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Socioeconomic and geographic variations in the prevalence, awareness, treatment and control of dyslipidemia in middle-aged and older Chinese

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HIGHLIGHTS

- Low HDL is the most common type of dyslipidemia in middle-aged and older Chinese.
- The prevalence of dyslipidemia is the highest in North China.
- The awareness, treatment and control of dyslipidemia are poor in Southwest China.

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ABSTRACT

Background and aims: Unevenly socioeconomic development and nutrition transition might bring large variations in the epidemiology of dyslipidemia. We aimed to estimate the prevalence, awareness, treatment and control of dyslipidemia in different socioeconomic statuses and geographic regions in China, and to assess the associated factors and comorbidities of dyslipidemia.

Methods: We included participants aged 45 years and above from a nationally representative investigation: the China Health and Retirement Longitudinal Study 2011. Dyslipidemia was defined based on the 2016 guideline of Chinese Prevention and Treatment of Dyslipidemia in adults. Multivariable logistic regression was adopted to assess the potentially associated factors and commodities of dyslipidemia.

Results: In 2010, the prevalence of dyslipidemia was 42.84% among people aged 45 years and above. Low level of high-density lipoprotein cholesterol (HDL-C) was the most common type of dyslipidemia. The awareness, treatment and control rates among dyslipidemic subjects were 20.27%, 14.41% and 4.94%, respectively. In dyslipidemic patients who were under treatment, the control rate was 34.26%. People aged 50–59 years were at a significantly higher risk of dyslipidemia than those aged 45–49 years. Male gender, living in North China, overweight, obesity, central obesity, hypertension, diabetes and hyperuricemia were significantly associated with a higher risk of dyslipidemia. Current alcohol drinking and underweight were linked to a lower prevalence of dyslipidemia.

Conclusions: Our study revealed a high prevalence of dyslipidemia among middle-aged and older Chinese. The awareness, treatment and control rates were far from ideal and geographic inequality was highlighted. More efforts are needed to prevent and manage dyslipidemia in China.

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1. Introduction

Cardiovascular disease (CVD), including coronary heart disease, stroke, peripheral vascular disease and other CVDs, is estimated to affect 422.7 million individuals worldwide in 2015 [1]. Furthermore, CVD is the leading cause of mortality and disability, accounting for 17.9 million or 32% of global deaths [1,2]. Although CVD was traditionally regarded as a disease of affluence and more prevalent in high-income countries (HIC), the burden of CVD in low- and middle-income countries (LMIC) has been remarkably increasing during the past decades [2–4]. In 2015, more than three quarters (80%) of the global CVD deaths occurred in LMIC [1]. For the largest LMIC-China, the past decades have seen a dramatic epidemiological transition driven by unhealthy lifestyles (e.g. inactivity, westernized diet), urbanisation and demographic ageing, placing CVD a considerable threat to the society and human health [5,6].

Dyslipidemia is a highly prevalent disorder characterised by one or more of the following abnormal lipid profiles: elevated concentration of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG) or decreased level of high-density lipoprotein cholesterol (HDL-C) [7]. Etiologically associated with the development of atherosclerosis, dyslipidemia has become a well-established risk factor for CVD morbidity and mortality [7,8]. In most LMIC, geographic and socioeconomic inequities remain barriers to optimal management of dyslipidemia [3,9]. Given that China is a rapidly developing country with large variations in economy levels, lifestyles, diets and health care resources across the nation, the prevalence, as well as the awareness, treatment and control, of dyslipidemia might vary remarkably in different socioeconomic status and geographic regions. Previous investigations of dyslipidemia in China have demonstrated significant demographic, geographic, ethnic and economic variations in terms of the prevalence, awareness, treatment and control, of dyslipidemia [10–14]. However, the difference across individual studies might be a reflection of various study designs or investigated samples, or due to various socioeconomic factors (e.g. urbanisation, economic level). Until recently, no study has explored the socioeconomic and geographic variations in the prevalence, awareness, treatment and control within China.

To fill this gap of knowledge, we aimed to estimate the prevalence, awareness, treatment and control of dyslipidemia in Chinese middle-aged and older adults by using a nationally representative investigation. An emphasis will be put on exploring the socioeconomic and geographic variations. In addition, we aimed to assess the associated factors and comorbidities of dyslipidemia in Chinese middle-aged and older adults.

2. Materials and methods

2.1. Study design and study population

Data adopted in this study came from the China Health and Retirement Longitudinal Study (CHARLS, available at http://charls.pku.edu.cn/en), a nationwide household-based survey of middle-aged and older Chinese [15,16]. CHARLS is an ongoing survey that has been approved by the Ethical Review Committee of Peking University and conducted by the National School for Development (China Centre for Economic Research) at Peking University. From 2011 onwards, CHARLS has been consecutively conducted and followed up for five rounds (in 2011, 2012, 2013, 2014 and 2015 respectively), among which only the 2011 baseline round had available blood data for analysis [17]. Given our study context, we used data in CHARLS 2011 throughout this study.

The study design and implement procedures of CHARLS have been described in detail before [15–17]. Briefly, samples in CHARLS were drawn by a four-stage, stratified, cluster sampling approach. First, after stratified by economic status, urban/rural setting and region, 150 counties from 28 provinces in Mainland China (except Hainan province, Ningxia Hui Autonomous Region and Tibet province) were randomly chosen using a probability-proportional-to-size (PPS) sampling technique. Then at the second step, three primary sampling units (PSU) were randomly selected from each of the 150 counties. The 450 PSU could be either communities in urban settings or administrative villages in rural settings. Third, at least 24 dwellings within each PSU were randomly selected using a specifically designed “CHARLS-GIS” software. Fourth, one member aged 45 years and above and his/her spouse were chosen from each household. In households where more than one individuals aged 45 years and above were available for the interview, only one was selected randomly. Finally, the household response rate in CHARLS 2011 was 80.5%, resulting in an overall of 17708 participants from 10257 households in the survey. Of the non-respondents (19.5%), 8.8% refused to participate, 8.2% were not able to be contacted and 2% were due to other reasons (e.g., health disability or interviewer-related reasons) [16].

2.2. Data collection

From June 2011 to March 2012, participants were interviewed using a structured questionnaire. Collected information included demographics, socioeconomic status, health-related behaviours, and medical history. All participants provided informed consents. Then, anthropometric measurements were taken for one time in 78.9% (n = 13978) of the study participants. Body weight was measured in light clothes and without shoes, using a digital body weight scale (OMRON Corporation, HN-286). Body height was measured without shoes, using a stadiometer (Seca Corporation, 213). Waist circumference (WC) was horizontally measured at the level of their navel without bulky clothing, using a soft measure tape. Weight was recorded to the nearest 0.1 kg, and height and WC were to the nearest 0.1 cm. Body mass index (BMI) was calculated as body weight (in kilograms) divided by squared height (in metres). Moreover, blood pressure was taken for three times at a 45-s interval, using an electronic sphygmomanometer (OMRON Corporation, HEM-7200). Both systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded to the nearest mmHg. The average of three readings was taken for analysis [15,16].

As part of the main survey, venous blood samples (8 ml for each subject) were collected from 66.9% (n = 11847) of the study participants. Within 2 h after blood collection, a complete blood count was conducted at the local sites. Then the specimen of whole blood was stored at 4 °C, and the remaining sample was stored at −20 °C. All the blood samples were transported to the central Laboratory in Beijing (Youanmen Center for Clinical Laboratory of Capital Medical University) within two weeks and stored at −80 °C for final analysis [15,17]. Glucose, TC, LDL-C, HDL-C and TG were measured by an enzymatic colorimetric test, glycated haemoglobin (HbA1c) was by a boronate-affinity high-performance liquid chromatography method and uric acid (UA) was by a uric acid plus method (ascorbate oxidase assay) [17].

2.3. Definitions

The primary definition of dyslipidemia was set based on the latest guideline of Chinese Prevention and Treatment of Dyslipidemia in adults [18]. An individual was considered as having dyslipidemia if his/her total cholesterol (TC) ≥ 240 mg/dL (6.22 mmol/L) or LDL-C ≥ 160 mg/dL (4.14 mmol/L) or HDL-C < 40 mg/dL (1.04 mmol/L), or triglyceride (TG) ≥ 200 mg/dL (2.26 mmol/L) or he/she was currently under antihyperlipidemic treatment, including taking traditional Chinese medicine, taking modern Western medicine and other treatments [18]. Awareness of dyslipidemia was defined as a self-reported physician diagnosis of dyslipidemia prior to the investigation. Treatment of dyslipidemia was defined as the current use of antihyperlipidemic treatment. Dyslipidemia was regarded as being controlled if TC < 240 mg/dL, LDL-C < 160 mg/dL, HDL-C ≥ 40 mg/dL, and TG < 200 mg/dL with treatment [13,19].

Table 1
Demographic, socioeconomic and geographic characteristics of the included subjects and the distribution of serum lipids.

Characteristic	Study subjects (9,525)	Lipid profile (mg/dL)			
		TC	LDL-C	HDL-C	TG
Age group					
45–49 years	1859 (21.88)	187.92 ± 34.15	112.62 ± 31.94	49.36 ± 13.41	104.43 (76.11–155.76)
50–59 years	3387 (34.51)	192.90 ± 38.52	116.73 ± 35.84	49.77 ± 15.48	105.32 (75.22–157.53)
60–69 years	2747 (25.44)	192.98 ± 42.27	116.12 ± 39.29	49.66 ± 17.30	111.51 (79.65–165.49)
≥70 years	1532 (18.18)	190.04 ± 36.04	115.40 ± 31.71	50.61 ± 14.48	105.32 (72.57–150.45)
Gender					
Male	4529 (48.80)	186.43 ± 36.41	112.05 ± 34.16	49.24 ± 15.82	99.12 (70.80–149.57)
Female	4996 (51.20)	195.96 ± 39.19	118.66 ± 35.79	50.35 ± 14.78	115.05 (81.42–163.73)
Education					
Illiterate	2713 (24.93)	196.27 ± 43.30	118.38 ± 39.16	51.99 ± 16.10	108.86 (77.88–158.41)
Literate	1753 (17.13)	189.33 ± 38.88	112.97 ± 35.95	50.10 ± 16.17	106.20 (75.22–150.45)
Primary education	2108 (21.88)	190.63 ± 38.69	114.70 ± 34.97	49.55 ± 16.28	107.08 (73.46–161.96)
Middle school education and above	2951 (36.07)	189.23 ± 33.56	115.02 ± 31.90	48.31 ± 13.55	104.43 (76.11–157.53)
Marital status					
Married or cohabiting	8445 (87.25)	191.00 ± 38.31	115.17 ± 35.22	49.61 ± 15.39	106.20 (76.11–158.41)
Single	1080 (12.75)	193.45 ± 36.80	117.25 ± 34.44	51.15 ± 14.75	107.97 (76.11–154.88)
Ln(PCE) by setting					
Rural	6116 (53.34)	192.40 ± 42.50	115.23 ± 38.80	51.99 ± 17.24	103.54 (73.46-152.22)
Bottom tertile	2066 (18.14)	191.72 ± 42.69	114.69 ± 39.12	52.80 ± 17.41	100.89 (71.68–146.02)
Middle tertile	2061 (17.55)	192.44 ± 42.16	116.04 ± 39.16	51.65 ± 17.13	103.54 (75.22–152.22)
Top tertile	1989 (17.65)	193.05 ± 42.60	114.99 ± 38.10	51.49 ± 17.12	105.32 (74.34–158.41)
Urban	3409 (46.66)	190.06 ± 32.77	115.67 ± 30.57	47.32 ± 12.66	111.51 (77.88-165.49)
Bottom tertile	1246 (13.00)	193.53 ± 39.74	115.87 ± 37.37	49.13 ± 16.15	111.51 (79.65–162.84)
Middle tertile	1126 (14.44)	191.43 ± 34.42	116.03 ± 30.99	48.15 ± 13.30	114.17 (81.42–167.26)
Top tertile	1037 (19.22)	186.69 ± 26.38	115.26 ± 25.39	45.46 ± 9.61	107.08 (76.11–165.49)
Region					
East China	2748 (28.84)	191.72 ± 37.42	116.98 ± 35.18	50.53 ± 15.00	101.78 (71.68–146.02)
North China	1410 (12.87)	187.79 ± 40.82	114.33 ± 37.26	46.48 ± 15.24	121.25 (82.31–173.46)
Northeast China	746 (8.89)	192.13 ± 34.79	115.79 ± 30.97	49.42 ± 13.89	108.86 (78.76–164.61)
Northwest China	796 (8.14)	178.09 ± 35.63	103.14 ± 31.65	48.16 ± 13.84	117.71 (83.19–177.00)
South Central China	2126 (25.20)	194.22 ± 36.17	119.47 ± 33.52	49.49 ± 14.94	104.43 (76.11–153.99)
Southwest China	1699 (16.07)	195.05 ± 41.48	113.25 ± 38.02	52.72 ± 17.13	101.78 (73.46–157.53)

Calculations were weighted; data were presented as n (%), means ± SD, median with lower and upper quartiles (for TG).

Regarding the socioeconomic characteristics, we classified the participants' educational attainment as illiterate, literate, primary education, and middle school education and above, and their marital status as married or cohabiting and single. For the assessment of economic status, we adopted per capita expenditures (PCE) as an indicator of household resources and wealth [11,20]. The terciles of the natural logarithm of PCE – Ln(PCE) were used to divide wealth levels, where the bottom tertile represented the poor and the top tertile referred to the rich. Given that large inequality exists in economic development between urban and rural China, the economic status was classified for urban and rural settings separately [21,22]. Geographically, we classified all participants into six regions- East China, North China, Northeast China, Northwest China, South Central China and Southwest China (see Supplementary Fig. 1 for more details).

For health behaviours, we classified the participants as never smoker, former smoker, and current smoker according to their smoking habits, and similarly as never drinker, former drinker, and current drinker according to their alcohol drinking habits. For nutritional status, we classified the participants as underweight (BMI < 18.5 kg/m^2), normal (BMI:18.5–22.9 kg/m^2), overweight (BMI: 23.0–27.4 kg/

Table 2
Prevalence of dyslipidemia by demographic, socioeconomic and geographic characteristics.

Characteristic	Prevalence, % (95% CI)				
	Elevated TC	Elevated LDL-C	Low HDL-C	Elevated TG	Dyslipidemia
Overall (crude)	10.09 (8.86–11.48)	9.63 (8.33–11.10)	27.46 (24.99–30.07)	15.42 (13.70–17.31)	42.84 (40.54–45.16)
Overall (age-standardized)	10.04 (9.81–11.43)	9.56 (8.27–11.03)	27.36 (24.94–29.93)	15.39 (13.67–17.28)	42.64 (40.33–44.98)
Age group					
45–49 years	8.54 (6.81–10.64)	6.86 (5.11–9.17)	24.93 (21.13–29.15)	15.23 (12.56–18.35)	36.90 (32.11–41.95)
50–59 years	10.85 (9.25–12.69)	10.90 (9.14–12.94)	27.58 (24.30–31.12)	15.70 (13.61–18.03)	43.74 (40.07–47.48)
60–69 years	11.39 (9.69–13.33)	10.81 (9.19–12.67)	28.84 (24.92–33.10)	16.97 (13.35–21.33)	46.04 (42.27–49.85)
≥70 years	8.71 (6.81–11.09)	8.88 (7.12–11.03)	28.35 (23.45–33.82)	12.94 (9.62–17.19)	43.79 (39.02–48.68)
	p = 0.025	p = 0.001	p = 0.465	p = 0.376	p = 0.035
Gender					
Male	7.78 (6.52–9.26)	7.38 (6.06–8.96)	30.17 (27.44–33.04)	14.02 (12.09–16.21)	42.62 (39.73–45.56)
Female	12.30 (10.74–14.04)	11.77 (10.17–13.58)	24.88 (21.89–28.13)	16.75 (14.58–19.17)	43.05 (40.43–45.70)
	p < 0.001	p < 0.001	p < 0.001	p = 0.030	p = 0.785
Education					
Illiterate	12.89 (10.93–15.13)	12.17 (10.17–14.50)	22.42 (19.94–25.11)	13.90 (12.06–15.97)	40.85 (38.27–43.47)
Literate	9.19 (7.64–11.02)	8.61 (7.03–10.50)	26.16 (22.89–29.72)	15.33 (12.68–18.42)	42.12 (38.33–46.00)
Primary education	10.42 (8.44–12.82)	9.83 (7.87–12.21)	30.01 (23.71–37.18)	16.65 (12.90–21.22)	45.11 (39.52–50.82)
Middle school education and above	8.39 (6.97–10.06)	8.23 (6.62–10.18)	30.01 (26.48–33.79)	15.75 (12.98–18.99)	43.18 (38.94–47.52)
	p < 0.001	p=0.003	p = 0.038	p = 0.534	p = 0.494
Marital status					
Married or cohabiting	9.78 (8.51–11.22)	9.27 (7.94–10.79)	27.88 (25.20–30.74)	15.98 (14.09–18.06)	42.90 (40.47–45.36)
Single	12.23 (9.76–15.22)	12.08 (9.70–14.94)	24.54 (20.87–28.63)	11.58 (9.08–14.66)	42.43 (38.01–46.99)
	p = 0.065	p = 0.025	p = 0.149	p = 0.015	p = 0.846
Ln(PCE) by setting†					
Rural	10.79 (9.25-12.55)	9.71 (8.19-11.49)	22.36 (20.06-24.84)	13.29 (11.66-15.11)	38.29 (35.99-40.65)
Bottom tertile	10.51 (8.40–13.07)	10.28 (7.95–13.19)	21.37 (18.50–24.55)	12.36 (10.04–15.12)	37.51 (34.34–40.80)
Middle tertile	10.48 (8.81–12.42)	9.38 (7.84–11.19)	23.08 (20.32–26.08)	13.17 (11.34–15.24)	38.24 (35.46–41.10)
Top tertile	11.39 (9.26–13.93)	9.46 (7.63–11.68)	22.66 (20.02–25.53)	14.37 (12.35–16.66)	39.15 (36.34–42.03)
	p = 0.659	p = 0.668	p = 0.461	p = 0.274	p = 0.593
Urban	9.30 (7.72-11.15)	9.53 (7.85-11.52)	33.29 (29.50-37.31)	17.85 (15.07-21.01)	48.03 (44.45-51.63)
Bottom tertile	11.48 (9.50–13.81)	11.50 (9.28–14.17)	30.01 (26.24–34.08)	16.26 (13.53–19.43)	46.56 (42.48–50.68)
Middle tertile	10.47 (8.33–13.08)	9.59 (7.47–12.24)	32.05 (27.98–36.41)	17.40 (13.25–22.51)	47.63 (42.72–52.57)
Top tertile	6.94 (4.76–10.01)	8.15 (5.57–11.76)	36.43 (29.69–43.76)	19.26 (15.29–23.97)	49.34 (43.43–55.26)
	p = 0.025	p = 0.204	p = 0.171	p = 0.450	p = 0.662
Region					
East China	9.79 (8.00–11.93)	9.86 (8.00–12.11)	25.17 (21.77–28.90)	12.58 (9.83–15.97)	39.80 (35.69–44.05)
North China	8.69 (6.99–10.76)	9.60 (7.28–12.55)	35.46 (28.50–43.10)	18.65 (14.10–24.24)	51.44 (45.63–57.20)
Northeast China	9.81 (7.45–12.80)	8.55 (6.09–11.89)	27.53 (22.69–32.96)	17.18 (13.00–22.35)	43.15 (36.78–49.76)
Northwest China	5.63 (3.61–8.66)	4.45 (2.73–7.18)	28.48 (19.16–40.10)	19.90 (10.22–35.16)	43.96 (33.44–55.05)
South Central China	11.50 (8.07–16.13)	11.70 (8.10–16.62)	29.12 (23.31–35.72)	14.81 (12.52–17.44)	44.91 (40.90–48.99)
Southwest China	11.96 (9.47–15.01)	9.19 (7.00–11.98)	21.98 (17.91–26.68)	15.63 (12.76–19.00)	37.42 (33.38–41.65)
	p = 0.118	p = 0.097	p = 0.073	p = 0.301	p = 0.023

Data are presented as weighted prevalence (95% CI).

m^2) and obese (BMI ≥27.5 kg/m^2) [23]. Central obesity was identified if a WC > 90 cm in males or > 85 cm in females [24]. Diabetes was defined by 1) a fasting blood glucose ≥126 mg/dL; or 2) a random blood glucose ≥200 mg/dL; or 3) an HbA1c concentration of 6.5% or above; or 4) a self-reported physician diagnosis; or 5) current use of antidiabetic drugs (including insulin, traditional Chinese medicine and modern Western medicine) [11,25]. Hypertension was defined by 1) an SBP ≥140 mmHg; or 2) a DBP≥90 mmHg; or 3) a self-reported physician diagnosis; or 4) current use of antihypertensive drugs (including traditional Chinese medicine and modern Western medicine) [11,26]. Hyperuricemia was defined as a level of UA ≥7.0 mg/dL in males or ≥6.0 mg/dL in females [11,27].

2.4. Statistical analysis

All calculations in this study were weighted by correcting household non-response in the initial sampling and individual non-response in the blood sampling [17]. The weighted prevalence of dyslipidemia and its components (elevated TC, elevated LDL-C, low HDL-C and elevated TG) was presented for different demographic (age and gender), socioeconomic (education, marriage, setting [urban *vs.* rural] and economic status) and geographic (the six regions) groups. Moreover, the awareness, treatment and control rates were also demonstrated. We also generated the age-standardized prevalence estimates by using the Chinese census population in 2010 [28]. The comparison of prevalence or rates between different groups was performed by Chi-square test. Multivariable logistic regression was adopted to assess the potentially associated factors and commodities of dyslipidemia.

We presented continuous variables by means and standard deviations (SDs), except for TG, which was by median with lower and upper quartiles due to its skewed distribution. Categorical data were presented by proportions and 95% confidence intervals (CIs). All analyses were conducted in Stata statistical software (version 14.0; Stata Corporation, College Station, TX, USA). All maps were drawn by ArcMap version 10.1 (Environmental Systems Research Institute, Redlands, CA, USA), with a base map of China obtained from the Global Administrative Area database (GADM, 2015, version 2.0; www.gadm.org). A p value of less than 0.05 was indicative of statistical significance. All tests were two-sided.

3. Results

3.1. Characteristics of study subjects

In CHARLS 2011, a total of 11847 participants provided blood samples, among whom, 223 were aged under 45 years and 2099 had incomplete demographic, socioeconomic or geographic data. Finally, 9525 subjects were included in our analysis (see Supplementary Fig. 2 for the selection process). The included and non-included subjects were generally similar in terms of demographics (age and gender), educational achievements and economic levels (see Supplementary Table 1 for more details).

The characteristics and lipid profile of the 9525 subjects are listed in Table 1. More than one-third of the study subjects were aged 50–59 years (34.51%) or received a middle school education and above (36.07). The proportion of females was slightly higher than that of males (51.20% *vs.* 48.80%). The majority (87.25%) of our study subjects were married or cohabiting, and more than half (53.34%) were rural dwellers. In addition, more than half of the study subjects were concentrating in two geographic regions-East China and South Central China.

3.2. Prevalence of dyslipidemia in middle-aged and older Chinese

As presented in Table 2, the crude prevalence of dyslipidemia in middle-aged and older Chinese was 42.84%, equivalent to a total of 190 million affected people (aged 45 years and above) in 2010. The age-standardized prevalence of dyslipidemia was 42.64%. Regarding the four components of dyslipidemia, elevated LDL-C was with the lowest prevalence (crude: 9.63%; age-standardized: 9.56%), while low HDL-C was with the highest prevalence (crude: 27.46%; age-standardized: 27.36%). People aged 60–69 years were with the highest prevalence of dyslipidemia, elevated TC, low HDL-C and elevated TG, whereas the prevalence of elevated LDL-C was the highest in the age group of 50–59 years (Supplementary Fig. 3). The prevalence of dyslipidemia was slightly higher in females than in males (43.05% *vs.* 42.62%). In addition, people who received primary education were with the highest prevalence of dyslipidemia (45.11%) than people who received other educational attainments. Married (or cohabiting) people and single ones were comparable at the prevalence of dyslipidemia (42.90% *vs.* 42.43%). An obvious urban-rural gap was observed, where the prevalence of dyslipidemia was lower in rural areas than in urban areas (38.29% *vs.* 48.03%). In both urban and rural settings, a gradually increasing trend of dyslipidemia prevalence with increased economic level was also observed. The geographic distributions of the prevalence of dyslipidemia and its four components are shown in Fig. 1. Among the six regions, North China had the highest prevalence of dyslipidemia (51.44%), whereas Southwest China had the lowest (37.42%).

3.3. Awareness, treatment and control of dyslipidemia

As demonstrated in Table 3, the rates of awareness, treatment and control among subjects with dyslipidemia were 20.27%, 14.41% and 4.94% respectively. In dyslipidemic patients who were under treatment, the control proportion was 34.26%. Dyslipidemic patients that were aged 60–69 years were with the highest rates of awareness and treatment (26.18% and 21.27%), and those aged 50–59 years were with the highest rate of control (5.64%) (Supplementary Fig. 4). Among dyslipidemic patients who were under treatment, the control rate decreased with advanced age. A slightly higher proportion of female patients were aware of their dyslipidemia and got treated than males. However, the control rates were higher in males than in females. Dyslipidemic patients who received a middle school education and above had the highest level of awareness (22.95%), and those who received primary education owed the highest level of treatment (16.03%). However, literate patients had the greatest control rates (8.24% in dyslipidemic patients; 52.69% in treated patients). Married (or cohabiting) patients had higher proportions of awareness and treatment than single patients, whereas single patients had higher control rates than married (or cohabiting) patients (5.64% in dyslipidemic patients; 42.22% in treated patients). The awareness and treatment rates were higher, but the control rates were much lower among urban patients than among rural patients. In both urban and rural settings, the awareness and treatment rates both increased with higher economic levels. In rural areas, the control rates were the highest in poor patients, whereas in urban areas, they were the highest in those with the middle economic level. Geographically (Supplementary Fig. 5), the rates of awareness and treatment were the highest in Northwest China, but the lowest in Southwest China. Patients in North China had the highest control rates, whereas Southwest China has the lowest control rate among dyslipidemic patients and Northwest China had the lowest among treated patients.

3.4. Associated factors and comorbidities of dyslipidemia

According to the multivariable logistic regression analyses (Table 4), people aged 50–59 years were at a significantly higher risk of dyslipidemia than those aged 45–49 years. Male gender, living in North China, overweight, obesity, central obesity, hypertension, diabetes and hyperuricemia were associated with a significantly higher risk of dyslipidemia, whereas current alcohol drinking and underweight were linked to a lower risk of dyslipidemia. Regarding the four components of dyslipidemia, old people aged 70 years and above were at a lower

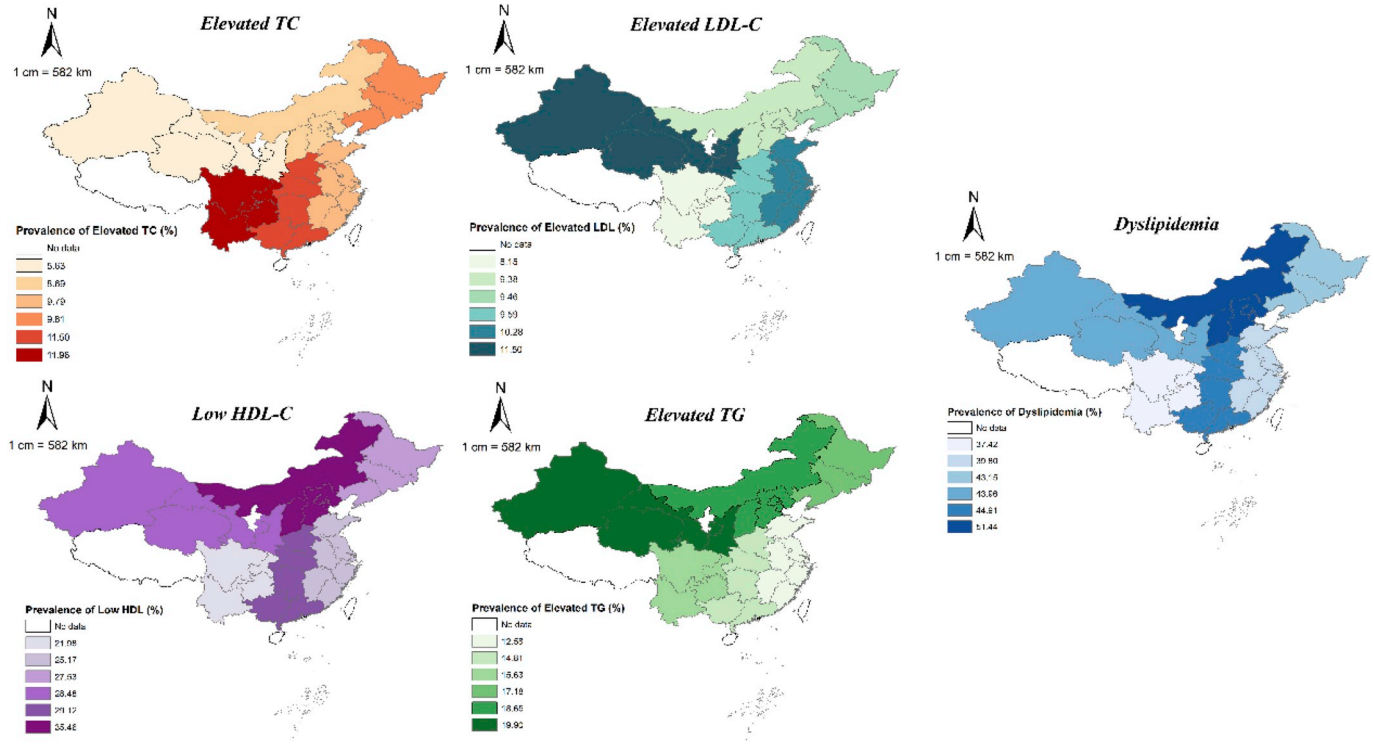

Fig. 1. Prevalence of dyslipidemia in different geographic regions.

risk of elevated TC and elevated TG, whereas those aged 50–69 years had a higher prevalence of elevated LDL-C than people aged 45–49 years. Females were more likely to have elevated TC, elevated LDL-C and elevated TG, but less likely to develop low HDL-C than males. Single individuals were at a higher risk of elevated TC and elevated LDL-C than married (or cohabiting) people. Compared with poor people in rural settings, rich or middle-economic dwellers in urban areas were more likely to have low HDL-C. Geographically, people in Northwest China were less likely to have elevated LDL-C, and those in Northeast China were more like to have elevated TG. Former smoking was a positively associated factor of elevated TC, and current smoking was associated with a higher risk of elevated TG. Current alcohol drinking was a negatively associated factor of low HDL-C. Overweight, obesity and central obesity were associated with a higher risk, but underweight was associated with a lower risk, of both low HDL-C and elevated TG. Hypertension was positively linked to elevated TC, elevated LDL-C and elevated TG. Diabetes and hyperuricemia were significant comorbidities of all the four components of dyslipidemia (elevated TC, elevated LDL-C, low HDL-C and elevated TG).

4. Discussion

In this nationally representative study, dyslipidemia was identified as a highly prevalent disorder among middle-aged and older Chinese, affecting almost half (43%) of the general people aged 45 years and above in 2010. Low HDL-C (< 40 mg/dL) was the most common lipid disorder, whereas elevated LDL-C (≥ 160 mg/dL) was the least common type. Despite the huge burden of dyslipidemia, only one in five (20%) dyslipidemic patients were aware of their condition, and 14% received treatment. The control rate was far from ideal, where only 5% of the dyslipidemic patients got controlled by treatment. Even among dyslipidemic patients who had access to antidyslipidemic medication, only 34% had their lipid profiles under control. We additionally identified male gender, living in North China, overweight, obesity, central obesity, hypertension, diabetes and hyperuricemia as positively associated factors or comorbidities of dyslipidemia, but current alcohol drinking and underweight were negatively associated factors.

The findings in this study are largely consistent with previous investigations on dyslipidemia among Chinese [12–14,19,29]. According to a systematic review and meta-analysis of dyslipidemia in China, the pooled prevalence of dyslipidemia was 40.9% in people aged 30 years and above, which is comparable to our estimate of 42.8% in those aged 45 years and above [19]. However, another large-scale investigation-the China National Survey of Chronic Kidney Disease (CNSCK) revealed a much lower prevalence estimate of 36.4% in Chinese adults [13]. The participants in CNSCK were much younger (18 years and above) than those in CHARLS 2011, where only middle-aged and older people aged 45 years and above participated. According to the significantly positive relation between advanced age and dyslipidemia prevalence as observed in CNSCK, it is not surprising that their prevalence estimates were lower than those in our study [13,30].

In comparison with middle-aged and older American, middle-aged and older Chinese were rather less affected by dyslipidemia (42.7% *vs.* 56.8%) [29]. Nationally, 20% of the dyslipidemic patients were aware of their diagnoses and 14% received treatment. Those proportions were largely less than that in the United States (US), where 73% of the dyslipidemic patients were aware of their conditions and 54% got treatment. Consequently, the control rate among dyslipidemic patients was much lower in China (5%) than that in the US (36%) [29]. Those huge gaps indicate the necessity of promoting health education and screening of dyslipidemia in the general Chinese to improve the awareness of this disease. In addition, adequate health resources and better health accessibility could also be useful in improving the treatment and control of dyslipidemia [29,31,32]. Across China, the awareness and treatment rates were as low as 6.5% and 4.1% in Southwest China. Consequently, the control rate in dyslipidemic patients was the lowest in Southwest China (1.6%). This is rather noteworthy. West China has long been an underdeveloped area whose economy and health resources are far worse than that in East and Central China [33]. The large variations of the awareness, treatment and control of dyslipidemia among regions, as demonstrated in this study, reflect a huge inequality of health resources between regions, more public health attention should be put on Southwest China. Among people who received treatment, the control rate was the lowest in

Table 3
Awareness, treatment and control of dyslipidemia by demographic, socioeconomic and geographic characteristics.

Characteristic	Within dyslipidemic subjects, % (95% CI)			Within treated subjects, % (95% CI)
	Awareness	Treatment	Control	Control
Overall (crude)	20.27 (17.38–23.51)	14.41 (11.96–17.27)	4.94 (3.86–6.29)	34.26 (26.17–43.38)
Age group				
45–49 years	16.58 (12.10–22.29)	7.62 (5.22–10.98)	3.72 (2.35–5.84)	48.78 (32.71–65.11)
50–59 years	17.97 (14.63–21.88)	12.08 (9.41–15.39)	5.64 (3.62–8.68)	46.66 (34.33–59.41)
60–69 years	26.18 (19.33–34.43)	21.27 (14.67–29.81)	5.49 (4.08–7.35)	25.81 (15.61–39.56)
≥70 years	19.58 (13.89–26.87)	15.64 (10.28–23.08)	4.04 (2.52–6.41)	25.81 (14.58–41.48)
	p = 0.083	> p = 0.006	p = 0.373	p = 0.024
Gender				
Male	19.84 (16.49–23.67)	13.72 (11.06–16.90)	5.15 (3.60–7.33)	37.56 (27.37–48.99)
Female	20.68 (16.76–25.24)	15.07 (11.46–19.58)	4.73 (3.57–6.26)	31.41 (21.22–43.79)
	p = 0.735	p = 0.567	p = 0.690	p = 0.420
Education				
Illiterate	15.91 (12.29–20.36)	12.44 (9.32–16.41)	4.45 (3.12–6.31)	35.79 (25.64–47.39)
Literate	21.31 (15.38–28.74)	15.64 (10.23–23.18)	8.24 (4.67–14.14)	52.69 (33.42–71.19)
Primary education	19.70 (13.51–27.83)	16.03 (9.75–25.21)	3.59 (2.39–5.37)	22.43 (10.53–41.52)
Middle school education and above	22.95 (19.23–27.15)	14.11 (11.43–17.31)	4.58 (3.33–6.27)	32.43 (23.23–43.21)
	p = 0.242	p = 0.703	p = 0.036	p = 0.061
Marital status				
Married or cohabiting	20.70 (17.70–24.05)	14.57 (12.01–17.56)	4.84 (3.70–6.29)	33.20 (24.54–43.17)
Single	17.30 (12.29–23.79)	13.35 (9.18–19.02)	5.64 (3.50–8.97)	42.22 (28.70–57.01)
	p = 0.275	p = 0.637	p = 0.558	p = 0.291
Ln(PCE) by setting†				
Rural	14.48 (11.97-17.42)	10.44 (8.41-12.89)	5.35 (4.05-7.04)	51.30 (44.02-58.51)
Bottom tertile	12.83 (9.61–16.93)	9.88 (7.36–13.15)	5.56 (3.87–7.92)	56.25 (44.47–67.36)
Middle tertile	14.68 (11.13–19.13)	10.78 (8.00–14.37)	5.37 (3.64–7.85)	49.82 (38.13–61.52)
Top tertile	15.89 (12.54–19.93)	10.65 (7.97–14.10)	5.14 (3.31–7.90)	48.22 (35.10–61.59)
	p = 0.405	p = 0.856	p = 0.938	p = 0.627
Urban	25.46 (21.35-30.07)	18.04 (14.34-22.44)	4.56 (3.02-6.84)	25.27 (16.02-37.47)
Bottom tertile	16.60 (12.47–21.75)	14.17 (10.40–19.02)	3.25 (2.00–5.25)	22.94 (14.65–34.06)
Middle tertile	25.29 (19.39–32.27)	18.87 (13.57–25.61)	5.49 (3.48–8.56)	29.12 (16.12–46.75)
Top tertile	31.19 (25.26–37.80)	19.91 (13.84–27.78)	4.71 (2.06–10.44)	23.68 (9.57–47.63)
	p = 0.001	p = 0.320	p = 0.507	p = 0.768
Region				
East China	20.83 (16.41–26.07)	12.83 (9.37–17.31)	5.47 (3.10–9.45)	42.61 (28.90–57.57)
North China	25.21 (20.33–30.82)	18.37 (15.48–21.65)	8.44 (5.85–12.04)	45.95 (33.85–58.55)
Northeast China	27.05 (19.42–36.32)	18.28 (13.41–24.41)	7.14 (4.29–11.66)	39.09 (20.83–61.02)
Northwest China	30.09 (19.85–42.80)	22.84 (14.98–33.21)	4.62 (2.22–9.37)	20.21 (9.13–38.97)
South Central China	18.80 (12.74–26.85)	15.20 (9.41–23.62)	3.47 (2.13–5.58)	22.81 (10.98–41.45)
Southwest China	6.51 (4.06–10.28)	4.14 (2.22–7.59)	1.63 (0.98–2.68)	39.27 (29.30–50.22)
	p < 0.001	p = 0.003	p = 0.007	p = 0.082

Data are presented as weighted prevalence (95% CI).

Table 4
Multivariable logistic regression analyses on associated factors and comorbidities for dyslipidemia.

Characteristic	Elevated TC	Elevated LDL-C	Low HDL-C	Elevated TG	Dyslipidemia
Age group					
45–49 years	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
50–59 years	1.27 (0.98–1.63)	1.84 (1.38–2.45)***	1.29 (0.84–1.99)	0.99 (0.80–1.23)	1.43 (1.01–2.03)*
60–69 years	1.05 (0.79–1.41)	1.45 (1.06–1.98)*	1.3 (0.83–2.06)	0.96 (0.57–1.61)	1.39 (0.94–2.05)
≥70 years	0.67 (0.46–0.99)*	1.14 (0.78–1.67)	1.32 (0.77–2.26)	0.50 (0.34–0.73)***	1.16 (0.76–1.77)
Gender					
Male	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Female	1.87 (1.41–2.48)***	1.76 (1.32–2.34)***	0.56 (0.47–0.66)***	1.34 (1.02–1.76)*	0.83 (0.71–0.98)*
Education					
Illiterate	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Literate	0.78 (0.60–1.01)	0.83 (0.63–1.10)	1.03 (0.81–1.3)	1.03 (0.81–1.31)	0.97 (0.80–1.17)
Primary education	0.96 (0.75–1.24)	0.93 (0.69–1.23)	1.24 (0.87–1.78)	1.09 (0.75–1.59)	1.05 (0.79–1.39)
Middle school education and above	0.76 (0.58–1.01)	0.79 (0.58–1.08)	1 (0.81–1.25)	0.86 (0.64–1.15)	0.85 (0.69–1.05)
Marital status					
Married or cohabiting	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Single	1.44 (1.05–1.97)*	1.46 (1.07–1.98)*	0.91 (0.68–1.21)	0.88 (0.64–1.20)	1.09 (0.87–1.37)
Ln(PCE) by setting†					
Rural					
Bottom tertile	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Middle tertile	0.98 (0.76–1.27)	0.92 (0.70–1.20)	1.07 (0.88–1.3)	1.04 (0.77–1.39)	0.97 (0.82–1.15)
Top tertile	1.15 (0.83–1.60)	1.01 (0.74–1.39)	1.10 (0.88–1.38)	1.27 (0.97–1.67)	1.14 (0.93–1.39)
Urban					
Bottom tertile	1.03 (0.74–1.42)	1.10 (0.80–1.51)	1.37 (1–1.88)	1.20 (0.82–1.74)	1.25 (1.00–1.58)
Middle tertile	1.14 (0.79–1.63)	1.03 (0.68–1.56)	1.53 (1.13–2.06)**	1.42 (0.98–2.06)	1.29 (0.98–1.70)
Top tertile	0.59 (0.32–1.09)	0.72 (0.38–1.35)	1.62 (1.04–2.53)*	1.49 (0.98–2.26)	1.31 (0.98–1.74)
Region					
East China	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
North China	0.76 (0.51–1.12)	0.84 (0.52–1.35)	1.4 (0.98–2.01)	1.22 (0.82–1.83)	1.39 (1.06–1.84)*
Northeast China	1.09 (0.72–1.64)	0.88 (0.52–1.48)	1.2 (0.89–1.62)	1.49 (1.03–2.15)*	1.29 (0.93–1.78)
Northwest China	0.61 (0.36–1.02)	0.52 (0.29–0.93)*	1.3 (0.73–2.32)	1.43 (0.74–2.79)	1.15 (0.73–1.80)
South Central China	1.20 (0.79–1.82)	1.18 (0.76–1.83)	1.18 (0.86–1.62)	1.07 (0.75–1.50)	1.24 (0.97–1.57)
Southwest China	1.20 (0.86–1.67)	0.92 (0.64–1.31)	0.97 (0.66–1.42)	1.39 (0.94–2.05)	1.04 (0.80–1.35)
Smoking					
Never smoker	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Former smoker	1.44 (1.03–2.02)*	1.18 (0.81–1.72)	1.08 (0.74–1.56)	1.30 (0.91–1.86)	1.10 (0.79–1.53)
Current smoker	1.16 (0.86–1.57)	1.09 (0.79–1.49)	1.09 (0.89–1.34)	1.44 (1.09–1.90)*	1.12 (0.94–1.35)
Alcohol drinking					
Never drinker	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Former drinker	0.78 (0.53–1.13)	0.83 (0.54–1.29)	0.89 (0.67–1.17)	0.84 (0.61–1.16)	0.92 (0.72–1.19)
Current drinker	1.17 (0.90–1.53)	0.98 (0.73–1.32)	0.57 (0.48–0.69)***	0.78 (0.58–1.06)	0.72 (0.61–0.85)***
Obesity					
Normal	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)

(*continued on next page*)

Table 4 (*continued*)

Characteristic	Elevated TC	Elevated LDL-C	Low HDL-C	Elevated TG	Dyslipidemia
Underweight	0.96 (0.61–1.52)	1.05 (0.66–1.67)	0.54 (0.38–0.77)**	0.51 (0.31–0.82)**	0.66 (0.51–0.86)**
Overweight	1.23 (0.95–1.59)	1.26 (0.94–1.68)	1.64 (1.33–2.03)***	1.44 (1.11–1.87)**	1.68 (1.40–2.03)***
Obese	1.17 (0.84–1.63)	1.08 (0.75–1.58)	2.12 (1.64–2.74)***	2.07 (1.47–2.92)***	2.32 (1.76–3.07)***
Central obesity	1.05 (0.83–1.33)	1.05 (0.80–1.37)	1.66 (1.36–2.01)***	1.58 (1.22–2.05)**	1.49 (1.23–1.80)***
Hypertension	1.31 (1.05–1.64)*	1.30 (1.05–1.60)*	1.05 (0.89–1.23)	1.32 (1.05–1.66)*	1.30 (1.12–1.51)**
Diabetes	2.01 (1.57–2.58)***	1.40 (1.04–1.87)*	1.58 (1.28–1.94)***	2.93 (2.41–3.57)***	2.03 (1.71–2.39)***
Hyperuricemia	2.74 (1.94–3.86)***	2.06 (1.38–3.07)***	1.91 (1.40–2.59)***	3.15 (2.14–4.61)***	2.49 (1.82–3.41)***

Calculations were weighted; data were presented as odds ratios (95% CI); the multivariable logistic regression was adjusted for all variables listed. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Northwest China, which could be a result of poor compliance, but needs further confirmation in future studies.

In our study, males were revealed to be at a higher risk of developing dyslipidemia than females, which is in accordance with findings in previous studies [13,14,19]. To make the situation even worse, the awareness and treatment rates in male patients were lower than in female patients, which in part reflects a worse health literacy in Chinese males. More attention should be given to males in health promotion programs of dyslipidemia. Although females were found to be less likely to develop dyslipidemia than males after controlling other demographic, socioeconomic, geographic factors and comorbidities, the prevalence of dyslipidemia in females was even slightly higher than in males as observed in this study. Therefore, we should never conclude that females are not the research and healthcare priority. Furthermore, females were at a higher risk of developing elevated TC, elevated LDL-C and elevated TG as revealed in our study [13]. Previous studies have suggested that females would have increased concentrations of TC, LDL-C and TG, but reduced concentration of HDL-C after menopause. Given our female study subjects were all aged 45 years and above, it is not surprising to observe this gender disparity in those four lipid disorders (elevated TC, elevated LDL-C, low HDL-C and elevated TG) [34,35].

As expected, we found that the prevalence of dyslipidemia gradually increased with higher economic levels. However, in the multivariable logistic regression, economic status was not found to be a significantly associated factor of dyslipidemia. Therefore, the variations of dyslipidemia among different economic levels might be a combined effect of different exposures to other economy-related risk factors for dyslipidemia, such as obesity, hypertension and diabetes [36]. The positive relation of overweight, obesity, central obesity, hypertension, diabetes, hyperuricemia and dyslipidemia, as revealed in our study, implies beneficial effects of healthy lifestyles (e.g. healthy diet, exercise) on preventing and managing dyslipidemia [7,18].

The prevalence of dyslipidemia varied geographically in China. Among the six regions, North China had the highest prevalence of dyslipidemia. However, the control rates in both dyslipidemic patients and those who were under treatment were the lowest in this region, highlining dyslipidemia as a serious public health problem. Surprising, no significant association between smoking and dyslipidemia was found in our study, which is inconsistent with previous findings in the general Chinese adults but in line with that in nonagenarians and centenarians [10,14,37]. In addition, current alcohol drinkers were found to have a lower prevalence of dyslipidemia and Low HDL-C than never drinkers. This negative association might be driven by the dose-response relationship between HDL-C concentration and alcohol consumption, where moderate alcohol consumption has been suggested to be associated with increased HDL-C levels [7,38,39]. Similarly, previous studies witnessed a reduced risk of CVD among moderate alcohol drinkers [40,41]. Given the potential risk of alcohol consumption on human health, we don't recommend alcohol drinking as a protective factor for dyslipidemia [42].

Despite the existence of other large-scale investigations that explored the prevalence, awareness, treatment and control of dyslipidemia in the Chinese population, to the best of our knowledge, our study is the first nationally representative investigation with the largest geographic coverage (28 out of 31 provinces). Our ability to explore geographic variations was therefore well-guaranteed. Another novel feature of this study is the adoption of PCE as the surrogate of household resources, a better welfare indicator than the gross domestic product per capita in developing countries [11,20]. Moreover, all blood specimens were tested with a standard protocol in a single laboratory, largely reducing the potential bias arising from different methodologies.

However, this study is not free from limitations. First, our study subjects were only middle-aged and older Chinese, the prevalence, awareness, treatment and control of dyslipidemia in younger age groups could not be explored. Second, we chose only to explore the geographic variations at the six regions, the prevalence, awareness, treatment and control of dyslipidemia in each province were not presented because of insufficient power in some specific provinces. Third, given the cross-sectional nature of the study design, only associations, rather than causality, could be inferred. Fourth, in the multivariable logistic regression, we only explored the association of dyslipidemia with a limited number of variables, other potential factors, such as dietary and exercise habits, family history of dyslipidemia, were not included due to the absence of relevant data.

To conclude, a high prevalence of dyslipidemia was revealed in middle-aged and older Chinese. The dominant component of dyslipidemia was low HDL-C. The awareness, treatment and control rates were far from ideal and varied dramatically among different geographic regions. More efforts are needed to prevent and manage dyslipidemia in China.

Conflicts of interest

The authors declared they do not have anything to disclose regarding conflict of interest with respect to this manuscript.

Author contributions

PS, WX and CZ: study conception and design; MZ, YX and XY: database preparation; PS, HW, ZF and XY: data analysis and interpretation of data; PS: first draft; all authors provided critical revisions of the article and final approval of the version to publish.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.atherosclerosis.2019.01.005.

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