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Morbidity and risk factors for multiple noncommunicable diseases in Northern China: a cross-sectional survey

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Abstract. – OBJECTIVE: This study aimed to determine the morbidity and comorbidity of glucolipid metabolic multiple noncommunicable diseases in a Chinese natural population and associated risk factors.

SUBJECTS AND METHODS: A cross-sectional survey with randomized sampling was conducted on a typical sample of 4,002 residents (aged 26-76 years) in the Pinggu District of Beijing. They were subjected to a questionnaire survey, physical examination, and laboratory examination to collect data. Multivariable analysis was used to establish the association between various risk factors and multiple noncommunicable diseases.

RESULTS: The overall prevalence rate of chronic glucolipid metabolic noncommunicable diseases was 84.28%. The most common type of noncommunicable diseases was dyslipidemia, abdominal obesity, hypertension, obesity, and type 2 diabetes. The prevalence rate of multiple noncommunicable diseases was 79.60%. Participants with dyslipidemia were at higher risk for underlying chronic diseases. Younger men and women after menopause were more likely to have multiple noncommunicable diseases compared to their older and younger counterparts, respectively. The results of multivariate logistic regression indicated that age above 50, male sex, high household income, low education level, and harmful alcohol consumption were independent risk factors for multiple noncommunicable diseases.

CONCLUSIONS: The prevalence of chronic glucolipid metabolic noncommunicable diseases in Pinggu was higher than at the national level. Men with multiple noncommunicable diseases were younger, while women after menopause were more likely to suffer from multiple noncommunicable diseases and the prevalence rate was higher than in men. Intervention programs that aim to target risk factors by sex and region-specific are urgently needed.

Key Words:
NCDs, Comorbidities, Prevalence.

Introduction

With continuous changes in industrialization, urbanization, aging, and lifestyle, chronic noncommunicable diseases (NCDs) have globally become the predominant public health challenge. Worldwide NCDs accounted for 74% of deaths in 2019, with 15.2 million people who succumbed to an NCD aged between 30 and 70 years old[1]. Metabolic diseases are the most common type of NCDs. In China, the number of people with chronic diseases has reached 300 million, and deaths caused by chronic diseases accounted for nearly 86% of total deaths, according to the Blue Book of Health Management[2]. In the last ten years, a near doubling of the average number of new chronic cases has been recorded year after year.

Over 650 million adults above 18 years of age were obese in 2016. The prevalence of obesity across the globe has almost tripled between 1975 and 2016[3]. Obesity rates in China have risen greatly in the past two decades, depicting an epidemic trend. Obesity and abdominal obesity are risk factors for dyslipidemia, diabetes, and hypertension[4,5]. These three conditions are also associated with a higher BMI[6]. Furthermore, apart from dyslipidemia being associated with overall fat, it is also associated with increased abdominal fat[7]. Obesity, abdominal obesity, dyslipidemia, diabetes, and hypertension often coexist and affect each other. However, limited data is available on the epidemiology of multiple NCDs (MNCDs), therefore, it is challenging to propose

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effective recommendations for the comprehensive prevention and treatment of multiple metabolic diseases. Only one previous study[8] showed that 40.5% of the study sample (2,447 participants) had MNCDs in Southern China, and the most reported combination of multiple diseases was hypertension with either dyslipidemia (9.95%) or diabetes (6.61%). In China, the rapid increase in the prevalence of NCDs is significantly higher than that of other regions. The coexistence of these diseases makes prevention and treatment more difficult. We urgently need to understand the causes and characteristics of these diseases to present evidence-based data to the government for the formulation of prevention and control policies. The Pinggu Metabolic Disease Study (PGMDS) cohort consists of a community population in a district of Beijing in Northern China, which was established to study the natural course and pathogenesis of chronic metabolic diseases. Based on the well-characterized PGMDS cohort, we had the opportunity to determine the prevalence of single and multiple glucolipid metabolic NCDs, including dyslipidemia, type 2 diabetes (T2D), obesity, and hypertension, and explore their potential risk factors.

Subjects and Methods

Study Design and Population

The study data were obtained from the PGMDS cohort. This cohort was established in the Pinggu district of Beijing, China, from September 2013 to July 2014. Based on the national Civil Registration system, a total of 6,583 participants were selected at random from 400,000 residents using a multistage stratified sampling method according to sex and age compositions to recruit participants from 25 different villages out of 5 towns and 7 resident committees of one street. Inclusion criteria included participants aged 26-76 years who were born in Pinggu or had been residing in Pinggu for a minimum of 5 years. The PGMDS protocol has been previously described in detail[9]. Finally, 4,002 participants were included, corresponding to an inclusion rate of 60.8%. After excluding 2 participants due to unavailable data on age or gender, 4,000 participants were ultimately enrolled in the present study.

The PGMDS received approval from the ethics committee of the Peking University Health Science Center and written informed consent was obtained from all the participants.

Data Collection

Trained researchers gathered every participant's baseline information including socio-demographics, medical history, family history of chronic disease, and other topics related to health using a comprehensive questionnaire while conducting an interview face-to-face in the study center.

The main anthropometric measurements were taken by qualified doctors and nurses per standard protocols and included height, weight, waist circumference (WC), and blood pressure. The body mass index (BMI) was calculated with the following formula: weight (kg)/height (m^2). WC was measured at the point in the middle between the margin of the lower rib and the iliac crest. Following five minutes of resting, the blood pressure was measured in a seated position for a total of three times, and the mean of the measurements was used for further analysis.

The annual household income was divided into three categories: <25,000 Chinese Yuan (CNY, 1000 CNY = 155 USD), 25,000-75,000 CNY, and ≥75,000 CNY. Education was classified as primary education or lower, middle school education, and college or higher. Sedentary time was classified as <1.5, 1.5-4.5, and ≥4.5 hours per day. Smoking status was defined as never smoked, a former smoker who had stopped smoking or averaged less than one cigarette daily, and a current smoker who reported smoking at least one cigarette daily. Alcohol consumption was categorized as 0, 0.1-140, 140.1-210, and >210 g/week in men and 0, 0.1-70, 70.1-140, and >140 g/week in women. Information on salt consumption was surveyed by asking the following question: "Is the salt consumption in your daily diet, light, medium, or high?"

Laboratory Measurements

Samples of blood were taken in the early morning during the fasting state to measure glucose, lipids, and biochemical profiles. A standard 75 g 2-h oral glucose tolerance test (OGTT) was performed to evaluate the glucose metabolism status in individuals without known diabetes. Plasma glucose was measured by applying the glucose hexokinase method. The cation-exchange high-pressure liquid chromatography (HPLC) method (Adams A1c HA-8160, Arkray, Kyoto, Japan) was used for the measurement of hemoglobin A1c (HbA1c). Plasma glucose, serum total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were measured using a biochemical analyzer (UnicelDxC 800; Beckman Coulter, Miami, FL, USA). Homeostasis model assessment of insulin-resistance (HOMA-IR) was calculated with the following formula: (fasting insulin mu/L) × (fasting plasma glucose (FPG) mmol/L)/22.5.

Disease Definition

According to the "Chinese guidelines on the prevention and treatment of dyslipidemia in adults"[10], dyslipidemia was defined as TC ≥ 5.18 mmol/L, TG ≥1.7 mmol/L, HDL-C <1.04 mmol/L, LDL-C ≥ 3.37 mmol/L, and/or the treatment of abnormal blood lipids.

T2D was defined as FPG ≥7.0 mmol/L and/or 75 g OGTT 2-h plasma glucose (2-hPG) ≥11.1 mmol/L, according to the WHO 1999 criteria[11], or a history of diabetes reported by the patient and diagnosed by a clinician, and/or the use of anti-diabetic drugs.

Participants were categorized as underweight (BMI <18.5 kg/m^2), normal weight (18.5-23.9 kg/m^2), overweight (24.0-27.9 kg/m^2), or obese (≥28.0 kg/m^2), based upon the standards as released by the working group on obesity in China[12]. Abdominal obesity was defined as WC ≥ 90 cm for men and ≥ 85 cm for women[13].

Hypertension was determined as average systolic blood pressure (SBP) ≥ 140 mmHg or average diastolic blood pressure (DBP) ≥ 90 mmHg, hypertension previously diagnosed by a clinician, and/or the use of antihypertensive drugs[14].

Statistical Analysis

All continuous variables were described as mean (SD) and categorical variables were described as numbers in percentages. For pairwise comparisons of continuous variables, the Mann-Whitney U test was applied. The Chi-squared test was used in the analysis of categorical variables and Bonferroni adjustment was implemented to perform pairwise comparisons. A Bonferroni-adjusted *p*-value <0.05/2 or 0.025 was defined as statistically significant. Multivariable logistic regression analyses were performed to calculate the odds ratio (OR) and 95% confidence interval (95% CI) of MNCDs (*vs.* Normal), with MNCDs being defined as the dichotomous outcome variables, and age, gender, residence, household income, education level, sedentary time, smoking status, alcohol consumption, and salt consumption as the risk factors which were included in the analyses. SPSS v.22 for Windows (IBM Corp., Armonk, NY, USA) was used to perform the statistical analyses. The level of statistical significance was defined at $p<0.05$.

Results

General Characteristics of the Study Population

The mean (SD) age of the 4,000 participants in total was 50.00 (11.92) years for 1,961 men, and 50.52 (11.58) years for 2,039 women, respectively. The menopausal status was self-reported by 50.88% of the women at the mean age of 50. Considering that there are obvious gender differences in the occurrence of NCDs, we compared and reported the results between men and women in the analysis. Overall, men had significantly higher WC, SBP, DBP, HbA1c, FPG, HOMA-IR, TG, and lower 2-hPG, fasting insulin, 2-h insulin, HDL-C, and LDL-C than women (**Supplementary Table I**). Furthermore, the mean levels of WC, SBP, HbA1c, FPG, 2-hPG, TC, HDL-C, and LDL-C generally increased with age. BMI, DBP, and TG gradually increased and reached their highest level at the age of 50 years after which they decreased with age. However, the opposite trend was observed in the levels of fasting insulin, 2-h insulin, and HOMA-IR (**Supplementary Table I**).

Prevalence of Single and Multiple Glucolipid Metabolic NCDs

The most common chronic glucolipid metabolic NCDs (prevalence rated from high to low) were dyslipidemia (70.98%), abdominal obesity (45.60%), hypertension (40.23%), obesity (28.70%), and T2D (18.68%). The prevalence of dyslipidemia, hypertension, and T2D was higher in men than in women. The prevalence of obesity and abdominal obesity showed no significant differences between men and women (Table I). The prevalence of hypertension and T2D increased with age in men as well as women before the age of 70. On the other hand, the prevalence of dyslipidemia, obesity, and abdominal obesity crossed at the age of 50, then decreased with age in men but increased in middle-aged as well as elderly women. The prevalence of NCDs in women increased swiftly following menopause and became even higher than that in men (**Supplementary Figure 1**).

Table I. Sex- and age-specific prevalence of various NCDs among all subjects.

	All (%)	Age (%)										*p*-value
		25~	30~	35~	40~	45~	50~	55~	60~	65~	70~	
Dyslipidemia	70.98	62.69	62.24	63.66	67.30	70.70	73.66	75.00	78.62	75.89	71.58	< 0.001
Men	76.39	73.87	82.58	87.66	83.33	78.95	73.55	71.27	72.57	69.37	65.17	< 0.001
Women	65.77**	48.89	39.57	43.02	50.97	63.49	73.77	78.60	84.75	80.99	77.66	< 0.001
T2d	18.68	2.99	6.46	6.31	13.19	17.02	21.61	26.79	26.73	33.20	24.04	< 0.001
Men	21.01	5.41	10.97	10.39	21.21	21.80	25.48	26.91	25.22	28.83	19.10	< 0.001
Women	16.43**	0.00	1.44	2.79	5.02	12.83	17.90	26.67	28.25	36.62	28.72	< 0.001
Obesity	28.70	28.86	28.23	31.53	32.12	27.72	26.97	30.71	28.95	27.67	18.03	0.049
Men	28.76	36.94	40.00	42.21	40.91	27.82	22.26	24.73	20.35	19.82	10.11	< 0.001
Women	28.64	18.89	15.11	22.35	23.17	27.63	31.48	36.49	37.67	33.80	25.53	< 0.001
Abdominal obesity	45.60	33.33	39.80	39.94	42.26	43.86	46.53	53.57	50.11	54.94	42.08	< 0.001
Men	47.17	41.44	54.84	59.09	56.44	44.74	46.13	45.45	38.94	45.05	32.58	< 0.001
Women	44.09	23.33	23.02	23.46	27.80	43.09	46.91	61.40	61.43	62.68	51.06	< 0.001
Hypertension	40.23	4.98	13.95	21.32	30.21	34.91	43.53	50.00	62.36	66.80	68.31	< 0.001
Men	42.02	8.11	21.29	32.47	39.77	39.47	45.48	46.18	56.64	59.46	67.42	< 0.001
Women	38.50*	1.11	5.76	11.73	20.46	30.92	41.67	53.68	68.16	72.54	69.15	< 0.001

Data are shown as proportion. Compared with men, *p <0.05, **p < 0.001.

The overall prevalence of the five most prevalent NCDs was 84.28%. However, 79.60% of the study sample had two diseases or more. The prevalence of people who had two, three, four, or more diseases was 20.25%, 20.53%, 13.30%, and 4.68%, respectively. Men with MNCDs were younger, while women after menopause were more likely to suffer from MNCDs of which the prevalence rate was higher than that of men (Figure 1). The combination of diseases containing dyslipidemia accounted for 52.50%, of which, the most common was dyslipidemia with abdominal obesity (38.70%) or hypertension (31.60%). The most frequently encountered combination of three diseases was dyslipidemia with abdominal obesity and obesity (23.18%). A higher proportion of abdominal obesity (54.53% *vs.* 23.77%, $p<0.001$), hypertension (44.52% *vs.* 29.72%, $p<0.001$), obesity (34.38% *vs.* 14.81%, $p<0.001$), and T2D (22.68% *vs.* 8.87%, $p<0.001$) was found in people with dyslipidemia compared with people without dyslipidemia (**Supplementary Table II**).

Characteristics of Subjects with or Without MNCDs

The characteristics of subjects were grouped into three categories: clinical factors (BMI, WC, SBP, DBP, HbA1c, FPG, 2-hPG, fasting insulin, 2-h insulin, HOMA-IR, TC, TG, HDL-C, and LDL-C); socioeconomic factors (age, gender, residence, household income, and education level), and lifestyle factors (sedentary time, smoking status, alcohol consumption, and salt consumption).

Overall, all clinical factors (except for HDL-C), age over 50, the male sex, a lower education level, smokers, drinkers, and high salt consumption significantly increased the prevalence rate from non-NCD (NNCD) to MNCDs, while an opposite tendency was observed in HDL-C, college or higher education, non-smokers, and non-drinkers. Place of residency whether urban or not had no effect on the prevalence of MNCDs. Different from other results, a significant relationship was observed in annual household income between groups in men and women, but no significant relationship in salt consumption. Moreover, smoking and alcohol consumption increased the prevalence of MNCDs in men, while the effect of age and education disappeared; in women, a reversed pattern was discovered. Surprisingly, a significant negative relation between sedentary time and the prevalence of MNCDs was found in women (Table II).

Analysis of the Risk Factors for MNCDs

We analyzed whether age, gender, residence, household income, education, sedentary time, smoking status, alcohol consumption, and salt consumption had effects on MNCDs independently of one another using multivariate logistic regression (**Supplementary Table III**). The results showed that age over 50, the male

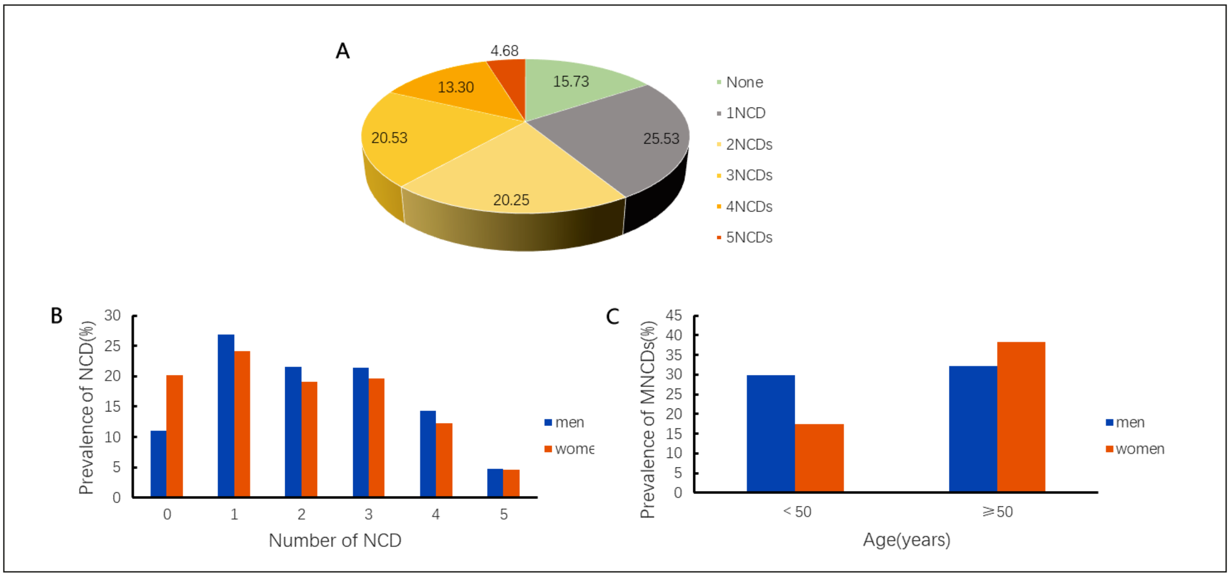

Figure 1. Prevalence of glucolipid metabolic NCDs. **A**, Pie chart of prevalence of NCDs among all subjects. **B**, Sex-specific prevalence of NCDs. **C**, Sex- and age-specific prevalence of MNCDs.

Table II. Characteristics of the subjects with or without MNCDs.

Characteristics	All			Men			Women		
	NNCD (n = 629)	MNCDs (n = 2350)	*p*-value	NNCD (n = 216)	MNCDs (n = 1217)	*p*-value	NNCD (n = 413)	MNCDs (n = 1133)	*p*-value
Anthropometry									
BMI (kg/m²)	22.71 ± 2.34	28.12 ± 3.48	< 0.001	22.67 ± 2.45	27.87 ± 3.45	< 0.001	22.73 ± 2.29	28.39 ± 3.50	< 0.001
WC (cm)	75.43 ± 6.40	92.79 ± 8.84	< 0.001	78.52 ± 6.14	94.53 ± 8.67	< 0.001	73.81 ± 5.92	90.92 ± 8.63	< 0.001
SBP (mmHg)	116.15 ± 11.12	136.12 ± 17.41	< 0.001	121.59 ± 10.44	135.94 ± 16.56	< 0.001	113.30 ± 10.38	136.30 ± 18.29	< 0.001
DBP (mmHg)	71.17 ± 8.09	82.62 ± 11.12	< 0.001	73.50 ± 8.03	84.24 ± 11.48	< 0.001	69.96 ± 7.86	80.90 ± 10.46	< 0.001
HbA1c (%)	5.42 ± 0.49	5.75 ± 0.58	< 0.001	5.48 ± 0.76	5.71 ± 0.63	< 0.001	5.39 ± 0.26	5.79 ± 0.53	< 0.001
FPG (mmol/L)	5.31 ± 0.47	5.92 ± 0.86	< 0.001	5.51 ± 0.47	6.01 ± 0.90	< 0.001	5.21 ± 0.44	5.81 ± 0.80	< 0.001
2-hPG (mmol/L)	6.13 ± 1.34	8.12 ± 2.83	< 0.001	6.16 ± 1.54	7.96 ± 2.96	< 0.001	6.12 ± 1.23	8.30 ± 2.68	< 0.001
Fasting Insulin (mu/L)	6.42 ± 3.30	11.52 ± 6.38	< 0.001	5.47 ± 3.06	11.32 ± 6.72	< 0.001	6.92 ± 3.32	11.74 ± 6.01	< 0.001
2-h Insulin (mu/L)	43.62 ± 31.50	82.57 ± 64.57	< 0.001	34.54 ± 30.97	72.47 ± 54.73	< 0.001	48.37 ± 30.76	93.34 ± 72.11	< 0.001
HOMA-IR	1.53 ± 0.83	3.08 ± 1.91	< 0.001	1.35 ± 0.79	3.07 ± 2.01	< 0.001	1.62 ± 0.83	3.09 ± 1.80	< 0.001
TC (mmol/L)	4.34 ± 0.48	5.11 ± 1.02	< 0.001	4.39 ± 0.49	5.02 ± 0.97	< 0.001	4.32 ± 0.48	5.20 ± 1.06	< 0.001
TG (mmol/L)	0.71 ± 0.32	1.91 ± 1.50	< 0.001	0.77 ± 0.33	2.09 ± 1.77	< 0.001	0.69 ± 0.31	1.72 ± 1.12	< 0.001
HDL-c (mmol/L)	1.34 ± 0.23	1.10 ± 0.30	< 0.001	1.30 ± 0.24	1.05 ± 0.32	< 0.001	1.36 ± 0.23	1.15 ± 0.27	< 0.001
LDL-c (mmol/L)	2.41 ± 0.47	3.02 ± 0.84	< 0.001	2.48 ± 0.48	2.94 ± 0.83	< 0.001	2.38 ± 0.47	3.10 ± 0.84	< 0.001

Continued

Table II *(Continued)*. Characteristics of the subjects with or without MNCDs.

Characteristics	All			Men			Women		
	NNCD (n = 629)	MNCDs (n = 2350)	*p*-value	NNCD (n = 216)	MNCDs (n = 1217)	*p*-value	NNCD (n = 413)	MNCDs (n = 1133)	*p*-value
Socioeconomic factors									
Gender (men (%))	216 (34.34)	1,217 (51.79)	< 0.001						
Age [< 50 (%)]	452 (71.86)	941 (40.04)	< 0.001	103 (47.69)	587 (48.23)	0.882	349 (84.50)	354 (31.24)	< 0.001
Residence [urban (%)]	295 (46.90)	1,070 (45.53)	0.541	93 (43.06)	579 (47.58)	0.220	202 (48.91)	491 (43.34)	0.051
Household income			0.140			0.002			< 0.001
< 25,000	105 (16.69)	464 (19.74)		47 (21.76)	161 (13.23)[a]		58 (14.04)	303 (26.74)[a]	
25,000-75,000	340 (54.05)	1,266 (53.87)		113 (52.31)	655 (53.82)		227 (54.96)	611 (53.93)	
≥ 75,000	184 (29.25)	620 (26.38)		56 (25.93)	401 (32.95)[a]		128 (30.99)	219 (19.33)[a]	
Education			< 0.001			0.422			< 0.001
Primary or lower	278 (44.20)	1,426 (60.68)[a]		121 (56.02)	658 (54.07)		157 (38.01)	768 (67.78)[a]	
Middle school	195 (31.00)	627 (26.68)[a]		52 (24.07)	343 (28.18)		143 (34.62)	284 (25.07)[a]	
College or higher	156 (24.80)	297 (12.64)[a]		43 (19.91)	216 (17.75)		113 (27.36)	81 (7.15)[a]	
Lifestyle factors									
Sedentary time			0.174			0.244			< 0.001
< 1.5 hours	176 (27.98)	705 (30.00)		63 (29.17)	330 (27.12)		113 (27.36)	375 (33.10)[a]	
1.5-4.5 hours	142 (22.58)	581 (24.72)		54 (25.00)	257 (21.12)		88 (21.31)	324 (28.60)[a]	
≥ 4.5 hours	311 (49.44)	1,064 (45.28)		99 (45.83)	630 (51.77)		212 (51.33)	434 (38.31)[a]	
Smoking			< 0.001			0.039			0.499
Never	459 (72.97)	1,366 (58.13)[a]		48 (22.22)	246 (20.21)		411 (99.52)	1,120 (98.85)	
Former	35 (5.56)	294 (12.51)[a]		34 (15.74)	287 (23.58)[a]		1 (0.24)	7 (0.62)	
Current	135 (21.46)	690 (29.36)[a]		134 (62.04)	684 (56.20)		1 (0.24)	6 (0.53)	
Alcohol consumption			< 0.001			0.040			0.124
0	423 (67.25)	1,297 (55.19)[a]		56 (25.93)	264 (21.69)		367 (88.86)	1,033 (91.17)	
Mild	131 (20.83)	520 (22.13)		91 (42.13)	447 (36.73)		40 (9.69)	73 (6.44)[a]	
Moderate	18 (2.86)	94 (4.00)		15 (6.94)	81 (6.66)		3 (0.73)	13 (1.15)	
Severe	57 (9.06)	439 (18.68)[a]		54 (25.00)	425 (34.92)[a]		3 (0.73)	14 (1.24)	
Salt consumption			0.027			0.385			0.573
Light	164 (26.07)	538 (22.89)		40 (18.52)	227 (18.65)		124 (30.02)	311 (27.45)	
Medium	326 (51.83)	1,175 (50.00)		112 (51.85)	575 (47.25)		214 (51.82)	600 (52.96)	
High	139 (22.10)	637 (27.11)[a]		64 (29.63)	415 (34.10)		75 (18.16)	222 (19.59)	

Data are presented as mean ± SD and number (%). [a]Significant difference when compared to NNCD.

sex, high household income, low education level, and harmful alcohol consumption were independent risk factors for MNCDs. In comparison to participants with lower education level, those with a higher degree in education were less prone to MNCDs. In line with expectations, heavy drinkers were more likely to have MNCDs and non-drinkers were healthier. Furthermore, people with a higher household income were more likely to suffer from MNCDs.

Discussion

Rapid economic growth, the acceleration of urbanization, alterations in dietary habits, and the embracement of unhealthy habits are the main contributors to the progression of metabolic disorders. It has been estimated that in the following decade, one billion people will be affected by the damaging consequences of metabolic disorders, making it the most common NCD worldwide by 2030[15].

In this study, a stratified random sampling survey strategy was adopted to analyze the disease prevalence of a natural population in Northern China. In the representative PGMDS cohort of Northern China, the most common chronic glucolipid metabolic NCDs and their prevalence were dyslipidemia (70.98%), abdominal obesity (45.60%), hypertension (40.23%), obesity (28.70%), and T2D (18.68%). The prevalence of various chronic glucolipid metabolic NCDs was higher than the national average in comparison to the results of other studies[16-20] that have been published recently.

In China, NCDs are responsible for 89% of all adult deaths, across all ages and both sexes[1]. In the present community-based cross-sectional epidemiological study, we found that five NCDs accounted for a prevalence rate of 84.28% in general; in addition, 79.60% of the study population had MNCDs. Moreover, participants with dyslipidemia were at higher risk for underlying chronic diseases, such as abdominal obesity, obesity, hypertension, or T2D. The most frequently encountered combination of multiple diseases was dyslipidemia with abdominal obesity (38.70%) or hypertension (31.60%). The most frequently encountered combination of three diseases was dyslipidemia with abdominal obesity and obesity (23.18%). By comparing the results from a previous study[8] in Southern China, it can be concluded that the prevalence of MNCDs differs greatly among different areas. The population in Northern China had a higher prevalence of MNCDs, and the most common NCD is dyslipidemia rather than hypertension. Apart from the differences in methodology and population demographics, local weather conditions, dietary customs, and different lifestyles may be conducive to the high prevalence of NCDs. Pinggu is located in the Northern region of China and has a cold climate, which has led to local people eating a comparatively bigger amount of animal fat and pickled vegetables and consuming more alcohol and less fresh fruits. This type of diet is associated with a high prevalence of dyslipidemia. In addition, the low temperature during the long winter limits people's time outdoors and opportunities to conduct physical activity, increasing the risk of becoming overweight or obese, and associated metabolic disorders[21].

No significant sex difference between abdominal obesity and obesity was found in the present study. In this study, the prevalence of abdominal obesity, defined by WC cut-off points, was significantly higher than obesity, defined by BMI classification criteria. To fully comprehend the obesity problem in Asia, it is necessary to understand the differences between the Asian and Western populations in regard to body composition, genetics, and lifestyle. More specifically, research has indicated that Asians have a higher likelihood of having abdominal fat deposition while their BMI is relatively lower[22]. In countries with low income, obesity is usually more common among middle-aged people (in particular women); while, it affects both men and women of all ages in countries with high income, although its prevalence is significantly higher in disadvantaged communities[23]. The population sample of this study is from a Beijing suburb, which is a community that is experiencing swift suburbanization in China. Rural, as well as urban populations, are encountering accelerated economical improvements, which have brought many changes to their daily lives. Urbanization in developing countries is related to an increased prevalence of numerous chronic diseases[24]. We hypothesize that this is related to not observing a significant difference in MNCDs among urban and rural areas in the present study.

Our study revealed that the prevalence of NCDs was higher in men than in women, except for obesity and abdominal obesity. Meanwhile, younger men and women after menopause were more likely to have MNCDs compared to their older and younger counterparts, respectively. Our results also indicated that the male sex could be an independent risk factor for MNCDs. Furthermore, harmful smoking and alcohol consumption and high income were the high-risk factors for men, while age over 50, low education level, low income, and less sedentary time were the high-risk factors for women. This occurrence may be the result of excessive accumulation and (or) abnormal distribution of visceral fat which results from being under an unfixed work style and an unhealthy lifestyle[25]. Because the primary labor force in society consists of men, higher income would result in more work stress. Actual studies[26] have shown that work stress is related to a higher risk of chronic disease in men. Moreover, the risk behavioral pattern of men with higher education, and that of young men in particular, which includes smoking habit and consuming alcohol, is associated with chronic NCDs[27]. Since estrogen is known for its protective effect on the level of lipids[28], the higher risk of MNCDs in women aged over 50 is associated with a decline in physical function and menopause. In addition, Chinese women commonly tend to delay seeking medical care until absolutely necessary to preserve the household income, which may lead to a harmful effect on their well-being and longevity[29]. It has been clearly established that education level and health outcomes are related to each other[30]. Studies[30] have shown that individuals with higher educational backgrounds report better health and have fewer chronic diseases compared to those of lower educational levels. Women, especially rural women, with a low education level and income, are more engaged in physical labor and have less sedentary time, which makes them prone to having MNCDs. We cannot exclude the notion that unknown biological variables may contribute to the differences between men and women, which should be studied in future research among this population.

The rise of NCDs is associated with the following four main risk factors: smoking, physical inactivity, excessive consumption of alcohol, and unhealthy diets. An important method in controlling NCDs is to concentrate on decreasing the risk factors related to these diseases[31]. By implementing NCD prevention and control in China, 1.7 million people can be saved among people between the ages of 30 and 70 by 2025[1]. Multivariate logistic regression analysis indicated that age over 50, the male sex, a high household income, low education level, and harmful alcohol consumption were independent risk factors for MNCDs. National guidelines adapted to local circumstances and interventions are necessary to enhance the recognition of MNCDs among physicians and to decrease the tribulation of adverse diseases. Our studies have indicated that the burden of MNCDs differs greatly among different sexes and regions, implying that sex- and region-specific policies are necessary.

Strengths and Limitations

This study has multiple strengths. To the best of our knowledge, the present study is the largest and most well-characterized community-based study among adults evaluating the morbidity and comorbidity of chronic glucolipid metabolic NCDs in China. The study is also novel in terms of including socioeconomic and lifestyle factors. In addition, the morbidity of MNCDs was analyzed separately in men and women and potential independent risk factors were analyzed related to the prevention and control of MNCDs. There are also certain limitations in this study that should be acknowledged. First, as the current study is based on data from a cross-sectional survey without a rigorous follow-up model, we cannot infer causal relationships between related risk factors and MNCDs. Second, because of differences in regions, lifestyles, and ethnicities, the surveyed region may not represent the situation in China as a whole or other regions. Therefore, more large-scale longitudinal studies should be conducted in the future to evaluate the association between various factors and MNCDs.

Conclusions

The prevalence of chronic glucolipid metabolic NCDs in Pinggu (Beijing, China) is higher than the national level, and nearly 80% of the residents have MNCDs. Men with MNCDs were younger, while women after menopause were more likely to have MNCDs and the prevalence rate was higher than in men. Intervention programs specifically tailored for different regions with the goal of modifying risk factors by sex are urgently needed.

Conflict of Interest
The Authors declare that they have no conflict of interests.

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Authors' Contribution

Linong Ji, Xiuying Zhang and Yufeng Li performed the conception and design of study; Li Qiu contributed to the analysis of data and wrote the manuscript; Xianghai Zhou performed the data acquisition; Xueyao Han contributed to the paper revision.

Availability of Data and Materials

All data generated or analyzed during this study are included in this article and its supplementary material.

Ethics Approval

The PGMDS received approval from the Ethics Committee of the Peking University Health Science Center (IRB00001052-12022). All procedures in the study were performed in accordance with the ethical standards of the Declaration of Helsinki.

Informed Consent

Written informed consent was obtained from all the participants.

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