Is metabolic syndrome the symbol of economic development and social transformation? Evidence from the China National Stroke Prevention Project

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Abstract

Background

Increase of Metabolic syndrome (MetS) is associated with economic development and changes of lifestyle. Understanding current prevalence and distribution of MetS in China is important for preventing associated health complications.

Methods

The present analysis used data from a nationally study in 2014-2015. We defined MetS by different definitions, and compared results of the present study and previous nationally representative studies to illustrate possible temporal changes in MetS prevalence.

Results

The estimated prevalence of MetS was 18.4% by the ATP III criteria, 34.0% by the revised ATP III criteria, and 26.9% by IDF criteria. The prevalence was higher in women, older adults, those with lower education level, and in economically developed regions. Contrasting with previous national studies, adults in urban areas had a lower rate of MetS than those in rural areas (odds ratio 0.94; 95% CI 0.92 -0.97). And rural adults had worse deterioration or less improvement in abdominal obesity, overweight, hypertension, and high fasting plasma glucose, than urban adults, which was particularly striking for women.

Conclusions

While measures to prevent and control cardiovascular diseases need to be strengthened in China, rapid increasing risk factors among rural residents and women should be prioritised in making public health policy decisions.

Key words: Metabolic syndrome; Prevalence; Trends; Epidemiology

Key Messages

1. Our study assessed prevalence and temporal changes of MetS among Chinese population with the most recently completed and the largest sample size.

2. The current prevalence of MetS was higher in women, older adults, those with lower education level, and in economically developed regions and the CVD risk factors among rural residents and women should be prioritised in making public health policy decisions.

3. A comparison of results of the present study and previous national studies showed that rural adults had worse deterioration or less improvement in abdominal obesity, overweight, hypertension, and high fasting plasma glucose, than urban adults, which was particularly striking for women.

Introduction

The morbidity and mortality of cardiovascular disease (CVD) are increasing in China, as in other low-and-middle income countries, while CVD mortality has been declining in high-income western countries since 1980s (1-3). The metabolic syndrome (MetS) refers to a cluster of metabolic factors associated with the risk of CVD, including abdominal obesity, high blood pressure, dyslipidaemia and dysglycaemia(4). The prevalence and distribution of MetS in population are important indicators for making public health decisions regarding the control of CVD epidemic(5).

There were several nationally representative studies that provided data on the prevalence of MetS in China. The International Collaborative Study of Cardiovascular Disease in Asia (InterASIA) in 2000-2001 was a cross-sectional study of a nationally representative sample of 15,540 Chinese adults aged 35-74 years(6). In 2007-2008, A sample of 46,024 Chinese aged 20 years and over were included in the National Diabetes and Metabolic Disorders Survey (NDMDS)(7). The China Health and Nutrition Survey (CHNS) in 2009 examined metabolic risk factors among a sample of 7488 adults(8). The 2010 China Noncommunicable Disease Surveillance (CNCDS) included 97,098 participants from 31 provinces in China(9). Results of these national studies showed an increasingly high prevalence of MetS in China. In addition, it was found that the prevalence of MetS was generally higher in women, among older adults, and in urban residents(6-9). However, it is often difficult to compare the results of different studies, due to different sampling methods, participant age range, and definitions of MetS used.

The China National Stroke Prevention Project (CSPP) survey in 2014-2015 was a recently completed cross-sectional study that included 109,551 participants aged ≥40 years from 30 provinces in China. In the present study, we used data from the CSPP to estimate the current prevalence of MetS in China. We also compared results of CSPP and previous nationally representative studies to reveal changes in the prevalence of MetS over time in China.

Methods

Design and participants of the CSPP study

The CSPP was administrated by the National Project Office of Stroke Prevention and Control, and carried out in 30 provinces in China from October 2014 to November 2015. Using a 2-stage stratified cluster sampling method, 200 project areas were firstly selected in proportion to the local population size and the numbers of counties. Then an urban community and a rural village were selected from each project area as primary sampling units according to geographical locations and suggestions from local hospitals. The cluster sampling method was used in every primary sampling unit and all residents aged≥40 years were surveyed during the primary screening.

All participants received information on the study and provided written informed consent to participate. Questionnaire completion and physical examination were conducted by trained staff in primary health care institutions, to collect data on demographic characteristics, medical history, behavioural risk factors, height, weight, waist circumference, and blood pressure. The assessment of stroke risk was based on the following variables: hypertension, atrial fibrillation, current smoking, dyslipidaemia, diabetes, physical inactivity, obesity or overweight (BMI ≥26kg/m^2), and family history of stroke. Participants with ≥3 risk factors or with prior TIA or stroke were considered at high risk of stroke, and those with <3 risk factor but having hypertension, diabetes, atrial fibrillation, or heart valve disorders were categorised as at intermediate risk of stroke. Low risk of stroke was defined as having <3 risk factors and without the above CVD conditions.

According to the screening plan, participants at high risk of stroke were invited for further laboratory tests, carotid ultrasound, and electrocardiogram. However, a large number of participants at intermediate or low risk of stroke were also undergone additional laboratory tests. A total of 726,451 participants were included in the CSPP survey in 2014-2015, and 109,551 of them received additional laboratory tests. In the current study, the analysis of MetS was based on data from 109,551 participants who had completed all

laboratory examinations.

Data from other relevant studies

Data from previous nationally representative studies of MetS in China were obtained to compare results of different studies and to illustrate changes in the prevalence of MetS over time. We were able to access the original data from the CHNS(8, 10). For other national scale studies of MetS in China (InterASIA(6), NDMDS(7), and CNDS(9)), we had to rely on results reported in published articles. We have attempted to make results from different studies as comparable as possible in terms of participant age and the definition of Mets in analysis.

Definition of Metabolic Syndrome

The metabolic syndrome was defined by different definitions, including National Cholesterol Education Programme (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (NCEP ATP III) criteria(11), revised NCEP ATP III for Asian-Americans(12), and the updated International Diabetes Federation (IDF)(13) definition (see Supplementary file-1).

Data Analysis

We calculated the prevalence of MetS by gender, age, location (urban or rural), and the level of socio-economic development, weighted by age and sex distribution of the 2014 population in China. Because relatively more participants at high risk of stroke were included in the analysis of MetS, the prevalence of MetS were weighted according to the level of stroke risk in all CSPP participants. The *t* test and Chi-square test were used for statistically testing continuous and categorical variables. Logistic regression analysis was conducted to estimate the association between MetS and other variables including age, gender, urban/rural location, education level, and economic development. In addition, the discrepancy in the prevalence of MetS between urban and rural areas was measured by using prevalence rate ratio(14). Analyses were conducted using SPSS 19.0 (SPSS Inc., Chicago, Ill).

Ethical approval

The CSPP study protocol was approved by the Ethics committee of the XuanWu Hospital Institutional Review Board, Capital Medical University (Beijing, China).

Results

Table 1 shows the basic characteristics of the 109,551 participants who were included in the analysis and 616,900 participants without laboratory tests. The included participants were relatively older, and less likely from rural areas or under developed regions. As expected, the risk of stroke was much higher for the included participants compared with those not included. The proportion of low risk participants was 40.2% for the included participants and 76.3% for those who were not included.

The estimated prevalence of MetS by the ATP III criteria without adjusting for stroke risk level was presented in supplementary file-2. The overall prevalence of MetS (ATP III criteria) was 25.1%, and it was clearly associated with the level of stroke risk (supplementary file-2). After adjusting for the stroke risk, the estimated prevalence of MetS for Chinese adults aged ≥40 in 2014-2015 was 18.4% by the ATP III criteria, 34.0% by the revised ATP III criteria, and 26.9% by the IDF criteria (Table 2). The prevalence of MetS was statistically significantly higher in women, older adults, rural residents, adults with low level of education, and in economically developed regions (Table 3).

Comparison of results of different studies

We were able to compare sex- and age-specific prevalence of MetS (using the ATP III definition) with the results of other three nationally representative studies (InterASIA(6), CHNS(8), and CNCDS(9)) (Figure 1). The prevalence of MetS in 2014-2015 by the CSPP study was generally higher than that in 2000-2001, but often lower than that in 2009 and 2010 (Figure 1). The high prevalence of MetS estimated by the CNCDS study in 2010 is particularly noteworthy, compared with other studies in 2000-2010, 2009, and 2014-2015.

Figure 2 shows the prevalence rate ratio of MetS in urban and rural areas, according to results of the CSPP and four previous studies(6-9). Results of previous studies indicated a higher prevalence of MetS in urban adults, with a prevalence rate ratio of 1.47 in 2000-2001,

1.27 in 2007-2008, 1.36 in 2009, and 1.18 in 2010. However, the overall prevalence rate ratio was 0.91 (95% CI: 0.89 -0.93), indicating a lower rate of MetS in urban adults, by 2014-2015 (Figure 2a). While rural and urban men had similar prevalence of MetS in 2014-2015 (Figure 2b), rural women had a much higher prevalence than urban women in 2014-2015 (Figure 2c).

Data from three nationally representative studies (InterASIA(6), CHNS(8), and CSPP) are available to compare the prevalence of MetS components in 2000-2001, 2009, and 2014-2015 in China (Table 4). The rate of abdominal obesity was increased by 134.5% between 2000-2001 and 2009, and the increase was much greater in men than in women, particularly in rural areas. The prevalence of abdominal obesity was increased by 142.4% in rural areas, much greater than that (75.6%) in urban areas, between 2000-2001 and 2009. The overall prevalence of abdominal obesity in China was somewhat reduced by -13.6% between 2009 and 2014-2015 (Table 4). However, the reduction in the prevalence of abdominal obesity between 2009 and 2014-2015 was more substantial in urban adults, particularly in men. Compared with that in urban adults, the prevalence of abdominal obesity in rural adults was lower in 2000-2001 (7.2% vs. 10.1%), similarly high in 2009 (17.5% vs. 17.7% or 18.7% vs. 18.8%), and higher in 2014-2015 (18.7% vs. 14.5%) (Table 4).

The overall prevalence of hypertriglyceridemia in China was increased by 36.9% between 2000-2001 and 2009, and by 8.9% between 2009 and 20014-20015 (Table 4). The increase was more substantial in rural adults than those in urban areas: 43.6% vs 10.7% during 2000-2001 and 2009, and 11.9% vs. 2.2% during 2009 and 2014-2015. The prevalence of hypertriglyceridemia was similarly high among rural and urban adults (38.0% vs 38.4%) by 2014-2015.

Results in Table 4 indicated a fluctuated change in the prevalence of low HDL cholesterol, reduced by -24.8% between 2000-2001 and 2009 and increased by 24.7% between 2009 and 2014-2015. The prevalence of low HDL cholesterol in 2014-2015 was actually similar to that in 2000-2001.

The overall prevalence of hypertension was not changed significantly between 2000-2001 and 2009, and increased by 15.9% between 2009 and 2014-2015 (Table 4). Particularly, the recent increase in the prevalence of hypertension was greater in rural adults than that in urban adults (29.7% vs. 4.5%). Rural adults had a higher prevalence of hypertension than those in urban areas (58.4% vs. 48.8%) by 2014-2015.

The overall prevalence of high fasting glucose or diabetes in China was increased by 10.5% between 2000-2001 and 2009, and reduced by -14.0% between 2009 and 2014-2015. Such changes were occurring mainly among male adults, particularly in rural areas. Compared with urban adults, the prevalence of fasting glucose or diabetes among rural men was increased more greatly (37.0% vs. 10.2%) between 2000-2001 and 2009, and reduced somewhat less (-20.3% vs. -29.4%) between 2009 and 2014-2015. The prevalence of high fasting glucose or diabetes was higher in urban areas in 2000-2001 and 2009, and the difference between rural and urban areas was no longer obvious by 2014-2015 (Table 4).

The prevalence of overweight in rural adults was increased by 24.5% between 2000-2001 and 2009 and by 14.2% between 2009 and 2014-2015, while it was reduced by -10.4% and -2.4%, respectively, in urban adults (Table 4). Compared with adults in urban areas, those in rural areas had a relatively low prevalence of overweight in 2000-2001 (26.6% vs. 39.1%) and in 2009 (33.1% vs. 35.1%), which was no longer the case in 2014-2015 (38.8% vs. 35.1%) (Table 4).

Discussions

The estimated prevalence of MetS among adults aged ≥40 years in 2014-2015 in China was 18.4% overall (13.2% in men and 23.7% in women) by the ATP III criteria. It was considerably higher by using the revised NCEP ATP III criteria (34.0% overall, 27.1% in men and 40.9% in women), or by using the IDF definition (26.9% overall, 18.4% in men and 35.7% in women). The overall rate of MetS (18.4% based on the ATP III definition) in China remains lower than that in the United States (about 35% among adults aged ≥20 years in 2011-2012)(15), in Europe (about 24%)(16), and in Brail (28.9%)(17). However, it is

already a serious public health problem due to the rapid population aging, behavioural and socioeconomic changes. According to the ATP III definition, 107 million Chinese adults aged 40-74 had metabolic syndrome. The number of adults with abdominal obesity and overweight was 96 million and 182 million, respectively, among adults aged 40-74 in 2014/15 in China. Furthermore, among Chinese adults aged 40-74 in 2014/15, there were 307 million with high blood pressure, 78 million with high fasting plasma glucose, 222 million with hypertriglyceridemia, and 182 million with low HDL cholesterol. The estimated number of adults with MetS will be much higher if the revised NCEP ATP III or IDF criteria were used.

Compared with results of previous cross-sectional studies, the prevalence of MetS estimated by the CSPP study in 2014-2015 was higher than that in 2000-2001, but often lower than the estimated prevalence in 2009 and 2010. A possible explanation is that public health measures taking to control cardiovascular conditions in China have some effects on reduced deterioration or increased improvement in MetS among adults. For example, the prevalence of abdominal obesity and high fasting plasma glucose among urban adults was lower in 2014-2015 than that in 2009. Because of different sampling and analysis methods, however, the results of the across-study comparison need to be interpreted with caution, and further studies are required to confirm the temporal trends in the prevalence of MetS in Chinese adults.

The CSPP study confirmed findings from previous studies that the prevalence of MetS was higher in women, older adults, those with low level of education, and in economically developed regions. Contrasting with previous nationally representative studies in China, the 2014-2015 CSPP study was the first to show that the MetS was more prevalent in rural areas than that in urban areas. The CSPP study revealed that rural adults had worse deterioration and/or less improvement in abdominal obesity, overweight, hypertension, and high fasting plasma glucose, than urban adults. In addition, the discrepancy in MetS between rural and urban adults was most striking for women.

Evidence from global nutrition transition suggested that urban residents generally have

higher prevalence of obesity and overweight in low-income or less developed nations, but rural residents will catch up quickly along with economic development(18). For example, although women with the highest wealth and education had the highest prevalence of overweight and obesity in 39 low and middle income countries, the increase of overweight was greater among women with the lowest wealth and education(19). The present study indicated that Chinese adults in rural areas are not only catching up quickly, but also possibly have overtaken those in urban areas regarding obesity and related MetS problems.

The speed of nutrition transition and socioeconomic development in China is uniquely rapid, which will lead to swift geographic and temporal changes in MetS. Cardiovascular diseases are expected to increase considerably in future due to population ageing and high prevalence of MetS. However, appropriate public health measures can be implemented to reduce the burden of cardiovascular diseases. It may be interesting to note that the CSPP study in 2014-2015 found a lower prevalence of abdominal obesity in urban adults, compared with the CHNS study in 2009. In addition, the estimated prevalence of high fasting plasma glucose for men in both rural and urban areas was lower in the CSPP study in 2014-2015 compared with that in the CHNS study in 2009. However, we should not be complacent as MetS components remain highly prevalent among Chinese adults. For example, the prevalence of high blood pressure is high in both rural and urban areas.

While efforts to prevent and control cardiovascular diseases need to be strengthened for the whole Chinese population, health decision makers need to be aware of rapid changes in the distribution of CVD risk factors by sub-population categories. Findings of the present study clearly indicate that CVD risk factors among rural residents and women should be prioritised in making public health policy decisions.

Strengths and Limitations

The CSPP study was a nationally representative study, the most recently completed, with the largest sample size to estimate the prevalence of MetS in China. In addition to the current prevalence of MetS in Chinese adults, we were able to show the possible temporal

changes in MetS prevalence by comparing results of the present study and previous nationally representative studies.

Some limitations of the study are worth mentioning. First, the present study included only participants who had additional laboratory test, and the prevalence of MetS will be over-estimated because high risk of stroke was more prevalent among them. However, we were able to cope with this problem by adjusting the estimated prevalence of MetS according to the distribution of stroke risk among all CSPP participants.

To show the possible temporal changes in MetS, we made cross-study comparisons. There may be many alternative explanations for the observed differences between the CSPP and previous studies. Although we have attempted to make the results of different studies as comparable as possible, it was difficult to be certain about the true causes of the difference between different cross-sectional studies. Availability of individual participant data from all relevant studies should help improve comparison of results across studies. However, so far we were able to access individual participant data for only one previous study (CHNS[8]), in addition to the CSPP study.

Conclusions

Prevalence of metabolic syndrome has been rapidly increasing and remains high, particularly in women and rural areas, among middle-aged and elderly adults in China. While efforts to prevent and control cardiovascular diseases need to be strengthened for the whole population, rapid increasing risk factors among rural residents and women should be prioritised in making public health policy decisions. It should also be a concern for health decision makers in other developing counties which are experiencing socio-economic transformation.

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Conflict of interests

The authors report no conflicts of interest

Figure legends:

Figure 1: Rates of prevalence of MetS (ATP III criteria) estimated by different nationally representative studies. Results of CHNS and CSPP were obtained by analyses of original individual participant survey data, while results of InterASIA and CNCDS were based on the published reports. The comparison of CSPP results and other studies for the 35-44 age group should be cautious as adults aged 35-39 were not included in the CSPP survey.

Figure 2: Ratio of prevalence rates of MetS in urban and rural areas in China, results from five nationally representative studies between 2000/01 and 2014/15.

References

1. Feigin VL, Forouzanfar MH, Krishnamurthi R, Mensah GA, Connor M, Bennett DA *et al.* Global and regional burden of stroke during 1990-2010: findings from the Global Burden of Disease Study 2010. *Lancet (London, England)* 2014; **383**(9913)**:** 245-54.

2. Yang G, Wang Y, Zeng Y, Gao GF, Liang X, Zhou M *et al.* Rapid health transition in China, 1990-2010: findings from the Global Burden of Disease Study 2010. *Lancet (London, England)* 2013; **381**(9882)**:** 1987-2015.

3. Teo KK, Dokainish H. The Emerging Epidemic of Cardiovascular Risk Factors and Atherosclerotic Disease in Developing Countries. *The Canadian journal of cardiology* 2017; **33**(3)**:** 358-365.

4. Lakka HM, Laaksonen DE, Lakka TA, Niskanen LK, Kumpusalo E, Tuomilehto J *et al.* The metabolic syndrome and total and cardiovascular disease mortality in middle-aged men. *Jama* 2002; **288**(21)**:** 2709-16.

5. Sundstrom J, Riserus U, Byberg L, Zethelius B, Lithell H, Lind L. Clinical value of the metabolic syndrome for long term prediction of total and cardiovascular mortality: prospective, population based cohort study. *BMJ (Clinical research ed.)* 2006; **332**(7546)**:** 878-82.

6. Gu D, Reynolds K, Wu X, Chen J, Duan X, Reynolds RF *et al.* Prevalence of the metabolic syndrome and overweight among adults in China. *Lancet (London, England)* 2005; **365**(9468)**:** 1398-405.

7. Hou X, Lu J, Weng J, Ji L, Shan Z, Liu J *et al.* Impact of waist circumference and body mass index on risk of cardiometabolic disorder and cardiovascular disease in Chinese adults: a national diabetes and metabolic disorders survey. *PLoS One* 2013; **8**(3)**:** e57319.

8. Xi B, He D, Hu Y, Zhou D. Prevalence of metabolic syndrome and its influencing

factors among the Chinese adults: the China Health and Nutrition Survey in 2009. *Preventive medicine* 2013; **57**(6)**:** 867-71.

9. Lu J, Wang L, Li M, Xu Y, Jiang Y, Wang W *et al.* Metabolic Syndrome Among Adults in China: The 2010 China Noncommunicable Disease Surveillance. *J Clin Endocrinol Metab* 2017; **102**(2)**:** 507-515.

10. CHNS. Online database: China Health and Nutrition Survey. UNC Carolina Population Center project. URL: http://www.cpc.unc.edu/projects/china/data/acknowledgement.html. Accessed on 06/06/2017. In: UNC Carolina Population Center project

11. NCEP. Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). *Jama* 2001; **285**(19)**:** 2486-97.

12. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA *et al.* Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation* 2005; **112**(17)**:** 2735-52.

13. Alberti KG, Zimmet P, Shaw J. The metabolic syndrome--a new worldwide definition. *Lancet (London, England)* 2005; **366**(9491)**:** 1059-62.

14. Zocchetti C, Consonni D, Bertazzi PA. Relationship between prevalence rate ratios and odds ratios in cross-sectional studies. *Int J Epidemiol* 1997; **26**(1)**:** 220-3.

15. Aguilar M, Bhuket T, Torres S, Liu B, Wong RJ. Prevalence of the metabolic syndrome in the United States, 2003-2012. *Jama* 2015; **313**(19)**:** 1973-4.

16. Scuteri A, Laurent S, Cucca F, Cockcroft J, Cunha PG, Manas LR *et al.* Metabolic syndrome across Europe: different clusters of risk factors. *Eur J Prev Cardiol* 2015; **22**(4)**:** 486-91.

17. de Carvalho Vidigal F, Bressan J, Babio N, Salas-Salvado J. Prevalence of metabolic syndrome in Brazilian adults: a systematic review. *BMC public health* 2013; **13:** 1198.

18. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition reviews* 2012; **70**(1)**:** 3-21.

19. Jones-Smith JC, Gordon-Larsen P, Siddiqi A, Popkin BM. Is the burden of overweight shifting to the poor across the globe? Time trends among women in 39 low- and middle-income countries (1991-2008). *International journal of obesity (2005)* 2012; **36**(8)**:** 1114-20.

Table 1. The main characteristics of CSPP participants in 2014-2015

Characteristic	Included (n=109551)	Not included (n=616900)	*P* value
Mean age(mean, SD)	59·23±11·01	56·88±11·44	<0·001
Age groups (%):			<0·001
40-49	22·8	32·3	
50-59	28·6	29·5	
≥60	48·6	38·2	
Sex (%):			<0·001
Men	45·4	47·0	
Women	54·6	53·0	
Education (%):			<0·001
Primary school and below	42·3	41·4	
Middle school	35·0	37·1	
High school or the equivalent	15·5	14·8	
University or other tertiary degree	7·3	6·7	
Location (%)			<0·001
Urban	52·3	46·6	
Rural	47·7	53·4	
Economic development (%)			<0·001
Under developed	19·4	30·3	
Intermediately developed	54·2	43·8	
Developed	26·4	25·9	
Stroke risk (%)			<0·001
Low	40·2	76·3	
Intermediate	10.0	14·5	
High (≥3 risk factors)	35·9	6·6	
History of TIA	5·7	1·2	
History of stroke	8·3	1·4	
Smoking status			<0·001
Current smokers (%)	18.0	3·5	
Former smokers (%)	3·4	0·5	
Current drinking (%)	13·8	1·8	<0·001
Physical inactivity (%)	28·4	16·7	<0·001

Table 2: Prevalence of MetS by different definitions in 2014-2015

	N	% (95% CI)		
		NCEP ATP III	**Revised NCEP ATP III**	**IDF**
Overall	109551	18·4% (18·2%, 18·7%	34·0% (33·7%, 34·3%)	26·9% (26·7%, 27·2%)
Sex:				
Men	49789	13·2% (12·9%, 13·6%)	27·1% (26·7%, 27·6%)	18·4% (18·1%, 18·8%)
Women	59762	23·7% (23·3%, 24·1%)	40·9% (40·5%, 41·3%)	35·7% (35.·3%, 36·1%)
Age group:				
40-49	24937	13·3% (12·8%, 13·7%)	27·3% (26·7%, 27·8%)	21·4% (20·8%, 21·9%)
50-59	31376	18·5% (18·1%, 19·0%)	34·2% (33·6%, 34·7%)	27·4% (26·8%, 27·9%)
>=60	53238	22·8% (22·4%, 23·2%)	39·4% (38·9%, 39·8%)	31·3% (30·9%, 31·7%)
Location:				
Urban	57298	17·8% (17·5%, 18·2%)	33·1% (32·7%, 33·5%)	26·7% (26·3%, 27·0%)
Rural	52253	19·6% (19·3%, 20·0%)	35·6% (35·1%, 36·0%)	27·7% (27·3%, 28·1%)
Economic:				
Underdeveloped	21272	15·1% (14·5%, 15·7%)	30·8% (30·2%, 31·5%)	23·6% (23·0%, 24·2%)
Intermediately	59365	19·0% (18·6%, 19·3%)	34·1% (33·7%, 34·5%)	28·7% (28·4%, 29·1%)
Developed	28914	19·7% (19·1%, 20·2%)	34·9% (34·3%, 35·5%)	26·3% (25·8%, 26·9%)
Smoking status:				
Never	86210	17·8% (17·6%, 18·1%)	33·3% (32·9%, 33·6%)	26·3% (26·0%, 26·6%)
Former	3672	32·2% (30·7%, 33·7%)	49·7% (48·1%, 51·3%)	41·7% (40·1%, 43·3%)
Current	19669	29·1% (28·4%, 29·7%)	47·2% (46·5%, 47·9%)	38·8% (38·1%, 39·5%)
Current drinking:				
No	94485	17·8% (17·5%, 18·1%)	32·8% (32·5%, 33·1%)	25·8% (25·5%, 26·1%)

Notes to Table 2: Estimated rates of the prevalence were weighted by 2014 population in China and adjusted by level of stroke risk in all CSPP participants.

Table 3: Association between MetS (defined by ATP III) and selected basic variables – results of logistic regression analysis.

Variables	Odds ratio	95% CI	P value
Sex			
Men	1·00		
Women	2·11	2·05-2·17	<0·001
Age			
40-49	1·00		
50-59	1·65	1·58-1·72	<0·001
≥60	2·05	1·97-2·13	<0.001
Location			
Rural	1·00		
Urban	0·94	0·92-0·97	<0·001
Education			
Primary school and below	1·00		
Middle school	1·01	0·98-1·04	0·692
High school or the equivalent	0·97	0·93-1.01	0·161
University or other tertiary degree	0·82	0·77-0.87	<0·001
Economic development			
Under developed	1·00		
Intermediately developed	1·08	1·04-1·12	<0·001
Developed	1·20	1·15-1·25	<0·001

Table 4: Prevalence of MetS components and changes over time by sex and location – comparison of results of different studies

	2000/01 InterASIA (35-74)	2009 CHNS		2014/15 CSPP (40-74)	Percent change % (P value)	
		(35-74)	(40-74)		2000/01- 2009	2009- 20014/15
Abdominal obesity						
Overall	7·7	18·1	19·1	16·5	134·5 (<0·001)	-13·6 (<0·001)
Men	1·7	7·9	7·8	4·8	366·5 (<0·001)	-38·1 (<0·001)
Women	13·9	27·4	29·5	25·9	97·3 (<0·001)	-12·2 (<0·001)
Rural:						
Overall	7·2	17·5	18·7	18·7	142·4 (<0·001)	0·1 (0·992)
Men	1·3	6·9	6·6	5·5	431·5 (<0·001)	-16·0 (0.098)
Women	13·4	27·4	29·9	29·5	104·5 (<0·001)	-1·2 (0·756)
Urban:						
Overall	10·1	17·7	18·8	14·5	75·6 (<0·001)	-23·0 (<0·001)
Men	3·1	8.5	9·0	4·3	175·.2 (<0·001)	-52·1 (<0·001)
Women	17·5	25·9	27·8	23·0	48·2 (<0·001)	-17·2 (0·001)
Hypertriglyceridemia						
Overall	24·8	33·9	35·1	38·2	36·9 (<0·001)	8·9 (<0·001)
Men	24·9	38·7	38·5	39·9	55·4 (<0·001)	3·7 (0·169)
Women	24·6	29·5	32·0	36·7	20·1 (<0·001)	14·8 (<0·001)
Rural:						
Overall	23·1	33·2	34·0	38·0	43·6 (<0·001)	11·9 (<0·001)
Men	22·1	37·5	37·1	39·8	69·5 (<0·001)	7·2 (0·032)
Women	24·2	29·1	31·1	36·8	20·3 (<0·001)	18·5 (<0·001)
Urban:						
Overall	32·3	35·8	37·6	38·4	10·7 (0·006)	2·2 (0·499)
Men	37·0	41·4	41·7	40·3	11·8 (0·022)	-3·3 (0·462)
Women	27·3	30·7	33·8	36·7	12·6 (0·034)	8·5 (0·069)
Low HDL cholesterol						
Overall	33·9	25·5	25·1	31·3	-24·8 (<0·001)	24·7 (<0·001)
Men	21·9	17·1	16·3	20·4	-21·7 (<0·001)	25·2 (<0·001)
Women	46·5	33·2	33·2	40·1	-28·5 (<0·001)	20·8 (<0·001)
Rural:						
Overall	33·5	24·1	23·7	29·3	-28·0 (<0·001)	23·7 (<0·001)
Men	29·7	15·8	14·8	20·9	-46·7 (<0·001)	41·5 (<0·001)
Women	47·3	32·0	31·9	36·1	-32·4 (<0·001)	13·2 (<0·001)
Urban:						
Overall	37·3	28·4	28·0	33·1	-23·8 (<0·001)	18·3 (<0·001)
Men	29·7	20·0	19·5	20·5	-32·8 (<0·001)	5·0 (0·504)
Women	45·3	36·0	35·7	43·4	-20·6 (<0·001)	21·6 (<0·001)

High blood pressure or medication use						
Overall	41·2	40·9	45·6	52·8	-0·7 (0·731)	15·9 (<0·001)
Men	44·2	45·7	49·5	55·8	3·3 (0·256)	12·8 (<0·001)
Women	38.0	36·5	42·0	50·6	-3·9 (0·191)	20·5 (<0·001)
Rural:						
Overall	41·5	40·3	45·0	58·4	-2·8 (0·250)	29·7 (<0·001)
Men	44·2	45·1	49·0	60·8	2·0 (0·568)	24·0 (<0·001)
Women	38·7	35·9	41·4	56·8	-7·4 (0·035)	37·2 (<0·001)
Urban:						
Overall	40·8	42·3	46·7	48·8	3·6 (0·289)	4·5 (0·108)
Men	45·1	47·1	50·5	52·5	4·5 (0·326)	4·1 (0·300)
Women	36·2	38·0	43·3	45·8	4·9 (0·325)	5·7 (0·168)
High fasting glucose or medication use						
Overall	12·7	14·0	15·7	13·5	10·5 (0·024)	-14·0 (<0·001)
Men	12·8	16·8	18·2	14·0	30·9 (<0·001)	-23·1 (<0·001)
Women	12·6	11·5	13·4	13·1	-8·7 (0·135)	-2·2 (0·686)
Rural:						
Overall	12·1	13·7	15·2	13·5	13·2 (0·016)	-11·0 (0·007)
Men	11·9	16·3	17·3	13·8	37·0 (<0·001)	-20·3 (<0·001)
Women	12·3	11·3	13·2	13·3	-8·5 (0·231)	0·8 (0·929)
Urban:						
Overall	15·1	14·9	16·9	13·7	-1·3 (0·829)	-18·8 (<0·001)
Men	16·2	17·9	20·1	14·2	10·2 (0·249)	-29·4 (<0·001)
Women	13·6	12·3	13·9	13·0	-9·9 (0·147)	-6·7 (0·409)
Overweight (BMI≥25.0kg/m2)						
Overall	28·9	34·1	34·9	36·7	18·1 (<0·001)	5·1 (0·009)
Men	26·9	34·3	33·9	36·6	27·4 (<0.001)	7·9 (0·007)
Women	31·1	34·0	35·8	36·7	9·4 (0·008)	2·5 (0·366)
Rural:						
Overall	26·6	33·1	34·0	38·8	24·5 (<0·001)	14·2 (<0·001)
Men	23·9	32·7	32·2	36·5	36·7 (<0·001)	13·4 (<0·001)
Women	29·5	33·6	35·6	40·7	13·7 (0·002)	14·2 (<0·001)
Urban:						
Overall	39·1	35·1	36·0	35·1	-10·4 (0·001)	-2·4 (0·452)
Men	39·9	36·7	36·7	37·0	-8·0 (0·090)	0·9 (0·873)
Women	38·1	33·6	35·3	33·5	-11·9 (0·007)	-5·2 (0·247)

Note: Age range for CHNS study(8) used were different to improve the comparability between studies: the InterASIA(6) aged 35-74; CHNS aged35-74 or 40-74, and CSPP aged 40-74. Percent change over time was calculated by: 100x(rate2-rate1)/rate1. ATP III definition was used: abdominal obesity: WC ≥102cm for men and WC ≥88cm for women;

high triglyceride: ≥1·7 mmol/L; low high-density-lipoprotein cholesterol: <1·03 mmol/L for men, and <1·29 mmol/L for women; high blood pressure: SBP ≥130 or DBP ≥85 mmHg or use of medication; high fasting plasma glucose: ≥6·105 mmol/L or use of medication. The estimated prevalence rates were weighted by sex and age structure of population in 2000 in China. Results of the CSPP survey were adjusted for stroke risk.

Figure 1: Rates of prevalence of MetS (ATP III criteria) estimated by different nationally representative studies.

Results of CHNS(8) and CSPP (the present study) were based on original individual participant data, while results of InterASIA(6) and CNCDS(9) were obtained from the published reports. For the 35-44 age group, the CSPP were based on data from participants aged 40-44.

Fig 1a

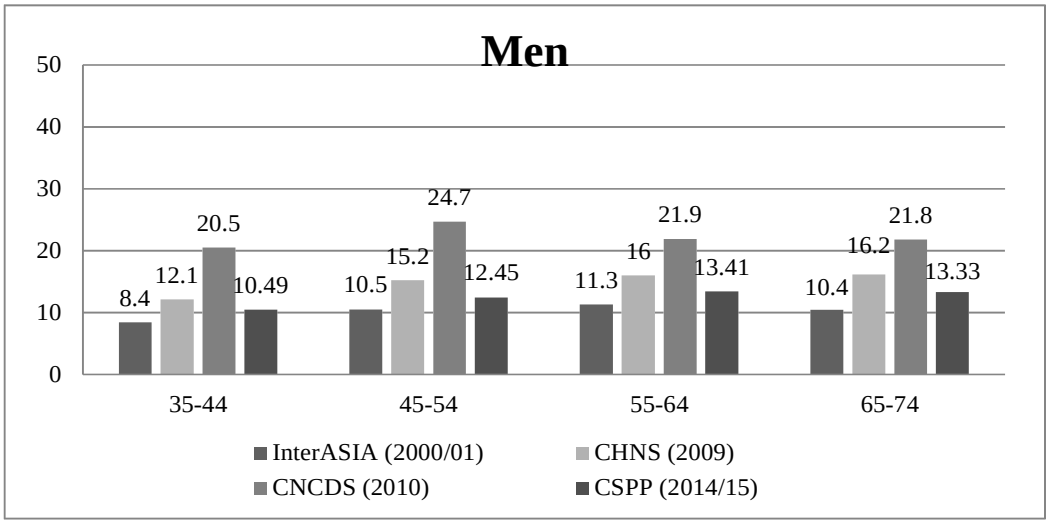


Fig 1b

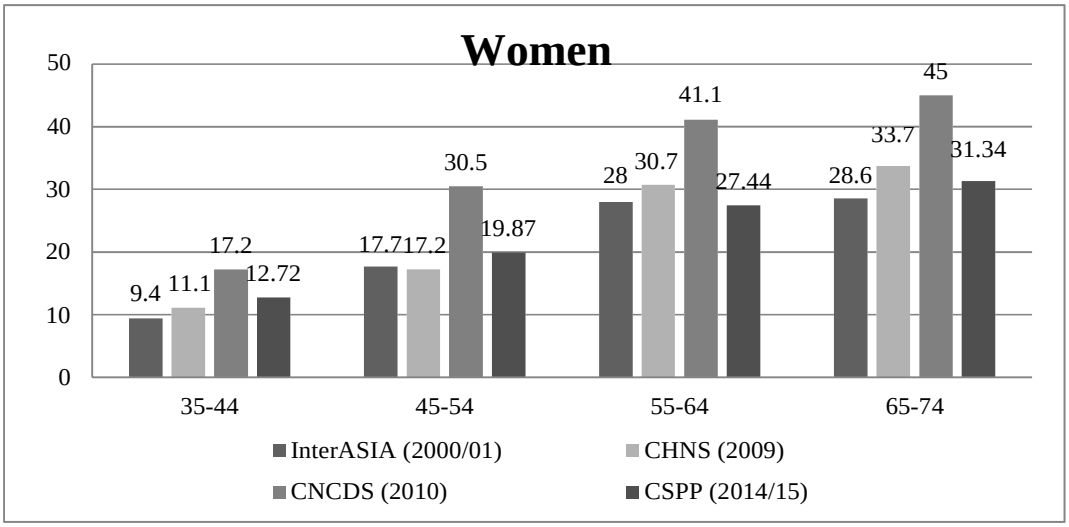


Figure 2: Ratio of prevalence rates of MetS in urban and rural residents in China, results from five nationally representative studies during 2000-2001 and 2014-2015.

Notes to Figure 2 - The five studies are InterASIA(6), CDMDS(7), CHNS(8), CNCDS(9), and CSPP survey. The prevalence rate ratio >1 indicates a higher prevalence in urban residents, and <1 indicates a lower prevalence in urban residents, compared with that in rural areas.

Fig 2a

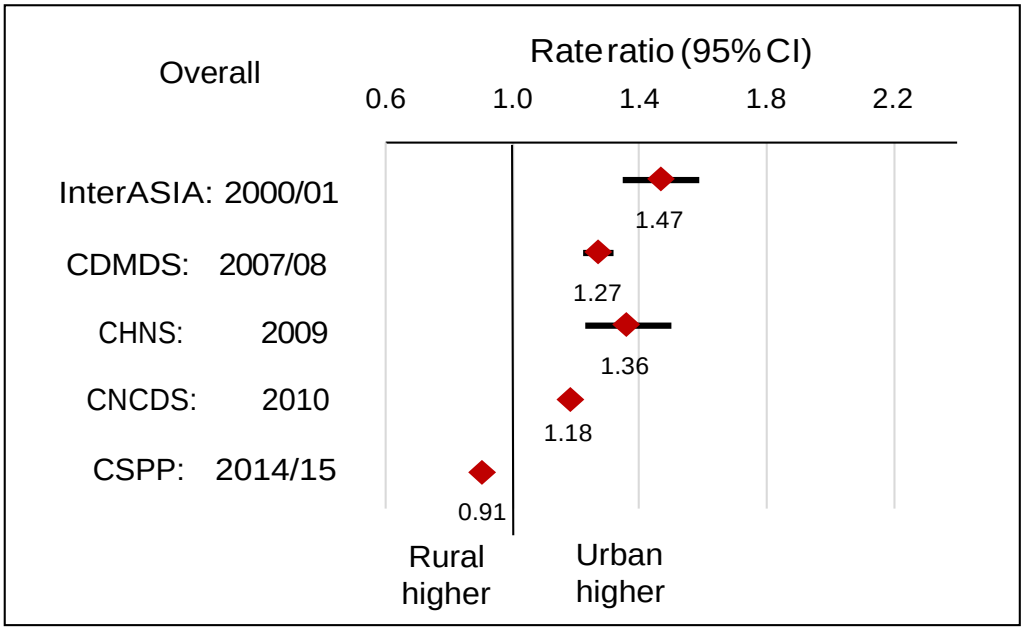


Fig 2b

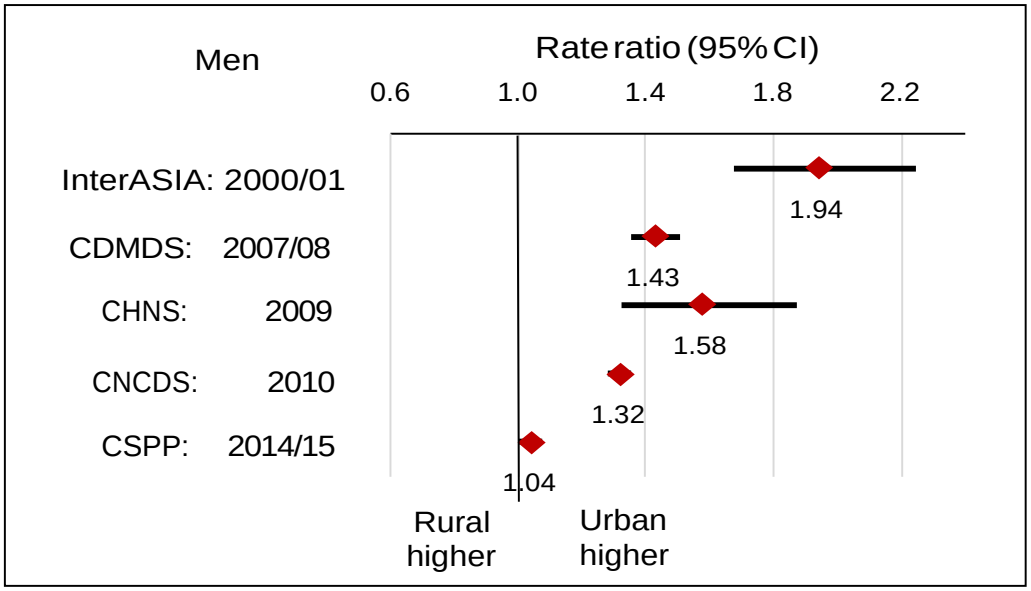
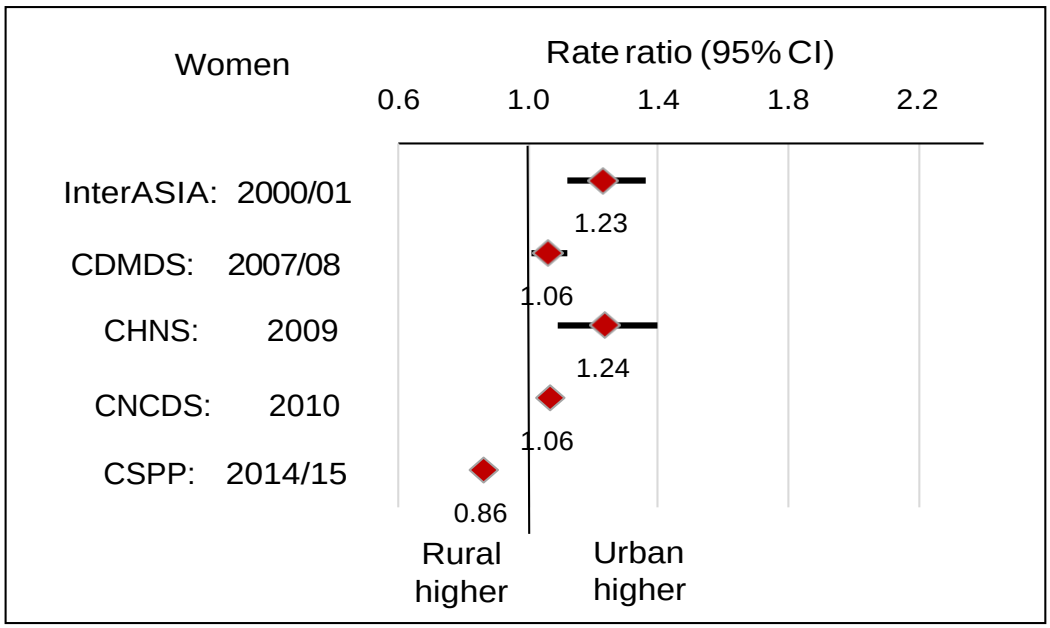


Fig 2c


Women
Rate ratio (95% CI)
0.6
1.0
1.4
1.8
2.2
InterASIA: 2000/01
1.23
CDMDS: 2007/08
1.06
CHNS: 2009
1.24
CNCDS: 2010
1.06
CSPP: 2014/15
0.86
Rural higher
Urban higher

SUPPLEMENTARY FILES

Supplementary file-1: Definition of the metabolic syndrome

Risk factors	NCEP ATP III(1)	Revised NCEP ATP III(2)	Updated IDF(3)
	At least three risk factors	At least three risk factors	Central obesity plus 2 or more risk factors
central obesity	Men: WC ≥102cm Women: WC ≥88cm	Men: WC ≥90cm Women: WC ≥80cm	Men: WC ≥90cm Women: WC≥80cm
High BP	SBP/DBP ≥130/85 mmHg or taking anti-hypertensive drugs	SBP/DBP ≥130/85 mmHg or taking anti-hypertensive drugs	SBP/DBP ≥130/85 mmHg or taking anti-hypertensive drugs
High fasting plasma glucose	Fasting glucose ≥6·1mmol/L or taking anti-diabetic drugs	Fasting glucose ≥ 5·6mmol/L or taking anti-diabetic drugs	Fasting glucose ≥ 5·6mmol/L or taking anti-diabetic drugs
High triglycerides	Triglycerides ≥1·7mmol/L	Triglycerides ≥1·7mmol/L	Triglycerides ≥1·7mmol/L
Low HDL-C	Men: HDL-C <1·03 mmol/L Women: HDL-C < 1·29 mmol/L	Men: HDL-C <1·03 mmol/L Women: HDL-C <1·29 mmol/L	Men: HDL-C <1·03 mmol/L Women: HDL-C < 1·29

1. NCEP. Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). Jama 2001; 285(19): 2486-97.

2. Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation 2005; 112(17): 2735-52.

3. Alberti KG, Zimmet P, Shaw J. The metabolic syndrome--a new worldwide definition. Lancet (London, England) 2005; 366(9491): 1059-62.

Supplementary file -2: Prevalence of MetS (ATP III criteria) -weighted by sex- age- structure of the 2014 population in China

	Low risk		Intermediate risk		High risk		Prior TIA		Prior stroke		All included	
	n	% (95%CI)	n	% (95%CI)	n	% (95%CI)	n	% (95%CI)	n	% (95%CI)	n	% (95%CI)
Overall	44029	12·7%(12·4-13·0)	10916	26·2%(25·3-27·0)	39301	40·3%(39·8-40·8)	6256	26·8%(25·7-27·8)	9049	35·3%(34·3-36·3)	109551	25·1%(24·9-25·4)
Sex:												
Men	19343	8·9%(8·5-9·3)	4431	18·0%(16·8-19·1)	19087	31·1%(30·5-31·8)	2311	20·9%(19·2-22·5)	4617	26·2%(24·9-27·4)	49789	19·2%(18·9-19·6)
Women	24686	16·6%(16·1-17·1)	6485	34·4%(33·3-35·6)	20214	49·5%(48·8-50·2)	3945	32·6%(31·2-34·1)	4432	44·5%(43·0-46·0)	59762	31·1%(30·7-31·5)
Age group:												
40-49	16426	10·6%(10·1-11·1)	1346	25·5%(23·2-27·9)	5658	37·2%(35·9-38·5)	954	23·3%(20·6-25·9)	553	33·7%(29·7-37·6)	24937	18·4%(17·9-18·8)
50-59	13421	13·0%(12·5-13·6)	3113	26·7%(25·2-28·3)	11139	42·1%(41·1-43·0)	1716	29·2%(27·1-31.4)	1987	35·9%(33·8-38·0)	31376	27·0%(26·5-27·4)
>=60	14182	14·9%(14·3-15·5)	6457	26·4%(25·4-27·5)	22504	42·4%(41·7-43·0)	3586	28·7%(27·3-30·2)	6509	36·7%(35·6-37·9)	53238	31·4%(31·0-31·8)
Location:												
Urban	26049	11·3%(10·9-11·7)	5943	24·7%(23·6-25·8)	17995	43·5%(42·8-44·2)	3024	27·5%(25·9-29·1)	4287	37·3%(35·9-38·8)	57298	24·0%(23·6-24·3)
Rural	17980	14·8%(14·3-15·4)	4973	27·7%(26·4-28·9)	21306	37·6%(36·9-38·2)	3232	26·6%(25·0-28·1)	4762	33·6%(32·2-34·9)	52253	25·6%(26·2-26·9)
Economic:												
Underdeveloped	6487	9·9%(9·2-10·7)	1490	24·6%(22·4-26·8)	9692	34·6%(33·7-35·5)	1663	26·2%(24·1-28·3)	1940	32·0%(29·9-34·1)	21272	24·0%(23·4-24·6)
Intermediately	26905	13·1%(12·7-13·5)	5987	26·4%(25·2-27·5)	18255	42·1%(41·4-42·9)	3191	27·1%(25·6-28·6)	5027	34·8%(33·5-36·1)	59365	24·8%(24·4-25·1)