ELSEVIER

Atherosclerosis xxx (2007) xxx–xxx

ATHEROSCLEROSIS

www.elsevier.com/locate/atherosclerosis

Significant lipid, adiposity and metabolic abnormalities amongst 4535 Indians from a developing region of rural Andhra Pradesh

Clara Kayei Chow[a,d,*], Shanthi Naidu[c], Krishnam Raju[c], Rama Raju[b], Rohina Joshi[a], David Sullivan[d], David S. Celermajer[d,e], Bruce C. Neal[a]

[a] The George Institute for International Health, University of Sydney, PO Box M 201, Camperdown, Missenden Road, Sydney 2050, Australia
[b] Byrraju Foundation, Hyderabad, India
[c] CARE Foundation, Hyderabad, India
[d] Royal Prince Alfred Hospital, Sydney, Australia
[e] Department of Medicine, University of Sydney, Australia

Received 19 October 2006; received in revised form 9 February 2007; accepted 23 February 2007

Abstract

Background and objective: Both migrant and local urban populations of Asian Indians have high rates of cardiovascular disease. Metabolic risk factors appear key to this phenomenon but data from rural India are few. We sought to determine the prevalence and distribution of lipids, obesity and metabolic syndrome in a rural region of Andhra Pradesh.
Methods: Sampling was done in 20 villages representative of the project area with an age- and sex-stratified group of 4535 adults ≥30 years selected at random from a local census list. The sample represented 13% of all adults ≥30 years in the 20 villages with a response rate of 81%. All participants had interviewer administered questionnaire, physical examination and fasting finger-prick glucose. Every fourth individual had venous blood testing for lipid profile ($n = 1085$). Analysis was done using weighting to obtain estimates of risk factor levels for the adult population in the 20 villages. In addition to standard WHO and 2005 NCEP-ATPIII classifications, exploratory 'Asian' definitions were used for overweight and abdominal obesity.
Results: The population mean levels of total, LDL, HDL-cholesterol and triglycerides were 4.5 (4.4–4.6) mmol/L, 2.8 (2.7–2.9) mmol/L, 1.1 (1.06–1.13) mmol/L, 1.5 (1.4–1.6) mmol/L for men; and 4.8 (4.7–4.9) mmol/L, 3.0 (3.0–3.1) mmol/L, 1.2 (1.16–1.22) mmol/L, 1.3 (1.2–1.4) mmol/L for women. 18.4% of men and 26.3% of women were overweight rising to 32.4% of men and 41.4% of women if 'Asian' definitions were used. Criteria for NCEP-ATPIII metabolic syndrome were met by 26.9% of men and 18.4% of women with figures of 32.5% and 23.9%, respectively, if 'Asian' waist cut-offs were substituted.
Conclusions: Dyslipidaemia, adiposity and metabolic syndrome were common in this rural Indian population and prevalence was much greater if proposed Asian definitions for adiposity were used. Metabolic risk factors likely play a major role in cardiovascular disease in this region.

Keywords: Rural India; Metabolic syndrome; Lipids; Adiposity; Overweight; Obesity; Survey

1. Introduction

Markedly abnormal levels of cardiovascular risk factors and high rates of cardiovascular disease have been observed

* Corresponding author. Tel.: +612 9993 4500; fax: +612 9993 4502.
E-mail address: cchow@george.org.au (C.K. Chow).

0021-9150/$ – see front matter © 2007 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.atherosclerosis.2007.02.027

in both local and migrant populations of South Asians [1–5]. Lipids, obesity and metabolic factors appear to have been key determinants of the burden of cardiovascular disease amongst the mainly urban populations studied to date [6–8]. Information about levels of cardiovascular risk factors in rural populations of South Asia is much more sparse but is of great importance. Large proportions of the populations of developing countries in the Asian subcontinent live in rural regions, many of which are now making the rapid social and economic transition already seen in urban areas [9,10]. Furthermore, the few data available suggest that the pattern of metabolic risk factors in rural regions of developing countries is not always predictable. In China, for example, the prevalence of metabolic syndrome in rural males is only about one half that observed in men from urban areas while rates in rural women are almost those of their urban counterparts [11]. And in Latin America there is evidence from rural communities showing young adults to have a higher prevalence of metabolic syndrome than the corresponding age group in the cities [12].

Deteriorating levels of cardiovascular risk factors in large rural populations can have profound effects on the urban-rural distribution of people at high risk of cardiovascular disease in a nation. In Thailand, for example, while levels of most risk factors were lower in rural regions, the very large proportion of the population living in the countryside means that the absolute number of people at high cardiovascular risk in rural areas likely now equals or exceeds that of the cities [13]. A similar transition may occur in India, a country in which some 70% of the population resides in rural areas. Recent data suggest that developing rural parts of the country are following the transition of urban India with high rates of diabetes and a large proportion of mortality now attributable to ischaemic heart disease and stroke [14,15]. There are, however, few data about the levels of lipids, obesity and metabolic syndrome in rural India and the likely current and future role of these risk factors on cardiovascular disease in rural areas is uncertain. We conducted a high-quality survey to determine the prevalence and distribution of lipids, obesity and metabolic syndrome in a developing rural region of India to resolve some of this uncertainty. We also sought to quantify the impact that proposed 'Asian' definitions for some risk factors [16,17] might have on the proportions of the population defined as abnormal.

2. Methods

The study was conducted as part of the Andhra Pradesh Rural Health Initiative (APRHI) whose members and details are listed in acknowledgements. The study was approved by the Ethics Committees of the CARE Hospital, Hyderabad in India, and the University of Sydney in Australia. All participants provided informed consent and the study was done in line with the Declaration of Helsinki and subsequent amendments.

2.1. Survey design and sampling method

Twenty villages participating in a broad-based rural development initiative run by the Byrraju Foundation, a local non-governmental organisation and collaborator in APRHI, were selected from the East and West Godavari regions of Andhra Pradesh. Villages were chosen to be broadly representative of these two districts on the basis of their population size and distance from the nearest large town. The most recently collated population lists for these 20 villages were compiled by the Byrraju Foundation in 2002. These lists included age, sex and contact details of all individuals living in the 20 villages and thus enabled selection of a stratified random sample of individuals over the age of 30 years from 8 groups defined by age (30–39, 40–49, 50–59, 60+) and sex. Using this method of sampling and data analysis techniques based on weighting enabled estimation of risk factor levels overall and for each age and sex group for the population living in the 20 villages. This sampling and analysis strategy was used to simultaneously ensure maximally precise estimates for each age and sex group while providing for calculation of an overall population estimate using sample weights. While simple random sampling would have provided precise estimates overall and for younger age groups, estimates for older individuals (amongst whom most vascular disease occurs) would have been imprecise because the adult population is dominated by individuals of young and middle age.

2.2. Data collection and measurements

Survey work was conducted in 2005. For each individual that consented to participate, trained study staff administered a structured questionnaire [18], performed a brief physical examination and performed a fasting finger-prick glucose using B-Braun USV meters (Melsungen, Germany). Every fourth individual had a fasting venous blood sample drawn. The examination included two sitting measurements of blood pressure using an Omron M2 manual inflation monitor and measurements of body weight, height, waist and hip with participants wearing light clothing without shoes. Participants were asked to fast overnight and if their reported fasting time was less than 8-h on the day of testing, they were asked to return fasting the next day.

Venous blood samples collected in the villages were immediately refrigerated in a generator-powered portable refrigerator and then transferred over ice to the field laboratory within 4 h of collection for separation of serum and plasma by centrifugation. Plasma glucose was measured by a GOD-POD method using Merck Pte Ltd, Singapore reagents on a ALFA Biotech PLD-951 semiautomated analyzer and the remainder of the sample was then frozen at −20 °C. Frozen samples were shipped to a central internationally accredited laboratory in the CARE hospital, Hyderabad, India where at completion of the survey all samples were tested for creatinine, total cholesterol and cholesterol sub-fractions. Total cholesterol and triglycerides were determined using

CHOD-PAP and GPO-POD methods, respectively (Beckman Synchron Cx System reagents, Fullerton, U.S.). HDL cholesterol was quantified by the Catalase CHOD-PAP procedure, direct assay (Randox reagents, Antrim, UK). LDL cholesterol was measured by Detergent Technology CHOD-PAD direct assay (Daichi, Tokyo, Japan). Creatinine was measured using the Kinetic Jaffee method. All biochemistry was measured using a Beckman Coulter Synchron Cx9 Clinical system ALX. In addition to this laboratory's own quality control processes an external quality assurance program was instituted using quality control materials provided by the Royal College of Pathologists Australia.

2.3. Definitions

Abnormalities of total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein (LDL) cholesterol and triglycerides were defined according to National Cholesterol Education Program Expert Panel Adult Treatment Panel (NCEP-ATP III) guidelines [19]. Overweight and obesity were defined according to conventional World Health Organisation (WHO) cut points of body mass index (BMI) of $\geq$25 kg/m^2 and $\geq$30 kg/m^2 respectively as well as by cut points recommended by the WHO for Asian populations ($\geq$23 kg/m^2 and $\geq$27.5 kg/m^2) [20]. Likewise, abnormalities of waist were categorised both according to NCEP-ATP III guidelines and suggested lower cut points for Asians (men > 90 cm, women > 80 cm) [21]. The metabolic syndrome was defined according to the 2005 updated NCEP-ATP III guidelines on the basis of the presence of three or more of abdominal obesity, elevated triglycerides ($\geq$150 mg/dL), low HDL cholesterol (men < 40 mg/dL, women < 50 mg/dL), high blood pressure ($\geq$130/$\geq$85 mmHg) or raised fasting glucose ($\geq$100 mg/dL) with drug treatment for abnormalities of cholesterol, cholesterol sub-fractions, blood pressure or glucose considered to indicate an abnormality [21]. A second 'Asian' definition of the metabolic syndrome was also used, with abdominal obesity defined by the lower cut points (men > 90 cm, women > 80 cm) as recommended by the updated NCEP-ATP III guidelines and the International Diabetes Federation (IDF) guidelines [21,22].

2.4. Statistical analysis

Statistical analyses were carried out using STATA 8.0. All results reported are weighted estimates for the total adult population 30 years and above resident in the 20 study villages in the Godavari region. Overall and stratum-specific estimates of risk factor levels are reported. Weights used in analyses were the population to sample size ratios for each combination of age, sex and village. These weights adjust results for the unequal probabilities of selection consequent upon the stratified sampling technique and took into account non-response. Separate weights were used for the 4535 individuals interviewed and the 1085 individuals with venous blood samples. At the time of analysis, collection of another round of household data commencing in 2004 was finished by the Byrraju Foundation. This more recent data on population age and sex structure was used for weighting to ensure estimates of population risk factor levels were as up-to-date as possible. The age and sex distribution of the population had not changed greatly compared with the 2002 population, with the average ratio of population weights calculated to be 0.98 and ranging from 0.89 to 1.07 across the eight age and sex strata. Means and proportions are presented with standard errors (S.E.) or with 95% confidence intervals. Risk factor levels were compared between groups using independent *t*-tests for continuous variables and chi-square tests for proportions. Associations with age were tested using linear regression and logistic regression models. All tests accounted for the sampling method and weighting and $2p < 0.05$ was considered to indicate a result unlikely to have arisen by chance.

3. Results

Of the 6985 selected for inclusion in the study on the basis of the 2002 local Byrraju census, 5627 individuals were still living in the villages in 2005 and were invited to participate in the study. 4535 agreed and provided informed consent. The response rate of residents was 81%, ranging from 71% to 89% across the 20 villages and between 77% and 86% across the eight age and sex groups. Amongst respondents, data from the questionnaire and physical examination were more than 99% complete but 3% were excluded from the analyses on the basis of there being no fasting blood sample available. The population was rural with 54% of the population working as unskilled manual labourers (mainly in agriculture and aquaculture) and only 47% being literate. The mean monthly income per household was US$51 (Inter-quartile range $23–55). The prevalence of cardiovascular disease (previous medical diagnosis of heart attack, angina or stroke) was 6.6% (5.8–7.4) overall, 7.1% (5.9–8.3) for men and 6.0% (4.9–7.1) in women. The prevalence of hypertension (SBP $\geq$ 140 or DBP $\geq$ 90 or medical diagnosis/treatment of hypertension) was 27.0% (25.7–28.4) overall, 26.6% (24.6–28.6) for men and 27.5% (25.6–29.4) in women. The prevalence of current smoking was 25.2% (23.9–26.6) overall, 45.2%(42.8–47.7) in men and 4.8% (3.8–5.8%) in women.

3.1. Lipid levels

Mean levels of total cholesterol, LDL-cholesterol, HDL-cholesterol and triglycerides were 4.6, 2.9, 1.1 and 1.4 mmol/L, respectively (Table 1). Total cholesterol, LDL cholesterol and HDL cholesterol levels were higher in women (all $p < 0.001$) but triglycerides levels were higher in men ($p = 0.02$). Total cholesterol, LDL cholesterol and triglycerides increased with age (all $p \leq 0.005$) but no association of age with HDL cholesterol levels was detected ($p = 0.3$).

Table 1
Mean levels with standard errors of lipoproteins, weight, waist, BMI and WHR by age and sex in 20 villages in rural Andhra Pradesh, 2005

	Total cholesterol (mmol/L)		LDL-cholesterol (mmol/L)		HDL-cholesterol (mmol/L)		Triglycerides (mmol/L)		Weight (kg)		Waist (cm)		BMI (kg/m^2)		WHR	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Overall	4.6	0.04	2.9	0.03	1.1	0.01	1.4	0.04	54.4	0.20	78.1	0.19	21.9	0.07	0.87	0.001
30–39	4.3	0.08	2.7	0.06	1.1	0.02	1.2	0.06	54.3	0.36	75.5	0.33	21.6	0.13	0.86	0.002
40–49	4.8	0.09	3.0	0.07	1.2	0.02	1.4	0.06	56.4	0.41	80.1	0.39	22.6	0.14	0.88	0.002
50–59	5.0	0.07	3.2	0.06	1.2	0.02	1.5	0.09	55.3	0.45	80.2	0.40	22.5	0.16	0.88	0.002
60+	4.7	0.08	2.9	0.06	1.2	0.02	1.5	0.08	51.5	0.37	78.3	0.36	21.4	0.14	0.88	0.002
Men																
Men, all	4.5	0.06	2.8	0.05	1.1	0.02	1.5	0.06	57.9	0.29	80.6	0.27	21.6	0.09	0.91	0.002
30–39	4.3	0.12	2.7	0.10	1.1	0.03	1.4	0.12	57.7	0.54	78.0	0.50	21.1	0.18	0.89	0.003
40–49	4.6	0.15	2.9	0.10	1.1	0.04	1.5	0.11	59.5	0.59	82.4	0.56	22.2	0.19	0.92	0.003
50–59	4.8	0.11	3.1	0.09	1.1	0.03	1.4	0.06	59.1	0.62	82.9	0.58	22.1	0.20	0.92	0.003
60+	4.4	0.10	2.7	0.08	1.1	0.03	1.5	0.10	55.5	0.50	80.6	0.49	21.0	0.16	0.92	0.003
Women																
Women, all	4.8	0.06	3.0	0.04	1.2	0.02	1.3	0.05	50.7	0.27	75.5	0.25	22.3	0.11	0.83	0.001
30–39	4.4	0.11	2.8	0.08	1.2	0.03	1.0	0.05	51.0	0.48	72.9	0.44	22.0	0.20	0.82	0.003
40–49	5.0	0.10	3.2	0.09	1.2	0.03	1.3	0.06	52.8	0.55	77.6	0.52	23.1	0.21	0.84	0.003
50–59	5.2	0.09	3.3	0.07	1.2	0.02	1.7	0.17	51.4	0.61	77.4	0.53	22.8	0.25	0.84	0.003
60+	5.0	0.12	3.1	0.08	1.2	0.03	1.5	0.12	47.8	0.54	76.2	0.52	21.8	0.22	0.84	0.003

High total cholesterol was recorded in 7.2% and high LDL cholesterol in 7.3%, with high total cholesterol more common in women than men ($P = 0.03$) but no significant difference between sexes detected for LDL cholesterol ($p = 0.08$), Tables 2 and 3. The prevalence of low HDL cholesterol was 30.5% and the prevalence of high triglycerides was 11.0%, with both abnormalities more common in men than women (both $p \leq 0.002$), Tables 4 and 5. The prevalence of lipid abnormalities by age mirrored the patterns seen for mean lipid levels.

3.2. Adiposity

The mean weight of the population was 54.4 kg, the mean waist circumference was 78.1 cm, the mean waist:hip ratio (WHR) was 0.87 and the mean BMI was 21.9 kg/m^2 (Table 1). Weight, waist circumference and waist:hip ratio were all greater in men (all $p < 0.001$) but mean BMI was greater in women ($p < 0.001$). Waist and WHR both increased with age (both $p \leq 0.001$), weight decreased with age ($p < 0.001$) and no association was found between age and BMI ($p = 0.6$).

Table 2
Prevalence of desirable, borderline high and high total-cholesterol according to ATPIII guidelines by age and sex in rural Andhra Pradesh, 2005

	TC < 200 mg/dL		TC 200–239 mg/dL		TC ≥ 240 mg/dL	
	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)
Overall	69.8	1.6	23.0	1.5	7.2	0.9
30–39	79.3	2.9	17.5	2.7	3.2	1.2
40–49	66.4	3.4	24.6	3.1	9.0	2.0
50–59	62.2	3.8	27.3	3.6	10.5	2.1
60+	64.8	3.0	26.4	2.8	8.8	1.8
Men						
Men, total	73.5	2.3	21.1	2.2	5.4	1.1
30–39	79.6	4.3	16.2	4.1	4.2	1.9
40–49	68.8	4.8	24.7	4.5	6.5	2.3
50–59	62.1	5.5	30.2	5.3	7.7	2.7
60+	78.3	3.5	17.5	3.3	4.2	1.7
Women						
Women, total	66.1	2.3	24.9	2.1	9.0	1.3
30–39	79.0	3.7	18.7	3.6	2.3	1.3
40–49	63.6	4.8	24.5	4.2	11.8	3.3
50–59	62.3	5.3	24.3	4.7	13.5	3.4
60+	52.2	4.6	34.8	4.4	13.1	3.1

Percentage and standard errors.

Please cite this article in press as: Chow CK, et al., Significant lipid, adiposity and metabolic abnormalities amongst 4535 Indians from a developing region of rural Andhra Pradesh, Atherosclerosis (2007), doi:10.1016/j.atherosclerosis.2007.02.027

Table 3
Prevalence of optimum, borderline high, high and very high LDL-cholesterol according to ATPIII guidelines by age and sex in rural Andhra Pradesh, India 2005

	LDL < 130 mg/dL		LDL 130–159 mg/dL		LDL 160–189 mg/dL		LDL ≥ 190 mg/dL	
	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)
Overall	69.7	1.7	23.0	1.5	5.8	0.8	1.5	0.5
30–39	78.2	2.9	16.8	2.5	4.1	1.5	0.9	0.7
40–49	65.5	3.5	27.1	3.3	5.5	1.4	1.9	1.2
50–59	61.9	3.8	26.3	3.5	9.3	2.2	2.4	0.9
60+	67.2	3.0	25.2	2.8	6.0	1.5	1.6	0.8
Men								
Men, total	72.3	2.4	22.0	2.2	4.7	1.2	0.9	0.5
30–39	78.5	4.3	14.8	3.4	5.1	2.7	1.6	1.3
40–49	68.5	5.0	27.4	4.9	3.8	1.8	0.2	0.2
50–59	61.4	5.5	27.7	5.3	9.6	3.3	1.3	0.9
60+	75.7	3.8	22.3	3.7	1.5	0.8	0.6	0.6
Women								
Women, total	67.1	2.3	23.9	2.1	6.8	1.1	2.2	0.8
30–39	77.9	3.9	18.8	3.7	3.1	1.5	0.2	0.2
40–49	62.1	4.9	26.8	4.5	7.4	2.2	3.7	2.6
50–59	62.5	5.3	24.9	4.6	9.0	2.9	3.7	1.6
60+	59.3	4.5	27.9	4.1	10.3	2.8	2.5	1.3

Percentage and standard errors.

The proportion with a waist measurement above NCEP ATPIII recommended levels was 7.6%, the proportion with a BMI ≥ 25 kg/m^2 was 22.3%and the proportion with a BMI ≥ 30 kg/m^2 was 4.2%, Table 6.

3.3. Metabolic syndrome

The prevalence of NCEP-ATPIII defined metabolic syndrome in adults 30 years and over was 24.6% with a greater prevalence in men, 28.6% than women 20.4% ($p = 0.03$) and an increasing prevalence with age ($p < 0.001$) (Table 6). Amongst men with metabolic syndrome, defining risk factors in order of most common to least common were an abnormal fasting glucose, an elevated blood pressure, a low HDL cholesterol level, high triglycerides, and abdominal obesity. Amongst women with metabolic syndrome, defining risk factors in order of most common to least common were an abnormal fasting glucose, an elevated blood pressure, high triglycerides, a low HDL cholesterol level, and abdominal obesity (Fig. 2).

Table 4
Prevalence of low, normal and high HDL-cholesterol according to ATPIII guidelines by age and sex in rural Andhra Pradesh, India 2005

	HDL < 40 mg/dL		HDL 40–59 mg/dL		HDL ≥ 60 mg/dL	
	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)
Overall	30.5	1.7	61.8	1.8	7.8	1.0
30–39	34.3	3.3	57.6	3.5	8.1	2.1
40–49	27.1	3.2	65.6	3.4	7.3	1.8
50–59	29.1	3.4	66.7	3.5	4.2	1.2
60+	29.3	2.9	60.2	3.1	10.5	1.9
Men						
Men, total	38.9	2.6	54.1	2.6	7.0	1.5
30–39	43.5	5.1	48.2	5.2	8.3	3.3
40–49	34.1	4.9	58.4	5.1	7.6	2.7
50–59	40.8	5.5	54.4	5.6	4.8	1.9
60+	36.2	4.2	57.9	4.3	5.9	2.1
Women						
Women, total	21.8	2.0	69.6	2.3	8.6	1.3
30–39	25.2	4.1	67.0	4.4	7.9	2.5
40–49	19.3	3.9	73.7	4.3	7.0	2.2
50–59	17.0	3.5	79.5	3.8	3.5	1.5
60+	22.9	3.9	62.3	4.5	14.8	3.2

Percentage and standard errors.

Please cite this article in press as: Chow CK, et al., Significant lipid, adiposity and metabolic abnormalities amongst 4535 Indians from a developing region of rural Andhra Pradesh, Atherosclerosis (2007), doi:10.1016/j.atherosclerosis.2007.02.027

Table 5
Prevalence of normal, borderline high, high and very high Tryglycerides according to ATPIII guidelines by age and sex in rural Andhra Pradesh, India 2005

	TG < 150 mg/dL		TG 150–199 mg/dL		TG 200–499 mg/dL		TG ≥ 500 mg/dL	
	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)
Overall	75.8	1.5	13.1	1.2	9.8	1.0	1.2	0.4
30–39	83.2	2.5	8.1	1.9	8.2	1.8	0.5	0.5
40–49	72.4	3.3	16.0	2.9	10.2	2.1	1.1	0.7
50–59	71.3	3.5	18.6	3.0	8.8	1.9	1.2	1.2
60+	71.6	2.9	13.3	2.1	12.7	2.1	2.3	0.9
Men								
Men, total	71.4	2.4	14.2	1.8	12.6	1.7	1.5	0.6
30–39	74.0	4.4	10.6	3.0	14.4	3.5	1.1	1.1
40–49	64.1	5.1	19.8	4.5	13.3	3.5	2.0	1.3
50–59	74.9	4.6	20.1	4.3	5.0	1.8	0.0	0.0
60+	73.8	3.8	8.3	2.2	15.0	3.3	2.9	1.2
Women								
Women, total	80.3	1.9	11.9	1.6	7.0	1.1	0.8	0.5
30–39	92.4	2.5	5.6	2.2	2.1	1.2	0.0	0.0
40–49	81.7	3.9	11.6	3.6	6.7	2.1	0.0	0.0
50–59	67.6	5.3	17.1	4.2	12.8	3.4	2.5	2.5
60+	69.7	4.2	18.0	3.5	10.6	2.8	1.8	1.3

Percentage and standard errors.

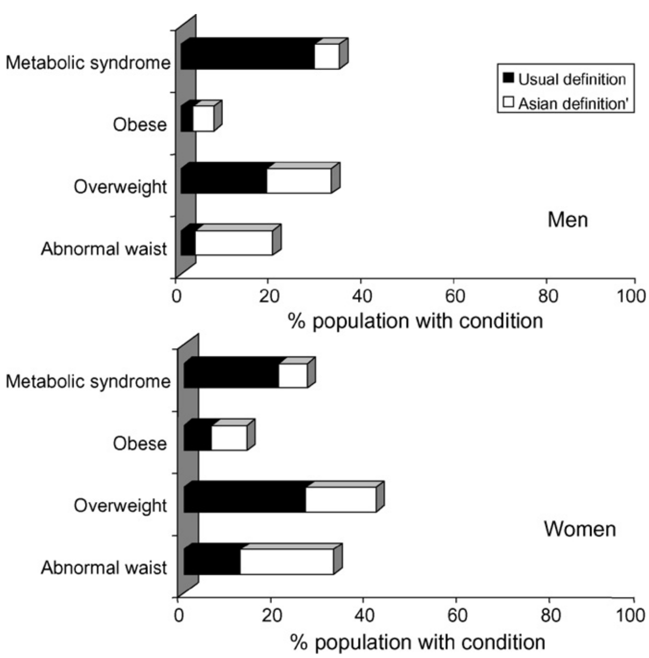

Fig. 1. Prevalence of metabolic syndrome, obesity, overweight and abnormal waist amongst men and women in rural Andhra Pradesh according to usual NCEP-ATPIII and 'Asian' definitions.

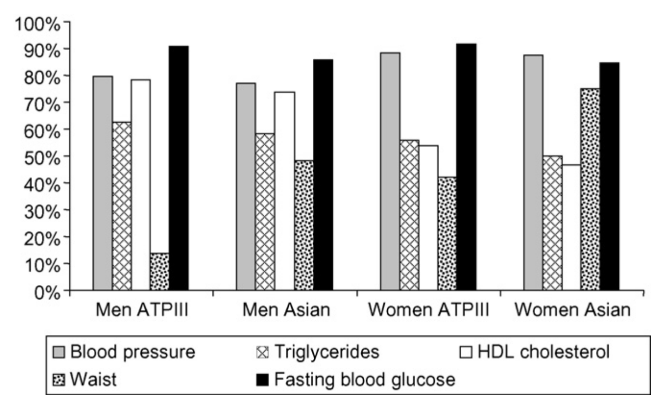

Fig. 2. Distribution of risk factors amongst men and women with metabolic syndrome according to usual NCEP-ATPIII and 'Asian' definitions.

3.4. Impact of usual versus 'Asian' cut offs

Using the suggested lower Asian cut-offs for waist abnormality [17] increased the proportion with an abnormal waist measurement to 26.0% overall, 19.7% for men and 32.4% for women (Fig. 1). Using recommended lower Asian cut-offs for BMI [16] increased the proportion overweight to 36.8% with prevalence of 32.4% for men and 41.4% for women and increased the proportion obese to 10.3% with prevalence of 7.0% for men and 13.6% for women Fig. 1 (Table 6). If the suggested lower cut offs for waist circumference abnormality were used in an Asian definition for metabolic syndrome, the overall proportion with the syndrome increased to 30.2% with prevalence of 33.6% for men and 26.6% for women. In addition, the proportion with an abnormal waist circumference rose markedly and the proportion with each of the other abnormalities fell (Fig. 2).

4. Discussion

This survey shows that a substantial proportion of the rural population of the East and West Godavari regions of Andhra Pradesh has dyslipidaemia, abnormal levels of adiposity and the metabolic syndrome. If suggested lower Asian cut points for metabolic and weight abnormalities are used, the magnitude of the problem is even greater than that sug-

Table 6
Prevalence of abnormalities of waist, body mass index and the metabolic syndrome overall and by age and sex for usual and 'Asian' cut offs by age and sex in rural Andhra Pradesh, India 2005

	Abnormal waist				Overweight				Obese				Metabolic syndrome*			
	Usual definition waist = 102/88 cm		Asian definition waist = 90/80 cm		Usual definition BMI ≥ 25 kg/m^2		Asian definition BMI ≥ 23 kg/m^2		Usual definition BMI ≥ 30 kg/m^2		Asian definition BMI ≥ 27.5 kg/m^2		Usual definition waist 102/88 cm		Asian definition waist 90/80 cm	
	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)	%	S.E. (%)
Overall	7.6	0.4	26.0	0.7	22.3	0.7	36.8	0.8	4.2	0.3	10.3	0.5	24.6	1.5	30.2	1.6
30–39	3.6	0.6	17.5	1.2	18.6	1.3	33.2	1.6	2.8	0.5	7.1	0.8	9.3	2.0	12.1	2.2
40–49	10.1	1.0	31.6	1.6	26.9	1.5	42.7	1.7	5.6	0.8	12.9	1.2	28.1	3.3	38.0	3.6
50–59	8.7	0.9	33.5	1.7	26.8	1.6	42.0	1.8	4.7	0.7	12.8	1.2	32.0	3.7	36.5	3.8
60+	10.1	1.0	27.5	1.4	19.6	1.2	32.2	1.5	4.6	0.7	10.3	1.0	38.7	3.1	44.5	3.2
Men																
Men, all	3.0	0.4	19.7	1.0	18.4	1.0	32.4	1.2	2.5	0.4	7.0	0.6	28.6	2.2	33.6	2.3
30–39	1.1	0.6	11.0	1.6	14.3	1.8	28.4	2.3	1.9	0.7	3.7	1.0	12.0	3.2	14.8	3.4
40–49	4.8	1.1	24.7	2.2	22.2	2.1	37.6	2.4	3.7	1.0	10.8	1.6	35.5	5.1	43.3	5.2
50–59	3.3	0.8	29.5	2.4	24.8	2.3	38.7	2.6	2.1	0.7	10.1	1.6	31.7	5.1	36.3	5.3
60+	3.7	0.7	20.0	1.7	15.6	1.5	27.4	1.9	2.4	0.6	5.3	0.9	44.1	4.4	49.6	4.4
Women																
Women, all	12.2	0.8	32.4	1.1	26.3	1.0	41.4	1.2	6.0	0.5	13.6	0.8	20.4	1.9	26.6	2.1
30–39	6.1	1.1	23.9	1.9	22.8	1.9	37.9	2.1	3.6	0.7	10.5	1.4	6.5	2.4	9.4	2.8
40–49	16.2	1.8	39.4	2.3	32.4	2.2	48.5	2.4	7.7	1.3	15.4	1.7	19.6	4.0	32.0	4.9
50–59	14.2	1.7	37.7	2.5	28.8	2.3	45.5	2.6	7.4	1.3	15.5	1.8	32.3	5.3	36.8	5.4
60+	16.0	1.7	34.6	2.2	23.4	1.9	36.7	2.2	6.7	1.2	15.0	1.7	33.8	4.3	39.8	4.5

Percentage and standard errors.
* Usual definition according to 2005 NCEP-ATPIII criteria—presence of three or more of abdominal obesity males > 102 cm, females > 88 cm, elevated triglycerides (≥150 mg/dL), low HDL cholesterol (men < 40 mg/dL, women < 50 mg/dL), high blood pressure ≥130/≥85 mmHg or raised fasting glucose (≥100 mg/dL)), drug treatment for abnormalities of cholesterol, sub-fractions, blood pressure or glucose was counted as abnormal [21]. 'Asian' definition of the metabolic syndrome was above except with abdominal obesity defined by the lower cut points (men > 90 cm, women > 80 cm).

Please cite this article in press as: Chow CK, et al., Significant lipid, adiposity and metabolic abnormalities amongst 4535 Indians from a developing region of rural Andhra Pradesh, Atherosclerosis (2007), doi:10.1016/j.atherosclerosis.2007.02.027

gested by the usual definitions. In conjunction with the effects of a previously reported high prevalence of diabetes [15], these abnormalities are likely to be an important driver of the high rates of cardiovascular mortality previously reported for this population [14]. While the findings for this region may not necessarily be indicative of the situation for rural India as a whole, they do provide an important early warning of the direction that metabolic risk factors and cardiovascular disease are likely to take as rural regions of India develop. Over the coming decades economic and social transformation in India will continue apace and many rural areas are likely to develop comparable levels of risk factors to those observed here. Corresponding substantial increases in cardiovascular diseases will likely ensue, with major implications for population health and rural health service provision.

There is rather little other information about population levels of lipids, adiposity and metabolic syndrome in rural India. Only six prior studies provide data about lipids from representative samples of a rural population and all are from the North [23–28]. Just two of these studies, one from Punjab [23] and the other from Uttar Pradesh [25] included a large sample size although the validity and practicality of comparisons between those data and ours is somewhat limited by differences in the methodologies used and the summary measures reported. In rural Punjab the proportion of adults aged 30 years and over with abnormal total cholesterol levels was similar to that observed here although the proportion reported overweight was somewhat lower. In Uttar Pradesh mean total and LDL-cholesterol levels were lower, mean HDL cholesterol levels were higher and triglyceride levels were comparable to those observed in Andhra Pradesh although mean BMI was again somewhat lower.

Compounding the paucity of cross-sectional data describing levels of lipids, adiposity and metabolic syndrome in rural India is an almost complete absence of data about the temporal changes that are occurring in cardiovascular risk factors in these regions. Some data suggest that hypertension and diabetes may be increasing in prevalence [29,30] but information about other risk factors is unavailable. Even the direction of trends in the prevalence of cardiovascular disease remains somewhat uncertain. While epidemiological models project large increases in cardiovascular disease in rural areas, a recent review of the literature identified no upward trend in the prevalence of coronary heart disease, although the project was significantly limited by the small quantity and limited comparability of the data available [31].

Information about cardiovascular disease in urban centres in India is more comprehensive and recent reports show generally worse levels of lipids, adiposity, and metabolic syndrome than in rural regions. For example, in the Jaipur Heart Watch 3 survey, adults 20 years and over selected from the Punjabi Bhatia community had a raised total cholesterol in about one third, overweight in almost two thirds and NCEP-ATP III defined metabolic syndrome in more than 40% [32]. In the preceding Jaipur Heart Watch 2 survey done some 2 years earlier the corresponding levels of those metabolic risk factors recorded were also higher than those reported by the few studies from rural areas but not as elevated as the levels seen in the most recent survey [5]. Very high levels of total cholesterol have also been reported from an urban population in Thiruvananthapuram in the South [33] although cholesterol levels in the Chennai Urban Population Study were not different from those observed in this study of rural Andhra Pradesh [34].

The prevalence of metabolic syndrome observed in rural Andhra Pradesh was high and above that recently reported by studies of representative samples of the Hong Kong and Taiwanese populations and only slightly less than that reported for urban and rural Thailand combined [35]. The proportion of those with the metabolic syndrome with abnormal fasting glucose levels was particularly high in rural Andhra Pradesh, a finding that is consistent with observations of disproportionately high rates of glucose intolerance and diabetes in a number of South Indian populations [4,36–38]. The rates of metabolic syndrome observed here are, however, low in comparison to the very high prevalence reported for some urban parts of India. In urban Chennai, for example more than 40% of adults aged 20–75 years met the criteria for metabolic syndrome [3], a prevalence beyond that reported for the United States [35,39] and comparable to the very high rates observed amongst Aboriginal communities in Canada [40].

Substantial variation in what constitutes the metabolic syndrome in different populations has been noted previously [35], raising uncertainty about the validity of current definitions of adiposity and metabolic syndrome for Asian populations [41]. Proposed new cut points for abnormality of BMI [16] and waist [17] have been suggested for Asian populations and their application significantly increases the prevalence of measures of adiposity if applied to this population from rural Andhra Pradesh. Incorporating the 'Asian' waist cut off into the definition of metabolic syndrome both increases the prevalence by about one-third and shifts the pattern of abnormalities somewhat towards that of other countries [35]—the proportion with an abnormal waist measurement increases and the proportions with each of the other abnormalities all slightly decrease.

The large sample size of this study ensured that the overall estimates of risk factor levels were fairly precise. Likewise the careful sampling procedure, good response rates, largely complete data and sophisticated statistical weighting process should have minimized systematic errors. While even the low rates of non-participation observed here may have introduced biases, it is unlikely that any bias would be so large in magnitude as to alter the main conclusions of this survey. Some reassurance about the reliability of the project findings is also provided by their broad comparability to other studies done in urban and rural India [23,25] and the known effects of rapid socioeconomic development on risk factor levels in other communities [42].

In conclusion, two main points arise form these data. First, dyslipidaemia, adiposity and metabolic syndrome are common in this rural Indian population and are more common if proposed lower Asian cut offs are used. The levels of risk factors observed here suggest that rural areas of India will follow the trends seen in urban India and the West, with very significant implications for rural health. The second main point is that the pattern of abnormalities observed amongst those meeting criteria for the metabolic syndrome was once again different to that reported in other populations [35]. The heterogeneity of metabolic abnormalities observed between populations with metabolic syndrome in different countries provides further support for the argument that metabolic syndrome is a definitional clustering of risk factors rather than a specific disease entity. For most countries, but particularly developing countries with limited health care resources, it is not clear that routine assessment of metabolic syndrome will add much to other absolute risk-based approaches to the treatment and prevention of cardiovascular disease.

Conflict of interest and source of funding

Funding support for the India-based component of this project was provided by the Byrraju Foundation and the Initiative for Cardiovascular Health Research in Developing Countries. Program Grants from the NHMRC - National Health and Medical Research Council of Australia (S. MacMahon #358395), and a contribution from the George Foundation made possible the Australian component of the work. Clara Chow is supported by an NHMRC scholarship and Bruce Neal by a Fellowship from the National Heart Foundation of Australia. None of the investigators have conflicts of interest in this work.

Acknowledgements

Andhra Pradesh Rural Health Initiative (APRHI) has been developed as a collaboration between four partners, The Byrraju Foundation in Hyderabad, India, The Centre for Chronic Disease Control (CCDC) in Delhi, India, The Care Foundation in Hyderabad, India and The George Institute for International Health in Sydney, Australia.

We would like to acknowledge the support of our field monitors Dr. S. Iyengar, Dr. Magnolia Cardona (GI), Dr. G. Ramakrishna (CCDC), Dr. Uma Snehi (CCDC), Dr. Ravi Raju (BF), Mr. A. Sukumar (BF); and the survey interviewers from the Roda Mistry College of Social Work and Research Center, Osmania University, Hyderabad. We also would like to thank the chairpersons, village committees and communities of the 20 villages visited in the survey for their tremendous support of the project.

References

[1] Heng DM, Lee J, Chew SK, et al. Incidence of ischaemic heart disease and stroke in Chinese, Malays and Indians in Singapore: Singapore Cardiovascular Cohort Study. Ann Acad Med, Singapore 2000;29(2):231–6.
[2] Bhopal R. What is the risk of coronary heart disease in South Asians? A review of UK research. J Public Health Med 2000;22(3):375–85.
[3] Ramachandran A, Snehalatha C, Satyavani K, et al. Metabolic syndrome in urban Asian Indian adults—a population study using modified ATP III criteria. Diab Res Clin Pract 2003;60(3):199–204.
[4] Anand SS, Yusuf S, Vuksan V, et al. Differences in risk factors, atherosclerosis, and cardiovascular disease between ethnic groups in Canada: the Study of Health Assessment and Risk in Ethnic groups (SHARE). Lancet 2000;356(9226):279–84.
[5] Gupta R, Gupta VP, Sarna M, et al. Prevalence of coronary heart disease and risk factors in an urban Indian population: Jaipur Heart Watch-2. Indian Heart J 2002;54(1):59–66.
[6] Ma S, Cutter J, Tan CE, et al. Associations of diabetes mellitus and ethnicity with mortality in a multiethnic Asian population: data from the 1992 Singapore National Health Survey. Am J Epidemiol 2003;158(6):543–52.
[7] Ramachandran A, Snehalatha C, Latha E, et al. Clustering of cardiovascular risk factors in urban Asian Indians. Diab Care 1998;21(6):967–71.
[8] McKeigue PM, Ferrie JE, Pierpoint T, et al. Association of early-onset coronary heart disease in South Asian men with glucose intolerance and hyperinsulinemia. [Article]. Circulation 1993;87(1):152–61.
[9] Ramachandran A, Snehalatha C, Latha E, et al. Rising prevalence of NIDDM in an urban population in India. Diabetologia 1997;40(2):232–7.
[10] Yusuf SRS, Ounpuu S, Anand S. Global burden of cardiovascular diseases: Part II: Variations in cardiovascular disease by specific ethnic groups and geographic regions and prevention stategies. Circulation 2001;104(23):2855–64.
[11] Gu D, Reynolds K, Wu X, et al. Prevalence of the metabolic syndrome and overweight among adults in China. Lancet 2005;365(9468):1398–405.
[12] Bustos P, da Silva AAM, Amigo H, et al., Metabolic syndrome in young adults from two socioeconomic Latin American settings. Nut Metabol Cardiovasc Dis, 2006, Epub ahead of print.
[13] InterASIA. Cardiovascular risk factor levels in urban and rural Thailand—The International Collaborative Study of Cardiovascular Disease in Asia (InterAsia Collaborative Group). Eur J Cardiovasc Prevent Rehabil 2003;10(4):249–57.
[14] Joshi R, Cardona M, Iyengar S, et al. Chronic diseases now a leading cause of death in rural India—mortality data from the Andhra Pradesh rural health initiative. Int J Epidemiol 2006;35(6):1522–9.
[15] Chow CK, Raju PK, Raju R, et al. The prevalence and management of diabetes in rural India. Diab Care 2006;29(7):1717–8.
[16] WHO-Expert-Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363(9403):157–63.
[17] Tan CE, Ma S, Wai D, et al. Can we apply the National Cholesterol Education Program Adult Treatment Panel definition of the metabolic syndrome to Asians? Diab Care 2004;27(5):1182–6.
[18] Chow CK, Cardona M, Raju PK, et al. Cardiovascular disease and risk factors among 345 adults in rural India—the Andhra Pradesh rural health initiative. Int J Cardiol 2007;116:180–5.
[19] 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) Final Report. Circulation 2002;106(25):3143–421.
[20] Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organ Tech Rep Ser 1995;854:1–452.
[21] 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.

[22] Zimmet P, Magliano D, Matsuzawa Y, et al. The metabolic syndrome: a global public health problem and a new definition. J Atheroscler Thromb 2005;12(6):295–300.
[23] Wander GS, Khurana SB, Gulati R, et al. Epidemiology of coronary heart disease in a rural Punjab population—prevalence and correlation with various risk factors. Indian Heart J 1994;46(6):319–23.
[24] Gupta R, Gupta HP, Kumar N, et al. Lipoprotein lipids and the prevalence of hyperlipidaemia in rural India. J Cardiovasc Risk 1994;1(2):179–84.
[25] Singh RB, Rastogi V, Niaz MA, et al. Serum cholesterol and coronary artery disease in populations with low cholesterol levels: the Indian paradox. Int J Cardiol 1998;65(1):81–90.
[26] Chadha SL, Gopinath N, Shekhawat S, et al. Urban-rural differences in the prevalence of coronary heart disease and its risk factors in Delhi. Bull World Health Org 1997;75(1):31–8.
[27] Lubree HG, Rege SS, Bhat DS, et al. Body fat and cardiovascular risk factors in Indian men in three geographical locations. Food Nutr Bull 2002;23(4 Suppl):146–9.
[28] Sharma S. Clinical, biochemical, electrocardiographic and noninvasive hemodynamic assessment of cardiovascular status in natives at high to extreme altitudes (3000 m–5500 m) of the Himalayan region. Indian Heart J 1990;42(5):375–9.
[29] Gupta R, al-Odat NA, Gupta VP, et al. Hypertension epidemiology in India: meta-analysis of 50 year prevalence rates and blood pressure trends. J Hum Hypertens 1996;10(7):465–72.
[30] Ramachandran A, Snehalatha C, Baskar AD, et al. Temporal changes in prevalence of diabetes and impaired glucose tolerance associated with lifestyle transition occurring in the rural population in India. Diabetologia 2004;47(5):860–5.
[31] Ahmad N, Bhopal R. Is coronary heart disease rising in India? A systematic review based on ECG defined coronary heart disease. Heart 2005;91(6):719–25.
[32] Gupta R, Sarna M, Thanvi J, et al. High prevalence of multiple coronary risk factors in Punjabi Bhatia community: Jaipur Heart Watch-3. Indian Heart J 2004;56(6):646–52.
[33] Joseph A, Kutty VR, Soman CR, et al. High risk for coronary heart disease in Thiruvananthapuram city: a study of serum lipids and other risk factors. Indian Heart J 2000;52(1):29–35.
[34] Mohan V, Deepa R, Rani SS, et al. Prevalence of coronary artery disease and its relationship to lipids in a selected population in South India: The Chennai Urban Population Study (CUPS No. 5). J Am Coll Cardiol 2001;38(3):682–7.
[35] Patel A, Huang KC, Janus ED, et al. Is a single definition of the metabolic syndrome appropriate?—A comparative study of the USA and Asia. Atherosclerosis 2006;184(1):225–32.
[36] Cappuccio FP. Ethnicity and cardiovascular risk: variations in people of African ancestry and South Asian origin. J Hum Hypertens 1997;11(9):571–6.
[37] Bhopal R, Unwin N, White M, et al. Heterogeneity of coronary heart disease risk factors in Indian, Pakistani, Bangladeshi, and European origin populations: cross sectional study. BMJ 1999;319(7204):215–20.
[38] Hughes K, Yeo PP, Lun KC, et al. Cardiovascular diseases in Chinese, Malays, and Indians in Singapore. II. Differences in risk factor levels. J Epidemiol Commun Health 1990;44(1):29–35.
[39] National Health and Nutrition Examination Survey (NHANES III), P.R. Institute, Editor. 1988–94, Social Science Research Institute, Pennsylvania. p. NHANESIII data download site.
[40] Pollex RL, Hanley AJ, Zinman B, et al. Metabolic syndrome in aboriginal Canadians: prevalence and genetic associations. Atherosclerosis 2006;184(1):121–9.
[41] Deepa M, Farooq S, Datta M, et al. Prevalence of metabolic syndrome using WHO, ATPIII and IDF definitions in Asian Indians: the Chennai Urban Rural Epidemiology Study (CURES-34). Diab Metab Res Rev 2006.
[42] Yusuf SRS, Ounpuu S, Anand S. Global burden of cardiovascular diseases: part I: general considerations, the epidemiologic transition, risk factors, and impact of urbanization. Circulation 2001;104(22):2746–53.

Please cite this article in press as: Chow CK, et al., Significant lipid, adiposity and metabolic abnormalities amongst 4535 Indians from a developing region of rural Andhra Pradesh, Atherosclerosis (2007), doi:10.1016/j.atherosclerosis.2007.02.027