslipidemia. Individuals with diabetes or CKD had a higher prevalence of anemia than those without these conditions.

### 3.3 Association between anemia and related variables

Binary logistic regression analysis was carried out with presence or absence of anemia as the dependent variable, and factors in univariate analysis as independent variables to determine the factors influencing anemia. Primary education(adjusted odds ratio (*AOR*)=0.89, 95%*CI*:0.84-0.94), junior school education and above (*AOR*=0.72, 95%*CI*:0.68-0.76) current-smoker (*AOR*=0.84, 95%*CI*:0.78-0.89), non-habitual drinker (*AOR*=0.86, 95%*CI*:0.81-0.92), habitual drinker (*AOR*=0.81, 95%*CI*:0.75-0.87), overweight (*AOR*=0.67, 95%*CI*:0.64-0.70), obesity(*AOR*=0.57, 95%*CI*:0.53-0.61), central obesity (*AOR*=0.86, 95%*CI*:0.82-0.89), hypertension (*AOR*=0.86, 95%*CI*:0.83-0.89), and dyslipidemia (*AOR*=0.81, 95%*CI*:0.78-0.84) were independently associated with lower odds for the presence of anemia (Fig. 1), while age 70-74 years (*AOR*=1.10, 95%*CI*:1.06-1.15) , age 75-79 years (*AOR*=1.37, 95%*CI*:1.31-1.44), age ⩾ 80 years (*AOR*=1.96, 95%*CI*:1.86-2.06), underweight (*AOR*=2.06, 95%*CI*:1.93-2.20), diabetes (*AOR*=1.23, 95%*CI*:1.19-1.28), and CKD (*AOR*=1.41, 95%*CI*:1.36-1.46) were independently associated with greater odds (Fig. 1). However, there was no significant difference in the risk of anemia in relation to sex.

## 4. Discussion

This was the first large-scale cross-sectional survey to report the prevalence of anemia in older adults (aged 65 years or older) living in an urban district of China. This study demonstrated that the prevalence of anemia was relatively high, representing a public health problem in Shenzhen. After controlling for the confounding factors we found that the prevalence of anemia varied with education level, age group, smoking status, drinking habit, BMI, central obesity, and some non-communicable diseases.

The prevalence of anemia among older adults in an urban district in China in the current study was 15.43%, which was higher than the 12.86% reported in previous national studies in China,[11] but lower than the 18.90% reported in the 2009 national survey in China.[13] The difference in prevalence rates among these studies may have been caused by differences in study design, sample size, and/or the age of the study participants.

The current study found a significant negative correlation between anemia prevalence and educational level. This was consistent with studies conducted in Nepal and Pakistan, which confirmed that a low educational level was a risk factor for anemia.[27] This relationship probably occurs because higher levels of education enable

people to earn more and thus escape from the poverty trap. Multivariate analysis also identified older age as an independent risk factor for anemia, consistent with the findings of other related studies.[3, 28] The prevalence of anemia increased with age, with a two-to-three-fold increase (26.89% vs. 12.72%) in people aged > 80 years, suggesting the need for routine screening for anemia in this high-risk subgroup.

Current smokers had a lower risk of anemia than never smokers. Similarly, previous studies showed that smoking was negatively correlated with the risk of anemia.[29,30] A multiple logistic regression analysis of the health check-up database of St. Luke's International Hospital in Tokyo between April 2016 and March 2017 revealed that Japanese women (35–49 years) who were current smokers had a 25% lower risk of anemia compared with non-smokers, after adjusting for the covariates.[30] Increased Hb levels in smokers were associated with elevated carboxyhemoglobin (HbCO), a stable complex of Hb and carbon monoxide (CO), because of the exposure to excess CO caused by smoking.[31] The form of HbCO decreases oxygen delivery, and smokers had compensatory elevated Hb to increase erythropoiesis and maintain oxygen transportation.[32] This might explain why adaptation to excess CO during smoking was reflected by increases in Hb and RBC mass.[33] Habitual drinking was also associated with a decreased risk of anemia, with a corresponding OR of 0.81, consistent with a Korean study.[29] However, the direct causality of this negative correlation between alcohol drinking and anemia is still unclear.[29] Given the potential risks of alcohol and tobacco consumption to human health, we do not recommend increasing alcohol consumption or smoking to protect against anemia.

We also found a negative association between increased BMI and anemia prevalence, in accord with other studies conducted in China, the United States, Nepal, and Pakistan.[27, 34] The reasons for being underweight may include poor distribution of inadequate food within the family, food insecurity, poverty, and micronutrient deficiencies, which tend to coexist with other macronutrient deficiencies. The underlying mechanism accounting for the significant negative association between overweight or obesity and anemia risk is unclear; however there are several possible explanations. First, obese participants are less likely to be malnourished, because excess calorie intake leads to obesity,[35] and overnutrition in obese participants may thus be associated with a significant reduction in anemia risk. Second, obese participants may have a variety of other diseases that could increase Hb levels, such as obstructive sleep apnea and other obesity-related breathing disorders, which lead to chronic tissue hypoxia and increased red blood cells.[36]

We found that older people with diabetes had higher rates of anemia than non-diabetics, consistent with previous studies.[37] Evidence indicates that the incidence and prevalence of anemia in diabetic patients is often associated with erythropoietin deficiency caused by diabetic kidney damage.[38] Other researchers have also shown a link between anemia and hypertension, as shown in our current study.[21]

This study showed that the prevalence of anemia was low among individuals with dyslipidemia. A study by Zaribaf et al. found a significant positive correlation between Hb levels and dyslipidemia.[39] However, this study differed from our study in that it assessed the relationship between anemia and lipids in premenopausal women,

whereas our study focused on older adults (aged 65–113 years).[39] In contrast, a study conducted by other researchers in women of childbearing age found no significant association between serum LDL and anemia.[39] The reasons for the different results in terms of the relationship between dyslipidemia and anemia deserve further investigation. Patients with CKD have defects in renal endocrine function, resulting in decreased erythropoietin secretion by the kidney, leading to nephrogenic anemia.[40] Nearly half of all patients with CKD have anemia.[40] The current study found the similar results.

This study had some limitations. First, it was a cross-sectional study and could only infer correlation, not causation. Second, randomized sampling would represent the best design for testing the prevalence of anemia and its associated factors among older adults; however, large random sampling was not practically feasible and we therefore adopted a convenient sampling method to recruit older adult participants. This was a major factor preventing the extrapolation of the results to the general population. Finally, renal disease was assessed based on a one-time GFR measurement, possibly leading to overestimation of the actual prevalence of CKD. However, these limitations do not affect the significance of the results, which provide the first evidence of the prevalence and risk factors of anemia among older adults in urban China.

## 5. Conclusion

In conclusion, anemia is prevalent among the older adult population in China, with older age, underweight, diabetes, CKD, and anemia being positively associated with anemia, and higher education level, current-smoker, drinker, overweight, obesity, central obesity, hypertension, and dyslipidemia being negatively associated. Screening of high-risk populations, and treatment of senile anemia should be top priorities in Shenzhen, and should be listed as important public health intervention measures for implementation.

**Acknowledgments**

We are grateful to all the volunteers for their participation in the present study, and to all the investigators for their support and hard work during this survey.

**Author Contributions**

WN, XY, and JX: study conception and design. WN, XY, YS, HZ, YZ, and JX: performance of research. XY and YS: data analysis and interpretation. WN and XY: writing the original draft. WN and JX: Writing the review and editing. All authors have read and agreed to the published version of the manuscript.

**Funding**

This study was supported by the Science and Technology Planning Project of Shenzhen City, Guangdong Province, China (Grant No. JCYJ20180703145202065)，

the Science and Technology Planning Project of Shenzhen City, Guangdong Province, China(Grant No. KCXFZ20201221173600001) Shenzhen Medical Key Discipline Construction Fund, and Sanming Project of Medicine in Shenzhen (Grant No. SZSM201811093).

## Conflicts of Interest

The authors declare no conflict of interest.

## Patient consent for publication

Not required.

## Ethics approval

This study was approved by the ethical review committee of the Center for Chronic Disease Control of Shenzhen.

## Data sharing statement

All data generated or analyzed during this study are included in this published article. No additional data are available.

## References

1. Working Group on "Expert Consensus on nutrition Prevention and Treatment of Iron deficiency Anemia" of Chinese Nutrition Society. Expert consensus on nutrition prevention and treatment of iron deficiency anemia. *Acta Nutrimenta Sinica* **2019**; 41,417-426.
2. Stevens GA, Finucane MM, De-Regil LM, *et al*. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: a systematic analysis of population-representative data. *Lancet Glob Health* **2013**; 1, e16-25.
3. Bianchi VE. Role of nutrition on anemia in elderly. *Clin Nutr ESPEN* **2016**; 11, e1-e11.
4. Wu WC, Rathore SS, Wang Y, et al. Blood transfusion in elderly patients with acute myocardial infarction. *N Engl J Med* **2001**; 345, 1230-1236.
5. Groenveld HF, Januzzi JL, Damman K, *et al*. Anemia and mortality in heart failure patients a systematic review and meta-analysis. *J Am Coll Cardiol* **2008**, 52, 818-827.
6. Ezekowitz JA MF, Armstrong PW. Anemia is common in heart failure and is associated with poor outcomes: insights from a cohort of 12065 patients with new-onset heart failure. *Circulation* **2003**; 107, 223-225.
7. Penninx BW, Guralnik JM, Onder G, *et al*. Anemia and decline in physical performance among older persons. *Am J Med* **2003**; 115, 104-110.
8. Penninx BW, Pahor M, Cesari M, *et al*. Anemia is associated with disability

and decreased physical performance and muscle strength in the elderly. *J Am Geriatrics Soc* **2004**; 52, 719-724.

9. Cesari M, Penninx BW, Lauretani F, *et al*. Hemoglobin levels and skeletal muscle: results from the InCHIANTI study. *J Gerontol A Biol Sci Med Sci* **2004**;59:249-254.
10. National Bureau of Statistics. Bulletin of the Seventh National Population Census (No. 5). http://www.stats.gov.cn/tjsj/tjgb/rkpcgb/qgrkpcgb/202106/t20210628_1818824.html. Accessed September 26 **2021**
11. Qin T, Yan M, Fu Z, *et al*. Association between anemia and cognitive decline among Chinese middle-aged and elderly: evidence from the China health and retirement longitudinal study. *BMC Geriatr* **2019**; 19, 305.
12. Chang J, Wang Y. Reports of China Nutrition and Health Survey (2010–2013). Peking University Medical Press Co. LTD, Beijing, **2016**.
13. Xu X, Hall J, Byles J, *et al*. Dietary pattern, serum magnesium, ferritin, C-reactive protein and anaemia among older people. *Clin Nutr* **2017**; 36, 444-451.
14. Wu Y, Ye H, Liu J, *et al*. Prevalence of anemia and sociodemographic characteristics among pregnant and non-pregnant women in southwest China: a longitudinal observational study. *BMC Pregnancy Childbirth* **2020**; 20, 535.
15. Ruan Y, Guo Y, Kowal P, *et al*. Association between anemia and frailty in 13,175 community-dwelling adults aged 50 years and older in China. *BMC Geriatr* **2019**; 19:327.
16. Zhang Q, Qin G, Liu Z, *et al*. Dietary Balance Index-07 and the Risk of Anemia in Middle Aged and Elderly People in Southwest China: A Cross Sectional Study. *Nutrients* **2018**; 10, 162.
17. Zhang L, Wang F, Wang L, *et al*. Prevalence of chronic kidney disease in China: a cross-sectional survey. *Lancet* **2012**; 379, 815-822.
18. Zhang M, Liu S, Yang L, *et al*. Prevalence of smoking and knowledge about the smoking hazards among 170,000 Chinese adults: a nationally representative survey in 2013-2014. *Nicotine Tob Res* **2019**; 21, 1644-1651.
19. Pottel H, Hoste L, Dubourg L, Ebert N, *et al*. An estimated glomerular filtration rate equation for the full age spectrum. *Nephrol Dial Transplant* **2016**; 31,798-806.
20. World Health Organization. Haemoglobin Concentrations for the Diagnosis of Anaemia and Assessment of Severity. https://apps.who.int/iris/bitstream/handle/10665/85839/WHO_NMH_NHD_MNM_11.1_eng.pdf?ua=1. Accessed July 21 **2021**.
21. Lee YG, Chang Y, Kang J, *et al*. Risk factors for incident anemia of chronic diseases: A cohort study. PLoS One **2019**; 14, e0216062.
22. Writing Group of 2018 Chinese Guidelines for the Management of Hypertension, Chinese Hypertension League, Chinese Society of Cardiology, Chinese Medical Doctor Association Hypertension Committee, Hypertension

Branch of China International Exchange and Promotive Association for Medical and Health Care, Hypertension Branch of Chinese Geriatric Medical Association. 2018 Chinese guidelines for the management of hypertension. *Chin J Cardiovasc Med* **2019**; 24, 24-56.

23. Qaseem A, Wilt TJ, Rich R, *et al*. Pharmacologic Treatment of Hypertension in Adults Aged 60 Years or Older to Higher Versus Lower Blood Pressure Targets: A Clinical Practice Guideline From the American College of Physicians and the American Academy of Family Physicians. *Ann Intern Med* **2017**; 166, 430-437.
24. Wang Q, Zhang X, Fang L, *et al*. Prevalence, awareness, treatment and control of diabetes mellitus among middle-aged and elderly people in a rural Chinese population: A cross-sectional study. *PLoS One* **2018**; 13, e0198343.
25. Joint committee for guideline revision. 2016 Chinese guidelines for the management of dyslipidemia in adults. *J Geriatr Cardiol* **2018**; 15, 1-29.
26. National Health Commission of the People´s Republic of China. Criteria of Weight for Adults. http://www.nhc.gov.cn/ewebeditor/uploadfile/2013/08/20130808135715967.pdf. Accessed September 26 **2021**
27. Harding KL, Aguayo VM, Namirembe G, *et al*. Determinants of anemia among women and children in Nepal and Pakistan: An analysis of recent national survey data. *Matern Child Nutr* **2018**; Suppl 4, e12478.
28. Fiseha T, Adamu A, Tesfaye M, *et al*. Prevalence of anemia in diabetic adult outpatients in Northeast Ethiopia. *PLoS One* **2019**; 14, e0222111.
29. Chun MY, Kim JH, Kang JS. Relationship between Self-Reported Sleep Duration and Risk of Anemia: Data from the Korea National Health and Nutrition Examination Survey 2016-2017. *Int J Environ Res Public Health* **2021**; 18:4721.
30. Hisa K, Haruna M, Hikita N, *et al*. Prevalence of and factors related to anemia among Japanese adult women: Secondary data analysis using health check-up database. *Sci Rep* **2019**;9:17048.
31. Nordenberg D, Yip R, Binkin NJ. The effect of cigarette smoking on hemoglobin levels and anemia screening. *JAMA* **1990**;264:1556-1559.
32. Sharma AJ, Addo OY, Mei Z, *et al*. Reexamination of hemoglobin adjustments to define anemia: altitude and smoking. *Ann N Y Acad Sci* **2019**;1450:190-203.
33. Pollini G, Maugeri U, Bernardo A, *et al*. Erythrocytes parameters due to aging, smoking, alcohol consumption and occupational activity in a working population of petrochemical industry. The Pavia Study. *G Ital Med Lav* **1989**;11:237-240.
34. Qin Y, Melse-Boonstra A, Pan X, *et al*. Anemia in relation to body mass index and waist circumference among Chinese women. *Nutr J* **2013**. doi: 10.1186/1475-2891-1112-1110.
35. Dandona P, Aljada A, Chaudhuri A, et al. Metabolic syndrome: a comprehensive perspective based on interactions between obesity, diabetes, and inflammation. *Circulation* **2005**;111,1448-1454.

36. Schwartz AR, Patil SP, Laffan AM, *et a*l. Obesity and obstructive sleep apnea: pathogenic mechanisms and therapeutic approaches. *Proc Am Thorac Soc* **2008**; 5, 185-192.
37. Gauci R, Hunter M, Bruce DG, *et al*. Anemia complicating type 2 diabetes: Prevalence, risk factors and prognosis. *J Diabetes Complication*s **2017**; 31, 1169-1174.
38. Thomas MC. The High Prevalence of Anemia in Diabetes Is Linked to Functional Erythropoietin Deficiency. *Semin Nephrol* **2006**; 26, 275-282.
39. Zaribaf F, Entezari MH, Hassanzadeh A, *et al*. Association between dietary iron, iron stores, and serum lipid profile in reproductive age women. *J Educ Health Promot* **2014**; 3: DOI: 10.4103/2277-9531.127586.
40. Ryu SR, Park SK, Jung JY, *et al*. The Prevalence and Management of Anemia in Chronic Kidney Disease Patients: Result from the KoreaN Cohort Study for Outcomes in Patients With Chronic Kidney Disease (KNOW-CKD). *J Korean Med Sci* **2017**; 32, 249-256.

## Tables

**Table 1** Sociodemographic and other characteristics of older adults living in Shenzhen community (*N* =121, 981 )

| Characteristics | Total | 95%*CI* |
|---|---|---|
| Age (years) | 71.28 ± 5.58 | 71.25-71.31 |
| Hb(g/dL) | 13.64 ± 1.67 | 13.63-13.65 |
| BMI (Kg/m2) | 23.83 ± 3.17 | 23.81-23.85 |
| SBP (mm Hg) | 134.71 ± 17.69 | 134.61-134.81 |
| DBP (mm Hg) | 77.23 ± 10.31 | 77.18-77.29 |
| WC (cm) | 85.1 ± 8.82 | 85.05-85.15 |
| FBG (mmol/L) | 5.96 ± 1.9 | 5.95-5.97 |
| TC(mmol/L) | 5.21 ± 2 | 5.20-5.23 |
| TG(mmol/L) | 1.57 ± 1.14 | 1.57-1.58 |
| LDL-C(mmol/L) | 3.09 ± 1.05 | 3.08-3.09 |
| HDL-C(mmol/L) | 1.39 ± 0.51 | 1.39-1.39 |
| eGFR | 68.74 ± 16.7 | 68.65-68.83 |
| Sex, n(%) | | |
| Male | 54649 (44.07%) | 43.78-44.34 |
| Female | 69358 (55.93%) | 55.66-56.22 |
| Education level, n(%) | | |
| Not educated | 9888 (8.11%) | 7.95-8.26 |
| Primary education | 43441 (35.61%) | 35.34-35.88 |
| Junior school education and above | 68652 (56.28%) | 56.00-56.56 |
| Smoking status, n (%) | | |
| Current smoker | 10023 (8.22%) | 8.06-8.37 |
| Ex-smoker | 7546 (6.19%) | 6.05-6.32 |
| Never-smoker | 104412 (85.59%) | 85.40-85.79 |
| Drinking habit, n (%) | | |
| Non-drinker | 101661 (83.34%) | 83.13-83.55 |
| Non-habitual drinker | 12571 (10.31%) | 10.14-10.48 |
| Habitual drinker | 7749 (6.35%) | 6.22-6.49 |

Table 2 Prevalence of anemia in older adults living in Shenzhen community, according to sociodemographic and other characteristics

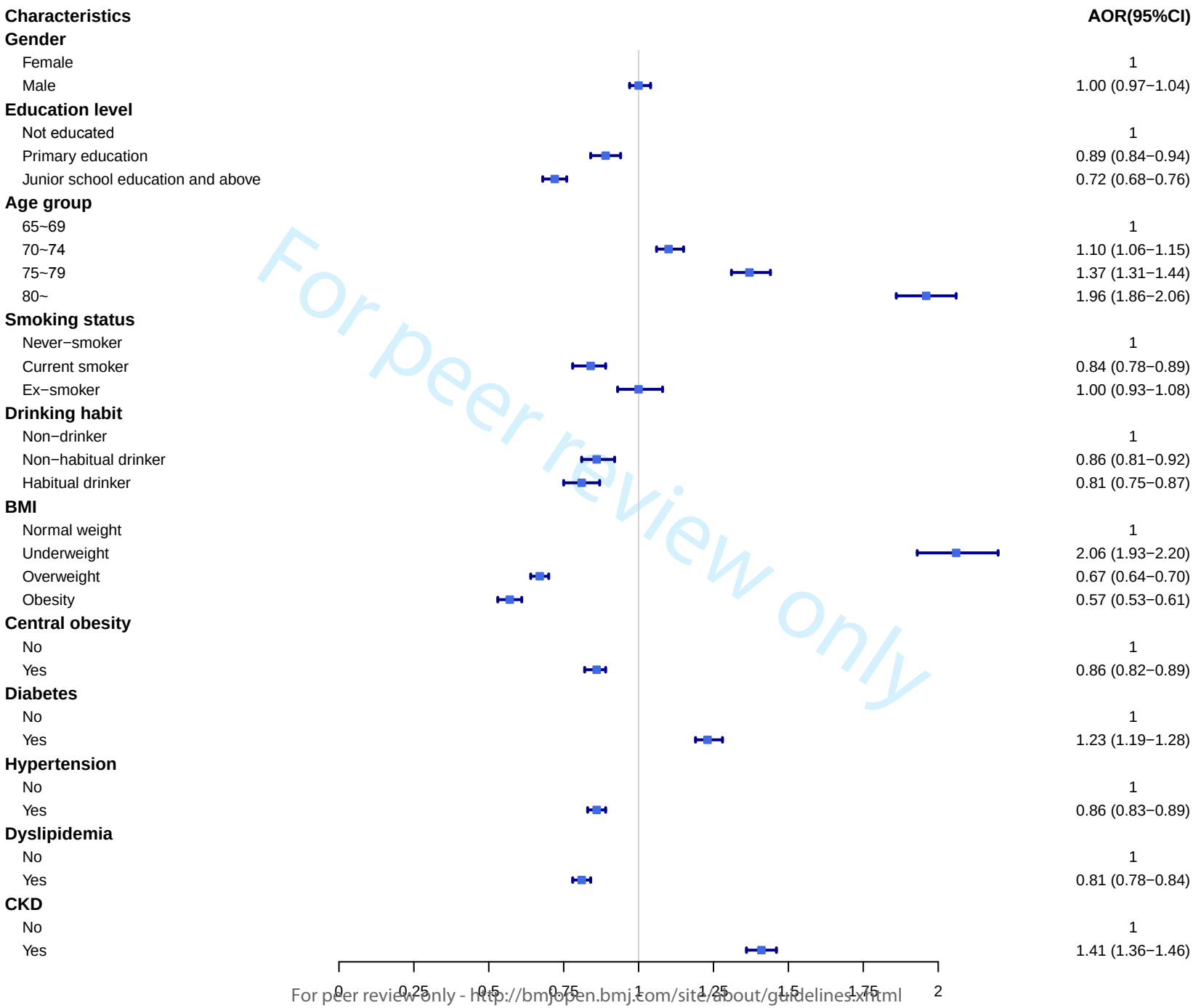
| Characteristics | Total | Number of anemia | Prevalence of anemia(%) | 95%*CI* | $\chi^2$ Value | *P* Value |
|---|---|---|---|---|---|---|
| Total | 121981 | 18820 | 15.43 | 15.23-15.63 | | |
| Sex | | | | | 22.36 | ＜0.001 |
| Male | 53743 | 7946 | 14.79 | 14.49-15.09 | | |
| Female | 68238 | 10874 | 15.94 | 15.66-16.21 | | |
| Education level | | | | | 263.21 | ＜0.001 |
| Not educated | 9888 | 2027 | 20.50 | 19.70-21.30 | | |
| Primary education | 43441 | 7240 | 16.67 | 16.32-17.02 | | |
| Junior school education and above | 68652 | 9553 | 13.92 | 13.66-14.17 | | |
| Age group | | | | | 1201.99 | ＜0.001 |
| 65～69 | 60043 | 7635 | 12.72 | 12.45-12.98 | | |
| 70～74 | 32750 | 4730 | 14.44 | 14.06-14.82 | | |
| 75～79 | 16599 | 3070 | 18.50 | 17.90-19.09 | | |
| 80～ | 12589 | 3385 | 26.89 | 26.11-27.66 | | |
| Smoking status | | | | | 68.89 | ＜0.001 |
| Current smoker | 10023 | 1253 | 12.50 | 11.85-13.15 | | |
| Ex-smoker | 7546 | 1047 | 13.87 | 13.09-14.65 | | |
| Never-smoker | 104412 | 16520 | 15.82 | 15.60-16.04 | | |
| Drinking habit | | | | | 130.24 | ＜0.001 |
| Non-drinker | 101661 | 16302 | 16.04 | 15.81-16.26 | | |
| Non-habitual drinker | 12571 | 1589 | 12.64 | 12.06-13.22 | | |
| Habitual drinker | 7749 | 929 | 11.99 | 11.27-12.71 | | |
| BMI | | | | | 1522.11 | ＜0.001 |
| Low weight | 4496 | 1504 | 33.45 | 32.07-34.83 | | |
| Normal weight | 61532 | 11041 | 17.94 | 17.64-18.25 | | |
| Overweight | 44644 | 5175 | 11.59 | 11.29-11.89 | | |
| Obesity | 11309 | 1100 | 9.73 | 9.18-10.27 | | |
| Central obesity | | | | | 540.10 | ＜0.001 |
| Yes | 49051 | 5897 | 12.02 | 11.73-12.31 | | |
| No | 72930 | 12923 | 17.72 | 17.44-18.00 | | |
| Diabetes | | | | | 27.05 | ＜0.001 |
| Yes | 27220 | 4520 | 16.61 | 16.16-17.05 | | |
| No | 94761 | 14300 | 15.09 | 14.86-15.32 | | |
| Hypertension | | | | | 63.27 | ＜0.001 |
| Yes | 67835 | 9883 | 14.57 | 14.30-14.83 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| No | 54146 | 8937 | 16.51 | 16.19-16.82 | | |
| Dyslipidemia | | | | | 211.72 | <0.001 |
| Yes | 54564 | 7354 | 13.48 | 13.19-13.76 | | |
| No | 67417 | 11466 | 17.01 | 16.72-17.29 | | |
| CKD | | | | | 624.34 | <0.001 |
| Yes | 37927 | 7574 | 19.97 | 19.57-20.37 | | |
| No | 84054 | 11246 | 13.38 | 13.15-13.61 | | |

A two-sided value of $P < 0.05$ was considered to be statistically significant.

## Figure legends

Fig 1 Risk factor analyses of the prevalence of anemia in older adults living in Shenzhen community



**STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies***

| Section/Topic | Item # | Recommendation | Reported on page # |
|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | Page 1 |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | Page 2 |
| **Introduction** | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | Page 4 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | Page 4 |
| **Methods** | | | |
| Study design | 4 | Present key elements of study design early in the paper | Page 4 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Page 4 |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants | Page 4 |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Page 5-6 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Page 5-6 |
| Bias | 9 | Describe any efforts to address potential sources of bias | Page 6 |
| Study size | 10 | Explain how the study size was arrived at | Page 4 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Not applicable |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | Page 6 |
| | | (*b*) Describe any methods used to examine subgroups and interactions | Not applicable |
| | | (*c*) Explain how missing data were addressed | Not applicable |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy | Not applicable |
| | | (*e*) Describe any sensitivity analyses | Not applicable |
| **Results** | | | |

| | | | |
|---|---|---|---|
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Page 4 |
| | | (b) Give reasons for non-participation at each stage | Not applicable |
| | | (c) Consider use of a flow diagram | Not applicable |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | Page7 |
| | | (b) Indicate number of participants with missing data for each variable of interest | Not applicable |
| Outcome data | 15* | Report numbers of outcome events or summary measures | Page 7 |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | Page 7 |
| | | (*b*) Report category boundaries when continuous variables were categorized | Page 7 |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | Page 7 |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | Not applicable |
| **Discussion** | | | |
| Key results | 18 | Summarise key results with reference to study objectives | Page 7-8 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | Page 8-9 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | Page 7-9 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | Page 9 |
| **Other information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | Page 9 |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

# Anemia and associated factors among older adults in an urban district in China: a large-scale cross-sectional study



| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID | bmjopen-2021-056100.R3 |
| Article Type: | Original research |
| Date Submitted by the Author: | 30-Jan-2022 |
| Complete List of Authors: | Ni, Wenqing; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Yuan, Xueli; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Sun, Yuanying; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Zhang, Hong; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Zhang, Yan; Shenzhen Center for Chronic Disease Control, Department of Elderly Health Management<br>Xu, Jian; Shenzhen Nanshan Center for Chronic Disease Control, Department of Elderly Health Management |
| Primary Subject Heading: | Epidemiology |
| Secondary Subject Heading: | Epidemiology, Public health |
| Keywords: | Anaemia < HAEMATOLOGY, EPIDEMIOLOGY, Risk management < HEALTH SERVICES ADMINISTRATION & MANAGEMENT |
| | |

*I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.*

*The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.*

*Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.*

# Anemia and associated factors among older adults in an urban district in China: a large-scale cross-sectional study

Wenqing Ni[1#], Xueli Yuan[1#], Yuanying Sun[1], Hongmin Zhang[1], Yan Zhang[1], Jian Xu[1]

[1]Department of Elderly Health Management, Shenzhen Center for Chronic Disease Control, Shenzhen, Guangdong, 518020, China

# These authors contributed equally to this work.

*Corresponding author :
Jian Xu, Ph.D.
Shenzhen Center for Chronic Disease Control
No.2021, Buxin Rd. Shenzhen, Guangdong 518020, P.R. China

Tel: 86-755-25506942
Fax: 86-755-25506942
E-mail: anniexu73@126.com

## Abstract

**Objective**: Anemia leads to poor health outcomes in older adults; however, most current research in China has focused on younger adults. The present study aimed to investigate the prevalence of anemia and its associated factors in older adults in an urban district in China.

**Design**: A cross-sectional study.

**Setting**: An urbanized region, Shenzhen, China.

**Participants**: A total of 121,981 participants aged ≥ 65 years were recruited at local community health service centers in Shenzhen from January to December 2018.

**Primary outcomes**: The prevalence of anemia was analyzed and potential associated factors were evaluated.

**Results**: The mean hemoglobin level was13.64 ± 1.67g/dL and the prevalence of anemia was 15.43%. The prevalences of mild, moderate, and severe anemia were 12.24%, 2.94%, and 0.25%, respectively. Anemia was positively associated with older age, being underweight (adjusted odds ratio (*AOR*): 2.06, 95% confidence interval (*CI*): 1.93–2.20), diabetes (*AOR*: 1.23, 95% *CI*: 1.19–1.28), and chronic kidney disease (*AOR*: 1.41, 95% *CI*: 1.36–1.46), and inversely with higher education level, current-smoker (*AOR*: 0.84, 95% *CI*: 0.78–0.89), non-habitual drinker (*AOR*: 0.86, 95% *CI*: 0.81–0.92), habitual drinker (*AOR*: 0.81, 95% *CI*: 0.75–0.87), overweight (*AOR*: 0.67, 95% *CI*: 0.64–0.70), obesity (*AOR*: 0.57, 95% *CI*: 0.53–0.61), central obesity (*AOR*: 0.86, 95% *CI*: 0.82–0.89), hypertension (*AOR*: 0.86, 95% *CI*: 0.83–0.89), and dyslipidemia (*AOR*: 0.81, 95% *CI*: 0.78–0.84).

**Conclusion**: Anemia is prevalent among people aged 65 years and older in China. Screening of high-risk populations and treatment of senile anemia should be a top priority in Shenzhen, and should be listed as important public health intervention measures for implementation.


**Keywords**: older adults, anemia, epidemiologic study, risk factor

## Strengths and limitations of this study

■ This was the first large-scale cross-sectional study to assess the prevalence of anemia and its factors in an urban district in China.

■ This study had a sufficiently large sample size to detect significant differences in the prevalence of anemia among older adults.

■ Convenience sampling was used to enroll the population sample.

■ The dataset used in this study did not provide information on the dietary behavior of the participants.

# 1. Introduction

Anemia results from an inadequate number of erythrocytes which leads to a decreased ability to carry oxygen to meet the body's physiological demands. It is characterized by reduced levels of hemoglobin (Hb) in the blood in affected individuals. Anemia may occur at all stages of life, however, older people are among the most vulnerable.[1,2] Globally, 11.0% of men and 10.2% of women aged 65 years and older are anemic.[3] Anemia is a risk factor for a variety of adverse outcomes in the older population, including hospitalization, disability and mortality.[1] Previous studies found higher mortality rates in people aged 65 years and older hospitalized for myocardial infarction, patients with systolic and diastolic chronic heart failure (CHF), and in older CHF patients with anemia.[4-6] Anemia is also an independent risk factor for decline in physical performance and has a negative impact on quality of life, physical functioning, and muscle strength in older individuals.[7-9] Early identification and treatment of anemia is therefore an important strategy to improve the quality of life of older adults with anemia.

In China, 13.5% of the total population (approximately 190.64 million people) were aged 65 years or older in 2020,[10] and increasing life expectancy and declining fertility rates mean that China is experiencing an ongoing aging process. In line with the aging of the population, anemia has become an important public health problem in China. The China Health and Retirement Longitudinal Study showed a prevalence of anemia in middle-aged and older Chinese residents of 12.86% from 2011 to 2012,[11] and the 2010–2012 China National Nutrition and Health Survey found a prevalence of anemia in older Chinese people of 12.6%.[12] Preventing anemia and improving the health of older adults in China are thus urgent issues. However, the only previous trial for preventing anemia examined the use of iron-fortified soy sauce in some cities in China, which aimed to reduce the prevalence of iron-deficiency anemia among women of reproductive age.[13] The prevention of anemia in older adults thus still presents a challenge, and limited measures have been taken to address this public health problem.

Clarifying the risk factors of anemia in the older adults will help to identify the population at risk of anemia, and promote the development of targeted screening and intervention measures. Economic development, living standards, body mass index (BMI), chronic disease and specific risk factors, chronic kidney disease (CKD), older age are important factors affecting anemia.[1,3,14,15] Most previous studies focused on the prevalence of anemia among middle-aged and older adults in urban and rural districts of China, but there is a lack of large-sample studies of anemia among older adults in urban districts.[11,12,16,17] This study therefore aimed to examine the prevalence of anemia and its related factors among people aged 65 or older in an urban district of China, to help develop strategies for future interventions and the prevention of anemia in older adults living in urban districts in China.

# 2. Materials and methods

## 2.1 Study population

We recruited participants aged 65 years and older from the lists of all residents registered at local community health centers in Shenzhen by convenient sampling method, from January 2018 to December 2018. The staff of the local community health centers recruited older adults in their community to participate in the survey by pasting posters, placing leaflets, telephone, distributed electronic posters via Wechat. The eligibility criteria were as follows: (1) lived in Shenzhen for more than 6 months; (2) able to participate in the study and give informed consent; and (3) conscious and able to cooperate to complete the face-to-face interview, medical examinations and biomedical tests. Prisoners are not free to visit community health centres, and we excluded residents living in prisons. A total of 141,684 individuals were recruited in this study, accounting for 36.9% (141,684/383,700) of the resident older adult population in Shenzhen according to the 2015 population census. Data were collected at examination centers in local community health centers in the participants' residential areas. Participants were asked to complete a questionnaire, provide a fasting blood sample, and undergo physical examinations. A total of 19,703 respondents were excluded because of failure to fulfil one or all of these requirements. Finally, 121,981 participants (86.09%) were included in the final data analysis.

**2.2 Questionnaire survey**

Prior to the study, all investigators completed a training course to understand the methodology and process of the study. Working manuals containing questionnaire techniques, blood pressure measurement, anthropometric measurements, biological sample collection, and processing information were distributed to all the investigators.

Data were recorded by face-to-face interview 1 hour after blood collection. Detailed sociodemographic characteristics and health parameters were collected by a standardized questionnaire including age, sex, education level, marital status, past medical history, family health history, lifestyle behaviors, and medication use. Participants were categorized according to the level of education into three categories: not educated; primary education; and junior high school education and above. Regarding drinking habits, participants were classified as habitual drinkers (drink at least once a day), non-habitual drinkers (six times a week to once a month), or non-drinker (almost never).[18] Based on a previous study, we divided participants into current smokers, ex-smokers, and never-smokers.[19]

**2.3 Physical examination**

Anthropometric examinations were carried out in the morning after overnight fasting by standard methods. Body height, weight and waist circumference (WC) of the participants were measured, and BMI was calculated. Blood pressure was measured twice in both arms supported at heart level with the participants in a sitting position, using a calibrated electronic sphygmomanometer and the higher level was recorded and used for statistical analysis. To obtain accurate readings, the participants were asked to rest for at least 5 min before the measurement, or if they had engaged in excessive exercise prior to the visit, to rest for at least 30 min before the measurement.

**2.4 Blood sample collection and biochemical analyses**

Venous blood samples were taken after overnight fasting for at least 8 hours. All

blood samples were analyzed in clinical laboratories at the grade 2 hospitals to which the community health centers were directly affiliated. All the laboratories had successfully completed a standardization and competency program. Fasting venous blood was used to measure levels of Hb, plasma glucose, creatinine, total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) using an automatic biochemistry analyzer. Biochemical analysis of fresh blood samples was completed within 4 hours. Serum creatinine was used to calculate the estimated glomerular filtration rate (eGFR) using the full age spectrum equation.[20]

**2.5 Operational definitions/measurements**

Anemia was defined as a Hb concentration < 13 g/dL in men and < 12 g/dL in women, according to World Health Organization standards.[21] The severity of anemia was classified as mild (11–11.9 g/dL (women), 11–12.9 g/dL (men)), moderate (8–10.9 g/dL), and severe (<8 g/dL).[21] CKD was defined as eGFR < 60 mL/min/1.73 $m^2$.[22] A diagnosis of hypertension was considered in participants with three consecutive high readings (⩾140 mm Hg systolic blood pressure and/or ⩾90 mm Hg diastolic blood pressure) with 2-week intervals or self-reported treatment with antihypertensive medication within the previous 2 weeks.[23, 24] Participants who met one of the following three criteria were diagnosed with diabetes: (1) previously diagnosed by professional doctors, (2) fasting plasma glucose (FBG) ≥ 7.0 mmol/L, and (3) 2-hour plasma glucose level ≥ 11.1 mmol/L.[25] High TC, high TG, high LDL-C, and low HDL-C were diagnosed according to the 2016 Chinese Guidelines for the Management of Dyslipidemia in Adults.[26] In this study, we defined dyslipidemia as an abnormal concentration of one or more lipid components or the use of anti-dyslipidemia medications in the past 2 weeks.

Participants were divided into four groups based on the adult weight criteria published by the Ministry of Health of China (WS/T 428-2013): BMI < 18.5 kg/$m^2$ (low weight), BMI ≥ 18.5 kg/$m^2$ and <24.0 kg/$m^2$ (normal weight), BMI ≥ 24.0 kg/$m^2$ and < 28.0 kg/$m^2$ (overweight), and BMI ≥ 28.0 kg/$m^2$ (obesity). A WC ≥ 90 cm for men and ≥85 cm for women was defined as central obesity.[27]

**2.6 Statistical analyses**

Descriptive statistics, including means and standard deviations, were used to compute continuous variables. Numerical data were expressed as percentages and compared by $\chi^2$ tests. Multivariate logistic regression analysis was performed to explore the associations between the prevalence of anemia and associated risk factors. In the multivariate logistic regression model, the prevalence of anemia was defined as the dependent variable, and sex, education level, age group, smoking status, drinking habit, BMI, central obesity, diabetes, hypertension, dyslipidemia and CKD were defined as the independent variables. Data analysis was carried out using SAS 9.4 (Institute, Cary, NC, USA). A two-sided value of $P < 0.05$ was considered to be statistically significant.

**2.7 Participants and public involvement**

Neither the study participants nor the public were involved in the design, recruitment or conduct of the study. All the participants had the option of receiving a

health check and biochemical results when they visited the local community health centers.

### 2.8 Ethical Approval Statement

The study received ethical approval from the Center for Chronic Disease Control in Shenzhen(Grant No: SZCCC-201802, SZCCC-2020-018-01-PJ). The study complied with the guidelines of the Declaration of Helsinki. Written informed consent was obtained from all participants before the collection of data and conducting the study. For participants who were not educated, the participants and a proxy (family member) who accompanied the participant in the survey were informed orally (participant) and in writing (proxy) about the purpose, process, methods, benefits, and health risks of the study. During the informed consent process, uneducated older adults and their proxies were able to consult the investigators with questions at any time. After explaining the concept of informed consent, uneducated older adults provided verbal agreement, and written informed consent to participate in the study was provided by their proxy. The consent processes were approved by the committee of the Center for Chronic Disease Control of Shenzhen.

## 3. Results

### 3.1 Characteristics of participants

The characteristics of the study participants are shown in Table 1. The mean age was 71.28 ± 5.58 years (range 65–103 years). There were 54,649 men and 69,358 women, and > 50% of participants had a minimum of a junior school education. Among the study population, 8.22% were current smokers and 6.35% were habitual drinkers. The mean Hb, BMI, SBP, DBP, WC, FBG, TC, TG, LDL-C, HDL-C, and eGFR values among all 121,981 participants were 13.64 ± 1.67 g/dL, 23.83 ± 3.17 kg/m$^2$, 134.71 ± 17.69 mmHg, 77.23 ± 10.31 mmHg, 85.10 ± 8.82 cm, 5.96 ± 1.90 mmol/L, 5.21 ± 2.00 mmol/L, 1.57 ± 1.14 mmol/L, 3.09 ± 1.05 mmol/L, 1.39 ± 1.05 mmol/L, and 68.74 ± 16.70 mL/min/1.73m$^2$, respectively. A total of 100,762 participants (82.60%) had at least one chronic disease, with hypertension (55.61%), dyslipidemia (44.73%), CKD (31.09%), and diabetes (22.31%) being the most prevalent (data not shown).

### 3.2 Prevalence of anemia in different subgroups

The overall prevalence anemia was 15.43% and the prevalences (95% confidence intervals(*CI*)) of mild, moderate and severe anemia were 12.24% (12.05-12.42), 2.94% (2.84-3.03) and 0.25% (0.23-0.28), respectively. The prevalence of anemia among subpopulations is shown in Table 2. Anemia was significantly more prevalent in women than in men and generally increased with age. The prevalence was lower among individuals with at least primary-level education, and lower in current smokers and habitual drinkers compared with their counterparts. The prevalence of anemia was higher in participants with low weight and lower in those with overweight, obesity, central obesity, hypertension, or dyslipidemia. Individuals with diabetes or CKD had a higher prevalence of anemia than those without these conditions.

### 3.3 Association between anemia and related variables

Binary logistic regression analysis was carried out with presence or absence of

anemia as the dependent variable, and factors in univariate analysis as independent variables to determine the factors influencing anemia. Primary education(adjusted odds ratio (*AOR*)=0.89, 95%*CI*:0.84-0.94), junior school education and above (*AOR*=0.72, 95%*CI*:0.68-0.76) current-smoker (*AOR*=0.84, 95%*CI*:0.78-0.89), non-habitual drinker (*AOR*=0.86, 95%*CI*:0.81-0.92), habitual drinker (*AOR*=0.81, 95%*CI*:0.75-0.87), overweight (*AOR*=0.67, 95%*CI*:0.64-0.70), obesity(*AOR*=0.57, 95%*CI*:0.53-0.61), central obesity (*AOR*=0.86, 95%*CI*:0.82-0.89), hypertension (*AOR*=0.86, 95%*CI*:0.83-0.89), and dyslipidemia (*AOR*=0.81, 95%*CI*:0.78-0.84) were independently associated with lower odds for the presence of anemia (Fig. 1), while age 70-74 years (*AOR*=1.10, 95%*CI*:1.06-1.15) , age 75-79 years (*AOR*=1.37, 95%*CI*:1.31-1.44), age ≥ 80 years (*AOR*=1.96, 95%*CI*:1.86-2.06), underweight (*AOR*=2.06, 95%*CI*:1.93-2.20), diabetes (*AOR*=1.23, 95%*CI*:1.19-1.28), and CKD (*AOR*=1.41, 95%*CI*:1.36-1.46) were independently associated with greater odds (Fig. 1). However, there was no significant difference in the risk of anemia in relation to sex.

## 4. Discussion

This was the first large-scale cross-sectional survey to report the prevalence of anemia in older adults (aged 65 years or older) living in an urban district of China. This study demonstrated that the prevalence of anemia was relatively high, representing a public health problem in Shenzhen. After controlling for the confounding factors we found that the prevalence of anemia varied with education level, age group, smoking status, drinking habit, BMI, central obesity, and some non-communicable diseases.

The prevalence of anemia among older adults in an urban district in China in the current study was 15.43%, which was higher than the 12.86% reported in previous national studies in China,[11] but lower than the 18.90% reported in the 2009 national survey in China.[13] The difference in prevalence rates among these studies may have been caused by differences in study design, sample size, and/or the age of the study participants.

The current study found a significant negative correlation between anemia prevalence and educational level. This was consistent with studies conducted in Nepal and Pakistan, which confirmed that a low educational level was a risk factor for anemia.[28] This relationship probably occurs because higher levels of education enable people to earn more and thus escape from the poverty trap. Multivariate analysis also identified older age as an independent risk factor for anemia, consistent with the findings of other related studies.[3, 29] The prevalence of anemia increased with age, with a two-to-three-fold increase (26.89% vs. 12.72%) in people aged > 80 years, suggesting the need for routine screening for anemia in this high-risk subgroup.

Current smokers had a lower risk of anemia than never smokers. Similarly, previous researches revealed that smoking was decrease the risk of anemia.[15,30] Sharma and co-researchers found that women aged 35-49 years who were current smokers had a 25% lower risk of anemia compared with non-smokers, after adjusting for the covariates.[30] Elevated Hb levels in smokers were associated with elevated

carboxyhemoglobin (HbCO), a stable compound of Hb and carbon monoxide (CO), due to exposure to excess CO as a result of smoking.[31] The form of HbCO reduces oxygen delivery, and smokers had compensatory elevated Hb to increase erythropoiesis and maintain oxygen transportation.[32] This might explain why adaptation to excess CO during smoking was shown by increase in Hb and red blood cell mass.[33] Habitual drinking was also associated with a decreased risk of anemia, with a corresponding *OR* of 0.81, consistent with a Korean study.[15] However, the direct causality of this negative correlation between alcohol drinking and anemia is still unclear.[15] Given the potential risks of alcohol and tobacco consumption to human health, we do not recommend increasing alcohol consumption or smoking to protect against anemia.

We also found a negative association between increased BMI and anemia prevalence, in accord with other studies conducted in China, the United States, Nepal, and Pakistan.[28, 34] The reasons for being underweight may include poor distribution of inadequate food within the family, food insecurity, poverty, and micronutrient deficiencies, which tend to coexist with other macronutrient deficiencies. The underlying mechanism accounting for the significant negative association between overweight or obesity and anemia risk is unclear; however there are several possible explanations. First, obese participants are less likely to be malnourished, because excess calorie intake leads to obesity,[35] and overnutrition in obese participants may thus be associated with a significant reduction in anemia risk. Second, obese participants may have a variety of other diseases that could increase Hb levels, such as obstructive sleep apnea and other obesity-related breathing disorders, which lead to chronic tissue hypoxia and increased red blood cells.[36]

We found that older people with diabetes had higher rates of anemia than non-diabetics, consistent with previous studies.[37] Evidence indicates that the incidence and prevalence of anemia in diabetic patients is often associated with erythropoietin deficiency caused by diabetic kidney damage.[38] Other researchers have also shown a link between anemia and hypertension, as shown in our current study.[22]

This study showed that the prevalence of anemia was low among individuals with dyslipidemia. A study by Zaribaf et al. found a significant positive correlation between Hb levels and dyslipidemia.[39] However, this study differed from our study in that it assessed the relationship between anemia and lipids in premenopausal women, whereas our study focused on older adults (aged 65–113 years).[39] In contrast, a study conducted by other researchers in women of childbearing age found no significant association between serum LDL and anemia.[39] The reasons for the different results in terms of the relationship between dyslipidemia and anemia deserve further investigation. Patients with CKD have defects in renal endocrine function, resulting in decreased erythropoietin secretion by the kidney, leading to nephrogenic anemia.[40] Nearly half of all patients with CKD have anemia.[40] The current study found the similar results.

This study had some limitations. First, it was a cross-sectional study and could only infer correlation, not causation. Second, randomized sampling would represent the best design for testing the prevalence of anemia and its associated factors among older

adults; however, large random sampling was not practically feasible and we therefore adopted a convenient sampling method to recruit older adult participants. This was a major factor preventing the extrapolation of the results to the general population. Finally, renal disease was assessed based on a one-time GFR measurement, possibly leading to overestimation of the actual prevalence of CKD. However, these limitations do not affect the significance of the results, which provide the first evidence of the prevalence and risk factors of anemia among older adults in urban China.

## 5. Conclusion

In conclusion, anemia is prevalent among the older adult population in China, with older age, underweight, diabetes, and CKD being positively associated with anemia, and higher education level, current-smoker, drinker, overweight, obesity, central obesity, hypertension, and dyslipidemia being negatively associated. Screening of high-risk populations, and treatment of senile anemia should be top priorities in Shenzhen, and should be listed as important public health intervention measures for implementation.

**Acknowledgments**

We are grateful to all the volunteers for their participation in the present study, and to all the investigators for their support and hard work during this survey.

**Author Contributions**

WN, XY, and JX: study conception and design. WN, XY, YS, HZ, YZ, and JX: performance of research. XY and YS: data analysis and interpretation. WN and XY: writing the original draft. WN and JX: Writing the review and editing. All authors have read and agreed to the published version of the manuscript.

**Funding**

This study was supported by the Science and Technology Planning Project of Shenzhen City, Guangdong Province, China (Grant No. JCYJ20180703145202065)，the Science and Technology Planning Project of Shenzhen City, Guangdong Province, China(Grant No. KCXFZ20201221173600001), Shenzhen Medical Key Discipline Construction Fund, and Sanming Project of Medicine in Shenzhen (Grant No. SZSM201811093).

**Conflicts of Interest**

The authors declare no conflict of interest.

**Patient consent for publication**

Not required.

## Ethics approval

This study was approved by the ethical review committee of the Center for Chronic Disease Control of Shenzhen.

## Data sharing statement

All data generated or analyzed during this study are included in this published article. No additional data are available.

## References

1. Working Group on "Expert Consensus on nutrition Prevention and Treatment of Iron deficiency Anemia" of Chinese Nutrition Society. Expert consensus on nutrition prevention and treatment of iron deficiency anemia. *Acta Nutrimenta Sinica* **2019**; 41,417-426.
2. Stevens GA, Finucane MM, De-Regil LM, *et al*. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: a systematic analysis of population-representative data. *Lancet Glob Health* **2013**; 1, e16-25.
3. Bianchi VE. Role of nutrition on anemia in elderly. *Clin Nutr ESPEN* **2016**; 11, e1-e11.
4. Wu WC, Rathore SS, Wang Y, et al. Blood transfusion in elderly patients with acute myocardial infarction. *N Engl J Med* **2001**; 345, 1230-1236.
5. Groenveld HF, Januzzi JL, Damman K, *et al*. Anemia and mortality in heart failure patients a systematic review and meta-analysis. *J Am Coll Cardiol* **2008**, 52, 818-827.
6. Ezekowitz JA MF, Armstrong PW. Anemia is common in heart failure and is associated with poor outcomes: insights from a cohort of 12065 patients with new-onset heart failure. *Circulation* **2003**; 107, 223-225.
7. Penninx BW, Guralnik JM, Onder G, *et al*. Anemia and decline in physical performance among older persons. *Am J Med* **2003**; 115, 104-110.
8. Penninx BW, Pahor M, Cesari M, *et al*. Anemia is associated with disability and decreased physical performance and muscle strength in the elderly. *J Am Geriatrics Soc* **2004**; 52, 719-724.
9. Cesari M, Penninx BW, Lauretani F, *et al*. Hemoglobin levels and skeletal muscle: results from the InCHIANTI study. *J Gerontol A Biol Sci Med Sci* **2004**;59:249-254.
10. National Bureau of Statistics. Bulletin of the Seventh National Population Census (No. 5). http://www.stats.gov.cn/tjsj/tjgb/rkpcgb/qgrkpcgb/202106/t20210628_1818824.html. Accessed September 26 **2021**
11. Qin T, Yan M, Fu Z, *et al*. Association between anemia and cognitive decline among Chinese middle-aged and elderly: evidence from the China health and

retirement longitudinal study. *BMC Geriatr* **2019**; 19, 305.

12. Chang J, Wang Y. Reports of China Nutrition and Health Survey (2010–2013). Peking University Medical Press Co. LTD, Beijing, **2016**.
13. Xu X, Hall J, Byles J, *et al*. Dietary pattern, serum magnesium, ferritin, C-reactive protein and anaemia among older people. *Clin Nutr* **2017**; 36, 444-451.
14. Wu Y, Ye H, Liu J, *et al*. Prevalence of anemia and sociodemographic characteristics among pregnant and non-pregnant women in southwest China: a longitudinal observational study. *BMC Pregnancy Childbirth* **2020**; 20, 535.
15. Chun MY, Kim JH, Kang JS. Relationship between Self-Reported Sleep Duration and Risk of Anemia: Data from the Korea National Health and Nutrition Examination Survey 2016-2017. *Int J Environ Res Public Health* **2021**; 18:4721.
16. Ruan Y, Guo Y, Kowal P, *et al*. Association between anemia and frailty in 13,175 community-dwelling adults aged 50 years and older in China. *BMC Geriatr* **2019**; 19:327.
17. Zhang Q, Qin G, Liu Z, *et al*. Dietary Balance Index-07 and the Risk of Anemia in Middle Aged and Elderly People in Southwest China: A Cross Sectional Study. *Nutrients* **2018**; 10, 162.
18. Zhang L, Wang F, Wang L, *et al*. Prevalence of chronic kidney disease in China: a cross-sectional survey. *Lancet* **2012**; 379, 815-822.
19. Zhang M, Liu S, Yang L, *et al*. Prevalence of smoking and knowledge about the smoking hazards among 170,000 Chinese adults: a nationally representative survey in 2013-2014. *Nicotine Tob Res* **2019**; 21, 1644-1651.
20. Pottel H, Hoste L, Dubourg L, Ebert N, *et al*. An estimated glomerular filtration rate equation for the full age spectrum. *Nephrol Dial Transplant* **2016**; 31,798-806.
21. World Health Organization. Haemoglobin Concentrations for the Diagnosis of Anaemia and Assessment of Severity. https://apps.who.int/iris/bitstream/handle/10665/85839/WHO_NMH_NHD_MNM_11.1_eng.pdf?ua=1. Accessed July 21 **2021**.
22. Lee YG, Chang Y, Kang J, *et al*. Risk factors for incident anemia of chronic diseases: A cohort study. PLoS One **2019**; 14, e0216062.
23. Writing Group of 2018 Chinese Guidelines for the Management of Hypertension, Chinese Hypertension League, Chinese Society of Cardiology, Chinese Medical Doctor Association Hypertension Committee, Hypertension Branch of China International Exchange and Promotive Association for Medical and Health Care, Hypertension Branch of Chinese Geriatric Medical Association. 2018 Chinese guidelines for the management of hypertension. *Chin J Cardiovasc Med* **2019**; 24, 24-56.
24. Qaseem A, Wilt TJ, Rich R, *et al*. Pharmacologic Treatment of Hypertension in Adults Aged 60 Years or Older to Higher Versus Lower Blood Pressure Targets: A Clinical Practice Guideline From the American College of

Physicians and the American Academy of Family Physicians. *Ann Intern Med* **2017**; 166, 430-437.

25. Wang Q, Zhang X, Fang L, *et al*. Prevalence, awareness, treatment and control of diabetes mellitus among middle-aged and elderly people in a rural Chinese population: A cross-sectional study. *PLoS One* **2018**; 13, e0198343.
26. Joint committee for guideline revision. 2016 Chinese guidelines for the management of dyslipidemia in adults. *J Geriatr Cardiol* **2018**; 15, 1-29.
27. National Health Commission of the People´s Republic of China. Criteria of Weight for Adults. http://www.nhc.gov.cn/ewebeditor/uploadfile/2013/08/20130808135715967.pdf. Accessed September 26 **2021**
28. Harding KL, Aguayo VM, Namirembe G, *et al*. Determinants of anemia among women and children in Nepal and Pakistan: An analysis of recent national survey data. *Matern Child Nutr* **2018**; Suppl 4, e12478.
29. Fiseha T, Adamu A, Tesfaye M, *et al*. Prevalence of anemia in diabetic adult outpatients in Northeast Ethiopia. *PLoS One* **2019**; 14, e0222111.
30. Hisa K, Haruna M, Hikita N, *et al*. Prevalence of and factors related to anemia among Japanese adult women: Secondary data analysis using health check-up database. *Sci Rep* **2019**;9:17048.
31. Nordenberg D, Yip R, Binkin NJ. The effect of cigarette smoking on hemoglobin levels and anemia screening. *JAMA* **1990**;264:1556-1559.
32. Sharma AJ, Addo OY, Mei Z, *et al*. Reexamination of hemoglobin adjustments to define anemia: altitude and smoking. *Ann N Y Acad Sci* **2019**;1450:190-203.
33. Pollini G, Maugeri U, Bernardo A, *et al*. Erythrocytes parameters due to aging, smoking, alcohol consumption and occupational activity in a working population of petrochemical industry. The Pavia Study. *G Ital Med Lav* **1989**;11:237-240.
34. Qin Y, Melse-Boonstra A, Pan X, *et al*. Anemia in relation to body mass index and waist circumference among Chinese women. *Nutr J* **2013**. doi: 10.1186/1475-2891-1112-1110.
35. Dandona P, Aljada A, Chaudhuri A, et al. Metabolic syndrome: a comprehensive perspective based on interactions between obesity, diabetes, and inflammation. *Circulation* **2005**;111,1448-1454.
36. Schwartz AR, Patil SP, Laffan AM, *et a*l. Obesity and obstructive sleep apnea: pathogenic mechanisms and therapeutic approaches. *Proc Am Thorac Soc* **2008**; 5, 185-192.
37. Gauci R, Hunter M, Bruce DG, *et al*. Anemia complicating type 2 diabetes: Prevalence, risk factors and prognosis. *J Diabetes Complication*s **2017**; 31, 1169-1174.
38. Thomas MC. The High Prevalence of Anemia in Diabetes Is Linked to Functional Erythropoietin Deficiency. *Semin Nephrol* **2006**; 26, 275-282.
39. Zaribaf F, Entezari MH, Hassanzadeh A, *et al*. Association between dietary iron, iron stores, and serum lipid profile in reproductive age women. *J Educ Health Promot* **2014**; 3: DOI: 10.4103/2277-9531.127586.

40. Ryu SR, Park SK, Jung JY, *et al*. The Prevalence and Management of Anemia in Chronic Kidney Disease Patients: Result from the KoreaN Cohort Study for Outcomes in Patients With Chronic Kidney Disease (KNOW-CKD). *J Korean Med Sci* **2017**; 32, 249-256.

## Tables

**Table 1** Sociodemographic and other characteristics of older adults living in Shenzhen community (*N* =121, 981 )

| Characteristics | Total | 95%*CI* |
|---|---|---|
| Age (years) | 71.28 ± 5.58 | 71.25-71.31 |
| Hb(g/dL) | 13.64 ± 1.67 | 13.63-13.65 |
| BMI (Kg/m2) | 23.83 ± 3.17 | 23.81-23.85 |
| SBP (mm Hg) | 134.71 ± 17.69 | 134.61-134.81 |
| DBP (mm Hg) | 77.23 ± 10.31 | 77.18-77.29 |
| WC (cm) | 85.1 ± 8.82 | 85.05-85.15 |
| FBG (mmol/L) | 5.96 ± 1.9 | 5.95-5.97 |
| TC(mmol/L) | 5.21 ± 2 | 5.20-5.23 |
| TG(mmol/L) | 1.57 ± 1.14 | 1.57-1.58 |
| LDL-C(mmol/L) | 3.09 ± 1.05 | 3.08-3.09 |
| HDL-C(mmol/L) | 1.39 ± 0.51 | 1.39-1.39 |
| eGFR | 68.74 ± 16.7 | 68.65-68.83 |
| Sex, n(%) | | |
| Male | 54649 (44.07%) | 43.78-44.34 |
| Female | 69358 (55.93%) | 55.66-56.22 |
| Education level, n(%) | | |
| Not educated | 9888 (8.11%) | 7.95-8.26 |
| Primary education | 43441 (35.61%) | 35.34-35.88 |
| Junior school education and above | 68652 (56.28%) | 56.00-56.56 |
| Smoking status, n (%) | | |
| Current smoker | 10023 (8.22%) | 8.06-8.37 |
| Ex-smoker | 7546 (6.19%) | 6.05-6.32 |
| Never-smoker | 104412 (85.59%) | 85.40-85.79 |
| Drinking habit, n (%) | | |
| Non-drinker | 101661 (83.34%) | 83.13-83.55 |
| Non-habitual drinker | 12571 (10.31%) | 10.14-10.48 |
| Habitual drinker | 7749 (6.35%) | 6.22-6.49 |

Table 2 Prevalence of anemia in older adults living in Shenzhen community, according to sociodemographic and other characteristics

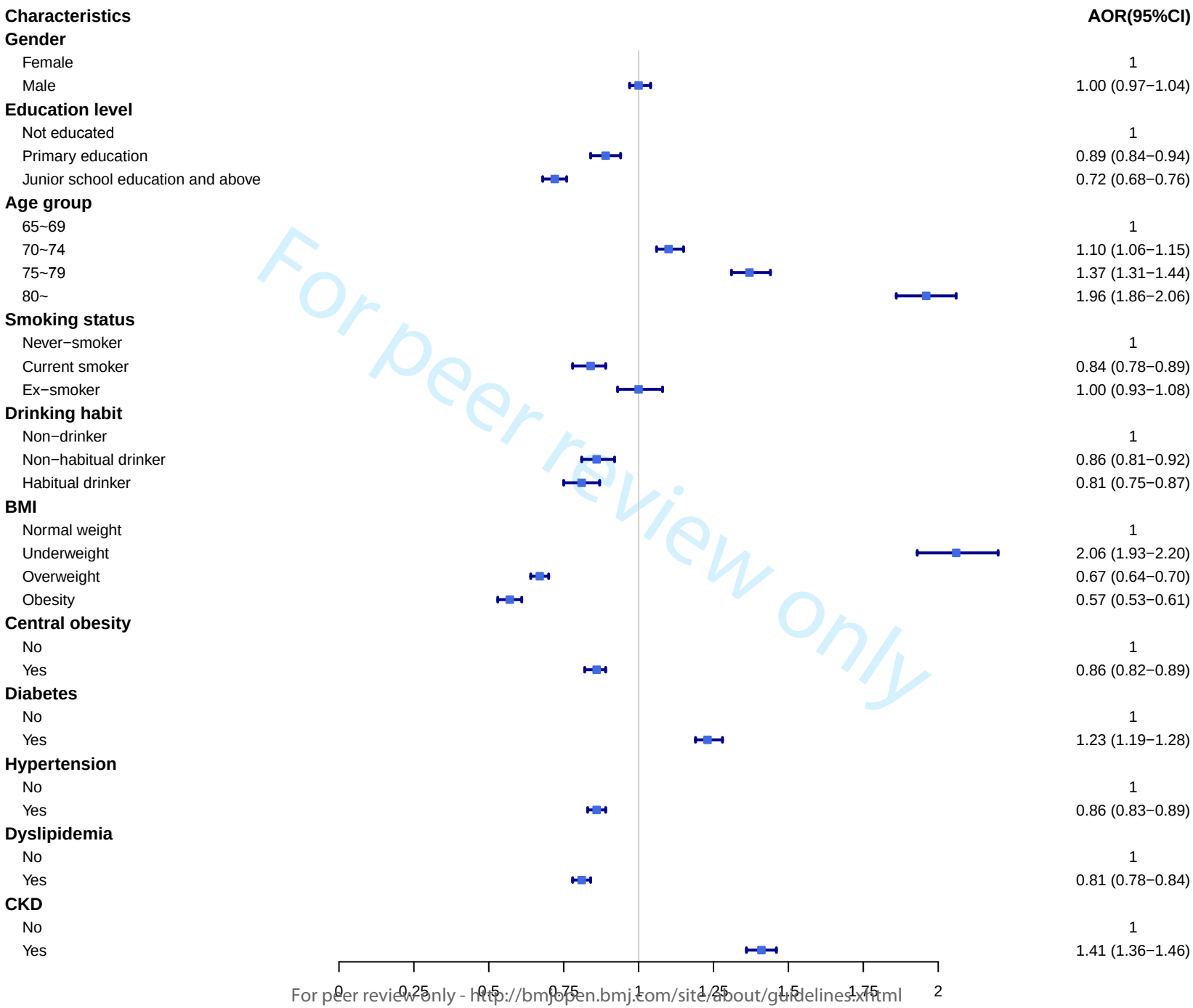
| Characteristics | Total | Number of anemia | Prevalence of anemia(%) | 95%*CI* | $\chi^2$ Value | *P* Value |
|---|---|---|---|---|---|---|
| Total | 121981 | 18820 | 15.43 | 15.23-15.63 | | |
| Sex | | | | | 22.36 | ＜0.001 |
| Male | 53743 | 7946 | 14.79 | 14.49-15.09 | | |
| Female | 68238 | 10874 | 15.94 | 15.66-16.21 | | |
| Education level | | | | | 263.21 | ＜0.001 |
| Not educated | 9888 | 2027 | 20.50 | 19.70-21.30 | | |
| Primary education | 43441 | 7240 | 16.67 | 16.32-17.02 | | |
| Junior school education and above | 68652 | 9553 | 13.92 | 13.66-14.17 | | |
| Age group | | | | | 1201.99 | ＜0.001 |
| 65～69 | 60043 | 7635 | 12.72 | 12.45-12.98 | | |
| 70～74 | 32750 | 4730 | 14.44 | 14.06-14.82 | | |
| 75～79 | 16599 | 3070 | 18.50 | 17.90-19.09 | | |
| 80～ | 12589 | 3385 | 26.89 | 26.11-27.66 | | |
| Smoking status | | | | | 68.89 | ＜0.001 |
| Current smoker | 10023 | 1253 | 12.50 | 11.85-13.15 | | |
| Ex-smoker | 7546 | 1047 | 13.87 | 13.09-14.65 | | |
| Never-smoker | 104412 | 16520 | 15.82 | 15.60-16.04 | | |
| Drinking habit | | | | | 130.24 | ＜0.001 |
| Non-drinker | 101661 | 16302 | 16.04 | 15.81-16.26 | | |
| Non-habitual drinker | 12571 | 1589 | 12.64 | 12.06-13.22 | | |
| Habitual drinker | 7749 | 929 | 11.99 | 11.27-12.71 | | |
| BMI | | | | | 1522.11 | ＜0.001 |
| Low weight | 4496 | 1504 | 33.45 | 32.07-34.83 | | |
| Normal weight | 61532 | 11041 | 17.94 | 17.64-18.25 | | |
| Overweight | 44644 | 5175 | 11.59 | 11.29-11.89 | | |
| Obesity | 11309 | 1100 | 9.73 | 9.18-10.27 | | |
| Central obesity | | | | | 540.10 | ＜0.001 |
| Yes | 49051 | 5897 | 12.02 | 11.73-12.31 | | |
| No | 72930 | 12923 | 17.72 | 17.44-18.00 | | |
| Diabetes | | | | | 27.05 | ＜0.001 |
| Yes | 27220 | 4520 | 16.61 | 16.16-17.05 | | |
| No | 94761 | 14300 | 15.09 | 14.86-15.32 | | |
| Hypertension | | | | | 63.27 | ＜0.001 |
| Yes | 67835 | 9883 | 14.57 | 14.30-14.83 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| No | 54146 | 8937 | 16.51 | 16.19-16.82 | | |
| Dyslipidemia | | | | | 211.72 | <0.001 |
| Yes | 54564 | 7354 | 13.48 | 13.19-13.76 | | |
| No | 67417 | 11466 | 17.01 | 16.72-17.29 | | |
| CKD | | | | | 624.34 | <0.001 |
| Yes | 37927 | 7574 | 19.97 | 19.57-20.37 | | |
| No | 84054 | 11246 | 13.38 | 13.15-13.61 | | |

A two-sided value of $P < 0.05$ was considered to be statistically significant.

## Figure legends

Fig 1 Risk factor analyses of the prevalence of anemia in older adults living in Shenzhen community



**STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies***

| Section/Topic | Item # | Recommendation | Reported on page # |
|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | Page 1 |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | Page 2 |
| **Introduction** | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | Page 4 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | Page 4 |
| **Methods** | | | |
| Study design | 4 | Present key elements of study design early in the paper | Page 4 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Page 4 |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants | Page 4 |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Page 5-6 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Page 5-6 |
| Bias | 9 | Describe any efforts to address potential sources of bias | Page 6 |
| Study size | 10 | Explain how the study size was arrived at | Page 4 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Not applicable |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | Page 6 |
| | | (*b*) Describe any methods used to examine subgroups and interactions | Not applicable |
| | | (*c*) Explain how missing data were addressed | Not applicable |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy | Not applicable |
| | | (*e*) Describe any sensitivity analyses | Not applicable |
| **Results** | | | |

| | | | |
|---|---|---|---|
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Page 4 |
| | | (b) Give reasons for non-participation at each stage | Not applicable |
| | | (c) Consider use of a flow diagram | Not applicable |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | Page7 |
| | | (b) Indicate number of participants with missing data for each variable of interest | Not applicable |
| Outcome data | 15* | Report numbers of outcome events or summary measures | Page 7 |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | Page 7 |
| | | (*b*) Report category boundaries when continuous variables were categorized | Page 7 |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | Page 7 |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | Not applicable |
| **Discussion** | | | |
| Key results | 18 | Summarise key results with reference to study objectives | Page 7-8 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | Page 8-9 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | Page 7-9 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | Page 9 |
| **Other information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | Page 9 |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.