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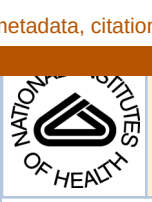

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The Expanding Burden of Cardiometabolic Risk in China: the China Health and Nutrition Survey

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Abstract

Background—China faces a major increase in cardiovascular disease, yet there is limited population-based data on risk factors, particularly in children.

Methods and Results—Fasting blood samples, anthropometry and blood pressure were collected on 9,244 children and adults aged ≥7 years in late 2009 as part of the national China Health and Nutrition Survey. Prevalent overweight, elevated blood pressure, and cardiometabolic risk factors: glucose, HbA1c, triglycerides (TG), total cholesterol (TC), high and low density lipoprotein cholesterol (HDL-C and LDL-C), and C-reactive protein (CRP) are presented.

Results—11% of Chinese children and 30% of Chinese adults are overweight. Rates of diabetes, dyslipidemia, hypertension, and inflammation are high and increased with age and were associated with urbanization. Approximately 42% of children have at least one of the following: pre-diabetes or diabetes, hypertension, high TC, LDL-C, TG, and CRP and low HDL-C, as do 70% males and 60% females aged 18–40 years and >86% of males and females ≥40 years.

Conclusions—HbA1c findings suggest that as many as 29.4 million Chinese children and 415.8 million Chinese adults may be prediabetic or diabetic. The high prevalence in less urban areas and across all income levels suggests that cardiometabolic risk is pervasive across rural and urban China.

Keywords

China; children; diabetes; cardio-metabolic; adults

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Introduction

Obesity rates in China across all age-gender groups have risen greatly in the past two decades with particularly profound increases in BMI in children at the upper portion of the distribution over the past decade[1, 2]. Concurrently, China has seen a major increase in cardiometabolic risk, including high rates of hypertension, stroke and diabetes [3–5]. Underlying factors, such as diet and physical activity have also changed, including increased consumption of refined carbohydrates, saturated fat, and added sugars, and declines in work, leisure and transport-related physical activity [1, 6]. These changes extend to poor and rural areas, where the most rapid increases in overweight and obesity have recently occurred [7]. With China's rapid economic growth, the burden of obesity has shifted to lower income groups, mirroring what is typically seen in high income countries [8]. Further complicating the disease profile in China is the relatively higher cardiometabolic risk at relatively low body mass index (BMI) [9] and at younger ages [10] in Asian populations as well as higher insulin resistance relative to Western populations, even at the same level of BMI [11].

Using a representative, randomly selected sample from nine provinces across China, with anthropometry, blood pressure measures and fasting blood samples from 9,244 individuals aged 7 and older, we examine age and sex-specific prevalence of overweight, hypertension, and biomarkers of diabetes, dyslipidemia, and inflammation. In addition, we examine differences in cardiometabolic risk factors across levels of urbanization and income. Further, we provide a comparative analysis of cardiometabolic risk relative to patterns in the US and in other Asian countries.

Methods

The China Health and Nutrition Survey (CHNS) is the only large-scale longitudinal, household-based survey in China [12]. The CHNS has followed individuals randomly selected from 228 communities and designed to represent a set of large provinces with a range of economic and demographic variation, covering approximately 56% of China's population, including Liaoning, Shandong, Heilongjiang, Henan, Jiangsu, Hubei, Hunan, Guizhou, and Guangxi (from north to south). The CHNS age and gender distribution is slightly older than that of the Chinese census for 2009, since Muslim provinces which have higher fertility rates that other parts of China were not included in the CHNS. Thus, CHNS includes approximately 3% more individuals aged 60 and older and 3% fewer children and adolescents compared to the national China census [12]. A multistage, random cluster process was used to draw the sample in each province, with the baseline survey in 1989, and fasting blood collected for the first time in 2009. The analysis sample includes 9,244 individuals aged 7 and older who provided fasting blood and anthropometry in 2009. Unlike other surveys, the number of individuals who provided anthropometry is slightly greater (79 more individuals) than those providing blood samples, likely due to the ordering of data collection. There were no statistically significant differences in overweight and age between individuals providing blood and anthropometry data. The sample of 2009 participants represented 85.6% of the 2006 participants. Survey protocols, instruments, and the process for obtaining informed consent for this study were approved by the institutional review committees of the University of North Carolina at Chapel Hill, the National Institute of Nutrition and Food Safety, Chinese Center for Disease Control and Prevention, and the China-Japan Friendship Hospital, Ministry of Health.

During home visits spanning 3 days, survey data were collected through interviews with each household member, including anthropometrics (height, weight, skinfold thicknesses and body circumferences), detailed individual and household level dietary data, measures of time spent in a wide range of daily activities and detailed individual, household and

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community socio-demographic data [12]. Individuals older than 7 years visited a neighbourhood clinic to have trained physicians collect fasting blood samples. Individuals unable to attend the clinic had blood samples collected at home. To avoid missing children in boarding schools and migrant workers, special efforts were made to schedule visits in early morning or in the weekend when these participants were at home. All interviewers had 7 days of training provided by the collaborating teams and were overseen via site visits to monitor data collection in each site visit by the University of North Carolina at Chapel Hill, the China Centers for Disease Control and Prevention and the China-Japan Friendship Hospital at selected locations in each province. Measurement of cardiometabolic disease risk factors.

Following an overnight fast, blood was collected by venipuncture and tested immediately for glucose and hemoglobin A1c (HbA1c). Plasma and serum samples were then frozen, and stored at −86 °C for later laboratory analysis. All samples were analyzed in a national central lab in Beijing (medical laboratory accreditation certificate ISO 15189:2007) with strict quality control. We focus on blood pressure [systolic and diastolic BP] and biomarkers of cardiometablic disease risk related to diabetes [fasting glucose measured with the GOD-PAP method (Randox Laboratories Ltd., UK), HbA1c via high-performance liquid chromatography system (model HLC-723 G7; Tosoh Corporation, Tokyo, Japan)]; dyslipidemia [total cholesterol (TC), high and low density lipoprotein cholesterol (HDL-C and LDL-C) all measured using glycerol-phosphate oxidase method and the PEG-modified enzyme method respectively by determiner regents (Kyowa Medex Co., Ltd, Tokyo, Japan) and triglycerides (TG) using glycerol-phosphate oxidase method and the PEG-modified enzyme method respectively by determiner regents (Kyowa Medex Co., Ltd, Tokyo, Japan). All lipids measures were on the Hitachi 7600 automated analyzer (Hitachi Inc., Tokyo, Japan); inflammation [high sensitivity C-reactive protein (CRP)] via the immunoturbidimetric method with Denka Seiken, Japan reagents (Hitachi 7600 automated analyzer, Hitachi Inc., Tokyo, Japan). Levels of biomarkers were categorized to represent risk using cutoff points recommended by the International Diabetes Federation (IDF) [13] or in other published literature, with separate cutoff points for adults and children, and for males and females where appropriate (Table 1).

Systolic (SBP) and diastolic (DBP) blood pressure were measured on the right arm, using mercury sphygmomanometers with appropriate cuff sizes. Measures were collected in triplicate after a 10 minute seated rest and the mean of the three measurements was used in analyses. Adult hypertension was determined (according to the IDF cut point (SBP/DBP ≥140/90 mmHg) or taking blood pressure medication. For youth <18 years, hypertension risk was defined as blood pressure above the 85th age, sex, and height-specific reference [14].

Overweight. Height was measured without shoes to the nearest 0.1 cm using a portable SECA stadiometer; weight was measured without shoes and in light clothing to the nearest 0.1 kg on a calibrated beam balance. For adults, overweight is defined as BMI ≥25 kg/m^2 and obesity as BMI ≥30 kg/m^2 [15]. For youth, age- and sex-specific reference data for the BMI ≥25 kg/m^2 and BMI ≥30 kg/m^2 equivalent cut-points from the International Obesity Task Force were used to classify overweight and obesity to be consistent with the adult definitions [16].

We also present population-specific BMI percentile distribution data by age to characterize trends in BMI in children and adolescents in China over the past two decades. Using quantile regression [17, 18], we characterize the mean BMI value associated with the population-specific 95th percentile in 10 and 15 year olds from 1991 to 2009 based on a regression of BMI data against age and age squared.

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Other variables—Age was recorded as the respondent's age on the date of exam and categorized into the following groups: 7–11, 12–17, 18–29, 30–39, 40–49, 50–59, 60–69, and ≥70 years). Urbanicity is defined using a multidimensional 12 component urbanization index that captures community-level physical, social, cultural, and economic environments and which represents the heterogeneity that would be otherwise missed in a urban/rural measure based only on population density (mean=67.2; SD=19.5) [19]. A high urbanization index represents a large population living closely together in a physical environment providing an efficient transport system; a communication network; good-quality health care; higher-level education; water, sewer, and electric lines. Household income is based on detailed measures of all income-earning activities of all household members (mean=37,979, SD=45,584 yuan). Tertiles of the urbanization index are used to define low, medium, and high urbanicity and household income per capita.

Comparative cardiometabolic risk data—For wider comparison with the US, we used most recently published data from the National Health and Nutrition Survey[20, 21, 22] and from the SEARCH for Diabetes in Youth study.[23] We used nationally representative data from the Korean Health and Nutrition Survey for individuals 10 and older collected in 2009, which we analyzed for this paper. We conducted a systematic other literature search for using the following key words alone and in combination: non–insulin-dependent diabetes mellitus, type 2 diabetes mellitus, inflammation, children, adolescents, youth, and then for adults to obtain nationally representative studies from Asia on this topic. We limited our review only to national or very large-scale studies, which limited the number or included studies.

Statistical Analyses

Statistical analyses were conducted using Stata (Release 11.0 SE, Stata Corporation, College Station, TX). For descriptive analyses, percentages were calculated for categorical variables, while means were calculated for continuous variables. The nonparametric test for trend was used to test for age differences in cardiometabolic risk factors. Logistic regression models were used to test for differences in risk factor prevalence by income or urbanization in age and sex-stratified models.

Results

Approximately 12% of children and adolescents were overweight (Table 2). Obesity was higher among the 7–11 year olds (3%) than among the 12–17 year olds (1%). Among adults, overweight increased with age with highest rates in middle aged adults; approximately 30% were overweight and 4% obese in the full sample.

All cardiometabolic risk factors (except low HDL-C in males) increased with age (p for trend, $p<0.0001$), Figures 1A–1C. Pre-diabetes (IFG and impaired HbA1c) and diabetes were highest in individuals older than 50 years (Figure 1A). Diabetes prevalence was similar when based on fasting glucose or HbA1c, although pre-diabetes was higher using HbA1c. Markers of dyslipidemia were comparatively high in females than males, with particularly high prevalence of dyslipidemia in individuals over the age of 40 years (Figure 1B). Similarly, elevated blood pressure and inflammation were comparatively higher in individuals over the age of 40 years (Figure 1C). Values for all risk markers are shown in Supplemental Table 1.

Of major public health relevance is the fact that in the pediatric population, 42% of children aged 7–17 had at least one of the following cardiometabolic risk factors: pre-diabetes/ diabetes (HbA1c ≥5.7%), hypertension, high TC, high LDL, low HDL, high TG, high CRP. In contrast, among adults aged 18 to 40 years, 70% of males and 60% of females had at least

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one risk factor, whereas approximately 83% of 40–60 year olds and over 90% of those 60 years and older had at least one elevated risk factor (Figure 2).

The observed elevated cardiometabolic risk factors at younger ages are consistent with distribution of overweight in the CHNS pediatric population. Elsewhere, we have shown that the mean BMI at the Chinese BMI 95th population-specific percentile at age 6 in 2006 was 24.8 kg/m^2, whereas the US 95th population-specific percentile for 6 year olds was 22.2 kg/m^2.[2.1] Looking across the past two decades, the increase in mean BMI at the population-specific BMI for China was biggest between 1991 and 2000 and between 2006 and 2009 and that the increase has been comparatively larger in 10 year olds than 13 year olds.

After adjusting for age, higher urbanization was associated with higher levels of most risk factors, although there were some sex differences in which specific markers related to urbanicity, particularly in individuals over the age of 40 years (Table 4). Urbanization was unrelated to impaired HbA1c and prehypertension (males and females). Comparing older (≥40 yr) to younger (<40) individuals, some interesting relationships emerged. The positive association of urbanization was stronger or seen only among older individuals for overweight, IFG, diabetes (males and females), and low HDL (males only). The direction of association of urbanization with risk indicators was opposite in older versus younger females for high TG, and prehyptertension. For these risk factors, prevalence was lower in the highest urbanization category among younger women, but higher in the highest urbanization category among older women.

Associations of elevated cardiovascular risk factors with income were less consistent. Higher income was associated with higher prevalence of overweight, diabetes and high TG only in males. Income was unrelated to lipids (except LDL in highest tertile), prehypertension, or CRP in males, and unrelated (positively) to all markers except overweight in the highest tertile in females. Higher income was associated with lower risk of high TG and high CRP in younger women, but with lower risk of diabetes and hypertension in older women (Table 4).

Comparison of CHNS findings to findings in the United States and other Asian countries

We compare our CHNS findings with other nationally representative studies from the US and the few published studies in Asia (Table 4). In Table 4A we show that diabetes and inflammation prevalence was higher in CHNS adolescents than in US adolescents. Although in the CHNS study we are unable to distinguish Type 1 and Type 2 diabetes, available evidence for East Asia suggests almost no Type 1 insulin dependent diabetes among youth [24–26]. Comparisons of diabetes across China, South Korea and Taiwan (the only other Asian countries with nationally representative data), suggests higher rates in China (Table 4B). For adults, on the other hand, diabetes prevalence is higher in South Korea, Hong Kong, Singapore, and Malaysia than in China (Table 4C).

Discussion

The observed findings indicate strong age-related differences in overweight and cardiometabolic risk. These estimates highlight the huge burden that the health care system will need to confront. Of particular concern is the relatively high risk in the pediatric population, important not only because of current impact on child health, but also because risk tends to track into adulthood and even worsen. Based on HbA1c, the currently recommended indicator for diabetes [27], we observed rates of diabetes of 0.9% and pre-diabetes of 14.9% in those aged 7–17 years. Although the CHNS data do not match the Chinese census (the CHNS sample has 3% more adults aged 60 and older and 3% fewer under the age of 19), we can approximate the numbers of individuals affected using Chinese

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census data from 2009 [28]. Using the census data, our findings suggest that about 1.7 million Chinese children under the age of 18 are diabetic and about 27.7 million are pre-diabetic. The high rates of pre-diabetes as measured by HbA1c in youth (15%) and adults (30%) portend a public health problem of massive proportion. Furthermore, over one-third of children under the age of 18 had high levels of at least one cardiometabolic risk factor and rates increase to 85% in those ≥40 years. Of additional concern is the high prevalence of cardiometabolic risk in less urban areas and across all income levels.

Of additional concern is the observation that diabetes and inflammation rates are higher in the Chinese pediatric population than in the US pediatric population and in other Asian countries. In contrast, diabetes rates among adults were comparable to those in the US and other Asian countries. Furthermore, obesity and pre-diabetes measured by HbA1c were twice as high in 7–11 versus 12–18 year olds, it is possible that the younger cohorts who are growing up in a very different environmental setting than the adolescents and adults grew up in and are thus experiencing more dramatic health consequences than the adolescent Chinese population. Coupled with the higher BMI values at the upper end of the distribution in Chinese youth, relative to that in the US, UK and Australia[1], the future health of the current pediatric generation of Chinese youth is concerning, particularly given the higher cardiometabolic risk at lower BMI in Asians [29–31].

We also observed age-related increases in cardiometabolic risk across all markers (with the exception of low HDL in males), paralleling the increase in overweight in this population. Diabetes, hypertension and inflammation were higher at older ages, despite a drop off in overweight. More than three quarters of adults had at least one elevated cardiometabolic risk factor, which increased to over 90% in individuals aged 60 and older. A recent study of diabetes in a large national study of Chinese adults, ages 20 yr and older [5], used fasting and 2-hour glucose levels to define impaired fasting glucose and diabetes. We calculated age- and sex-adjusted estimates (not shown) in the same age range as Yang to provide comparison between our results and theirs. Our overall age and sex-adjusted estimate of diabetes for adults aged 20 and older based on HbA1c (6.7%) is lower than the Yang age- and sex-standardized estimate of 9.7% for the same age group. In comparison with Yang et al., we observed an age- and sex-adjusted estimate of pre-diabetes of 30%, whereas Yang et al., found 15.5%. Compared to the fasting glucose cutoff point of 100 mg/dl (5.6 mmol/l), the HbA1c cutoff point of 5.7% is less sensitive but more specific and has a higher positive predictive value to identify people at risk for later development of diabetes [32]. Consistent with their study, we find similar age distributions and higher rates of diabetes in men compared to women. Our population study of cardiometabolic risk factors in Chinese adults is the most current data available.

In addition to age-related increases in risk and high rates of cardiometabolic risk in youth, we observed high prevalence of risk in less urban areas and in across all income levels, suggesting pervasive risk across all parts of China. This is of major concern as these risk factors were heretofore less common in rural China. In prior work, we have shown that the burden of overweight is shifting from the rich to the poor in China and other countries, and we have found comparatively rapid increases in obesity in rural and lower income populations [7]. In addition, we have shown an increased burden of obesity among women, but an opposite trend in men [8]. In the past in low in middle income countries, higher levels of chronic disease risk were associated with affluence. Our findings suggest that as cardiometabolic risk increases in China, even rural populations will be affected.

There are a few limitations to this analysis. This cross-sectional analysis does not examine temporal changes in cardiometabolc risk factors owing to the fact that biomarker data were only collected in the 2009 round of the CHNS. Despite the overall large sample size, some

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age and sex-specific subgroups are small, and thus may provide unstable estimates of prevalence for rarer outcomes. Our main objective was to determine the prevalence of a wide range of cardiometabolic risk factors by age and gender, and across urbanization and income. To provide comparability, we used conventional, anthropometric and cardiometabolic cutpoints. Nevertheless they may not represent true risk in this population if, for example, disease develops at lower BMI in Asian versus other populations, which is possible given higher visceral fat at the same level of BMI in Asians versus Europeans [9]. We used the BMI cutoff points of 25 and 30 kg/m^2 for adults and the IOTF 25 and 30 kg/m^2 equivalent for youth to allow for comparison of youth and adults. We did not exclude obese individuals from this analysis as we were interested in estimating risk in the full Chinese population; nonetheless when we exclude the 369 obese individuals in the sample from the analysis we find very similar results that with rounding are almost identical. We are not able to distinguish type 1 from type 2 diabetes in our sample, although no children reported insulin injection use. Whereas it is possible that the comparatively higher rates of pre-diabetes as measured by HbA1c in children versus adolescents could relate to type 1 diabetes, the rate of type 1 diabetes in China is among the lowest in the world, with an estimate of 0.1 per 100,000/year [33]. The differences in pre-diabetes and diabetes as measured by HbA1c versus fasting glucose in youth, could possibly relate to differential meaning of these measures in youth or transient increases in insulin resistance with puberty [34–37]. While we include comparative data from several countries, we were limited in the availability of published data, particularly in South East and South Asian countries.

Important strengths of the study include its population based design, representation of a wide range of urban and rural communities across China, its inclusion of fasting blood data for children down to the age of 7 year, and the wide range of biomarkers collected. The data from this national study suggests a high prevalence of overweight and elevated cardiometabolic risk factors in China that is higher across age groups and is evident even in the pediatric population. Further, rates were markedly high even in less urban and lower income groups within China. Our HbA1c results suggest a very high burden of chronic disease risk starting at a young age, with 1.7 million Chinese children 7–18 having diabetes (HbA1c), another 27.7 million considered pre-diabetic. For adults, the observed findings that suggest 82.1 million adults have diabetes and 334 million are pre-diabetic, are higher than that of Yang [5]. Further we provide evidence that this is just the beginning of high prevalence of elevated cardiometabolic risk factors, given the increase in overweight with age. Elsewhere we have discussed some of the economic burden of this coming crisis [6]. The observed findings foreshadow substantial and increasing chronic disease burden in China over the next several decades.

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Figure 1A.

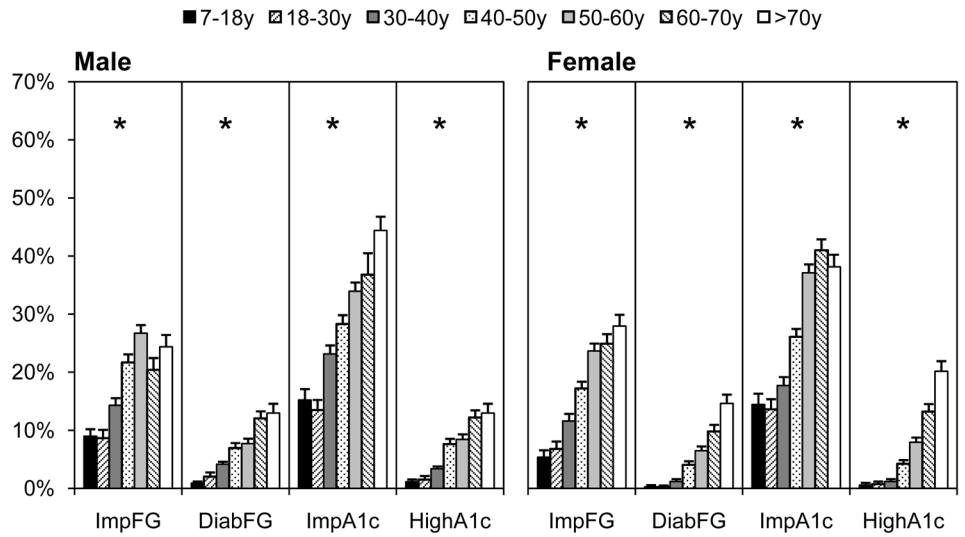

Figure 1B.

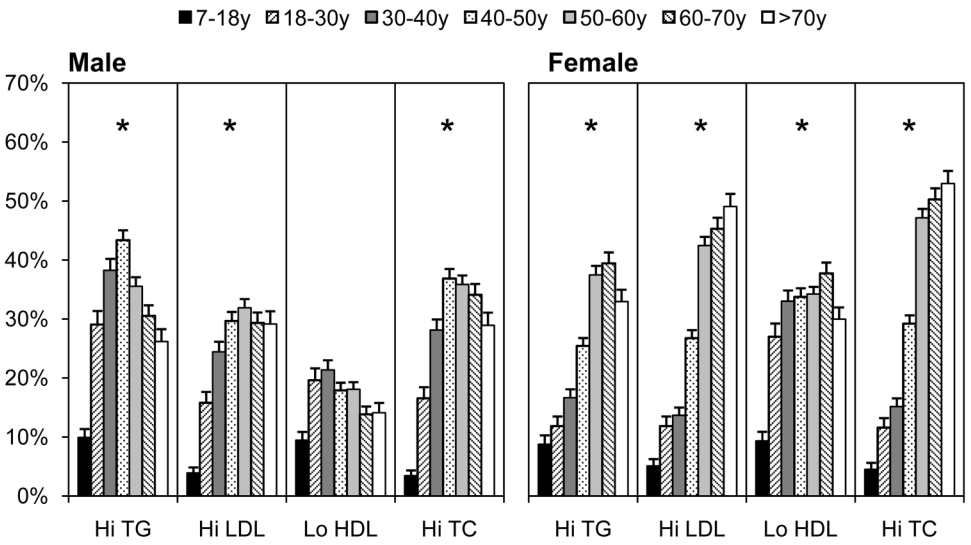

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Figure 1C.

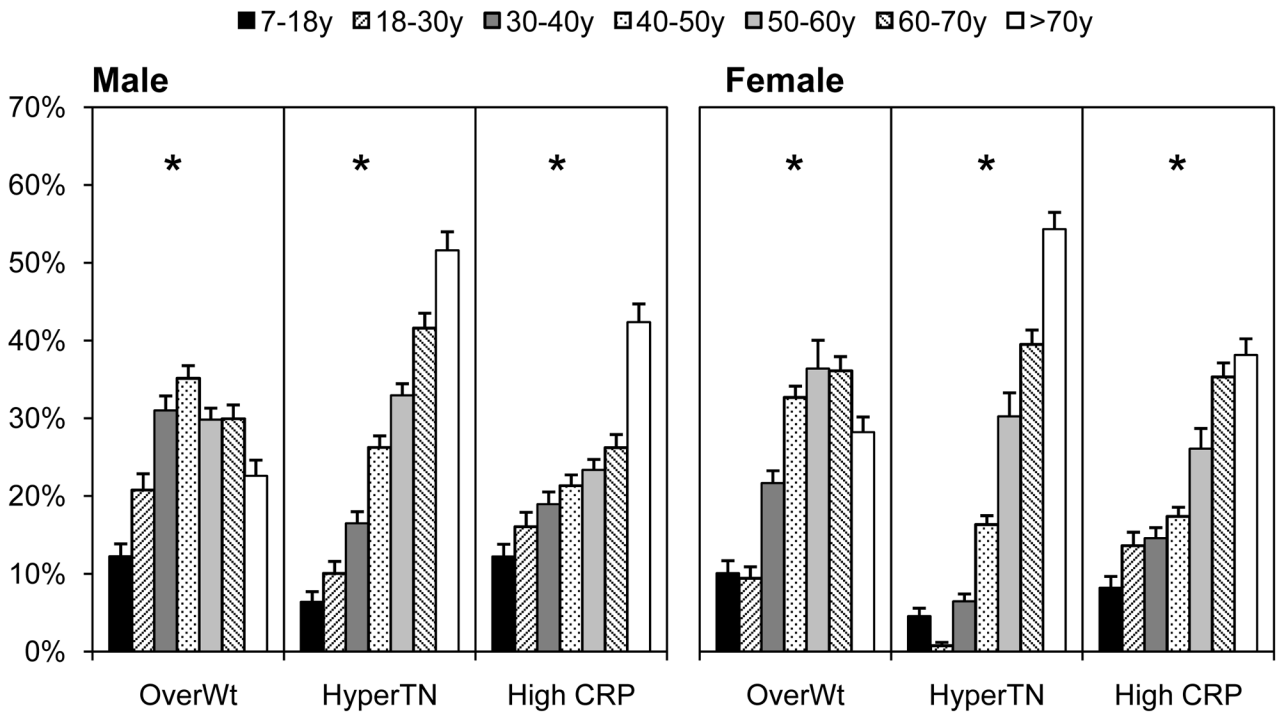

Figure 1.

A–C. Cardiometabolic Risk Across Several Indicators by Age, 2009 China Health And Nutrition Survey

Cutpoints shown in Table 1, abbreviations below

Over WT overweight

Imp FG impaired fasting glucose

Diab FG, diabetes based on fasting glucose

Imp A1c, impaired HbA1c

High A1c, hemoglobin HbA1c

High TG, triglycerides

High LDL, high low density lipoprotein cholesterol

Low HDL, low high density lipoprotein cholesterol

High TC, high total cholesterol

Hyper TN hypertension

High CRP, Inflammation measured by C-reactive protein

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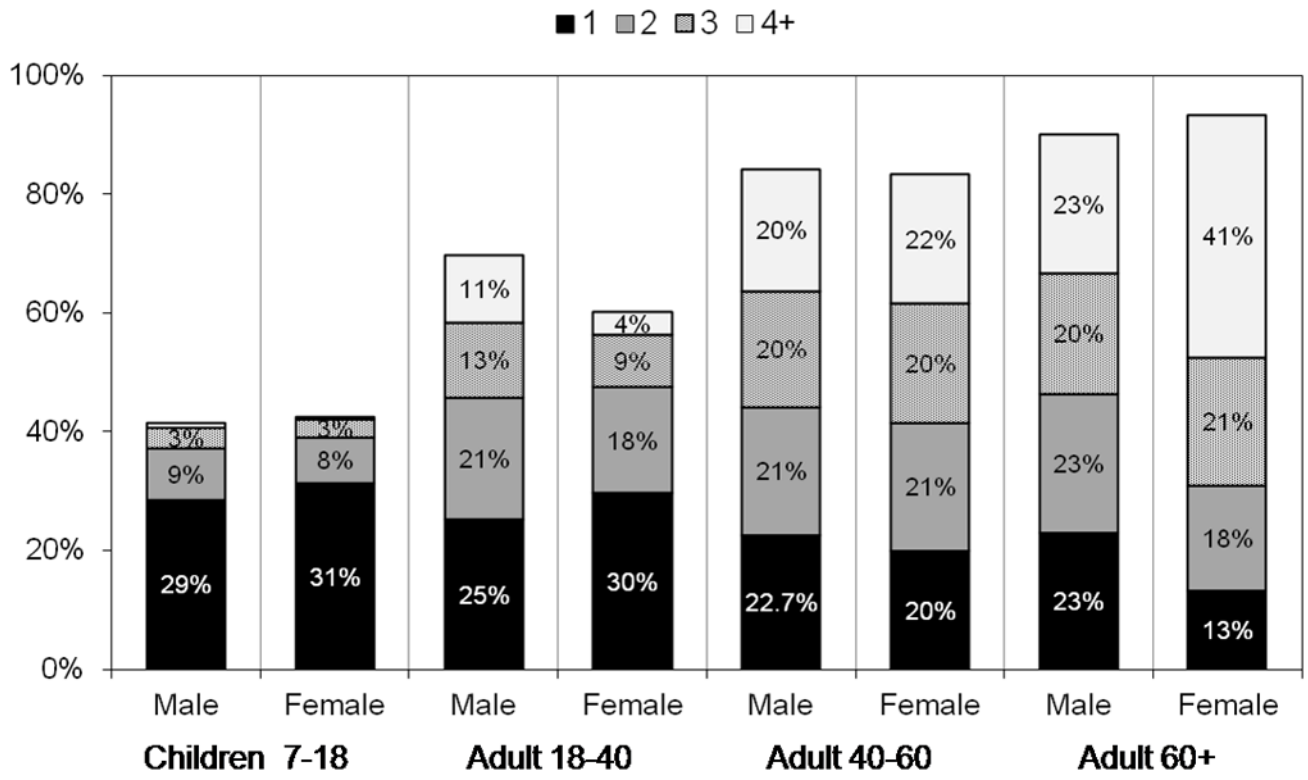

Figure 2.

Proportion of The CHNS Sample with at Least one Elevated Cardiometabolic Risk Factor by Age Group (age 7–17 Years; age 18–39 Years, age 40–60 years; and age ≥60 Years Proportion of the population with one or more of the following cardiometabolic risk factors: impaired/diabetic (HbA1c ≥5.7%), hypertension (140/90, or age-sex specific percentiles for pediatric population), high TC (≥200 mg/dL), high LDL (>130 mg/dL), low HDL(<40 mg/dL), high TG (≥150 mg/dL), high CRP High CRP (≥3).

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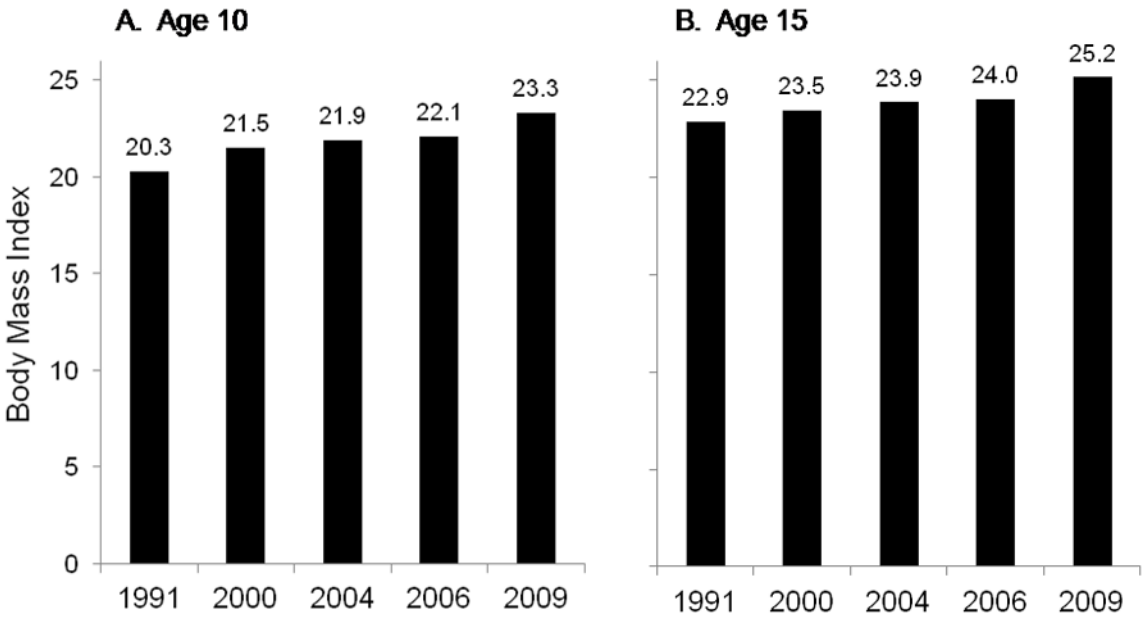

Figure 3.

Mean BMI value associated with the population-specific 95th percentile in 10 and 15 year olds from 1991 to 2009

Based on quantile regression models of BMI data against age and age squared

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Table 1

Biomarkers, laboratory analyses methods and definitions of cardiometabolic risk, 2009 China Health and Nutrition Survey fasting blood samples

Biomarker	Risk Indicator	Definition
Glucose	Impaired fasting glucose	Glucose ≥ 100 & < 126 mg/dL
	Diabetes	Glucose ≥ 126 mg/dL or taking diabetes medication
HbA1C	Impaired glucose control	HbA1c ≥ 5.7 & < 6.5%
	Diabetes	HbA1c ≥ 6.5% or taking diabetes medication
Total Cholesterol	High TC	≥ 200 mg/dL
HDL-C	Low HDL	Male: < 40 mg/dL; female < 50 mg/dL; pediatric < 40 mg/dL
LDL-C	High LDL	> 130 mg/dL
Triglycerides	High TG	≥ 150 mg/dL
High Sensitivity CRP	High GRP	≥ 3 mg/dL

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Table 2

Mean BMI and percent overweight and obese in CHNS participants

Age Group	N 4,417	Mean BMI (SD)	Overweight [BMI ≥ 25 (or pediatric equivalent[18])]; % (95% CI)	Obesity [BMI ≥ 30 (or pediatric equivalent[18])]; % (95% CI)
MALES				
7–11 * y	211	17.0 (2.9)	12.8 (10.5, 15.1)	3.2 (2.0, 4.4)
12–17 * y	205	19.0 (3.4)	11.7 (9.5, 14.0)	1.4 (0.6, 2.2)
Total 7–17 y	416	18.0 (3.4)	12.3 (10.6, 13.9)	2.3 (1.6, 3.0)
18–29 y	374	22.2 (3.5)	20.8 (18.7, 22.9)	2.3 (1.5, 3.1)
30–39 y	611	24.0 (3.5)	31.0 (29.1, 32.9)	4.5 (3.7, 5.3)
40–49 y	857	24.0 (3.3)	35.2 (33.5, 36.8)	4.8 (4.1, 5.5)
50–59 y	973	23.5 (3.2)	29.8 (28.4, 31.3)	3.4 (2.8, 3.9)
60–69 y	659	23.2 (3.4)	30.0 (28.2, 31.7)	3.3 (2.6, 4.0)
≥70 y	431	22.5 (4.0)	22.6 (20.6, 24.6)	4.1 (3.2, 5.0)
Total ≥18 y	3905	23.3 (3.4)	29.5 (28.8, 30.3)	3.8 (3.5, 4.1)

Age Group	N 4,827	Mean BMI (SD)	Overweight [BMI ≥ 25 (or pediatric equivalent[18])]; % (95% CI)	Obesity [BMI ≥ 30 (or pediatric equivalent[18])]; % (95% CI
FEMALES				
7–11 y *	160	16.3 (3.0)	12.2 (9.6, 14.8)	3.0 (1.7, 4.3)
12–17 y *	184	19.0 (3.0)	8.2 (6.2, 10.2)	1.1 (0.3, 1.8)
Total 7–17y	344	18.0 (3.2)	10.1 (8.5, 11.7)	2.0 (1.2, 2.7)
18–29 y	392	21.0 (3.0)	9.4 (8.0, 10.9)	0.8 (0.3, 1.2)
30–39 y	665	23.0 (3.4)	21.7 (20.1, 23.3)	3.9 (3.1, 4.6)
40–49 y	1039	24.0 (3.3)	32.7 (31.2, 34.1)	4.4 (3.8, 5.1)
50–59 y	1098	24.0 (3.3)	36.4 (35.0, 37.9)	4.6 (4.0, 5.2)
60–69 y	697	24.0 (4.0)	36.1 (34.3, 38.0)	5.7 (4.8, 6.6)
≥70 y	519	23.1 (4.0)	28.2 (26.2, 30.2)	5.6 (4.6, 6.5)
Total ≥18 y	4410	23.4 (4.0)	29.9 (29.2, 30.6)	4.4 (4.1, 4.7)

Age Group	N	Mean BMI (SD)	Overweight [BMI ≥ 25 (or pediatric equivalent[18])]; % (95% CI)	Obesity [BMI ≥ 30 (or pediatric equivalent[18])]; % (95% CI)
TOTAL POPULATION				
Pediatric	760	17.7 (3.3)	11.3 (10.1, 12.4)	2.2 (1.6, 2.7)
Adult	8315	23.4 (3.5)	29.7 (29.2, 30.2)	4.1 (3.9, 4.3)

* 7–17 year old age group broken into two categories given variation in growth for children and adolescents

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Table 3

Association of urbanization (first panel) and income (second panel) with cardiometabolic risk in younger and older adults.

Prevalence Odds ratios from logistic regression models, stratified by age

		Males		Females	
	Urbanization	**Age 18–40 years n=1,014**	**Age ≥40 years n=2,970**	**Age 18–40 years n=1,068**	**Age ≥40 years n=3,406**
Overweight	Low	1.00	1.00	1.00	1.00
	Med	1.16 (0.82, 1.64)	1.70 (1.39, 2.08)	0.84 (0.58, 1.24)	1.23 (1.03, 1.47)
	Hi	1.22 (0.86, 1.73)	1.86 (1.53, 2.27)	0.67 (0.45, 1.00)	1.20 (1.01, 1.43)
IFG	Low	1.00	1.00	1.00	1.00
	Med	0.84 (0.51, 1.38)	1.45 (1.16, 1.82)	1.31 (0.75, 2.30)	1.55 (1.24, 1.93)
	Hi	1.17 (0.73, 1.87)	1.72 (1.38, 2.14)	1.84 (1.08, 3.15)	1.88 (1.52, 2.33)
Diabetic	Low	1.00	1.00	1.00	1.00
	Med	1.48 (0.62, 3.51)	1.42 (1.03, 1.96)	0.97 (0.14, 6.92)	1.50 (1.06, 2.10)
	Hi	1.53 (0.64, 3.62)	1.75 (1.28, 2.38)	2.41 (0.46, 12.50)	2.01 (1.45, 2.78)
Impaired A1c	Low	1.00	1.00	1.00	1.00
	Med	0.83 (0.57, 1.20)	0.89 (0.73, 1.08)	0.80 (0.54, 1.18)	0.97 (0.81, 1.16)
	Hi	0.75 (0.51, 1.10)	0.87 (0.72, 1.05)	0.62 (0.41, 0.93)	0.96 (0.80, 1.15)
High A1c	Low	1.00	1.00	1.00	1.00
	Med	2.69 (0.95, 7.65)*	1.35 (0.98, 1.86)	2.92 (0.30, 28.26)*	1.86 (1.37, 2.53)
	Hi	2.12 (0.72, 6.27)*	1.77 (1.31, 2.39)	6.80 (0.83, 55.59)*	2.01 (1.49, 2.71)
High TG	Low	1.00	1.00	1.00	1.00
	Med	1.36 (0.98, 1.88)	1.43 (1.18, 1.73)	0.75 (0.50, 1.12)	1.12 (0.94, 1.34)
	Hi	1.96 (1.42, 2.70)	1.89 (1.57, 2.27)	0.64 (0.42, 0.97)	1.24 (1.04, 1.48)
High LDL	Low	1.00	1.00	1.00	1.00
	Med	1.71 (1.16, 2.53)	2.07 (1.70, 2.54)	1.16 (0.74, 1.83)	1.47 (1.23, 1.75)
	Hi	1.99 (1.35, 2.93)	1.82 (1.49, 2.23)	1.38 (0.89, 2.15)	1.61 (1.36, 1.91)
Low HDL	Low	1.00	1.00	1.00	1.00
	Med	1.24 (0.85, 1.81)	1.19 (0.92, 1.56)	0.67 (0.49, 0.92)	0.89 (0.74, 1.06)
	Hi	1.34 (0.92, 1.95)	2.29 (1.80, 2.92)	0.68 (0.49, 0.93)	1.17 (0.99, 1.39)
High TC	Low	1.00	1.00	1.00	1.00
	Med	1.63 (1.12, 2.36)	2.05 (1.69, 2.48)	1.40 (0.90, 2.18)	1.38 (1.17, 1.64)

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Prevalence Odds ratios from logistic regression models, stratified by age

		Males		Females	
	Urbanization	**Age 18–40 years n=1,014**	**Age ≥40 years n=2,970**	**Age 18–40 years n=1,068**	**Age ≥40 years n=3,406**
	Hi	1.86 (1.29, 2.68)	1.79 (1.48, 2.16)	1.41 (0.91, 2.19)	1.45 (1.23, 1.72)
Hypertension	Low	1.00	1.00	1.00	1.00
	Med	0.78 (0.55, 1.10)	1.20 (1.01, 1.44)	1.02 (0.64, 1.65)	1.14 (0.96, 1.35)
	Hi	0.89 (0.63, 1.26)	1.28 (1.07, 1.52)	0.54 (0.31, 0.94)	1.42 (1.21, 1.68)
Pre-HTN	Low	1.00	1.00	1.00	1.00
	Med	0.76 (0.50, 1.15)	1.07 (0.89, 1.28)	1.02 (0.54, 1.91)	1.11 (0.92, 1.32)
	Hi	0.63 (0.41, 0.98) *	1.13 (0.94, 1.36)	0.32 (0.13, 0.77)	1.32 (1.11, 1.57)
High CRP	Low	1.00	1.00	1.00	1.00
	Med	1.72 (1.14, 2.59)	1.05 (0.86, 1.28)	1.03 (0.68, 1.56)	1.13 (0.93, 1.37)
	Hi	1.66 (1.10, 2.51)	0.99 (0.81, 1.21)	0.86 (0.56, 1.32)	1.33 (1.11, 1.61)

		Males		Females	
	Income	**Age 18–40 years**	**Age ≥40 years**	**Age 18–40 years**	**Age ≥40 years**
Overweight	Low	1.00	1.00	1.00	1.00
	Med	1.00 (0.69, 1.44)	1.19 (0.97, 1.45)	0.68 (0.45, 1.02)	1.12 (0.94, 1.34)
	Hi	1.07 (0.75, 1.52)	1.59 (1.31, 1.93)	0.76 (0.51, 1.12)	1.29 (1.08, 1.54)
IFG	Low	1.00	1.00	1.00	1.00
	Med	0.98 (0.58, 1.66)	1.16 (0.93, 1.44)	0.88 (0.58, 1.35)	0.88 (0.74, 1.06)
	Hi	1.13 (0.69, 1.87)	1.20 (0.96, 1.49)	0.97 (0.65, 1.46)	1.08 (0.91, 1.30)
Diabetic	Low	1.00	1.00	1.00	1.00
	Med	0.59 (0.24, 1.45)	1.06 (0.77, 1.46)	4.05 (0.47, 34.84)	0.67 (0.49, 0.93)
	Hi	0.86 (0.39, 1.91)	1.51 (1.12, 2.04)	2.16 (0.22, 20.84)	0.88 (0.65, 1.17)
Impaired A1c	Low	1.00	1.00	1.00	1.00
	Med	0.75 (0.49, 1.12)	0.95 (0.78, 1.14)	0.85 (0.41, 1.18)	1.08 (0.84, 1.36)
	Hi	0.95 (0.65, 1.41)	1.04 (0.86, 1.26)	0.86 (0.42, 1.78)	0.93 (0.73, 1.20)
High A1c	Low	1.00	1.00	1.00	1.00
	Med	0.48 (0.17, 1.37)	0.94 (0.69, 1.29)	1.34 (0.32, 5.65)	0.73 (0.55, 0.97)
	Hi	0.92 (0.39, 2.12)	1.45 (1.08, 1.93)	0.71 (0.14, 3.56)	1.04 (0.80, 1.36)
High TG	Low	1.00	1.00	1.00	1.00

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		Males		Females	
	Income	**Age 18–40 years**	**Age ≥40 years**	**Age 18–40 years**	**Age ≥40 years**
	Med	1.27 (0.91, 1.79)	1.23 (1.02, 1.49)	0.77 (0.51, 1.16)	1.10 (0.92, 1.31)
	Hi	1.04 (0.75, 1.46)	1.33 (1.11, 1.61)	0.64 (0.42, 0.98)	1.16 (0.97, 1.38)
High LDL	Low	1.00	1.00	1.00	1.00
	Med	1.28 (0.85, 1.92)	1.08 (0.89, 1.31)	0.93 (0.59, 1.45)	1.10 (0.93, 1.30)
	Hi	1.34 (0.90, 1.98)	1.13 (0.93, 1.37)	0.76 (0.48, 1.19)	0.88 (0.75, 1.05)
Low HDL	Low	1.00	1.00	1.00	1.00
	Med	1.14 (0.76, 1.71)	1.21 (0.95, 1.53)	0.77 (0.55, 1.07)	1.01 (0.85, 1.20)
	Hi	1.12 (0.75, 1.65)	1.17 (0.92, 1.49)	0.85 (0.62, 1.17)	1.08 (0.91, 1.29)
High TC	Low	1.00	1.00	1.00	1.00
	Med	1.33 (0.90, 1.96)	0.99 (0.82, 1.19)	1.00 (0.65, 1.53)	1.13 (0.96, 1.33)
	Hi	1.28 (0.88, 1.87)	1.11 (0.92, 1.33)	0.65 (0.41, 1.01)	0.92 (0.77, 1.08)
Hypertension	Low	1.00	1.00	1.00	1.00
	Med	0.81 (0.57, 1.16)	0.92 (0.77, 1.10)	1.07 (0.64, 1.79)	0.85 (0.73, 1.01)
	Hi	0.62 (0.44, 0.89)	0.89 (0.74, 1.06)	0.80 (0.47, 1.37)	0.79 (0.67, 0.93)
Pre-HTN	Low	1.00	1.00	1.00	1.00
	Med	0.83 (0.53, 1.28)	0.95 (0.79, 1.14)	0.97 (0.47, 2.01)	0.87 (0.73, 1.03)
	Hi	0.65 (0.42, 1.02)	0.99 (0.82, 1.19)	0.81 (0.39, 1.69)	0.77 (0.64, 0.91)
High CRP	Low	1.00	1.00	1.00	1.00
	Med	0.92 (0.60, 1.41)	0.91 (0.74, 1.11)	0.79 (0.51, 1.20)	0.96 (0.80, 1.15)
	Hi	1.11 (0.74, 1.67)	0.85 (0.69, 1.03)	0.62 (0.40, 0.95)	1.03 (0.86, 1.24)

NOTE: urbanization and income categorized by tertiles, with approximately 300 per tertile in the 18–40 year age group and approximately 1,000 per tertile in the ≥40 year age group

* Unstable estimates due to n<10 in the reference category

Sex- and age (18–40 years; Age ≥40 years)-stratified crude logistic regression models including 3 levels each for urbanicity and income

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Table 4

Comparison of CHNS findings to findings in the United States and other Asian countries using fasting blood and C-reactive protein

Adolescent Males	CHNS (Aged 12–18 years)	United States Publications (Aged 12–19 years)
A. Adolescent Males only: CHNS and US adolescents		
HbA1c≥6.5%	1.9%	0.5% NHANES[20]
CRP ≥3 mg/dL	12.1%	8.5% NHANES[21]
Glucose ≥ 126 mg/dL	0.9%	0.28% NHANES[22]; 0.22% SEARCH [**][23]
IFG (100–126 mg/dL)	8.4%	20% NHANES[22]

Country	Glucose ≥ 126 mg/dL Plus Medication	IFG (100–126 mg/dL)
B. Adolescents: CHNS and other Asian countries		
CHNS ages 12–17	0.9%	8.4%
South Korea, KHANES 10–17 [**]	0.1%	5.3%
Taiwan 10–18[38]	<0.0	--

Country	Glucose ≥ 126 mg/dL Plus Medication	IFG (100–126 mg/dL)
C. Adults: CHNS, US, and other Asian countries		
CHNS ages 18 and older	6.9%	20.0%
NHANES 18 and over 2011[22] [*]	8.8%	--
South Korea, KHANES 10–17 [**]	8.1%	17.8%
Hong Kong[39]	9.8%	--
Malaysia[39]	11.0%	--
Thailand 2004[39]	6.7	--
Singapore 2004[40]	8.9 (men); 7.6 (women)	--
Malaysia[41]	12.6%	22.1%

--No data available

[*] Source: NHANES weighted to be national representative[22]

[**] Use of weighted data from the Korean Health and Nutrition Examination Survey 2009

[***] For both males and females