Metabolic Healthy Obesity is associated with higher incidence of mild decrease estimate glomerular rate in rural Northeast Chinese

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Abstract

Background

Metabolic healthy obesity (MHO), as one phenotype of obesity, seems associate with lower risk of cardiovascular disease. However, MHO has close relationship with higher incidence of metabolic syndrome and diabetes. This study aims to investigate the prevalence of MHO at baseline, changes of obese metabolic phenotype at follow-up and its relationship with incidence of mildly reduced estimated glomerular filtration rate (eGFR) in rural Northeast Chinese.

Methods

The Chronic Kidney Disease Epidemiology (CKD-EPI) equation was used to calculate eGFR. 4903 participants aged ≥ 35 years with eGFR > 90 ml/min/1.73 m^2 at baseline were enrolled and successfully followed up. All participants completed the questionnaires, anthropometric measurements, and blood test during baseline and follow-up. Mild renal dysfunction defined as mildly reduced eGFR between 60–90 ml/min/1.73 m^2.

Results

The prevalence of MHO was 20.04% in baseline (18.97% for women and 21.11% for men) which was secondary to metabolic abnormal obesity (MAO) (24.4%, 27.2% for women and 21.5% for men). 38.4% of women and 38.90% of men experienced phenotype changes during follow-up. The cumulative incidence of mildly reduced eGFR in MHO was 20.1% (17.7% for women and 22.3% for men) which was also secondary to MAO (20.8%, 18.6% for women and 23.5% for men). After adjusted possible confounders, MHO was associated with higher incidence of mildly reduced eGFR among women [OR (95%CI) = 1.64 (1.18, 2.25)] and men [OR (95%CI) = 1.62 (1.24, 2.11)] whereas MAO was related with higher incidence of mildly reduced eGFR among men only [OR (95%CI) = 1.74 (1.32, 2.29)].

Conclusion

MHO was associated with higher incidence of mildly reduced eGFR in both gender; however, there was a specific relationship between MAO and mildly reduced eGFR in men only. Therefore, it is necessary to monitoring kidney function among both MHO and MAO subjects.

Background

Mild nephropathy is used to define subjects with either mildly reduced estimated glomerular filtration rate (eGFR) or microalbuminuria. The National Health and Nutrition Examination Surveys (NHANES) held in United States, enrolled 20 to 75 years subjects reported approximately 36% had an eGFR of 60 to 89 ml/min/1.73 m^2, whereas in the Atherosclerosis Risk in the Communities (ARIC) study, 50% participants aged 45 to 64 years had mild reduction of eGFR[1, 2]. There were many studies claiming that mildly reduced eGFR was associated with increasing risk of cardiovascular diseases [1–4]. Furthermore, evidence indicated that when treating of cardiovascular risk factors, patients with mild reduction eGFR would experience a reduction in cardiovascular events and progression of renal disease [5]. Therefore, it is important to figure out the possible risk factors of mildly reduced eGFR in order to better control its complications.

Accumulative evidence indicates that obesity is becoming more and more prevalent among rural residents around the world [6, 7]. Study enrolled rural residents from Nepal reported that 27% male and 72% female were obese [8]. Data from rural Indian showed that in 2008, 10.1% of men and 14.6% of women were overweight (including obesity), whereas 17.3% of men and 24.7% of women in 2017 [9]. There is a higher rate of obesity in rural areas (37.7% vs. 32.5% for men; 33.4% vs.28.2% for women) than in urban in the USA [9]. Similarly, the prevalence of obesity in 15.8 million men in rural China was 33.3% [11], whereas the prevalence of obesity among 1.37 million rural Chinese women was 38.4% [12]. Obesity is associated with increasing mortality and high prevalence of metabolic disorders. Obesity has been confirmed as an important cause of kidney disease due to its close association with diabetes and hypertension [13]. Among them, 10–30% of obese subjects are lack of abnormal blood pressure or lipid profiles indicating a certain proportion of obese subjects are in a relatively healthy metabolic status [14, 15]. There were studies reporting metabolic healthy obesity (MHO) was associated with lower mortality and had a lower risk of developing metabolic diseases compared with metabolic abnormal obesity (MAO) [16, 17]. However, there is lack of data to evaluate the possible effect of MHO on the newly diagnosed mildly reduced eGFR. Hence, in the present study, firstly, we intend to estimate the prevalence of obese phenotype at the baseline, the changes of obese metabolic phenotype over time, and the cumulative incidence of mildly reduced eGFR at follow-up. Secondly, to figure the possible relationship between MHO and mildly reduced eGFR among rural Northeast Chinese.

Methods

Study population

The Northeast China Rural Cardiovascular Health Study (NCRCHS) is a community-based prospective cohort study carried out in rural areas of Northeast China. The design and inclusion criteria of the study has been described previously [18, 19]. In brief, a total of 11,956 participants aged ≥ 35 years were recruited from Dawa, Zhangwu and Liaoyang counties in Liaoning province between 2012 and 2013, using a multi-stage, randomly stratified cluster-sampling scheme. The study was approved by the Ethics Committee of China Medical University (Shenyang, China AF-SDP-07-1, 0–01). Detailed information was collected at baseline for each participant. In 2015 and 2017, participants were invited to attend a follow-up study. Of the 11,956 subjects, 1,256 participants

were not included due to missing contact information and 10,349 participants (86.6%) completed at least one follow-up visit. The median follow-up was 4.66 years. Written informed consent was obtained from all participants. The detailed inclusion process of participants is shown in Fig. 1.

Study variables

At baseline, detailed information on demographic characteristics and medical history were obtained by interview with a standardized questionnaire. Smoking and drinking status were defined as current use. Dietary pattern included were assessed by residents recall the foods that they eat. History of stroke, CHD and heart failure at baseline was defined as self-reported and confirmed by medical records. Weight and height were measured with participants in light weight clothing and without shoes. Waist circumference was measured at the umbilicus using a non-elastic tape. Body mass index (BMI) was computed as weight in kilograms divided by the square of height in meters. Blood pressure was assessed three times with participants seated after at least 5 min of rest using a standardized automatic electronic sphygmomanometer (HEM-907; Omron, Tokyo, Japan). Hypertension was defined as systolic blood pressure (SBP) ≥ 140 mm Hg and/or diastolic blood pressure (DBP) ≥ 90 mm Hg, and/or use of antihypertensive medications [20]. Fasting blood samples were collected in the morning from participants who had fasted at least 12 h. Fasting plasma glucose (FPG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglyceride (TG), serum creatinine and other routine blood biochemical indexes were analyzed enzymatically.

Definition

Estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation [21]. Mildly reduced eGFR was defined as eGFR between 60–90 ml/min/1.73 m^2. According to the World Health Organization Asia Pacific guidelines, BMI ≥ 25 kg/m2 was defined obesity [21]. Metabolic syndrome (MetS) was diagnosed follow the unify criteria from the meeting between several major organizations in 2009 (14): The presence of any 3 of 5 risk factors constitutes a diagnosis of metabolic syndrome. 1. Elevated waist circumference (population- and country-specific definitions): ≥90 cm for men; ≥80 cm for women (Asians; Japanese; South and Central Americans); 2. Elevated triglycerides (drug treatment for elevated triglycerides is an alternate indicator): ≥150 mg/dL (1.7 mmol/L); 3. Reduced HDL-C (drug treatment for reduced HDL-C is an alternate indicator) : <40 mg/dL (1.0 mmol/L) in men; <50 mg/dL (1.3 mmol/L) in women; 4. Elevated blood pressure (antihypertensive drug treatment in a patient with a history of hypertension is an alternate indicator): Systolic ≥ 130 and/or diastolic ≥ 85 mm Hg; 5. Elevated fasting glucose (drug treatment of elevated glucose is an alternate indicator): ≥100 mg/dL. MHO was considered as absence of MetS and with obesity [23]. Metabolically healthy non-obese (MHNO) was diagnosed as those without MetS and obesity. Metabolically abnormal non-obese (MANO) and metabolically abnormal obese (MAO) was defined as MetS coexistence with or without obesity.

Statistical analysis

Descriptive statistics were calculated for all the variables, including continuous variables (reported as mean values and standard deviations) and categorical variables (reported as numbers and percentages). Differences among categories were evaluated using t-test, ANOVA, non-parameter test or the $\chi 2$-test as appropriate. We used logistic regression analyses to estimate odds ratio (ORs) and 95% confidence intervals (CIs) for the evaluation of relationship between obese phenotype and mildly reduced eGFR after adjusting for possible confounders. All the statistical analyses were performed using SPSS version 17.0 software, and P values less than 0.05 were considered to be statistically significant.

Results

Baseline character of newly diagnosed mildly reduced eGFR

Residents with newly diagnosed mildly reduced eGFR were older and had higher value of SBP, DBP, BMI, WC and HDL-C, whereas lower eGFR than normal eGFR at bassline. Besides, mildly reduced eGFR tended to have higher rate of current smoking but not drinking at baseline.

BMI and FPG were higher among mildly reduced eGFR only among men while higher TC existed only among women. Furthermore, among women solely, the rate of current smoking was higher in mildly reduced eGFR.

Prevalence of obese phenotype at baseline and cumulative incidence of mildly reduced eGFR among different obese phenotype

Figure 2.A shown that in general, 46.5% of the residents without MetS or obesity, 20.0% were MHO, 9.1% were MANO and 24.4% were MAO. There was significant difference of the composition of obese phenotype among women and men. There was less women than men had neither MetS nor obesity. The rate of MAO was higher among women than men (27.3% vs. 21.5%). Figure 2B and C, represented the changes of obese metabolic phenotype over time. In all, 38.4% of women and 38.90% of men experienced phenotype changes during follow-up. The MHO group had a higher proportion of transition to MAO phenotype than the MHNP group in both women (28.26% vs. 4.99%) and men (32.3% vs. 8.09%). Figure 3 exhibited the cumulative incidence of mildly reduced eGFR among different obese phenotype. In general, the incidence among different obese phenotype were 15.8% in MHNO, 20.1% in MHO, 16.7% in MANO and 20.8% in MAO. There was an increasing trend of incidence among those with either MetS or obesity residents. The cumulative incidence showed significant difference among women and men. In women, the highest incidence of mildly reduced eGFR was among MANO while in women was among MAO in men. Besides, the incidence seemed relatively lower in MANO compared to MHNO among men but not women. There wass gender discrepancy of the incidence among obese phenotype.

Changes of metabolic parameters of different obese phenotype from 2012–2013 to 2015–2017

Table 2. Shown the changes of different metabolic parameters in obese phenotype. SBP, LDL-C, HDL-C and eGFR significantly decreased at follow-up whereas WC and TG increased at follow-up. BMI and DBP had both increase and decrease value among different obese phenotype. There was also gender difference among the changes of different metabolic parameters. The changes of DBP significantly varied among different obese phenotype among men but not women

whereas changes of HDL-C showed variation among women but not men. The changes of DBP was greater in MHO than in MHNO whereas changes of BMI and WC were higher in MHNO among men. While among women, changes of SBP, BMI, and HDL-C were greater in MHO rather than MHNO.

Table 1
Baseline characters of mildly reduced eGFR subjects.

Characteristics	Total			Female			Male		
	eGFR 60–90 (n = 881)	eGFR > 90 (n = 4022)	P-value	eGFR 60–90 (n = 400)	eGFR > 90 (n = 235)	P-value	eGFR 60–90 (n = 481)	eGFR > 90 (n = 1987)	P-value
Age (years)	55.28 ± 9.08	49.42 ± 8.00	< 0.001	55.46 ± 8.86	48.57 ± 7.69	< 0.001	55.13 ± 9.26	50.29 ± 8.23	< 0.001
SBP (mmHg)	150.38 ± 26.12	138.76 ± 21.37	< 0.001	150.91 ± 26.99	137.16 ± 22.07	< 0.001	149.93 ± 25.39	140.40 ± 20.50	< 0.001
DBP (mmHg)	83.27 ± 12.33	81.66 ± 11.23	< 0.001	81.21 ± 12.03	80.04 ± 10.70	0.050	84.98 ± 12.32	83.33 ± 11.52	0.005
BMI (kg/m^2)	25.30 ± 3.49	24.75 ± 3.74	< 0.001	25.32 ± 3.73	24.93 ± 3.86	0.065	25.28 ± 3.28	24.57 ± 3.60	< 0.001
WC (cm)	83.61 ± 9.59	81.65 ± 9.65	< 0.001	81.92 ± 9.77	80.38 ± 9.57	0.003	85.03 ± 9.21	82.95 ± 9.57	< 0.001
HbA_{1c} (%)	5.31 ± 0.69	5.34 ± 0.99	0.833	5.53 ± 0.68	5.30 ± 0.82	0.262	5.23 ± 0.68	5.37 ± 1.12	0.413
TC (mmol/L)	5.17 ± 1.44	5.11 ± 1.02	0.088	5.27 ± 1.08	5.06 ± 1.03	< 0.001	5.09 ± 1.01	5.16 ± 1.00	0.213
TG (mmol/L)	1.56 ± 1.74	1.53 ± 1.47	0.566	1.43 ± 0.87	1.45 ± 1.17	0.782	1.68 ± 2.21	1.62 ± 1.73	0.541
LDL-C(mmol/L)	3.06 ± 0.89	2.86 ± 0.79	0.080	3.21 ± 0.93	2.86 ± 0.81	< 0.001	2.95 ± 0.82	2.86 ± 0.77	0.041
HDL-C (mmol/L)	1.51 ± .42	1.45 ± 0.40	< 0.001	1.52 ± 0.37	1.44 ± 0.35	< 0.001	1.49 ± 0.46	1.46 ± 0.44	0.137
FPG (mmol/L)	5.73 ± 1.44	5.84 ± 1.70	0.059	5.70 ± 1.59	5.75 ± 1.60	0.575	5.75 ± 1.31	5.95 ± 1.79	0.028
eGFR ($ml/min/1.73\ m^2$)	98.88 ± 9.69	103.04 ± 10.29	< 0.001	99.88 ± 12.68	103.62 ± 10.50	< 0.001	98.05 ± 6.07	102.44 ± 10.04	< 0.001
Diet score	2.43 ± 1.10	2.47 ± 1.08	0.346	2.24 ± 1.09	2.30 ± 1.06	0.362	2.59 ± 1.08	2.65 ± 1.06	0.280
Current smoking (%)	376(42.7)	1517(37.7)	0.004	90(22.5)	285(14.0)	< 0.001	286(59.5)	1232(62.0)	0.164
Current drinking (%)	253(28.7)	1083(26.9)	0.149	14(3.5)	58(2.9)	0.286	239(49.7)	1025(51.6)	0.243

Data are mean ± SD or number (%). MHNO metabolically health non-obese, MHO metabolically healthy obese, MANO metabolically abnormal obese, MAO metabolically abnormal obese, SBP systolic blood pressure, DBP diastolic blood pressure, TC total cholesterol, TG triglyceride, LDL-C low-density lipoprotein cholesterol, HDL-C high-density lipoprotein cholesterol, FPG fasting plasma glucose;

Table 2
Changes of metabolic parameters of metabolic health non-obese (MHNO), metabolically healthy obese (MHO), metabolic abnormal non-obese (MANO) and abnormal obese (MAO) subjects from 2012–2013 to 2015–2017.

	Total					Men					Women			
	MHNO	MHO	MANO	MAO	P-value	MHNO	MHO	MANO	MAO	P-value	MHNO	MHO	MANO	MAO
△SBP (mmHg)	-4.51	-6.14*	-8.43*#	-8.67*#	< 0.001	-3.46	-3.50	-7.15*#	-6.27*#	0.003	-5.80	-9.12*	-9.16*	-10.6
△DBP (mmHg)	-0.83	0.19*	-1.86*#	-1.12#	0.001	-0.35	1.02*	-2.49*#	-1.22#	< 0.001	-1.43	-0.74	-1.51	-1.03
△BMI (kg/m^2)	0.63	-0.48*	0.44#	-0.39*$	< 0.001	1.18	0.27*	1.52#	0.82*#$	< 0.001	-0.04	-1.34*	-0.17#	-1.36
△WC (cm)	3.89	3.05*	2.35*	2.01*#	< 0.001	4.15	2.93*	2.69*	1.55*#	< 0.001	3.58	3.21	2.15*#	2.38*
△TC (mmol/L)	-0.27	-0.22	-0.33#	-0.30#	0.069	-0.29	-0.26	-0.32	-0.34	0.469	-0.25	-0.17	-0.33#	-0.27
△TG (mmol/L)	0.27	0.41*	0.04*#	0.12*#	< 0.001	0.26	0.40	-0.12*#	-0.001*#	< 0.001	0.28	0.41	0.14#	0.22*
△LDL-C(mmol/L)	-0.10	-0.14	-0.06*#	-0.10*#$	< 0.001	-0.11	-0.13	-0.10*	-0.11*#$	< 0.001	0.20	0.20	0.05*#	-0.00
△HDL-C (mmol/L)	-0.10	-0.14*	-0.06#	-0.10#$	0.001	0.19	0.12	0.06	-0.11	0.668	-0.08	-0.15*	-0.04*#	-0.10
△FPG (mmol/L)	0.02	0.09	-0.09	-0.05	0.072	0.07	0.11	-0.11	-0.04	0.262	-0.04	0.07	-0.08	-0.06
△eGFR (ml/min/1.73 m^2)	-3.36	-5.12*	-1.48*#	-4.41*$	< 0.001	-4.27	-5.25	-1.76*#	-4.62	0.004	-2.25	-4.98#	-1.31#	-4.24

* P < 0.05, vs, MHNO; # P < 0.05, vs. MHO; $ P < 0.005, vs. MANO; MHNO metabolically health non-obese, MHO metabolically healthy obese, MANO metabolica obese, MAO metabolically abnormal obese.

Association between mildly reduced eGFR and obese phenotype in different gender

In Table 3, we showed the association between mildly reduced eGFR and MHO. After adjusting for possible confounders, MHO was associated with higher cumulative incidence of mildly reduced eGFR in both men [OR (95%CI): 1.62 (1.32, 1.98)] and women [OR (95%CI): 1.63 (1.18, 2.25)]. Furthermore, MAO in men also increased the risk of mildly reduced eGFR compared to MHNO [OR (95%CI): 1.74 (1.32, 2.29)].

Table 3
Association between mildly reduced eGFR and obese phenotype in different gender.

	Model 1		Model 2		Model 3	
	OR (95%CI)	P-value	OR (95%CI)	P-value	OR (95%CI)	P-value
Total						
MHNO	1.00(reference)		1.00(reference)		1.00(reference)	
MHO	1.35(1.11,1.64)	0.002	1.63(1.33,1.99)	< 0.001	1.62(1.32,1.98)	< 0.001
MANO	1.11(0.84,1.46)	0.453	0.89(0.67,1.19)	0.438	0.87(0.65,1.17)	0.280
MAO	1.43(1.19,1.71)	< 0.001	1.48(1.22,1.78)	< 0.001	1.44(1.17,1.75)	< 0.001
Women						
MHNO	1.00(reference)		1.00(reference)		1.00(reference)	
MHO	1.36(1.01,1.83)	0.045	1.65(1.20,2.27)	0.002	1.63(1.18,2.25)	0.003
MANO	1.48(1.05,2.09)	0.026	0.98(0.67,1.41)	0.920	0.97(0.66,1.41)	0.860
MAO	1.43(1.10,1.87)	0.008	1.17(0.88,1.55)	0.309	1.18(0.87,1.59)	0.290
Men						
MHNO	1.00(reference)		1.00(reference)		1.00(reference)	
MHO	1.35(1.05,1.74)	0.021	1.59(1.22,2.07)	0.001	1.62(1.24,2.11)	0.001
MANO	0.67(0.41,1.09)	0.106	0.61(0.37,1.01)	0.053	0.61(0.37,1.01)	0.055
MAO	1.45(1.13,1.86)	0.003	1.72(1.33,2.23)	< 0.001	1.74(1.32,2.29)	< 0.001

Model 1. Unadjusted; Model 2. Adjusted for age, current smoking, current drinking; Model 3. Adjusted for age, current smoking, current drinking, chronic diseases, LDL-C, ALT, AST; MHNO metabolically health non-obese, MHO metabolically healthy obese, MANO metabolically abnormal obese, MAO metabolically abnormal obese.

Discussion

In the present situation, the prevalence of MHNO, MHO, MANO and MAO among rural Northeast residents was 46.5%, 20.0%, 9.1% and 24.4%, respectively. Meanwhile, the cumulative incidence of mildly reduced eGFR among MHNO, MHO, MANO and MAO was 15.5%, 20.1%, 16.7% and 20.8%. There was high proportion of subjects experienced obese metabolic phenotype alteration during the follow-up time. After adjusting the possible confounders, MHO was associated with higher cumulative incidence of mildly reduced eGFR among women and men. Furthermore, MAO was relevant to mild decrease eGFR among men only.

Renal dysfunction is closely related to many cardiovascular diseases (CVD) and is proved to relevant to higher morbidity and mortality [5]. At first, many studies focused on the severe chronic kidney diseases which characterized with extremely lower eGFR. However, as growing concern was put on mild reduction eGFR, cumulative evidence confirmed that mildly renal dysfunction also correlated with higher risk of CVD and cerebrovascular diseases [5]. Recently, there was study reported that eGFR was significantly correlated with slow coronary flow in patients with normal to mildly impaired renal function [24]. Furthermore, Khurram Nasir and colleagues claimed impaired reginal systolic and diastolic function was observed among subjects with mild and moderated reduction of renal function without clinical heart diseases [25]. Hence, it is necessary to routinely evaluating renal function in order to identify subjects with early cardiovascular risk. And the possible expiations for mildly reduced eGFR increasing CVD still controversial but some possible reasons were brought forward. Masanobu Yoshida concluded that mildly reduced eGFR was associated with increase arterial stiffness, which acting as a definite risk factor for CVD [26]. Besides, other study reported that endothelial dysfunction contributed to the excess in cardiovascular mortality in subjects with mild renal insufficiency [27]. Similarly, oxidative stress, the imbalance between prooxidant/antioxidant process, resulted in an increase of reactive oxygen species which diminished expression of the antioxidant enzymes caused the renal dysfunction [28]. In our study, the cumulative incidence of mildly reduced eGFR was 17.97% which was higher than other previous study also held in Asia [29]. Therefore, early detection and screening the possible risk factors of mild decrease kidney function is important strategy to reduce chronic kidney diseases.

In the present study, the prevalence of MHO at baseline was 19.0% among women and 21.1% among men. Among 11465 men and 16612 women in Europe, the age-standardized prevalence of MHO was 12% across all then cohorts [30]. The highest prevalence of MHO among men was 19% in the CHRIS study [30]. There was gender difference existed of the prevalence of MHO in other studies. In NCDS from the UK, men had significantly lower rate of MHO than women (9% vs. 28.4%) [31]. Similar difference had been found by earlier studies in Caucasian, Asian and African American subjects [31]. However, there was lack of gender difference in prevalence of MHO in our present study. And the relatively higher prevalence of MHO at baseline might be due to the definition difference. Prevalence of MHO in the present study was based on the an obesity WHO Asia Pacific guidelines definition using a BMI $\geq$ 25 kg/m^2 as many previous study but still underscoring the prevalent of MHO among rural Northeast residents [33, 34]. Several mechanisms might be relevant to this kind of obese phenotype, like maintance of insulin sensitivity, specific fat distribution, normal adipose tissue function and normal adipokine secretion pattern [31, 35]. In recent years, it was debated whether MHO individuals were really healthy, especially there was lack of general agreement on unified criteria to define MHO. Furthermore, subjects with MHO did not get significant improvement on their cardiovascular risk factors upon weight loss interventions and therefore might not benefit to

the same extent as subjects with MAO [36]. It's even harder for subjects with MHO to control their risk of gaining CVD. As for the MHO related risk factors, cumulative evidence confirmed the association between MHO and renal dysfunction. Some reported that subjects with persistent MHO had 2-fold more increase risk of chronic kidney disease [37], whereas others claimed that metabolic abnormalities, but not obesity caused the mild decrease eGFR [38]. In our study, we found that MHO was associated with higher cumulative incidence of mildly reduced eGFR in both women and men. This underscore the possible effect of MHO on renal function. Interestingly, MAO was associated with higher incidence of mildly reduced eGFR among men but not women. There was study intending to figure out the mechanism of the different metabolic characteristics of obesity, and concluding that a different metabolite panel was identified to be significant different in MHO and MAO groups, like L-kynurenine, glycerophosphocholine (GPC), glycerol 1-phosphate, glycolic acid and uric acid [39]. There might be some metabolite panel difference existed between women and men that making MAO was associated with mildly kidney dysfunction among men but not women.

Limitation

First, due to the lack of uniform criteria of metabolic healthy obesity, the rate of metabolic healthy obesity might have varied results which make the conclusion has bias. However, in the present study, we chose the relatively widely used definition [23]. Second, the calculation of eGFR was based on a single assessment of blood pressure which might introduce bias. Third, even though we excluded those with renal diseases at baseline, we did not adjusted some factors that might possible affect eGFR like medicine used. Fourth, using CKD-EPI equation calculated eGFR to estimate GFR might not be accurate.

Conclusion

In present study, we reported a relatively high prevalence of MHO and other obese phenotype at baseline. Besides, the changes of obese metabolic phenotype over time was dramatic and more emphasis should be put on those abnormal phenotype. MHO was associated with higher cumulative incidence of mildly reduced eGFR among women and men while MAO correlated with mild decrease eGFR only among men. Routine screening of kidney function should be recommended among subjects with MHO among rural Northeast China.

Declarations

Ethics approval and Consent to participate

The study was approved by the Ethics Committee of China Medical University (Shenyang, China AF-SDP-07-1, 0–01). All procedures were performed in accordance with ethical standards. Written consent was obtained from all participants after they had been informed of the objectives, benefits, medical items and confidentiality agreement regarding their personal information.

Consent for publication

All the participants gave consent for direct quotes from their interviews to be used in this manuscript.

Availability of data and materials

Enquiries regarding the availability of primary data should be directed to the principal investigator Professor Yingxian Sun (sunyingxiancmu1h@163.com).

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SSY contributed to the data collection, analysis and interpretation. XFG and HMY contributed to data collection. GXL and SSY contributed to the data analysis. YXS contributed to the study conception and design. All authors read and approved the final version of the manuscript.

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Figures

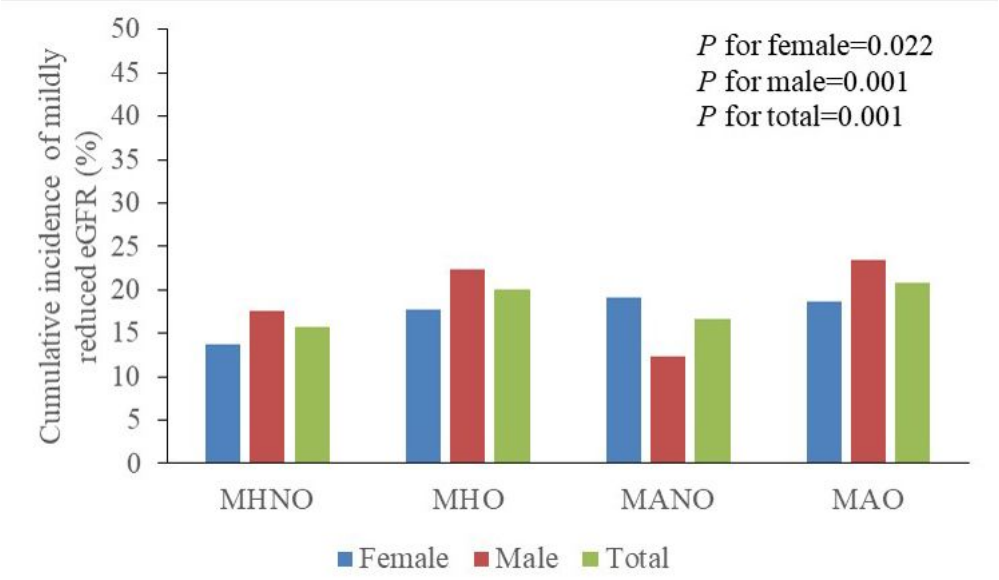

Figure 1

Cumulative incidence of mildly reduced eGFR among different obese phenotype at baseline. MHNO metabolically health non-obese, MHO metabolically healthy obese, MANO metabolically abnormal obese, MAO metabolically abnormal obese;

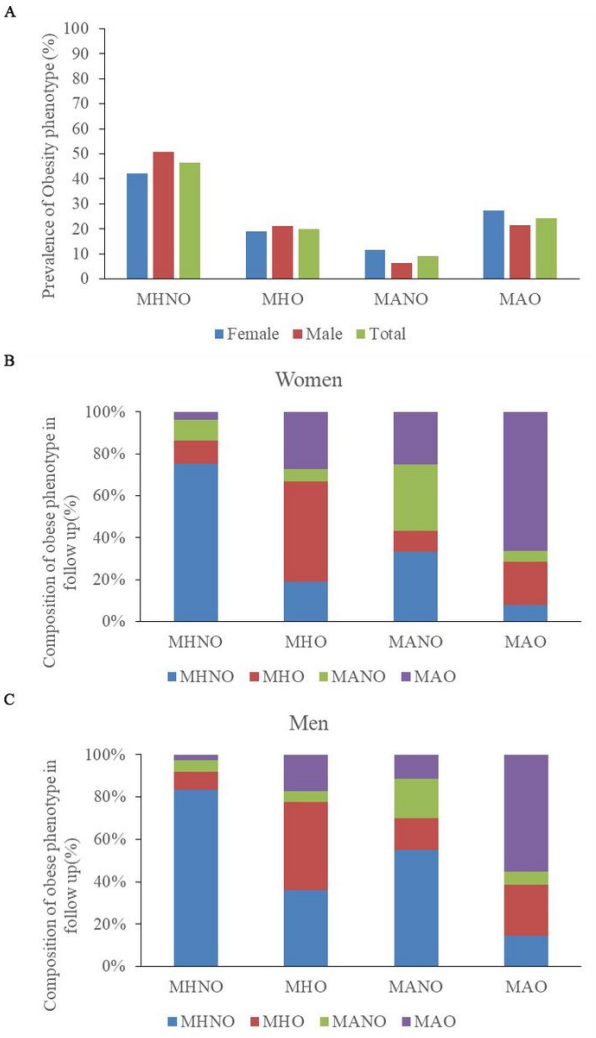

Figure 2

A. Prevalence of different obese phenotype at baseline. B.C. The changes of composition of obese phenotype in follow-up. MHNO metabolically health non-obese, MHO metabolically healthy obese, MANO metabolically abnormal obese, MAO metabolically abnormal obese;

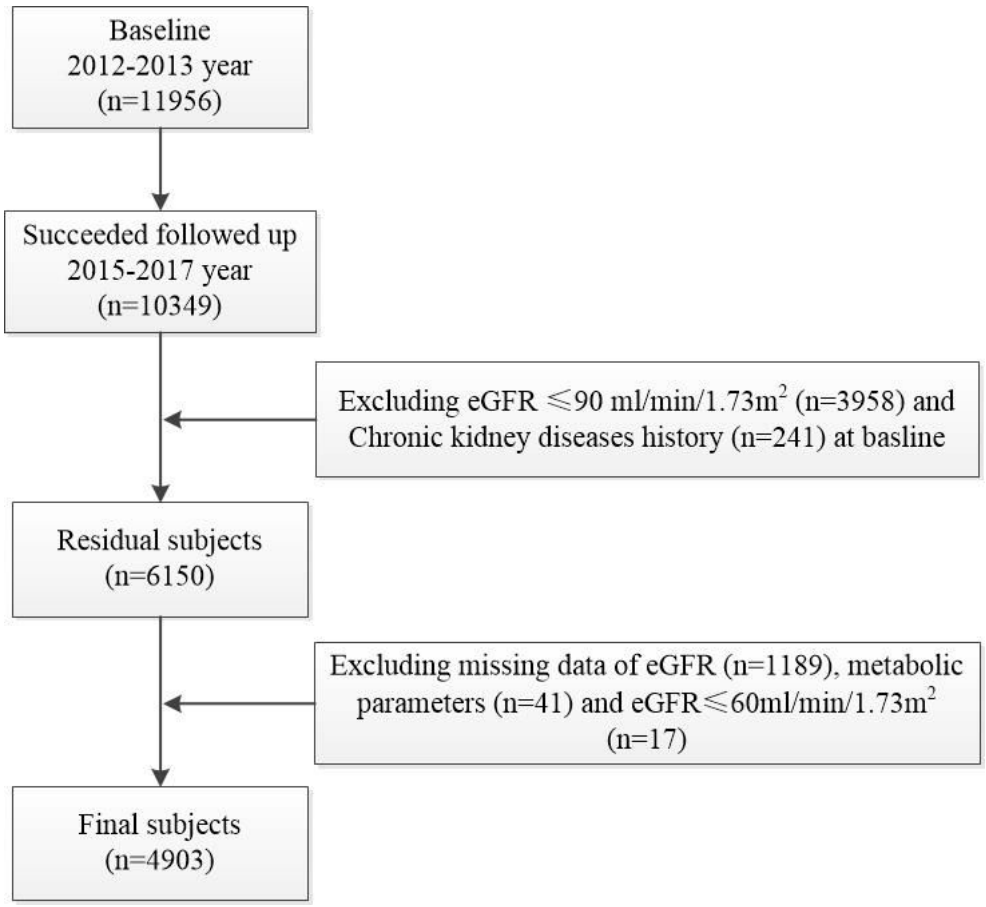

Figure 3

Flow chart of participants included in this study after inclusion and exclusion.