Serum Lipids and Lipoproteins in Chinese Men and Women

Wenying Yang, MD; Jianzhong Xiao, MD, PhD; Zhaojun Yang, MD; Linong Ji, MD; Weiping Jia, MD; Jianping Weng, MD; Juming Lu, MD; Zhongyan Shan, MD; Jie Liu, MD; Haoming Tian, MD; Qiuhe Ji, MD; Dalong Zhu, MD; Jiapu Ge, MD; Lixiang Lin, MD; Li Chen, MD; Xiaohui Guo, MD; Zhigang Zhao, MD; Qiang Li, MD; Zhiguang Zhou, MD; Guangliang Shan, MD, PhD; Jiang He, MD, PhD; on behalf of the China National Diabetes and Metabolic Disorders Study Investigators*

Background—Because of rapid change in lifestyle risk factors, cardiovascular disease has become the leading cause of death in China. We sought to estimate the national levels of serum lipids and lipoproteins among the Chinese adult population.

Methods and Results—We conducted a cross-sectional study in a nationally representative sample of 46 239 adults aged ≥20 years. Fasting serum total, high-density lipoprotein, and low-density lipoprotein cholesterol and triglycerides were measured by standard methods. The age-standardized estimates of total, high-density lipoprotein, and low-density lipoprotein cholesterol and triglycerides were 4.72 (95% confidence interval, 4.70–4.73), 1.30 (1.29–1.30), 2.68 (2.67–2.70), and 1.57 (1.55–1.58) mmol/L, respectively, in the Chinese adult population. In addition, 22.5% (21.8–23.3%) or 220.4 million (212.1–228.8) Chinese adults had borderline high total cholesterol (5.18–6.21 mmol/L), and 9.0% (8.5–9.5%) or 88.1 million (83.4–92.8) had high total cholesterol (≥6.22 mmol/L). The population estimates for borderline high (3.37–4.13 mmol/L), high (4.14–4.91 mmol/L), and very high (≥4.92 mmol/L) low-density lipoprotein cholesterol were 13.9% (13.3–14.5%) or 133.5 million (127.0–140.1), 3.5% (3.3–3.8%) or 33.8 million (31.2–36.5), and 3.0% (2.8–3.3%) or 29.0 million (26.3–31.8) persons, respectively. In addition, 22.3% (21.6–23.1%) or 214.9 million (207.0–222.8) persons had low high-density lipoprotein cholesterol (<1.04 mmol/L). The awareness, treatment, and control of borderline high or high total cholesterol were 11.0%, 5.1%, and 2.8%, respectively, in the Chinese adult population.

Conclusions—Serum total and low-density lipoprotein cholesterol levels were high and increasing in the Chinese population. Without effective intervention, atherosclerotic cardiovascular diseases may soar in the near future in China. **(*Circulation*. 2012;125:2212-2221.)**

Key Words: China ■ cross-sectional studies ■ lipids ■ lipoproteins ■ prevalence

With rapid economic development and resulting adverse changes in lifestyle (such as a high intake of dietary saturated fat and increased physical inactivity), cardiovascular diseases have become the leading cause of death in China.[1,2] For example, it was estimated that 43.8% of deaths in Chinese adults aged ≥40 years were attributable to heart disease and stroke during 1991–2000 in a national prospective cohort study.[2] Elevated serum lipids are one of the most important modifiable risk factors for cardiovascular disease in Western[3,4] and in Asian[5,6] populations. The Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group reported that mean total cholesterol declined in Australasia, North America, and Europe between 1980 and 2008 but increased in east and southeast Asia and Pacific regions.[7] These estimates, however, are modeled on the basis of serum total cholesterol data primarily from small regional studies.

Received September 2, 2011; accepted March 22, 2012.

From the China-Japan Friendship Hospital, Beijing, China (W.Y., J.X., Z.Y.); Peking University Peoples' Hospital, Beijing, China (L.J.); Shanghai Jiaotong University Affiliated Sixth People's Hospital, Shanghai, China (W.J.); Sun Yat-sen University Third Hospital, Guangzhou, China (J.W.); Chinese PLA General Hospital, Beijing, China (J. Lu); First Affiliated Hospital, Chinese Medical University, Liaoling, China (Z.S.); Shanxi Province People's Hospital, Shanxi, China (J. Liu); West China Hospital, Sichuan University, Sichuan, China (H.T.); Xijing Hospital, Fourth Military Medical University, Shaanxi, China (Q.J.); Affiliated Drum Tower Hospital of Nanjing University Medical School, Jiangsu, China (D.Z.); Xinjiang Uygur Autonomous Region's Hospital, Xinjiang, China (J.G.); Fujian Provincial Hospital, Fujiang, China (L.L.); Qilu Hospital, Qilu Hospital of Shandong University, Shandong, China (L.C.); Peking University First Hospital, Beijing, China (X.G.); Henan Province People's Hospital, Henan, China (Z. Zhao); Second Affiliated Hospital of Harbin Medical University, Heilongjiang, China (Q.L.); Xiangya Second Hospital, Hunan, China (Z. Zhou); Peking Union Medical College, Beijing, China (G.S.); and Tulane University School of Public Health and Tropical Medicine, New Orleans, LA (J.H.).

*See the Appendix in the online-only Data Supplement for a full list of the China National Diabetes and Metabolic Disorders Study Group.

The online-only Data Supplement is available with this article at http://circ.ahajournals.org/lookup/suppl/doi:10.1161/CIRCULATIONAHA.111.065904/-/DC1.

Correspondence to Wenying Yang, MD, Department of Endocrinology, China-Japan Friendship Hospital, Beijing, China, 100029. E-mail ywy_1010@yahoo.com.cn

National data on serum lipids and lipoproteins are scarce, especially in developing countries.

Clinical Perspective on p 2221

The objectives of the present study are as follows: (1) to provide current and reliable data on population levels of serum lipids and lipoproteins in the general adult population in China; (2) to estimate the prevalence, awareness, treatment, and control of hypercholesterolemia in the Chinese population; and (3) to examine the association between metabolic risk factors and levels of serum lipids and lipoproteins in the Chinese population.

Methods

Study Population

The China National Diabetes and Metabolic Disorders Study was conducted from June 2007 to May 2008. The details of the study population and methods have been published elsewhere.[8] In brief, we used a multiple-stage stratified sampling method to select a nationally representative sample of the general population aged ≥20 years in China (Figure 1 and Figure I in the online-only Data Supplement). The sampling process was stratified by geographic regions, urbanization, and economic development status. The first 2 stages of sampling to select provinces from geographic regions and to select cities and counties from provinces were not random. The next stages to select city districts from cities and rural townships from counties, as well as to select street districts from city districts and rural villages from townships, were random. This multistage stratified sampling process resulted in an oversampling of urban residents. In total, 152 urban street districts and 112 rural villages were selected. The final stage of sampling was stratified by gender and age distribution on the basis of China population data from 2006.[9] Only persons who had lived in their current residence for ≥5 years were eligible to participate. All individuals permanently living in county seats and larger urban settings (ie, prefectural-level cities, provincial-level cities, and municipalities) were considered urban residents, whereas individuals living in townships and villages were considered rural residents.

A total of 54 240 individuals were selected and invited to participate in the study. Of them, a total of 47 325 persons (18 976 men and 28 349 women) completed the study. The overall response rate was 87.3%: There were 81.0% men and 92.0% women, with 88.1% in urban areas and 82.7% in rural areas. After 538 persons with missing demographic information and 1030 who lacked lipids data were excluded, 45 757 adults were included in the final analysis.

Institutional review boards or ethics committees at all participating institutes approved the study protocol. Written informed consent was obtained from each participant before data collection.

Data Collection

Data collection was conducted in examination centers at local health stations or community clinics in the participants' residential area. During the clinic visits, trained research staff administered a standard questionnaire to collect information on demographic characteristics, personal and family medical history, and lifestyle risk factors.[10] The interview included questions related to the diagnosis and treatment of hypercholesterolemia or hypertriglyceridemia. Cigarette smoking was defined as having smoked at least 100 cigarettes in one's lifetime. Those who smoked tobacco products at the time of the survey were classified as current smokers. Information on the amount and type of alcohol consumed during the past year was collected, and alcohol drinking was defined as consuming alcohol at least once per week. Regular leisure-time physical activity was defined as participation in ≥30 minutes of moderate or vigorous activity per day at least 3 days per week. Socioeconomic status, education, occupation, and income were also recorded. The economic development of provinces or municipalities was defined on the basis of the gross domestic product per capita in 2006. Blood pressure, body weight, height, and waist circumference were measured by standard methods.[10] Body mass index was calculated as weight in kilograms divided by the square of height in meters.

Figure 1. Map of China with all 14 sampled provinces, autonomous regions, and municipalities.

Blood samples were drawn by venipuncture after at least 10 hours of overnight fasting to measure serum total, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) cholesterol, triglycerides, and plasma glucose. Blood specimens were processed at the field center and shipped by air to the central laboratories in each province. Serum cholesterol and triglycerides were assessed enzymatically with commercially available reagents at the clinical biochemical laboratories in each province. All clinical laboratories in this study successfully completed a standardization and certification program.

All study investigators and staff members successfully completed a training program that oriented them to both the aims of the study and the specific tools and methodologies employed. At the training sessions, interviewers were given detailed instructions on administration of the study questionnaire. Clinical staff members were trained to obtain blood pressure, anthropometry measurements, and blood specimens according to a standard protocol.[10]

Statistical Analysis

All statistical analyses were conducted with the use of SUDAAN software (version 10; Research Triangle Institute, Research Triangle Park, NC). All estimates were weighted to represent the total Chinese adult population aged ≥20 years based on Chinese population data from 2008 and the study sampling scheme and considered several features of the survey, including oversampling for female and urban residents, nonresponse, economic development, and other demographic or geographic differences between the sample and the total population. Standard errors were estimated by a technique appropriate to the complex survey design. All P values were 2-tailed and not adjusted for multiple testing.

Mean levels of total, HDL, and LDL cholesterol and triglycerides were estimated for the overall population and by urbanization (urban and rural) for men and women after age standardization to the population distribution in China in 2008.[11] Next, age-specific mean levels were determined for men and women. Serum total, HDL, and LDL cholesterol levels were classified on the basis of the Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults.[12] The prevalence estimates of total, HDL, and LDL cholesterol categories were calculated for the overall population and by gender with the use of the direct method according to the population distribution in China in 2008.[11] Estimated numbers of individuals by cholesterol categories were calculated by subgroup-specific prevalence by age, gender, geographic

Table 1. Demographic and Clinical Characteristics of Study Participants by Dyslipidemia Status in Urban and Rural China

	Urban		Rural	
	Dyslipidemia*	No Dyslipidemia	Dyslipidemia*	No Dyslipidemia
Age, y	47.7 (47.1–48.3)	44.0 (43.5–44.5)	46.3 (45.6–47.1)	44.7 (44.1–45.3)
Male, %	60.1 (58.4–61.7)	43.8 (42.5–45.1)	53.7 (51.5–55.9)	47.4 (45.7–49.1)
College or higher education, %	26.6 (25.2–28.1)	27.8 (26.7–28.8)	15.1 (13.6–16.8)	12.8 (11.8–13.8)
Current cigarette smoking,† %	25.0 (23.8–26.4)	22.8 (21.8–23.8)	28.5 (26.9–30.1)	28.7 (27.4–30.1)
Alcohol drinking,‡ %	20.7 (19.6–21.9)	21.8 (20.8–22.8)	23.5 (21.9–25.2)	23.3 (22.0–24.6)
Regular leisure-time physical activity,§ %	44.1 (42.4–45.9)	46.8 (45.6–48.1)	20.6 (18.8–22.5)	24.9 (23.4–26.5)
History of CVD, %	3.6 (3.1–4.2)	3.4 (2.6–4.5)	2.4 (1.9–3.0)	1.5 (1.2–2.0)
History of CHD, %	0.8 (0.5–1.1)	0.7 (0.4–1.3)	0.5 (0.3–0.8)	0.2 (0.1–0.4)
History of stroke, %	1.3 (1.0–1.6)	0.8 (0.6–1.1)	0.8 (0.6–1.2)	0.7 (0.4–1.1)
Hypertension, %	33.8 (32.4–35.2)	25.8 (24.7–27.0)	28.3 (26.7–30.0)	23.4 (22.1–24.8)
Use of antihypertensive medication, %	14.6 (13.6–15.7)	9.3 (8.5–10.2)	10.9 (9.8–12.1)	6.6 (5.9–7.4)
Diabetes mellitus, %	15.2 (14.1–16.5)	9.4 (8.6–10.2)	11.0 (9.8–12.2)	6.7 (6.0–7.6)
Use of antidiabetic medication, %	5.9 (5.0–6.9)	3.4 (2.9–3.9)	3.1 (2.5–3.8)	2.2 (1.8–2.7)
Body mass index, kg/m^2	24.8 (24.7–25.0)	23.5 (23.4–23.6)	24.3 (24.1–24.5)	22.9 (22.8–23.0)
Waist circumference, cm	84.3 (84.0–84.6)	80.2 (80.0–80.5)	82.5 (82.1–83.0)	78.3 (78.0–78.7)
Systolic BP, mm Hg	125.4 (124.8–125.9)	121.5 (121.1–121.9)	122.1 (121.4–122.9)	120.3 (119.7–121.0)
Diastolic BP, mm Hg	79.7 (79.3–80.1)	77.5 (77.2–77.8)	78.3 (77.8–78.8)	76.1 (75.8–76.5)
Fasting glucose, mmol/L	5.58 (5.46–5.69)	5.20 (5.17–5.24)	5.32 (5.26–5.38)	5.09 (5.05–5.13)
2-h postload glucose, mmol/L	7.68 (7.49–7.87)	6.74 (6.66–6.82)	7.05 (6.93–7.17)	6.50 (6.41–6.59)
Total cholesterol, mmol/L	5.02 (4.98–5.06)	4.64 (4.62–4.66)	4.81 (4.76–4.87)	4.55 (4.52–4.58)
LDL cholesterol, mmol/L	2.99 (2.95–3.03)	2.70 (2.69–2.72)	2.71 (2.67–2.76)	2.50 (2.47–2.52)
HDL cholesterol, mmol/L	1.12 (1.11–1.13)	1.40 (1.40–1.41)	1.09 (1.08–1.11)	1.42 (1.41–1.43)
Triglycerides, mmol/L	2.24 (2.20–2.29)	1.16 (1.15–1.17)	2.23 (2.17–2.29)	1.13 (1.11–1.14)

Mean values (95% confidence interval) or percentages (95% confidence interval) are shown. CVD indicates cardiovascular disease; CHD, coronary heart disease; BP, blood pressure; LDL, low-density lipoprotein; and HDL, high-density lipoprotein. To convert from millimoles per liter to milligrams per deciliter, divide by 0.05551 for glucose, by 0.02586 for total, HDL, and LDL cholesterol, and by 0.01129 for triglycerides.

*Dyslipidemia was defined as total cholesterol ≥6.22 mmol/L (≥240 mg/dL), and/or LDL cholesterol ≥4.14 mmol/L (≥160 mg/dL), and/or HDL cholesterol <1.04 mmol/L (<40 mg/dL), and/or use of lipid-lowering medications.

†Cigarette smoking was defined as having smoked ≥100 cigarettes in one's lifetime.

‡Alcohol drinking was defined as consumption of ≥30 g of alcohol per week for ≥1 y.

§Regular leisure-time physical activity was defined as participation in ≥30 minutes of moderate or vigorous activity per day ≥3 d/wk.

region, urbanization, economic development, and population size in China in 2008.

Results

Table 1 shows the demographic and clinical characteristics of study participants by dyslipidemia status in urban and rural areas.

Mean Lipid and Lipoprotein Levels

The age and gender-standardized mean levels of total, HDL, and LDL cholesterol and triglycerides were 4.72, 1.30, 2.68, and 1.57 mmol/L, respectively, in the general Chinese population aged ≥20 years (Table 2). Overall, the age-standardized mean levels of HDL cholesterol were slightly higher in women than in men, whereas the mean level of triglycerides was higher in men than in women. In addition, age-standardized mean levels of total and LDL cholesterol and triglycerides were significantly higher in residents living in urban compared with rural China (all $P<0.0001$). This was true for both men and women. In general, HDL and LDL cholesterol levels increased continuously over the entire age range in both men and women. Triglyceride levels increased with age until 49 years in men and 69 years in women and then decreased.

Prevalence of Dyslipidemia

The age-standardized prevalence of borderline high total cholesterol (5.18–6.21 mmol/L) and high total cholesterol (≥6.22 mmol/L) was 22.5% and 9.0%, respectively (Table 3). This represents 220 million Chinese adults aged ≥20 years with borderline high total cholesterol and 88 million persons with high total cholesterol. The prevalence of borderline high and high total cholesterol increased with age in both men and women (Figure 2, top). In addition, the prevalence of borderline high (25.1% versus 20.5% for men, $P<0.0001$; 24.4% versus 20.7% for women, $P=0.0003$) and high total cholesterol (10.2% versus 7.5% for men, $P=0.0001$; 10.0% versus 8.7% for women, $P=0.06$) was more common in urban residents than in rural residents (Figure 3, top).

The age-standardized prevalence of borderline high (3.37–4.13 mmol/L), high (4.14–4.91 mmol/L), and very high

Table 2. Mean (95% Confidence Interval) of Serum Total Cholesterol, HDL Cholesterol, LDL Cholesterol, and Triglyceride Levels in Chinese Adults Aged ≥20 Years, 2007–2008

	Serum Cholesterol, mmol/L*			Serum Triglycerides, mmol/L*
	Total	HDL	LDL	
Age-adjusted†				
Overall‡	4.72 (4.70–4.73)	1.30 (1.29–1.30)	2.68 (2.67–2.70)	1.57 (1.55–1.58)
Men	4.70 (4.68–4.73)	1.25 (1.24–1.26)	2.68 (2.66–2.70)	1.71 (1.68–1.74)
Women	4.73 (4.71–4.75)	1.35 (1.34–1.36)	2.69 (2.67–2.71)	1.42 (1.40–1.44)
P values for difference§	0.09	<0.0001	0.48	<0.0001
Urban‡	4.79 (4.77–4.81)	1.30 (1.29–1.30)	2.81 (2.79–2.83)	1.61 (1.59–1.63)
Men	4.79 (4.76–4.82)	1.23 (1.22–1.23)	2.81 (2.79–2.84)	1.82 (1.78–1.86)
Women	4.79 (4.76–4.81)	1.37 (1.36–1.38)	2.81 (2.78–2.83)	1.40 (1.38–1.43)
P values for difference§	0.76	<0.0001	0.62	<0.0001
Rural‡	4.66 (4.63–4.68)	1.30 (1.29–1.31)	2.58 (2.55–2.60)	1.53 (1.50–1.55)
Men	4.63 (4.59–4.67)	1.27 (1.25–1.28)	2.56 (2.53–2.59)	1.62 (1.58–1.67)
Women	4.69 (4.65–4.72)	1.34 (1.32–1.35)	2.59 (2.56–2.62)	1.43 (1.40–1.46)
P values for difference§	0.02	<0.0001	0.23	<0.0001
Sex- and age-specific				
Men, age, y				
20–29	4.36 (4.29–4.42)	1.22 (1.20–1.24)	2.46 (2.40–2.51)	1.47 (1.40–1.53)
30–39	4.67 (4.62–4.72)	1.22 (1.20–1.24)	2.65 (2.61–2.69)	1.84 (1.77–1.92)
40–49	4.79 (4.74–4.84)	1.26 (1.24–1.27)	2.69 (2.65–2.73)	1.90 (1.83–1.96)
50–59	4.83 (4.78–4.88)	1.26 (1.24–1.28)	2.78 (2.74–2.82)	1.74 (1.68–1.81)
60–69	4.83 (4.77–4.89)	1.28 (1.26–1.31)	2.81 (2.76–2.87)	1.51 (1.44–1.58)
≥70	4.86 (4.75–4.97)	1.29 (1.25–1.33)	2.80 (2.69–2.90)	1.56 (1.43–1.68)
P values for linear trend‖	<0.0001	<0.0001	<0.0001	0.07
Women, age, y				
20–29	4.24 (4.18–4.30)	1.35 (1.33–1.37)	2.37 (2.32–2.43)	1.07 (1.03–1.11)
30–39	4.39 (4.35–4.42)	1.34 (1.33–1.35)	2.43 (2.40–2.46)	1.19 (1.16–1.23)
40–49	4.71 (4.68–4.75)	1.34 (1.33–1.35)	2.67 (2.65–2.70)	1.43 (1.40–1.47)
50–59	5.13 (5.08–5.17)	1.35 (1.34–1.37)	2.97 (2.93–3.00)	1.71 (1.66–1.75)
60–69	5.21 (5.15–5.27)	1.36 (1.34–1.39)	3.03 (2.97–3.08)	1.74 (1.67–1.80)
≥70	5.24 (5.12–5.36)	1.38 (1.34–1.42)	3.04 (2.92–3.15)	1.67 (1.55–1.79)
P values for linear trend‖	<0.0001	0.08	<0.0001	<0.0001

HDL indicates high-density lipoprotein; LDL, low-density lipoprotein.

*To convert from millimoles per liter to milligrams per deciliter, divide by 0.02586 for total, HDL, and LDL cholesterol and by 0.01129 for triglycerides.

†Age-adjusted for the entire population by the direct method to the Chinese population estimates for the year 2008.

‡Additionally adjusted for sex.

§*P* values from ANCOVA.

‖*P* values from linear regression.

(≥4.92 mmol/L) LDL cholesterol was 13.9%, 3.5%, and 3.0%, respectively, which represents 134, 34, and 29 million persons, respectively, in the general adult Chinese population aged ≥20 years (Table 3). The prevalence of borderline high and high LDL cholesterol increased with age (Figure 2, bottom). In addition, the prevalence of borderline high (16.7% versus 10.9% for men, $P<0.0001$; 16.8% versus 12.0% for women, $P<0.0001$), high (4.8% versus 2.4% for men, $P<0.0001$; 4.8% versus 2.4% for women, $P<0.0001$), and very high (4.4% versus 1.9% for men, $P<0.0001$; 3.5% versus 2.5% for women, $P=0.01$) LDL cholesterol was higher in urban residents than in rural residents for both men and women (Figure 3, middle).

The age-standardized prevalence of low HDL cholesterol (<1.04 mmol/L) was 22.3% in the general adult population aged ≥20 years in China, which represents 215 million persons (Table 3). The age-standardized prevalence of low HDL cholesterol was higher in urban (28.7%) than in rural (25.7%) men ($P=0.01$). In contrast, it was higher in rural (19.1%) than in urban (15.7%) women ($P=0.0002$) (Figure 3, bottom).

Awareness, Treatment, and Control of Hypercholesterolemia

Among all participants who had borderline high total cholesterol (≥5.18 mmol/L) or who reported using cholesterol-

Table 3. Age-Adjusted Proportion (95% Confidence Interval) of ATP III Classification of Total, LDL, and HDL Cholesterol in Chinese Adults Aged ≥20 Years, 2007–2008

	Prevalence,* % (95% CI)			Estimated No. of Chinese Adults in 2008, No. in Millions (95% CI)		
	Overall	Men	Women	Overall	Men	Women
Serum total cholesterol, mmol/L (mg/dL)						
5.18 (<200)	68.5 (67.7–69.3)	68.7 (67.5–69.9)	68.3 (67.2–69.3)	672.4 (661.4–683.5)	335.0 (325.5–344.6)	337.4 (329.2–345.6)
5.18–6.21 (200–239)	22.5 (21.8–23.3)	22.6 (21.5–23.7)	22.4 (21.4–23.5)	220.4 (212.1–228.8)	110.1 (104.2–116.0)	110.3 (104.1–116.6)
6.22 (≥240)†	9.0 (8.5–9.5)	8.7 (8.1–9.4)	9.3 (8.7–10.0)	88.1 (83.4–92.8)	42.4 (39.1–45.7)	45.7 (42.3–49.1)
Serum LDL cholesterol, mmol/dL (mg/dL)						
<2.59 (<100)	47.7 (46.8–48.5)	47.1 (45.8–48.4)	48.2 (47.2–49.3)	458.1 (448.0–468.3)	224.2 (215.7–232.7)	233.9 (226.7–241.1)
2.59–3.36 (100–129)	31.9 (31.1–32.7)	32.7 (31.5–33.9)	31.1 (30.0–32.2)	306.1 (297.6–314.6)	155.6 (149.1–162.2)	150.4 (144.4–156.5)
3.37–4.13 (130–159)	13.9 (13.3–14.5)	13.6 (12.8–14.5)	14.2 (13.3–15.1)	133.5 (127.0–140.1)	64.9 (60.6–69.2)	68.7 (63.6–73.8)
4.14–4.91 (160–189)	3.5 (3.3–3.8)	3.5 (3.1–4.0)	3.5 (3.2–3.9)	33.8 (31.2–36.5)	16.8 (14.7–18.9)	17.0 (15.4–18.7)
≥4.92 (≥190)†	3.0 (2.8–3.3)	3.1 (2.7–3.5)	3.0 (2.6–3.4)	29.0 (26.3–31.8)	14.8 (12.9–16.6)	14.3 (12.3–16.2)
Serum HDL cholesterol, mmol/L (mg/dL)						
<1.04 (<40)	22.3 (21.6–23.1)	27.1 (25.9–28.3)	17.5 (16.6–18.5)	214.9 (207.0–222.8)	129.7 (123.2–136.2)	85.2 (80.3–90.2)
1.04–1.54 (40–59)	57.4 (56.5–58.2)	57.2 (55.9–58.4)	57.6 (56.4–58.8)	554.0 (543.0–565.1)	273.6 (264.9–282.3)	280.4 (272.0–288.8)
≥1.55 (≥60)	20.3 (19.7–21.0)	15.8 (14.9–16.7)	24.9 (24.0–25.9)	196.7 (190.1–203.2)	75.5 (70.9–80.0)	121.2 (116.3–126.2)

ATP III indicates Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults; LDL, low-density lipoprotein; HDL, high-density lipoprotein; and CI, confidence interval.

*Age-adjusted to the Chinese population estimates for the year 2008 by the direct method. Additional adjustment for sex was conducted for overall population.

†Includes persons on a lipid-lowering medication.

lowering medications, the proportions of those who were aware of their condition were 12.8% in men and 9.3% in women, the proportions of those who were treated were 6.1% in men and 4.1% in women, and the proportions of those who had a total cholesterol concentration <5.18 mmol/L were 3.3% in men and 2.2% in women. In addition, the proportions of those being treated who had a total cholesterol <5.18 mmol/L were 52.1% in men and 55.4% in women. Among those with high total cholesterol (≥6.22 mmol/L) or who reported using cholesterol-lowering medications, the proportions of awareness, treatment, and control (total cholesterol concentration <6.22 mmol/L) in men and women were 27.6% and 20.7%, 21.4% and 14.0%, and 18.3% and 11.2%, respectively. In addition, the proportions of those being treated who had a total cholesterol <6.22 mmol/L were 88.1% in men and 78.4% in women.

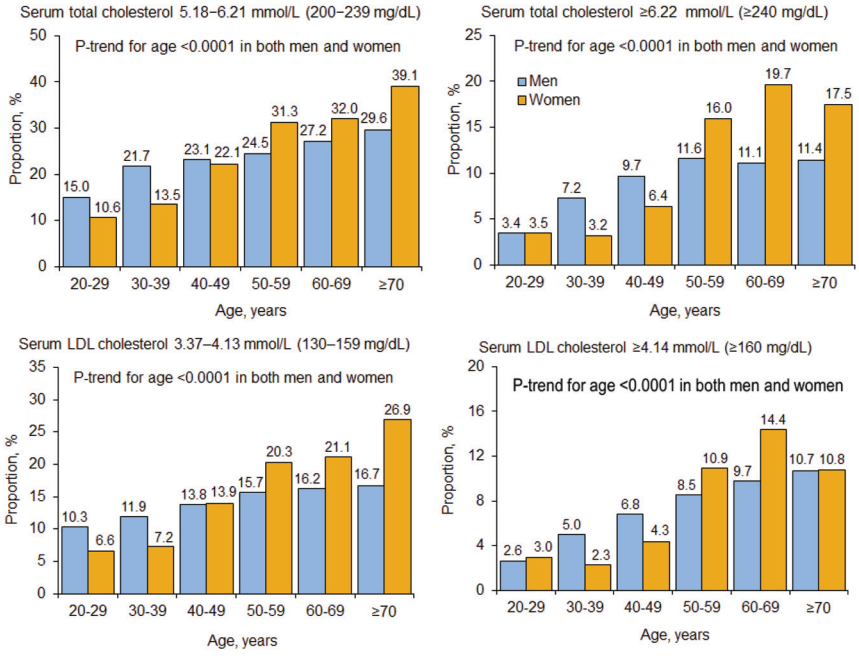

Figure 2. Age-specific proportion of individuals with borderline high and high total cholesterol (top) as well as borderline high and high low-density lipoprotein (LDL) cholesterol (bottom) among adults aged ≥20 years in China, 2007–2008.

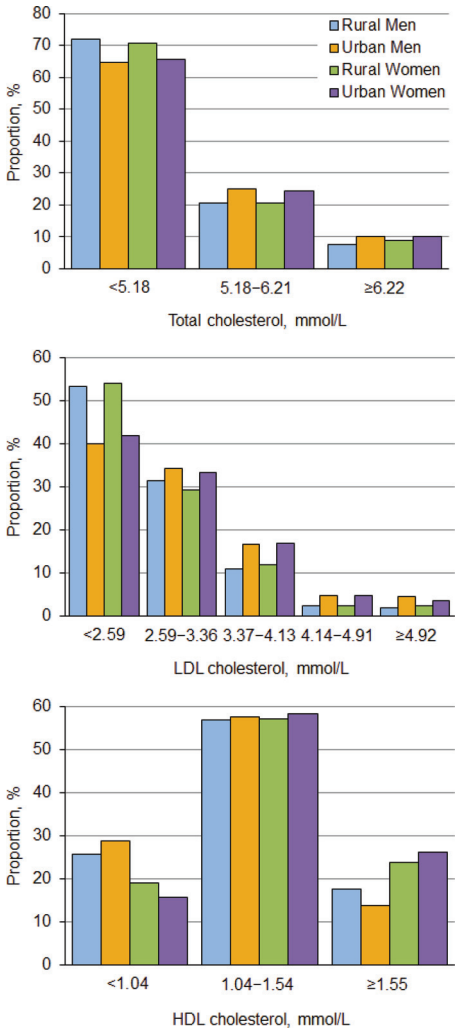

Figure 3. Age-standardized proportions of total cholesterol (top), low-density lipoprotein (LDL) cholesterol (middle), and high-density lipoprotein (HDL) cholesterol (bottom) according to the categories of the Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults among the Chinese population aged ≥20 years by gender and urbanization, 2007–2008.

The proportions of awareness, treatment, and control of high total cholesterol were higher in urban residents than in rural residents, although the difference in the control of borderline high total cholesterol was not statistically significant (Figure 4, top).

Among men and women who had borderline high LDL cholesterol (≥3.37 mmol/L) or who reported using cholesterol-lowering medications, 16.6% and 12.8% were aware of their condition, 9.6% and 6.4% were treated, and 6.6% and 4.1% had an LDL cholesterol <3.37 mmol/L, respectively. In addition, the proportions of those being treated who had an LDL cholesterol <3.37 mmol/L were 73.9% in men and 61.3% in women. Among those with high or very high LDL cholesterol (≥4.14 mmol/L) or who reported using cholesterol-lowering medications, the proportions of awareness, treatment, and control (LDL cholesterol <4.14 mmol/L) were 36.1% and 29.1%, 28.8% and 20.7%, and 25.3% and 16.8% in men and women, respectively. In addition, the proportions of those being treated who had an LDL cholesterol <4.14 mmol/L were 93.0% in men and 76.1% in women. The proportions of awareness, treatment, and control of high LDL cholesterol were not statistically different between urban and rural residents, except that urban residents had a higher awareness of borderline high LDL (Figure 4, bottom).

Metabolic Factors and Lipid and Lipoprotein Levels

There were strong, positive, and significant associations between body mass index, waist circumference, blood pressure, fasting plasma glucose, and 2-hour postload glucose with serum total and LDL cholesterol and triglycerides in both men and women (Table 4). Body mass index and waist circumference were inversely associated with HDL cholesterol in both men and women, but fasting and 2-hour postload glucose levels were inversely associated with HDL only in men.

Discussion

Our study indicates that mean levels of total and LDL cholesterol and triglycerides are much higher than reported previously in the general Chinese adult population.[13–16] Furthermore, our study suggests that 31.5% of the Chinese general population aged ≥20 years or 308 million persons have borderline high or high total cholesterol, whereas 20.4% or 196 million persons have a borderline high, high, or very high level of LDL cholesterol. Among those who have elevated total or LDL cholesterol, the proportions of patients who are aware, treated, and controlled are very low. The present study documents a large and increasing burden of high serum total and LDL cholesterol in the Chinese general population.

Several previous epidemiological studies reported serum lipid levels in Chinese populations.[13–16] The People's Republic of China–United States Collaborative Study included 8975 rural and urban residents aged 35 to 54 years from Beijing and Guangzhou, whereas the InterASIA Study included a nationally representative sample of 15 540 Chinese adults aged 35 to 74 years.[15] The 2002 China National Nutrition and Health Survey measured serum lipids in a nationally representative sample of 49 252 Chinese aged ≥18 years and provided the best comparison data for our study.[16] Overall mean serum total cholesterol level was 3.81 mmol/L (3.81 in men and 3.82 in women), HDL cholesterol level was 1.30 mmol/L (1.26 in men and 1.33 in women), and triglyceride level was 1.10 mmol/L (1.13 for men and 1.05 for women) in National Nutrition and Health Survey participants. Our study, which was conducted only 5 to 6 years later, documented a 23.9% (or 0.91 mmol/L) increase in total cholesterol and a 42.7% (or 0.47 mmol/L) increase in triglycerides. These increases are very dramatic and deserve further investigation. These increases are unlikely due to changes in laboratory measurement methods, because HDL cholesterol levels, which are influenced little by dietary changes, were identical in the 2 studies. The differences in sampling methods cannot explain the entire increase in serum lipid levels either. The 2002 National

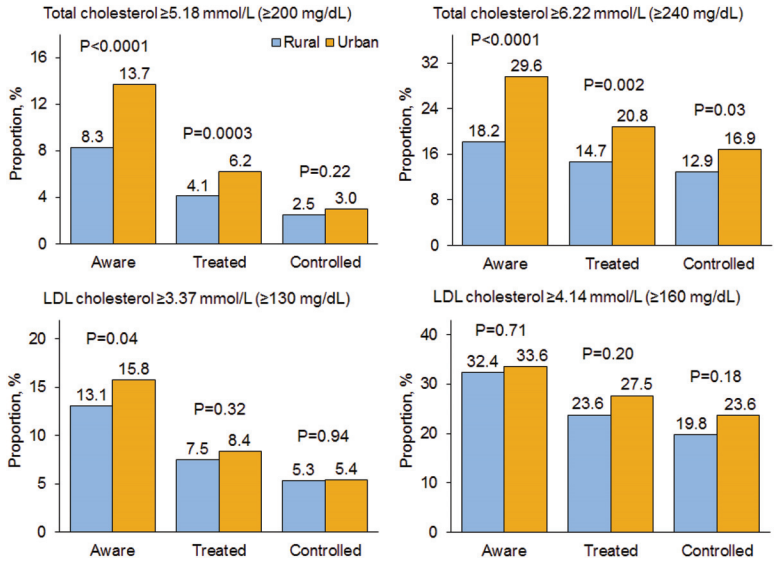

Figure 4. Awareness, treatment, and control of high total cholesterol (top) and high low-density lipoprotein (LDL) cholesterol (bottom) among the Chinese adult population aged ≥20 years by gender and urbanization, 2007–2008.

Nutrition and Health Survey oversampled rural Chinese populations, and the final lipid estimates were not weighted by the sampling scheme and the Chinese general population distribution. However, the mean levels of serum total cholesterol and triglycerides are significantly higher in both rural and urban residents in our study than those in the 2002 National Nutrition and Health Survey. Therefore, the observed rapid increase in serum total cholesterol and triglycerides is most likely real and could continue without effective intervention.

These study findings have important public health implications. Traditionally, mortality from atherosclerotic cardiovascular diseases has been infrequent in China and is estimated to be only approximately one tenth of that in Western populations.[17] Although cardiovascular diseases have rapidly increased recently, coronary heart disease mortality remained low. For example, coronary heart disease mortality (85.5/10^5 person-years) was only one third of stroke mortality (276.9/10^5 person-years) in the Chinese population.[2] A low serum total cholesterol level related to a low habitual dietary intake of fat and cholesterol was considered the main underlying reason for the low atherosclerotic cardiovascular mortality in China.[17] The present study noted a relatively high mean level of serum cholesterol but a low rate of hypercholesterolemia control. Clinical trials have documented that a 10% difference in serum cholesterol was associated with ≈15% difference in risk of coronary heart disease.[18] Without a national emphasis on prevention and control of hypercholesterolemia, atherosclerotic cardiovascular diseases will soar in the near future in China, which will add extra pressure to an already overburdened healthcare system.

In contrast to the experience of the Chinese population, serum cholesterol levels have declined in most populations in the world during the past several decades.[7,19–21] For example, the Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group estimated that total cholesterol declined ≈0.2 mmol/L per decade for both sexes in Australasia, North America, and Europe.[7] In the United States, the mean level of total cholesterol declined from 5.75 to 5.26 mmol/L during 1960–1962 and 1999–2002.[20] Additionally, the mean level of LDL cholesterol declined from 3.57 to 2.97 mmol/L during 1976–1980 and 2005–2006.[21] The rapid increase in serum lipid levels in the Chinese population is troublesome given the global trend of reduction of serum lipids. Economic growth and associated changes in lifestyle and diet might contribute to the increase in serum lipid levels in the Chinese population. For example, the mean level of serum cholesterol was much higher in the regions with faster economic growth, such as Shanghai and Beijing, in our study and others.[22,23] The proven approaches for lipid reduction in Western populations, including national and local cholesterol education programs; use of financial and regulatory mechanisms to encourage healthy lifestyle, including healthy diets; widespread use of statins and other lipid-lowering drugs; and population-based surveillance of serum cholesterol, can be applied to the Chinese populations for the prevention and control of high serum lipids.

Among individuals with elevated total and LDL cholesterol, the proportion of those who were aware, treated, or controlled for their condition was much lower than in Western populations[24] and should be a reason for great concern. To improve the awareness, treatment, and control of hypercholesterolemia, a comprehensive intervention approach targeting both population and individual levels should be applied.[12,25] The government and health policymakers can play an important role through healthcare system reform to provide coverage for routine cholesterol screening and make lipid-lowering medications affordable or reduce/eliminate drug copayments.

Our study indicated that obesity is an important determinant of serum lipid levels. These findings are consistent with previous reports.[26–28] Furthermore, our study indicates that lifestyle factors, such as cigarette smoking, alcohol consumption, and physical activity, are related to serum lipids. Lifestyle modification should be an important approach for the primary prevention of hypercholesterolemia in communities.[12,28–30]

Table 4. Age-Adjusted Mean (95% Confidence Interval) of Serum Lipid Levels by Metabolic Risk Factors

	Serum Cholesterol, mmol/L			Serum Triglycerides, mmol/L
	Total	HDL	LDL	
Men				
Body mass index, kg/m^2				
<25	4.58 (4.55–4.61)	1.29 (1.28–1.30)	2.59 (2.56–2.61)	1.44 (1.41–1.47)
25–29	4.91 (4.87–4.95)	1.19 (1.17–1.20)	2.85 (2.81–2.88)	2.14 (2.08–2.20)
≥30	5.05 (4.95–5.14)	1.16 (1.13–1.19)	2.87 (2.78–2.96)	2.46 (2.33–2.59)
P values for linear trend*	<0.0001	<0.0001	<0.0001	<0.0001
Waist circumference, cm				
<90	4.61 (4.58–4.64)	1.28 (1.27–1.29)	2.61 (2.59–2.63)	1.51 (1.48–1.55)
≥90	4.95 (4.91–4.99)	1.18 (1.17–1.19)	2.86 (2.82–2.89)	2.23 (2.17–2.29)
P values for linear trend*	<0.0001	<0.0001	<0.0001	<0.0001
Systolic/diastolic blood pressure, mm Hg				
<120/80	4.56 (4.51–4.61)	1.24 (1.23–1.26)	2.56 (2.52–2.60)	1.44 (1.39–1.48)
120–139/80–89	4.72 (4.68–4.76)	1.26 (1.24–1.27)	2.69 (2.65–2.72)	1.71 (1.67–1.76)
≥140/90	4.89 (4.84–4.94)	1.23 (1.22–1.25)	2.80 (2.76–2.84)	2.06 (1.99–2.13)
P values for linear trend*	<0.0001	0.28	<0.0001	<0.0001
Fasting plasma glucose, mmol/L (mg/dL)				
<5.6 (<100)	4.65 (4.62–4.67)	1.26 (1.25–1.27)	2.64 (2.62–2.66)	1.60 (1.57–1.64)
5.6–6.9 (100–125)	4.85 (4.80–4.90)	1.24 (1.22–1.26)	2.77 (2.72–2.81)	1.97 (1.90–2.05)
≥7.0 (≥126)	4.98 (4.86–5.11)	1.20 (1.16–1.24)	2.88 (2.79–2.97)	2.40 (2.19–2.61)
P values for linear trend*	<0.0001	0.002	<0.0001	<0.0001
2-h postload glucose, mmol/L (mg/dL)				
<7.8 (140)	4.65 (4.62–4.67)	1.26 (1.25–1.27)	2.65 (2.63–2.67)	1.61 (1.57–1.64)
7.8–11.1 (140–199)	4.91 (4.81–5.00)	1.25 (1.22–1.27)	2.75 (2.70–2.81)	2.04 (1.94–2.14)
≥11.1 (≥200)	5.01 (4.91–5.11)	1.18 (1.14–1.22)	2.89 (2.81–2.96)	2.52 (2.30–2.75)
P values for linear trend*	<0.0001	0.0003	<0.0001	<0.0001
Cigarette smoking				
Current smokers	4.68 (4.65–4.72)	1.24 (1.23–1.25)	2.65 (2.62–2.69)	1.74 (1.69–1.78)
Former smokers	4.74 (4.65–4.82)	1.25 (1.22–1.28)	2.67 (2.60–2.74)	1.84 (1.72–1.96)
Never smokers	4.72 (4.68–4.75)	1.26 (1.24–1.27)	2.70 (2.67–2.73)	1.64 (1.60–1.69)
P values for linear trend*	0.22	0.10	0.04	0.004
Women				
Body mass index, kg/m^2				
<25	4.66 (4.64–4.69)	1.37 (1.36–1.38)	2.63 (2.61–2.66)	1.31 (1.29–1.33)
25–29	4.94 (4.89–4.98)	1.31 (1.29–1.32)	2.83 (2.80–2.87)	1.67 (1.62–1.71)
≥30	4.92 (4.84–5.00)	1.28 (1.25–1.31)	2.83 (2.76–2.90)	1.80 (1.73–1.88)
P values for linear trend*	<0.0001	<0.0001	<0.0001	<0.0001
Waist circumference, cm				
<80	4.63 (4.60–4.66)	1.38 (1.37–1.39)	2.59 (2.57–2.62)	1.24 (1.21–1.27)
≥80	4.90 (4.86–4.93)	1.31 (1.30–1.32)	2.82 (2.79–2.84)	1.68 (1.64–1.71)
P values for linear trend*	<0.0001	<0.0001	<0.0001	<0.0001
Systolic/diastolic blood pressure, mm Hg				
<120/80	4.58 (4.54–4.61)	1.33 (1.32–1.34)	2.60 (2.57–2.63)	1.26 (1.23–1.29)
120–139/80–89	4.80 (4.76–4.83)	1.36 (1.34–1.37)	2.73 (2.70–2.76)	1.46 (1.43–1.50)
≥140/90	5.00 (4.93–5.06)	1.34 (1.32–1.35)	2.88 (2.83–2.93)	1.66 (1.60–1.72)
P values for linear trend*	<0.0001	0.64	<0.0001	<0.0001

(*Continued*)

Table 4. Continued

	Serum Cholesterol, mmol/L			Serum Triglycerides, mmol/L
	Total	HDL	LDL	
Fasting plasma glucose, mmol/L (mg/dL)				
<5.6 (<100)	4.68 (4.66–4.71)	1.35 (1.35–1.36)	2.65 (2.63–2.67)	1.35 (1.33–1.37)
5.6–6.9 (100–125)	4.92 (4.88–4.97)	1.34 (1.32–1.35)	2.84 (2.80–2.88)	1.61 (1.56–1.65)
≥7.0 (≥126)	5.19 (5.05–5.32)	1.32 (1.27–1.37)	3.01 (2.90–3.12)	2.00 (1.88–2.11)
P values for linear trend*	<0.0001	0.15	<0.0001	<0.0001
2-h postload glucose, mmol/L (mg/dL)				
<7.8 (140)	4.69 (4.66–4.71)	1.36 (1.35–1.36)	2.67 (2.65–2.69)	1.33 (1.31–1.36)
7.8–11.1 (140–199)	4.93 (4.87–4.99)	1.34 (1.32–1.36)	2.77 (2.72–2.82)	1.69 (1.63–1.76)
≥11.1 (≥200)	5.04 (4.93–5.15)	1.33 (1.29–1.38)	2.85 (2.75–2.95)	1.85 (1.74–1.96)
P values for linear trend*	<0.0001	0.34	0.0005	<0.0001
Cigarette smoking				
Current smokers	4.67 (4.55–4.78)	1.32 (1.28–1.37)	2.66 (2.57–2.76)	1.57 (1.46–1.67)
Former smokers	4.72 (4.52–4.92)	1.29 (1.22–1.36)	2.65 (2.46–2.85)	1.89 (1.60–2.19)
Never smokers	4.74 (4.72–4.76)	1.35 (1.34–1.36)	2.69 (2.67–2.71)	1.42 (1.40–1.44)
P values for linear trend*	0.21	0.25	0.57	0.005

HDL indicates high-density lipoprotein; LDL, low-density lipoprotein. To convert from millimoles per liter to milligrams per deciliter, divide by 0.02586 for total, HDL, and LDL cholesterol and by 0.01129 for triglycerides.

**P* values from linear regression.

Our study was conducted in a large representative sample of the Chinese adult population in which a high response rate was achieved. Standard protocols and instruments along with strict training processes for data collection and a vigorous quality assurance program were employed to ensure that the data we collected were of high quality. For all of these reasons, this study provides the most reliable and up-to-date information on lipids and lipoproteins in the adult population in China. Our study, however, also has several limitations. For instance, women were overrepresented in our study. The inclusion criteria of current residence for ≥5 years make a large number of male migrant workers ineligible for this study. In addition, the response rate was lower in men than in women. We took these issues into account when calculating statistical weights. However, if the lipid values of migrants to urban settings differ from those of nonmigrants in the same age group, the overall lipid levels in rural men are most likely to be underestimated. Dietary intake and work-related physical activity were not assessed in our study, and therefore their effect on serum lipids cannot be examined. Furthermore, we could not classify the study participants into Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults risk categories because of the lack of necessary information.

This large national survey of serum lipids and lipoproteins indicated that the mean serum total and LDL cholesterol and triglyceride levels were high and increasing in the Chinese population. Furthermore, the awareness, treatment, and control rates of hypercholesterolemia were low. Without effective intervention, atherosclerotic cardiovascular diseases are projected to soar in the near future in China. These study findings argue for a public health priority shift to focus more on the prevention and control of chronic diseases, such as hyperlipidemia and associated atherosclerotic cardiovascular diseases, in China.

Sources of Funding

This study was supported by the Chinese Medical Association Foundation and Chinese Diabetes Society. The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The authors had final responsibility for the decision to submit for publication.

Disclosures

None.

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CLINICAL PERSPECTIVE

Because of rapid changes in lifestyle risk factors, cardiovascular disease has become the leading cause of death in China. We sought to estimate the national levels of serum lipids and lipoproteins among the Chinese adult population. We conducted a cross-sectional study in a nationally representative sample of 46 239 adults aged ≥20 years. Fasting serum total, high-density lipoprotein, and low-density lipoprotein cholesterol and triglycerides were measured by standard methods. The age-standardized estimates of total, high-density lipoprotein, and low-density lipoprotein cholesterol and triglycerides were 4.72 (95% confidence interval, 4.70–4.73), 1.30 (1.29–1.30), 2.68 (2.67–2.70), and 1.57 (1.55–1.58) mmol/L, respectively, in the Chinese adult population. In addition, 22.5% (21.8–23.3%) or 220.4 million (212.1–228.8) Chinese adults had borderline high total cholesterol (5.18–6.21 mmol/L), whereas 9.0% (8.5–9.5%) or 88.1 million (83.4–92.8) had high total cholesterol (≥6.22 mmol/L). The population estimates for borderline high (3.37–4.13 mmol/L), high (4.14–4.91 mmol/L), and very high (≥4.92 mmol/L) low-density lipoprotein cholesterol were 13.9% (13.3–14.5%) or 133.5 million (127.0–140.1), 3.5% (3.3–3.8%) or 33.8 million (31.2–36.5), and 3.0% (2.8–3.3%) or 29.0 million (26.3–31.8) persons, respectively. In addition, 22.3% (21.6–23.1%) or 214.9 million (207.0–222.8) persons had low high-density lipoprotein cholesterol (<1.04 mmol/L). The awareness, treatment, and control of borderline high or high total cholesterol were 11.0%, 5.1%, and 2.8%, respectively, in the Chinese adult population. These data indicate that serum total and low-density lipoprotein cholesterol levels are high and increasing in the Chinese population. Without effective intervention, atherosclerotic cardiovascular diseases will soar in the near future in China.

Serum Lipids and Lipoproteins in Chinese Men and Women

Wenying Yang, Jianzhong Xiao, Zhaojun Yang, Linong Ji, Weiping Jia, Jianping Weng, Juming Lu, Zhongyan Shan, Jie Liu, Haoming Tian, Qiuhe Ji, Dalong Zhu, Jiapu Ge, Lixiang Lin, Li Chen, Xiaohui Guo, Zhigang Zhao, Qiang Li, Zhiguang Zhou, Guangliang Shan and Jiang He

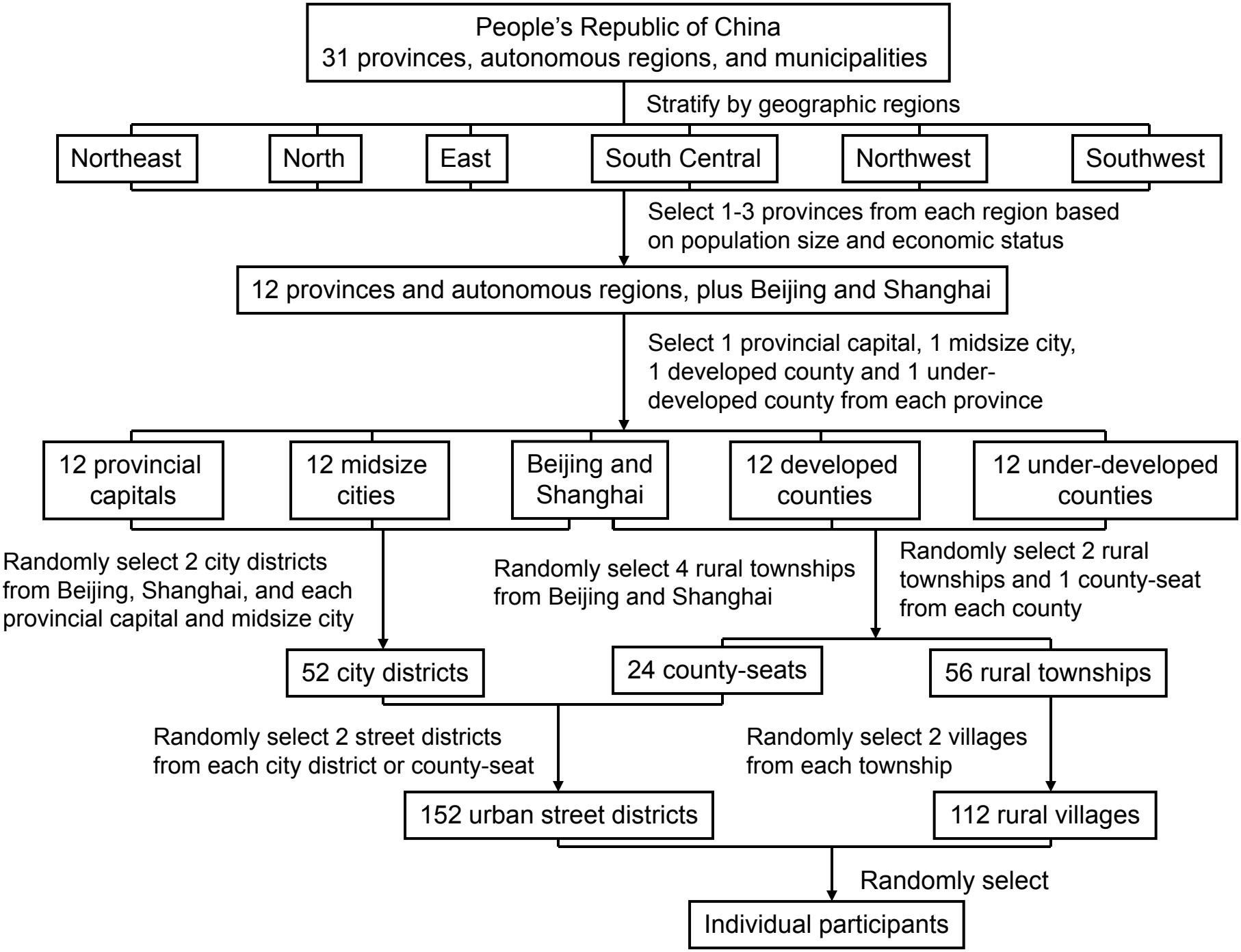
Circulation. 2012;125:2212-2221; originally published online April 9, 2012;
doi: 10.1161/CIRCULATIONAHA.111.065904
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Print ISSN: 0009-7322. Online ISSN: 1524-4539

SUPPLEMENTAL MATERIAL

Supplementary Figure

Flowchart of the multistage stratified sampling procedure in the China National Diabetes and Metabolic Disorder Study. In the first stage, 12 provinces and autonomous regions were selected from 6 geographic regions, in addition to the municipalities of Beijing and Shanghai. In the second stage, one midsize city (population 200,000-1,000,000), one developed and one underdeveloped county, which were at approximately the 67^{th} and 33^{rd} percentiles of gross domestic product (GDP) per capita among all counties within each province, respectively, were selected, plus the provincial capitals. The first two stages of sampling were not random. In the third stage, two city regions from Beijing, Shanghai, and each provincial capital and a midsize city were randomly selected (a total of 52 city districts). In addition, the county seat from each county, 24 in total were selected. Two rural townships were randomly selected from each county and four rural townships were randomly selected from the Beijing and Shanghai countryside (a total of 56 townships). In the fourth stage, two street districts or rural villages (about 500-1,000 households) were randomly selected from each urban city district (or county seat) and rural township, respectively. The final stage of sampling was stratified by gender and by age distribution based on the 2006 China Population Data.


People's Republic of China
31 provinces, autonomous regions, and municipalities
Stratify by geographic regions
Northeast
North
East
South Central
Northwest
Southwest
Select 1-3 provinces from each region based on population size and economic status
12 provinces and autonomous regions, plus Beijing and Shanghai
Select 1 provincial capital, 1 midsize city, 1 developed county and 1 under-developed county from each province
12 provincial capitals
12 midsize cities
Beijing and Shanghai
12 developed counties
12 under-developed counties
Randomly select 2 city districts from Beijing, Shanghai, and each provincial capital and midsize city
Randomly select 4 rural townships from Beijing and Shanghai
Randomly select 2 rural townships and 1 county-seat from each county
52 city districts
24 county-seats
56 rural townships
Randomly select 2 street districts from each city district or county-seat
Randomly select 2 villages from each township
152 urban street districts
112 rural villages
Randomly select
Individual participants

Appendix

China National Diabetes and Metabolic Disorders Study Group

Statistics analysis team:

Guangliang Shan, Peking Union Medical College, Beijing, China

Wenying Yang, Jianzhong Xiao and Zhaojun Yang, China-Japan Friendship Hospital, Beijing, China

Jiang He, Chung-Shiuan Chen, Tulane University School of Public Health and Tropical Medicine, New Orleans, LA, USA

Consulting members:

Kunsan Xiang, Jialun Chen, Changyu Pan, Zuzhi Fu

Field centers (all field centers contributed to this work equally)

China-Japan Friendship Hospital, Beijing, China: Wenying Yang (principal investigator), Jianzhong Xiao, Zhaojun Yang, Danjie Ruan (Huairou 1st Hospital), Yufeng Li (Pinggu Hospital), Shi Bu, Hongliang Li, Peng Wang, Xueli Liu, and Zhiyun Xiao.

Chinese PLA General Hospital, Beijing, China: Juming Lu (principal investigator), Jingtao Dou, Nan Jin, Jing Li, Shuyu Wang, Baojing Zhang, and Liguang Dong.

Third Hospital, Sun Yat-sen University, Guangzhou, China: Jianping Weng (principal investigator), Longyi Zeng, Panwei Mu, Yanhua Zhang, Qiuqiong Yu, Keyi Lin, Yan Sun, and Xiaodong Xu.

Shanghai Jiaotong University Affiliated Sixth People's Hospital, Shanghai, China: Weiping Jia (principal investigator), Xuhong Hou, Xiaojing Ma, Huijuan Lu, Dajing Zou (Changhai Hospital), Renming Hu (Huashan Hospital), Huilin Gu (Huayang Communities), Youhua Yao (Linfen Communities), Weizhen Shen (Pengpu Communities), Junbin Huang (Tianmu

Communities), and Zhijian Pan (Anting Communities)

Peking University Peoples' Hospital, Beijing, China: Linong Ji (principal investigator), Xianghai Zhou, Xueyao Han, Xiuying Zhang, Yingying Luo, Xiuqing Sun, Dong Zhao (Luhe Hospital), Huifang Xing (Mentougou Hospital), Lei Liu (Haidianqu), and Xinquan Zhang (Jingyuan Hospital)

The First Affiliated Hospital, Chinese Medical University, Liaoling, China: Zhongyan Shan (principal investigator), Yaxin Lai, Xiaochun Teng, Ling Shan, Jiani Wang, Liangfeng Shi, Sen Wang, Li Lu, Fengwei Jiang, and Beibei Wang.

Shanxi Province People's Hospital, Shanxi, China: Jie Liu (principal investigator), Ling Hu, and Yuying Hou (Shan Xi Medical University).

West China Hospital, Sichuan University, Sichuan, China: Haoming Tian (principal investigator), Xingwu Ran, Yan Ren, and Hongling Yu; the First People's Hospital of Liangshan Yi Nationality Autonomy District, Xichan City (Lisheng Cao, Hualin Lu, Xiaohua Xie); Yulin Community Health Center of Wuhou District, Chengdu (Xilian Gao); and the First Hospital of Longquyi District, Chengdu (Zhong Li).

Xijing Hospital, Fourth Military Medical University, Shaanxi, China: Qiuhe Ji (principal investigator), Fei Chen, and Yaping Zhang.

The Affiliated Drum Tower Hospital of Nanjing University Medical School, Jiangsu, China: Dalong Zhu (principal investigator), Yun Hu, Guoyu Tong, Ning Xu, Jinluo Cheng, Junjian Chen, Fei Wang, and Jiong Pei.

Xinjiang Uygur Autonomous Region's Hospital, Xingjiang, China: Jiapu Ge (principal investigator), Wan Yi, Rong Wang (Bayi Steel's Hospital), Gang Han, Huijie Mu (Habahe County Hospital), and Maimaiti Aireti (Moyu County Hospital).

Fujian Provincial Hospital, Fujian, China: Lixiang Lin (principal investigator), Gang Chen, Jingxin Zhao, Shuyu Yang, and Mingzhu Lin (Xiamen 1st Hospital), Yadong Zhang, Fengyuan Zhu (Sanming 1st Hosptial), Mei Tu (Longyan 1st Hospital), Shanghua Xu (Nanping 1st Hospital), and Weihong Lin (Jiangle County Hospital).

Qilu Hospital of Shandong University, Shandong, China: Li Chen (principal investigator), Yu Sun, Xiaolin Dong (Jinan Central Hospital), Yiling Fu, Kehua Zhou, Jinbo Liu, Zhenzuo Li, Yuxin Xu, Peng Lin, and Wenjuan Li.

Peking University First Hospital, Beijing, China: Xiaohui Guo (principal investigator), Junqing Zhang, Aimei Dong, Dongming Huang and Changchun Xue (Daxinqu Hospital) and Junqing Liu (Shichahai Community).

Henan Province People's Hospital, Henan, China: Zhigang Zhao (principal investigator), Guijun Qin, Yong Yan, Peiyu Yao, and Qinchu Li.

Haerbin Medical University Second Hospital, Heilongjiang, China: Qiang Li (principal investigator), Kaiting Chen, Nannan Wu, Yan Feng, Xiaoying Liu, and Guozhong Li. Xiangya Second Hospital, Hunan, China: Zhiguang Zhou (principal investigator), Weili Tang, Qiong Feng, Yuju Qin, Xinwen Qiu, Diaoxiang Xiao, Aiping Qin, Bin Liao, Zifang Gao, and Liang Xiang.