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Prevalence of metabolic syndrome in a north Indian hospital-based population with obstructive sleep apnoea

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***Background & objectives*: Obstructive sleep apnoea (OSA) is known to be associated with cardiovascular risk factors and metabolic syndrome (MS). The burden of MS in patients with OSA in India is unknown. We investigated the prevalence of MS and its components in a cross-sectional study in patients with and without OSA in a hospital-based population of a tertiary health care centre in New Delhi, India.**

***Methods*: Consecutive patients undergoing overnight polysomnography in the Sleep Laboratory of the Department of Internal Medicine of All India Institute of Medical Sciences (AIIMS) hospital, New Delhi, were studied. Anthropometry and body composition analysis, blood pressure (BP), fasting blood glucose, insulin resistance by homeostasis model assessment (HOMA-IR) and fasting blood lipid profile were measured. MS was defined using the National Cholesterol Education Program Adult treatment panel III criteria, with Asian cut-off values for abdominal obesity.**

***Results*: Of the 272 subjects recruited, 187 (82%) had OSA [apnoea-hypopnoea index (AHI)>5 events/h] while 40 (18%) had a normal sleep study. Prevalence of MS in OSA patients was 79 per cent compared to 48 per cent in non-OSA individuals [OR 4.15, (2.05-8.56), *P*<0.001]. Prevalence of OSA in mild, moderate and severe OSA was 66, 72 and 86 per cent, respectively (*P*<0.001). Patients with OSA were more likely to have higher BP [OR: 1.06 (1.02-1.11)], fasting insulin [OR: 1.18 (1.05-1.32)], HOMA-IR [OR: 1.61 (1.11-2.33)] and waist circumference [OR: 1.20 (1.13-1.27)].**

***Interpretation & conclusions*: Our findings suggest that OSA is associated with a 4-fold higher occurrence of MS than patients without OSA. The prevalence of MS increases with increasing severity of OSA, therefore, early detection will be beneficial.**

Key words Metabolic syndrome - obstructive sleep apnoea - prevalence - risk factors - South Asians - urban Indians

Obstructive sleep apnoea (OSA) is a condition in which there is collapse of the upper airway during sleep, as a result of which there is a decrease or complete cessation of airflow.[1] A population-based study in Delhi reported the prevalence of OSA to be as high as 9.3 per cent[2]. The association of OSA with increased cardiovascular morbidity and mortality[3] and various cardiovascular risk factors[4] is known for a long time. Various metabolic and morphological risk factors for cardiovascular disease such as obesity, hypertension, dyslipidaemia and insulin resistance are found to be co-existent in patients more often than explained by chance

alone. This clustering of risk factors is called metabolic syndrome (MS)[5]. OSA has been shown to be associated with these risk factors including hypertension[6,7], insulin resistance[8,9] and dyslipidaemia[10]. Given this association of both OSA and MS with cardiovascular disease it is logical to expect a relationship between the two. It has subsequently been shown that OSA is associated with MS[11]. A UK based study[10] showed the prevalence of MS in patient with OSA to be 85 per cent compared with 37 per cent in normal controls. In a Chinese study[12] it was 58 and 21 per cent, respectively. A north Indian population-based study[13] found the prevalence to be 77 and 40 per cent, respectively. OSA and MS are believed to act synergistically to increase cardiovascular risk and the co-occurrence of these conditions has been termed syndrome Z[14]. However, the data on the relationship between OSA and MS are conflicting with obesity being considered as an important confounder due to its independent association with OSA and other cardiovascular risk factors[15-17].

The prevalence of MS in patients of OSA has not been studied in hospital-based populations in India so far. The population-based data available are insufficient to guide decision making in sleep clinic patients as these patients represent a much more symptomatic cohort with probably a higher burden of MS than discovered by community-based studies. The present study was carried out to determine prevalence of MS in a hospital-based urban north Indian population with OSA and to correlate components of MS with OSA in patients presenting to sleep clinic of a tertiary health care centre in New Delhi, India.

Material & Methods

In this cross-sectional study consecutive patients undergoing polysomnography (PSG) in the Sleep Laboratory of the Department of Internal Medicine of All India Institute of Medical Sciences (AIIMS), New Delhi, between June 2008 and May 2010 were evaluated for enrolment. These patients were referred for PSG from the sleep related breathing disorders (SRBD) clinic of the Department of Internal Medicine, AIIMS hospital, New Delhi. Referral of patients for PSG was on discretion of physicians in the sleep clinic, usually for symptoms of excessive daytime somnolence or snoring. Males and females, aged 30-65 yr, and naïve to continuous positive airway pressure (CPAP) treatment were included. Patients having hypothyroidism, chronic renal failure, chronic liver disease and patients with coronary artery disease and left ventricular dysfunction were excluded from the study. Patients with history of chronic corticosteroid use or hormone replacement therapy were also excluded. Approval for study protocol was obtained from the AIIMS ethics committee and written informed consent was taken from each participant.

Sleep assessment: All subjects underwent overnight 16-channel polysomnography (PSG) conducted in Sleep Laboratory of the Department of Internal Medicine at AIIMS hospital, New Delhi, by trained technicians using a Rembrandt 7.3 version PSG machine (Medicare Technologies, USA) as described elsewhere[18]. Recorded sleep data were scored manually according to standard criteria[19] by experienced laboratory technicians blinded to clinical data. Apnoea and hypopnoea were defined according to the Chicago criteria as recommended by the American Academy of Sleep Medicine[20]. OSA was defined as apnoea-hypopnoea index (AHI)>5 events/h. Severity of OSA was graded as, mild OSA: AHI ≥5 and <15 events/h, moderate OSA: AHI ≥15 and <30 events/h, and severe OSA: AHI ≥30 events/h[21]. Patients without OSA were referred to as normal. Obstructive sleep apnoea syndrome (OSAS) was defined as the presence of OSA with excessive daytime sleepiness (EDS). EDS was assessed using the Epworth Sleepiness Scale (ESS)[22] based on the subject's response to eight questions regarding probability of dozing under specific situations with a 4-point scale. A score of 10 or more was considered suggestive of EDS.

Anthropometry, body composition analysis and blood pressure measurements: Blood pressure, body weight, body composition analysis, neck circumference (NC), neck length (NL), waist circumference (WC), hip circumference (HC) and biceps, triceps, subscapular and suprailiac skin-fold thicknesses were measured using standard methods as described earlier[23]. Percentage predicted neck circumference (PPNC) was computed using Davies and Strading formula as, PPNC = (1000 x NC) / [(0.55 x Height) +310][24]. Body weight was measured to the nearest 0.5 kg in erect position without footwear, wearing light indoor clothes by a Tanita Body composition analyzer (model TBF 300 GS, Tanita corporation, Tokyo, Japan) along with fat mass, per cent body fat and fat-free mass.

Biochemical tests: At the end of the sleep study on the next morning, blood samples were taken from each subject and the following tests were done: fasting blood glucose (by glucose oxidase method) using Roche Hitachi 912 Chemistry Analyzer (Hitachi, Tokyo, Japan), fasting plasma insulin (by ELISA, R&D systems, Minneapolis, MN, USA), and lipid

profile [total cholesterol, triglyceride (TG) and HDL-cholesterol were measured using immunocolorimetric assay, LDL cholesterol was calculated using Friedewald equation][25]. Insulin resistance was calculated using the homeostasis model assessment (HOMA-IR) method using FBS and fasting plasma insulin, previously validated against the hyperinsulinaemic euglycaemic clamp[26].

Metabolic syndrome: Metabolic syndrome was defined as per the National Cholesterol Education Program - Adult Treatment Panel III criteria[27], with the cut-off for defining abdominal obesity taken as waist circumference ≥90cm in males and ≥80cm in females as recommended by the World Health Organization guidelines for South Asians[28].

Sample size estimation: Assuming prevalence of MS to be 70 per cent in OSA, to estimate the prevalence of MS in patients of OSA with an absolute precision of ±10 per cent with a 2 sided 95% confidence interval, 84 subjects with OSA were required to be studied.

Statistical analysis: Statistical analyses were performed using a statistical software package (Stata 11.0 for Windows, Stata Corporation, College Station, TX, USA). Continuous variables were summarized as mean ± SD or median (range) and categorical variables as proportions, n (%). Comparison between groups was done by independent Student's t-test and Mann-Whitney test for parametric and non-parametric variables, respectively and Chi-square and Fisher's exact test for categorical variables. Chi square test was used to compare prevalence of MS in various categories of OSA with non-OSA using logistic regression to derive odds ratios. Trend for increase in prevalence of MS with increasing severity of OSA was assessed by Cuzick's test for trend for ordinal data[29]. $P<0.05$ was considered significant.

Results

Of the 227 patients recruited, 187 (82%) had OSA defined by an AHI >5 events/h. Subjects with OSA were more likely to be male, older in age, had higher ESS, BMI, per cent body fat, fat mass, per cent predicted neck circumference and skin fold thicknesses (Table I). By definition, they had higher AHI and arousal index (Table II). There were more alcohol consumers and smokers in the OSA group, although it did not reach statistical significance.

Diastolic blood pressure, fasting plasma insulin, HOMA-IR, waist circumference and waist-hip ratio were significantly higher in subjects with OSA compared to non-OSA individuals (Table III). There was a trend towards increased systolic blood pressure, fasting blood glucose, triglycerides and LDL cholesterol but did not reach statistical significance. There was no significant difference in total cholesterol, HDL cholesterol, non-HDL cholesterol and HDL:total cholesterol levels between the groups. Of the 187 patients with OSA, 148

Table I. Comparison of demographic and anthropometric characteristics in apnoeics and non-apnoeics

	OSA (n=187)	Non-OSA (n=40)
Age (yr)	46 ± 8*	42 ± 12
Male	153 (82)**	25 (63)
Smokers	41 (22)	4 (10)
Alcohol consumers	48 (26)*	3 (8)
Body mass index (kg/m^2)	33.5 ± 7.0***	27.7 ± 6.9
Per cent body fat	32.4 ± 9.1***	26.5 ± 10.3
Fat mass (kg)[a]	26.8 (10.6-93.8)***	18.1 (4.9-78.3)
PPNC (%)	100 ± 8***	89 ± 7
TSFT (mm)	20 ± 8	18 ± 9
SSFT (mm)	29 ± 7**	26 ± 9
BSFT (mm)	15 ± 6***	11 ± 6
SIFT (mm)	35 ± 8	33 ± 10

[a]Data presented as median (range). All other data presented as mean ± SD or n (%)

PPNC, percentage predicted neck circumference; TSFT, triceps skin fold thickness; SSFT, subscapular skin fold thickness; BSFT, biceps skin fold thickness; SIFT, suprailiac skin fold thickness

P *<0.05, **<0.01, ***<0.001 compared to non-OSA

Table II. Comparison of polysomnographic characteristics in apnoeics and non-apnoeics

Parameters	OSA (n=187)	Non-OSA (n=40)
Epworth sleepiness scale score[a]	12 (0-24)	5 (0-23)
Apnoea-hypopnoea index (/h)[a]	38.8 (5.4-126.2)	0.9 (0-4.6)
Arousal index(/h)[a]	22.9 (0.2-200.9)	2.6 (0-14.1)
Sat O_2 <90% (%)[a,b]	10.2 (0-99.5)	0.3 (0-10.9)
ΔSaO_2 (%)[c]	24.8 ± 13.7	9.8 ± 6.5
ΔSaO_2 <10	13 (7)	25 (63)
ΔSaO_2 ≥10 & <20	61 (33)	13 (32)
ΔSaO_2 ≥20 & <30	60 (33)	1 (3)
ΔSaO_2 ≥30	53 (28)	1 (3)

[a]Data presented as median (range). All other data presented as n(%)

[b]Sat O_2 <90% (%) = percentage of total sleep time spent in hypoxia (SpO2 <90%)

[c]ΔSaO_2 (%) = baseline saturation – minimum saturation during sleep study

All characteristics significantly different ($P<0.001$) in OSA and non-OSA

Table III. Comparison of various components of metabolic syndrome in apnoeics and non-apnoeics

	OSA (n=187)	Non-OSA (n=40)	OR (95% CI)
Systolic BP (mm Hg)	133 ± 13	129 ± 12	1.02 (1.00-1.06)
<130	67 (35.8)	19 (47.5)	1
≥130	120 (64.2)	21 (52.5)	1.62 (0.81-3.23)
Diastolic BP (mm Hg)	88 ± 9*	83 ± 8	1.06 (1.02-1.11)
<85	64 (34.2)	22 (55.0)	1
≥85	123 (65.8)	18 (45.0)	2.35 (1.18-4.69)
Fasting blood glucose (mg/dl)	112 ± 33	103 ± 24	1.02 (1.00-1.03)
<110	102 (54.4)	29 (72.5)	1
≥110	85 (45.6)*	11(27.5)	2.20 (1.04-4.66)
Fasting insulin (mU/l)	11.7 ± 6.0**	8.3 ± 2.3	1.18 (1.05-1.32)
HOMA-IR[a]	8.9 (1.8-48.0) *	5.5 (4-24.4)	1.61 (1.11-2.33)
Waist circumference (cm)	114 ± 13***	97 ± 9	1.20 (1.13-1.27)
Normal	0 (0)	5 (12.5)	-
Abnormal[b]	187 (100) ***	35 (87.5)	-
Waist-hip ratio (%)	104.4 ± 7.7***	96.3 ± 7.3	1.17 (1.10-1.24)
Total cholesterol (mg/dl)	190.0 ± 39.8	183.0 ± 38.4	1.00 (1.00-1.01)
Triglyceride (mg/dl)	168.5 ± 74.3	152 ± 86.2	1.00 (1.00-1.01)
<150	81 (43.3)	22 (55)	1
≥150	106 (56.7)	18 (45)	1.60 (0.80-3.18)
HDL (mg/dl)	43.5 ± 14.0	43.9 ± 8.1	1.0 (0.97-1.02)
Normal	76 (40.6)	19 (47.5)	1
Abnormal[c]	111 (59.4)	21 (52.5)	1.32 (0.67- 2.62)
LDL (mg/dl)	112.0 ± 33.8	102.0 ± 30.1	1.01 (1.00-1.02)
Non HDL cholesterol (mg/dl)	146.5 ± 38.4	139.1 ± 36.4	1.01 (1.00-1.01)
HDL:Cholesterol (%)	23.6 ± 7.2	24.6 ± 5.1	0.134 (.001-12.21)

[a]Data presented as median (range). All other data presented as mean ± SD or n (%); [b]Defining cut-off: ≥90 cm for males and ≥ 80 cm for females; [c]Defining cut-off: <40mg/dl for males and <50mg/dl for females
P *<0.05, **<0.01, ***<0.001 compared to non-OSA

(79%) had MS compared with 19 (48%) in the non-OSA group (OR= 4.19, 95% CI=2.05, 8.56) (Table IV). Subgroup analysis showed an increasing prevalence of MS with increasing severity of OSA [66%, OR: 2.13 (0.87-5.21), 72% OR: 2.87 (1.10-7.49) and 86% OR: 7 (2.95-4.62) for mild, moderate and severe OSA, respectively compared to non-OSA group]. Cuzick's test for trend showed a significant (*P*<0.001) trend for increase in prevalence of MS with increasing severity of OSA (Table IV).

Table IV. Prevalence of metabolic syndrome in obstructive sleep apnoea

	Metabolic syndrome	OR (95% CI)
No OSA (n=40)	19 (48)	1
Mild OSA (n=41)	27 (66)	2.13 (0.87-5.21)
Moderate OSA (n=36)	26 (72)	2.87 (1.10-7.49)
Severe OSA (n=110)	95 (86)	7 (2.95-4.62)
All OSA (n=187)	148 (79)	4.19 (2.05-8.56)

P<0.001 for Cuzick's test for trend
OSA, obstructive sleep apnoea. Data presented as n (%)

Discussion

In this study we found a 79 per cent prevalence of MS in OSA patients compared with 48 per cent in the control group. These values are higher than those seen in previous studies[12,13]. This is probably due to the fact that these were community-based studies and participants had a lower BMI compared to the present study. Our study being hospital-based is expected to have a higher prevalence of MS due to a referral bias. Compared to the only previous hospital-based study reporting prevalence of MS in OSA[10] the present study has lower values, probably due to ethnic differences in the patient populations and a much higher BMI of participants in the study by Coughlin *et al*[10]. Diastolic blood pressure, fasting plasma insulin, HOMA-IR, waist

circumference and WHR were also higher in patients with OSA, with a trend towards higher systolic blood pressure, fasting blood glucose, triglycerides and LDL cholesterol. Body composition analysis showed higher fat mass, per cent body fat and skin fold thicknesses in patients of OSA. These findings are in concordance with previous studies showing OSA to be associated with higher BP[30], insulin resistance[8] and deranged lipid profile and body composition[31]. While all studies are in agreement with the higher prevalence of MS in OSA, the data on association of individual components of MS are conflicting[8-10,16,17] due to differences in ethnicities, source of recruitment of the study population and power of the studies.

The increasing prevalence of MS with increasing severity of OSA suggests an association of OSA with MS. However, a causative role cannot be inferred from these data alone, since obesity is a significant confounder in studies involving OSA and MS, as it is a major risk factor for both conditions; 40-90 per cent obese individuals have OSA and about 70 per cent of OSA patients have obesity[32-34]. Only a longitudinal study would be able to definitely prove whether OSA precedes and causes MS or vice versa, and whether obesity is the predisposing factor for both these conditions.

The clinical implications are that there is a high prevalence of MS in patients presenting to sleep clinics with symptoms suggestive of OSA, irrespective of whether they have OSA or not. The prevalence of MS is even higher if they actually have OSA. MS as a whole and its components individually are very likely to be present in patients with OSA and this risk increases with the severity of metabolic syndrome. Screening for MS components along with the work up of OSA will allow early detection of these cases. This relationship of MS with OSA can also explain the mechanism for increased mortality in patients with OSA.

The present study has some limitations. Being a hospital-based study there was referral bias with more symptomatic patients likely to be referred to our hospital. The non-OSA group did not reflect absolutely normal individuals and they were more likely to have hypertension, diabetes, dyslipidaemia and obesity than healthy volunteers. However, this would serve to decrease the difference found between the two groups rather than increase it. Matching for obesity, an important potential confounder was not done. An ideal study design would have been to use BMI and per cent body fat matched controls to eliminate confounding. However, this would have substantially decreased the sample size of the control group and hence the statistical power of the study.

The strengths of the present study include *(i)* a large sample size of 227 patients with 187 of them being apnoeics with a resultant power of 97% to detect a significant difference between the groups for the prevalence of MS at the values found in this population; *(ii)* exclusion of OSA in control group by performing a full overnight PSG study in each one of them; *(iii)* diagnosis of OSA by full overnight, supervised, in-hospital PSG study; *(iv)* use of AHI cut-off of ≥5 events/h in accordance with the results of the Sleep Heart Health Study which reported association of hypertension with OSA at these cut-off values; *(v)* inclusion of both males and females in the study allowing extrapolation of these results to both these groups.

This is perhaps the first hospital-based study to investigate the prevalence of MS in patients with OSA from India. It differs from previous community-based studies from India and China[12,13]. In conclusion, our study showed that the prevalence of MS was four times higher in patients of OSA than controls and the prevalence increased with increasing severity of OSA. Therefore, patients with MS should be investigated for OSA and vice versa, as early detection and correction of these conditions may result in significant decrease in morbidity and mortality.

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References

1. Vecchierini MF. Obstructive sleep apnoea-hypopnoea syndrome: evolution of an old concept. *Neurochirurgie* 2006; *52* : 432-42.
2. Reddy EV, Kadhiravan T, Mishra HK, Sreenivas V, Handa KK, Sinha S, *et al*. Prevalence and risk factors of obstructive sleep apnea among middle-aged urban Indians: A community-based study. *Sleep Med* 2009; *10* : 913-8.
3. Shahar E, Whitney C, Redline S, Lee ET, Newman AB, Javier Nieto F, *et al*. Sleep-disordered breathing and cardiovascular disease: cross-sectional results of the Sleep Heart Health Study. *Am J Respir Crit Care Med* 2001; *163* : 19-25.
4. Wilcox I, McNamara SG, Collins FL, Grunstein RR, Sullivan CE. ''Syndrome Z'': the interaction of sleep apnoea, vascular risk factors and heart disease. *Thorax* 1998; *53* (*Suppl*): S25-8.

5. Reaven G. metabolic syndrome: pathophysiology and implications for management of cardiovascular disease. *Circulation* 2002; *106* : 286-8.
6. Peppard PE, Young T, Palta M, Skaturd J. Prospective study of the association between sleep-disordered breathing and hypertension. *N Eng J Med* 2000; *342* : 1378-84.
7. Wolk R, Shamsuzzaman AS, Somers VK. Obesity, sleep apnea, and hypertension. *Hypertension* 2003; *42* : 1067-74.
8. Ip MS, Lam B, Ng MM, Lam WK, Tsang KW, Lam KS. Obstructive sleep apnea is independently associated with insulin resistance. *Am J Respir Crit Care Med* 2002; *165* : 670-6.
9. Punjabi N, Sorkin J, Katzel L, Goldberg AP, Schwartz AR, Smith PL. Sleep-disordered breathing and insulin resistance in middle-aged and overweight men. *Am J Respir Crit Care Med* 2002; *165* : 677-82.
10. Coughlin SR, Mawdsley L, Mugarza JA, Calverley PM, Wilding JP. Obstructive sleep apnoea is independently associated with an increased prevalence of metabolic syndrome. *Eur Heart J* 2004; *25* : 735-41.
11. Basta M, Vgontzas A. Metabolic abnormalities in obesity and sleep apnea are in a continuum. *Sleep Med* 2007; *8* : 5-7.
12. Lam JC, Lam B, Lam CL, Fong D, Wang JK, Tse HF, *et al*. Obstructive sleep apnea and the metabolic syndrome in community-based Chinese adults in Hong Kong. *Respir Med* 2006; *100* : 980-7.
13. Sharma SK, Reddy EV, Sharma A, Kadhiravan T, Mishra HK, Sreenivas V, *et al*. Prevalence and risk factors of syndrome Z in urban Indians. *Sleep Med* 2010; *11* : 562-8.
14. Nock NL, Li L, Larkin EK, Patel SR, Redline S. Empirical evidence for "syndrome Z": a hierarchical 5-factor model of the metabolic syndrome incorporating sleep disturbance measures. *Sleep* 2009; *32* : 615-22.
15. Stoohs RA, Facchini F, Guilleminault C. Insulin resistance and sleep-disordered breathing in healthy humans. *Am J Respir Crit Care Med* 1996; *154* : 170-4.
16. Gruber A, Horwood F, Sithole J, Ali NJ, Idris I. Obstructive sleep apnoea is independently associated with the metabolic syndrome but not insulin resistance state. *Cardiovasc Diabetol* 2006; *5* : 22.
17. Sharma SK, Kumpawat S, Goel A, Banga A, Ramkrishnan L, Chaturvedi P. Obesity and not obstructive sleep apnea is responsible for metabolic abnormalities in a cohort with sleep disordered breathing. *Sleep Med* 2007; *8* : 12-7.
18. Sharma SK, Kurian S, Malik V, Mohan A, Banga A, Pandey RM, *et al*. A stepped approach for prediction of obstructive sleep apnea in overtly asymptomatic obese subjects: a hospital based study. *Sleep Med* 2004; *5* : 351-7.
19. Rechtschaffen A, Kales AA, editors. *A manual of standardized terminology, techniques and scoring for sleep stages of human subjects*. Washington, DC: Government Printing Office. NIH Publication No. 204; 1968.
20. Iber C, Ancoli-Israel S, Chesson A, Quan SF for the American Academy of Sleep Medicine. *The AASM manual for the scoring of sleep and associated events: Rules, terminology and technical specifcations*. Westchester: American Academy of Sleep Medicine; 2007.
21. Epstein LJ, Kristo D, Strollo PJ Jr, Friedman N, Malhotra A, Patil SP, *et al*. Adult Obstructive Sleep Apnea Task Force of the American Academy of Sleep Medicine. Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults. *J Clin Sleep Med* 2009; *5* : 263-76.
22. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep* 1991; *14* : 540-5.
23. Sharma SK, Kumpawat S, Banga A, Goel A. Prevalence and risk factors of obstructive sleep apnea syndrome in a population of Delhi, India. *Chest* 2006; *130* : 149-56.
24. Davies RJ, Stradling JR. The relationship between neck circumference, radiographic pharyngeal anatomy and obstructive sleep apnoea. *Eur Respir J* 1990; *3* : 504-9.
25. Bairaktari E, Hatzidimou K, Tzallas C, Vini M, Katsaraki A, Tselepis A, *et al*. Estimation of LDL cholesterol based on the Friedewald formula and on apo B levels. *Clin Biochem* 2000; *33* : 549-55.
26. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia* 1985; *28* : 412-9.
27. Expert panel on Detection, Evaluation and Treatment of high blood cholesterol in adults. 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* : 2486-97.
28. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* 2004; *363* : 157-63.
29. Cuzick J. A Wilcoxon-Type test for trend. *Stat Med* 1985; *4* : 87-9.
30. Davies CW, Crosby JH, Mullins RL, Barbour C, Davies RJ, Stradling JR. Case-control study of 24 hour ambulatory blood pressure in patients with obstructive sleep apnoea and normal matched control subjects. *Thorax* 2000; *55* : 736-40.
31. Ip MS, Lam KS, Ho C, Tsang KW, Lam W. Serum leptin and vascular risk factors in obstructive sleep apnea. *Chest* 2000; *118* : 580-6.
32. Daltro C, Gregorio PB, Alves E, Abreu M, Bomfim D, Chicourel MH, *et al*. Prevalence and severity of sleep apnea in a group of morbidly obese patients. *Obes Surg* 2007; *17* : 809-14.
33. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep-disordered breathing among middle-aged adults. *N Engl J Med* 1993; *328* : 1230-5.
34. Young T, Peppard PE, Gottlieb DJ. Epidemiology of obstructive sleep apnea: a population health perspective. *Am J Respir Crit Care Med* 2002; *165* : 1217-39.

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