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Microalbuminuria and the metabolic syndrome and its components in the Chinese population

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Abstract

Background Microalbuminuria and the metabolic syndrome (MetS) have both been linked to chronic kidney disease and cardiovascular disease. This study investigated the association between urinary albumin-to-creatinine ratio (ACR) and MetS and its components.

Materials and methods A total of 2311 subjects aged 40 years and over were recruited in 2004 in a metropolitan city in Taiwan. The biochemical indices, such as fasting glucose levels, urinary albumin, urinary creatinine and anthropometric indices, were measured. We defined microalbuminuria as a urinary ACR ranging from 30 to 300 mg g^{-1} creatinine. MetS was defined using the American Heart Association and the National Heart, Lung and Blood Institute (AHA/NHLBI) and the International Diabetes Federation (IDF) definitions. The relationship between MetS and microalbuminuria was examined using multiple logistical regression analysis.

Results Subjects with microalbuminuria had higher age, body mass index (BMI), waist circumference, blood pressure, fasting plasma glucose, triglycerides, total cholesterol (TCHOL)/high-density lipoprotein cholesterol (HDL-C) ratio, prevalence of diabetes mellitus and hypertension and lower HDL-C than subjects with normoalbuminuria. After adjusting for age and BMI, microalbuminuria was associated with the individual components of MetS, except in central obesity in women and elevated fasting glucose in men. After adjusting for age, BMI, smoking and alcohol consumption status, multiple logistical regressions revealed that microalbuminuria is strongly associated with MetS in both genders and according to both definitions. The odds ratio of having MetS using the AHA/NHLBI and IDF definition was 1·76 (1·16–2·67) and 1·73 (1·06–2·83) in men and 2·19 (1·38–3·50) and 2·09 (1·24–3·51) in women, respectively.

Conclusions Microalbuminuria was strongly associated with MetS and its components. There is an increased likelihood of having MetS if subjects have microalbuminuria.

Keywords Chinese, general population, metabolic syndrome, microalbuminuria.
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Introduction

The term 'metabolic syndrome' (MetS) refers to a constellation of symptoms, including impaired glucose metabolism, dyslipidaemia, hypertension and central obesity, and is associated with subsequent development of type 2 diabetes and cardiovascular diseases [1–3] Subjects with MetS are at increased risk of cardiovascular disease mortality and all-cause mortality [2,4,5]. In 1998, the World Health Organization (WHO) proposed the first definition of MetS [6]. Since then, the National Cholesterol Education Programme's Adult Treatment Panel III (NCEP-ATPIII) [7], the European Group for the Study of Insulin Resistance [8], the American College of Endocrinology and American Association of Clinical Endocrinologists [9], the International Diabetes Federation (IDF) [10], and the American Heart Association and the National Heart, Lung and Blood

Institute (AHA/NHLBI) [11] have formulated definitions. These definitions comprise four essential components: impaired glucose metabolism, dyslipidaemia, hypertension and central obesity, but they differ in the detail and criteria. The obvious difference between the WHO definition and that proposed by other institutions is the addition of microalbuminuria. Depending on the criteria used and different age groups, the prevalence of MetS in the USA and Europe is approximately 20% to 60% in adults [12,13] while in Asians the prevalence is around 10–30% [13–15].

Microalbuminuria has been linked to a greater risk for future cardiovascular disease, renal disease, atherosclerosis and cardiovascular disease mortality and all-cause mortality [16–19]. Microalbuminuria is relatively common in people with diabetes, hypertension and MetS. However, the mechanism between microalbuminuria and increased risk for cardiovascular disease and other conditions is not completely understood. The endothelial dysfunction theory has been proposed as the underlying mechanism of MetS in numerous studies [20–22]. Microalbuminuria has also been linked with MetS in some studies [23–25] and the inclusion of microalbuminuria as part of MetS had been proposed in some studies [24,25] but not others [26]. Although numerous studies have examined the relationship between various definitions of MetS and microalbuminuria, few studies have focused on the relationship in the Asian population and the definition proposed by the AHA/NHLBI and the IDF. Therefore, the purpose of this study is to examine the association between microalbuminuria and MetS, as defined by the AHA/NHLBI and the IDF, in a representative sample of adults in Taiwan.

Materials and methods

Study population and sampling method

The target population consisted of residents aged 40 and above in Taichung, Taiwan, in October 2004. There were a total of 363 543 residents in this area during the time of the study, which represented about 4·09% of the national population of the same age. A two-stage sampling design was used to recruit residents, with sampling rate proportional to size (SRPS) within each stage. A total of 4280 individuals were selected. During household visits we identified 750 individuals that were not eligible and, therefore, we excluded them from the study sample. The reasons for exclusion included death ($n = 18$), hospitalization or imprisonment ($n = 14$), living abroad ($n = 39$), moving out ($n = 411$), living in their children's house ($n = 7$), mistake in the sampling frame ($n = 59$) and not being at home during three visits made by interviewers ($n = 202$). Among 3530 individuals selected, 2359 agreed to participate. Thus, the overall response rate was 66·8%. There were nine subjects who did not complete the urine albumin test and those with macroalbuminuria (defined as a urinary albumin-to-creatinine ratio (ACR) above 300 mg g^{-1} creatinine; $n = 39$) were also excluded. The final population was 2311 subjects.

Anthropometric index and laboratory tests

Trained staff measured height, waist circumference (WC) and hip circumference (HipC), measured to the nearest 0·1 cm, and weight measured to the nearest 0·1 kg. WC was taken at the midway point between the inferior margin of the last rib and the crest of the ilium in a horizontal plane. HipC was taken as the distance around the pelvis at the point of maximal protrusion of the buttocks. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). BMI was categorized into four groups according to the obesity definition from WHO. [27]: (1) Underweight: BMI < 18·5 kg m^{-2}; (2) Normal weight: 18·5 ≤ BMI < 25 kg m^{-2}; (3) Overweight: 25 ≤ BMI < 30 kg m^{-2}; (4) Obese: BMI > 30 kg m^{-2} . The same staff measured blood pressure (BP) in the right arm using an appropriately sized cuff and a standard mercury sphygmomanometer in a seated position. The physicians measured BP using the same methods in the same arm while they did the physical examination. If the differences of BP measured between trained staff and physicians exceed 5 mmHg (either systolic BP or diastolic BP), then the BP measurement was taken for a third time by the same physicians. The average of these BP measurements was recorded. Mean arterial pressure (MAP) was calculated as (2 × diastolic BP + systolic BP)/3. Blood was drawn in the morning after a 12 h overnight fast and was sent for analysis within 4 h of collection. Biochemical markers such as total cholesterol (TCHOL), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides, fasting glucose, creatinine and uric acid were analysed by a biochemical autoanalyser (Beckman Cou, Fullerton, CA, USA) at the Department of Clinical Laboratory (China Medical University Hospital, Taichung, Taiwan). Because 24 h urine collections were not possible for cultural and logistical reasons, the urinary ACR in the morning urine sample, with which it correlates well, was used as a surrogate marker of albumin excretion rate. Urinary creatinine (Jaffe's kinetic method) and albumin (colorimetyl bromcresol purple) were measured by an autoanalyser. The interassay precision coefficient of variation was < 3·0% for both creatinine and albumin concentrations.

Sociodemographical factors and life style behaviours

Age, gender, employment, education, dietary habits, physical activity and medical history were collected by self-administered questionnaires. Smoking and alcohol consumption history were divided into three classes as follows: never, former and current.

Metabolic syndrome and microalbuminuria

MetS was defined clinically, based on the presence of three or more of the following AHA/NHLBI MetS criteria [11]: (1) central obesity (WC ≥ 90 cm in men and ≥ 80 cm in women), (2) high triglyceride levels (≥ 1·7 mmol L^{-1} or on drug treatment for elevated triglycerides), (3) low HDL-C level (< 1·03 mmol L^{-1} in men and < 1·29 mmol L^{-1} in women

or on drug treatment for reduced HDL-C), (4) high blood pressure (systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg or on antihypertensive drug treatment in a patient with a history of hypertension) and (5) high fasting plasma glucose concentrations (≥ 5·6 mmol L^{-1} or on drug treatment for elevated glucose). The IDF definition of MetS [10] includes central obesity as a necessary component plus any two of the above-mentioned criteria. Diabetes mellitus was defined as fasting serum glucose ≥ 7·0 mmol L^{-1} or a history of diabetes mellitus and received oral hypoglycaemic agents or insulin treatment. Urinary ACR ranging from 30 mg g^{-1} creatinine to 300 mg g^{-1} creatinine and less than 30 mg g^{-1} creatinine was defined as microalbuminuria and normoalbuminuria, respectively [28].

Statistical analysis

The data are presented as means and SD unless indicated otherwise. Student's *t*-test was used to compare mean values. Log transformation was used for variables with significant deviation from normal distribution, assessed by the Kolmogorov–Smirnov test before further analyses. The χ^2-test was used to compare the differences in prevalence of microalbuminuria across the age and BMI groups. Binary logistical regression was used to estimate the odds ratios (ORs) of MetS and its individual components according to microalbuminuria status. Multivariate logistical regression analysis was used to estimate the ORs of MetS by age, microalbuminuria status, BMI, smoking and alcohol consumption status. Multivariate linear regression analysis was also used to clarify the association between urinary ACR and fasting glucose levels, MAP, WC, triglycerides and HDL-C. All statistical tests were two-sided at the 0·05 significance level. These statistical analyses were performed using the PC version of SPSS statistical software (13th version, SPSS Inc., Chicago, IL, USA).

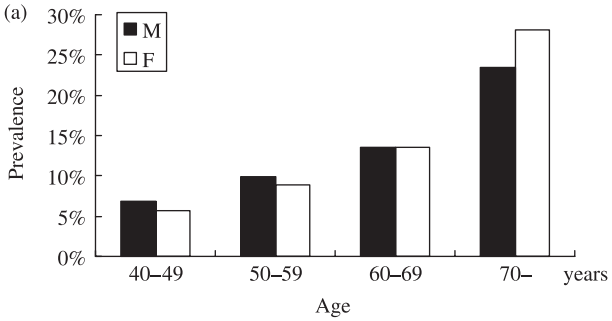
Ethics approval for patient recruitment and analysing the data was obtained from the Institutional Review Board of the China Medical University Hospital.

Results

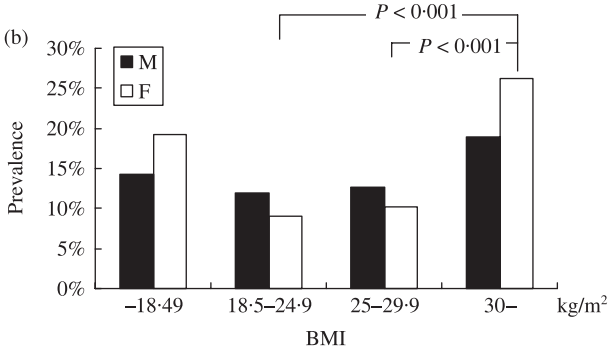
A total of 2311 subjects aged 40 years and above (1123 men and 1188 women, mean age 58·4 ± 12·4 and 55·0 ± 10·4 years) were studied. The prevalence of microalbuminuria in middle-aged Chinese people in Taiwan was 11·5% (12·6% in men and 10·4% in women) (data not shown). The microalbuminuria group had higher age, BMI, WC, systolic BP, diastolic BP, MAP, fasting glucose, triglycerides, TCHOL/HDL-C ratio, prevalence of diabetes mellitus and hypertension, and lower HDL-C than the normoalbuminuria group (Table 1). The prevalence of MetS was 39·1% (44·0% in men and 34·5% in women) using the AHA/NHLBI definition and 25·2%(27·3% in men and 23·2% in women) using the IDF definition, respectively (data not shown).

The crude ORs of having microalbuminuria were significantly higher in subjects with the individual components of MetS than subjects without (OR > 1, $P < 0·05$ in each analysis (Table 2). For example, the crude ORs of having microalbuminuria was 3·78 (95% confidence interval (CI) = 2·72–5·28, 3·06 in men and 4·43 in women) in subjects with elevated BP and 2·26 (1·75–2·92, 1·66 in men and 3·05 in women) in subjects with elevated fasting glucose (Table 2). After adjusting for age, BMI and gender microalbuminuria was significantly associated with the individual components of MetS, except for central obesity in women and elevated fasting glucose in men (Table 2).

The prevalence of microalbuminuria increased with age in men and women (Fig. 1a). The relationship between the prevalence of microalbuminuria and BMI groups using the WHO obesity definition [27] revealed a J shaped curve in men and women (Fig. 1b).



Test for trend: $P < 0.001$ in both genders.



BMI was categorized into four groups according to the World Health Organization definition for obesity as text.

Figure 1 (a) Age and the prevalence of microalbuminuria (prevalence %, number); The prevalences of microalbuminuria were 6·9% (23/331), 9·9% (33/334), 13·6% (27/199), 23·4% (59/252) in men and 5·7% (26/453), 8·9% (34/380), 13·6% (32/236), 28·1% (32/114) in women in age range 40–49, 50–59, 60–69, 70 years old and above. (b) BMI and the prevalence of microalbuminuria (prevalence %, number); The prevalences of microalbuminuria were 14·3% (2/14), 11·9% (74/621), 12·7% (54/425), 19·0% (12/63) in men and 19·2%(5/26), 9·0% (71/787), 10·2% (32/314), 26·2% (16/61) in women in BMI < 18·5, 18·5–24·9, 25–29·9, ≥ 30 kg m^{-2}.

Table 1 Basic characteristics according to microalbuminuria status

	Normoalbuminuria* ($n = 2045$)	Microalbuminuria* ($n = 266$)	*P*-value
Age (years)†	55·9 ± 11·2	63·0 ± 12·2	< 0·001
Men: *n* (%)	981 (48·0%)	142 (53·4%)	–
Height (cm)†	160·9 ± 7·9	159·9 ± 8·9	0·083
Body weight (kg)†	62·9 ± 10·8	64·4 ± 12·3	0·065
BMI (kg m^{-2})†	24·2 ± 3·3	25·1 ± 3·7	< 0·001
WC (cm)†	80·9 ± 9·9	85·1 ± 10·4	< 0·001
Systolic BP (mmHg)†	133·1 ± 20·4	151·2 ± 24·7	< 0·001
Diastolic BP (mmHg)†	77·9 ± 11·9	85·2 ± 13·9	< 0·001
MAP (mmHg)†	96·3 ± 14·0	107·2 ± 16·3	< 0·001
Fasting glucose (mmol L^{-1})†	5·58 ± 1·26	6·54 ± 2·37	< 0·001
TCHOL (mmol L^{-1})†	5·25 ± 0·96	5·29 ± 1·07	0·822
Triglycerides (mmol L^{-1})†	1·32 ± 0·99	1·68 ± 1·35	< 0·001
HDL-C (mmol L^{-1})†	1·20 ± 0·33	1·11 ± 0·29	< 0·001
LDL-C (mmol L^{-1})	3·29 ± 0·86	3·32 ± 0·97	0·637
TCHOL/HDL-C†	4·62 ± 1·25	4·96 ± 1·24	< 0·001
BUN (mmol L^{-1})†	4·57 ± 1·48	5·34 ± 2·10	< 0·001
Creatinine (μmol L^{-1})†	77·7 ± 21·6	90·6 ± 43·1	< 0·001
Diabetes mellitus (%)‡	22·5%	50·0%	< 0·001
Hypertension (%)§	41·5%	72·2%	< 0·001

Data are means ± SD or percentage.

Abbreviations: ACR, urine albumin-to-creatinine ratio; BMI, body mass index; WC, waist circumference; BP, blood pressure; MAP, mean arterial pressure; TCHOL, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

*Normoalbuminuria: ACR < 30 mg g^{-1} creatinine; microalbuminuria: 300 mg g^{-1} creatinine ≥ ACR ≥ 30 mg g^{-1} creatinine.

†Statistics were tested using the log-transformed values.

‡Diabetes mellitus: defined as fasting glucose ≥ 7·0 mmol L^{-1} or history of diabetes mellitus and received oral hypoglycaemic agents or insulin treatment.

§Hypertension: defined as systolic BP ≥ 140 mmHg or diastolic BP ≥ 90 mmHg or history of hypertension and received oral antihypertensive drug treatment.

Student's *t*-test for unpaired data was used for the comparison of mean values between groups; χ^2 test was used to compare the categorized variable.

Table 2 Crude and adjusted odds ratios* (ORcru and ORadj) of having microalbuminuria among men, women and total population using the prevalence of individual components of the metabolic syndrome as predictor variables ($N = 2311$)

	Men ($n = 1123$) ORcru/ORadj* (95% CI)	Women ($n = 1188$) ORcru/ORadj* (95% CI)	Total ($N = 2311$) ORcru/ORadj* (95% CI)†
Central obesity	1·99 (1·39–2·84)/1·73 (1·07–2·80)	2·33 (1·60–3·39)/1·40 (0·84–2·34)	2·15 (1·66–2·78)/1·58 (1·12–2·25)
Elevated BP	3·06 (1·87–5·00)/2·13 (1·26–3·59)	4·43 (2·81–6·99)/2·64 (1·58–4·41)	3·78 (2·72–5·28)/2·42 (1·68–3·49)
Elevated fasting glucose	1·66 (1·17–2·37)/1·37 (0·95–1·98)	3·05 (2·09–4·45)/2·15 (1·44–3·20)	2·26 (1·75–2·92)/1·72 (1·32–2·26)
Elevated triglycerides	1·80 (1·25–2·58)/1·95 (1·33–2·86)	2·63 (1·76–3·93)/1·98 (1·30–3·02)	2·17 (1·66–2·83)/1·99 (1·50–2·63)
Reduced HDL-C	1·64 (1·15–2·35)/1·60 (1·10–2·34)	1·92 (1·29–2·86)/1·63 (1·07–2·47)	1·73 (1·33–2·26)/1·62 (1·23–2·15)

Abbreviations as Table 1, CI: confidence interval; BP, blood pressure; HDL-C, high-density lipoprotein cholesterol; Reference group were patients with normoalbuminuria (ACR < 30 mg g^{-1} creatinine).

*ORadj (Adjusted odds ratios): odds ratios with adjustment for age and BMI in each gender, and age, BMI and gender in total.

Table 3 shows the ORs for microalbuminuria given specific components of MetS. After simultaneously controlling for the components of MetS, as well as age and gender, the association between microalbuminuria and all the components of MetS remained statistically significant.

Table 4 shows the association between urinary ACR and the components of MetS. Using multivariate linear regression analysis, after adjusting for age and gender, all the components of MetS were strongly associated with urinary ACR (Table 4, models 1–5). After simultaneously controlling for the components of MetS, as well as age and gender, urinary ACR was still associated with MAP and fasting glucose level (Table 4, model 6).

Using multivariate logistical regression with MetS as the outcome variable (using the AHA/NHLBI definition in model 1 and using the IDF definition in model 2), we found

Table 3 Odds ratios of having microalbuminuria simultaneously adjusted for age, gender and all the components of the metabolic syndrome

	ORs* (95% C.I.)	*P*-value
Central obesity	1·35 (1·02–1·78)	0·037
Elevated BP	2·07 (1·44–2·99)	< 0·001
Elevated fasting glucose	1·48 (1·13–1·96)	0·005
Elevated triglycerides	1·53 (1·14–2·06)	0·005
Reduced HDL-C	1·40 (1·05–1·86)	0·023
Age	1·04 (1·03–1·05)	< 0·001
Gender	1·06 (0·81–1·40)	0·668

*OR, odds ratio, adjusted for age, gender and all other components in table.

Abbreviations as Tables 1 and 2. BP, blood pressure; HDL-C, high-density lipoprotein cholesterol.

that age, BMI, and microalbuminuria were independent variables associated with MetS in each gender (Table 5). Compared with the subjects with normoalbuminuria, the subjects with microalbuminuria had higher ORs of having MetS in both MetS definition and genders. After adjusting for age, BMI, smoking and alcohol consumption status, the adjusted ORs of having MetS was 1·76 (95% C.I. = 1·16–2·67, model 1) and 1·73 (1·06–2·83, model 2) in men and 2·19 (1·38–3·50, model 1) and 2·09 (1·24–3·51, model 2) in women, respectively (Table 5). MetS was associated with smoking in women using the AHA/NHLBI definition. Compared with those who had never smoked, the adjusted ORs of having MetS using the AHA/NHLBI definition in women was 2·35 (95% C.I. = 1·03–5·37, model 1) for former smokers and 5·04 (1·39–18·3, model 1) for current smokers, respectively (Table 5). BMI was also associated with MetS as defined by both the AHA/NHLBI and the IDF and in both genders after adjusting for age, microalbuminuria, smoking status and alcoholic consumption status (Table 5).

Discussion

In this population-based study, we demonstrated that subjects with microalbuminuria were strongly associated with MetS and its individual components, regardless of the definition used, in middle-aged Chinese people in Taiwan. Among these individual components of MetS, the association was significant even after simultaneously controlling for the components of MetS as well as age and gender. Microalbuminuria is an early sign of chronic kidney disease. Chen and colleagues [29] showed that MetS is strongly associated with chronic kidney disease and that it might actually be an important factor in its cause. De Jong and colleagues [30] also found that microalbuminuria is associated with an enhanced risk for cardiovascular mortality and also with an enhanced risk for progressive renal failure, not only in diabetic patients, but also in hypertensive and in non-diabetic, non-hypertensive subjects. Thus, the linking between MetS

Table 4 Multivariate linear regression models showing regression coefficients with urinary ACR§ as dependent variable and listed variables as independent variables. All were adjusted for age and gender

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
MAP (mmHg)	0·44 (0·35–0·53)‡	–	–	–	–	0·36 (0·26–0·45)‡
Glucose (mmol L^{-1})	–	4·01 (3·15–4·86)‡	–	–	–	3·30 (2·43–4·16)‡
HDL-C (mmol L^{-1})			–7·58 (–11·6–3·51)‡	–	–	–2·21 (–6·44–2·01)
Triglycerides (mmol L^{-1})	–	–	–	3·37 (2·17–4·58)‡	–	1·06 (–0·22–2·34)
WC (cm)	–	–	–	–	0·37 (0·23–0·52)‡	0·03 (–0·12–0·19)

‡$P < 0·001$; §abbreviations as Tables 1 and 2. MAP, mean arterial pressure = (2 × diastolic BP + systolic BP)/3; WC, waist circumference; urinary ACR, urinary albumin-to-creatinine ratio.

Table 5 Odds ratios (95% confidence interval) of having the metabolic syndrome using the AHA/NHLBI and the IDF definition derived from a multiple logistical regression analysis using age, gender, BMI, alcohol consumption, smoking, physical activity and ACR groups as independent variables

Variable	Model 1[a] (MetS1)		Model 2[b] (MetS2)	
Gender	M	F	M	F
Age	1·04 (1·02–1·05)‡	1·08 (1·06–1·10)‡	1·04 (1·03–1·06)‡	1·08 (1·06–1·10)‡
BMI	1·52 (1·43–1·61)‡	1·41 (1·34–1·48)‡	2·03 (1·86–2·22)‡	1·69 (1·58–1·82)‡
§Normoalbuminuria	1·00 (Reference)	1·00 (Reference)	1·00 (Reference)	1·00 (Reference)
§Microalbuminuria	1·76 (1·16–2·67)†	2·19 (1·38–3·50)†	1·73 (1·06–2·83)*	2·09 (1·24–3·51)†
**Smoking				
Never	1·00 (Reference)	1·00 (Reference)	1·00 (Reference)	1·00 (Reference)
Former	1·34 (0·95–1·89)	2·35 (1·03–5·37)*	1·45 (0·94–2·24)	1·96 (0·70–5·49)
Current	0·91 (0·63–1·32)	5·04 (1·39–18·3)*	1·03 (0·45–1·63)	3·16 (0·69–14·4)
**Alcohol consumption				
Never	1·00 (Reference)	1·00 (Reference)	1·00 (Reference)	1·00 (Reference)
Former	1·28 (0·94–1·75)	0·88 (0·53–1·48)	1·11 (0·75–1·66)	0·70 (0·35–1·39)
Current	1·29 (0·78–2·13)	1·49 (0·32–6·93)	1·21 (0·66–2·21)	4·87 (0·80–29·6)

*$P < 0·05$, †$P < 0·01$, ‡$P < 0·001$.
Items were defined by the AHA/NHLBI[a] and the IDF[b].
§Normoalbuminuria, ACR < 30 mg g^{-1} creatinine; microalbuminuria, 300 mg g^{-1} creatinine ≥ ACR ≥ 30 mg g^{-1} creatinine.
**Alcohol consumption and smoking were categorized and described in text.

and chronic kidney disease was possible through the effect of microalbuminuria. These results indicated that microalbuminuria may be a renal component of MetS. This was also found in other studies [4,24].

Microalbuminuria reflects transvascular albumin leakage, which has been proposed to indicate increased endothelial permeability [20,22]. Studies in both diabetic [22] and non-diabetic [31] individuals have shown that elevated urinary albumin excretion is associated with abnormalities of endothelial function, which is recognized as an early event of atherosclerosis. Microalbuminuria is also a marker of vascular dysfunction in the kidneys and systemic vasculature. Hypertension and elevated blood pressure have long been associated with microalbuminuria [24,32,33]. Elevated blood pressure causes an increase in intraglomerular capillary pressure, which leads to the leakage of albumin [34]. Wang and colleagues [33] also found that microalbuminuria may be a useful biomarker for identifying individuals most likely to develop hypertension. Microalbuminuria may be an indicator of early vascular complications of hypertension.

The association between high glucose, as defined by the AHA/NHLBI, and microalbuminuria has not been previously examined. Previous studies [22,35,36] found that microalbuminuria is positively associated with the degree of insulin resistance and hyperglycaemia. A recent study of the general population in the USA showed that lower levels of blood pressure and plasma glucose (fasting plasma glucose level ≥ 6·2 mmol L^{-1}) were strongly associated with microalbuminuria [24]. However, in our study, we found that elevated BP was the component of MetS most associated with microalbuminuria (Table 2). Even after simultaneously adjusting for other components of MetS, as well as age and gender, the adjusted ORs for elevated BP was higher than the other components (Table 3). It means that an elevated BP component, rather than the other components of MetS, has the largest power to identify whether subjects are at risk of microalbuminuria. Measuring blood pressure is an easy, cheap, and non-invasive method. From this viewpoint, we can easily identify subjects who are at risk of microalbuminuria. Subjects with high blood pressure should also have their urine ACR checked to see if they have microalbuminuria.

Furthermore, our results indicate that a lower fasting plasma glucose level of ≥ 5·6 mmol L^{-1} is strongly associated with the presence of microalbuminuria. To our knowledge, this is the first time that fasting hyperglycaemia above 5·6 mmol L^{-1} has been proven to be statistically significant with microalbuminuria in an Asian population.

From the pathophysiological viewpoint, urinary ACR and the components of MetS (such as blood pressure, fasting glucose level *et al.*) were all continuous variables, so we also analyzed the association between these factors using multivariate linear regression. After adjustment for age and gender, we found that urinary ACR was strongly associated with all the components of MetS. This evidence further demonstrates that urinary ACR were strongly associated with MetS.

Many studies have shown that obese and underweight individuals are at increased risk for all-cause mortality [37–39]. Microalbuminuria has been linked to a greater risk for future cardiovascular disease, renal disease, atherosclerosis and all-cause mortality and cardiovascular disease mortality [16–19]. The association between microalbuminuria and obesity is unclear. For example, Konta and colleagues [40] found that microalbuminuria was not associated with obesity in the Japanese general population. A cohort study [41], however, showed that subjects with a high WC or those with MetS at baseline were more likely to develop elevated albuminuria compared with subjects with a normal WC or

those without MetS. In our study, we found that central obesity, using the AHA/NHLBI Asian cut-off point [11], was strongly associated with microalbuminuria after adjusting for the components of MetS as well as age and gender. We also found that underweight individuals had a higher prevalence of microalbuminuria than normal weight subjects using the WHO obesity definition [27] (Fig. 1b). Therefore, microalbuminuria seems to be associated with underweight and increased all-cause mortality. Further study is necessary to clarify the association.

Dyslipidaemia has been shown to be a risk factor for cardiovascular disease and increased all-cause and cardiovascular mortality [11]. Microalbuminuria has been reported to independently predict all-cause and cardiovascular mortality [16–18]. The relationship, however, between dyslipidaemia and microalbuminuria was inconsistent in previous studies [42,43]. In our study, we found that both hypertriglyceridaemia and low HDL-C were associated with microalbuminuria after simultaneously adjusting for the components of MetS, as well as age and gender.

A prior study [24] in the American population found that microalbuminuria is only associated with high fasting glucose and high BP components of MetS. In our study microalbuminuria was found to be associated with MetS and its individual components, as defined by the AHA/NHLBI and the IDF. Even while concurrently adjusting for the components of MetS, as well as age and gender, the association among microalbuminuria and all the components of MetS remained statistically significant. Isomaa and colleagues [4] examined the relationship between individual components of MetS using the WHO definition and subsequent risk for cardiovascular death in a European longitudinal study. They concluded that microalbuminuria was the strongest risk factor for cardiovascular morbidity and mortality when compared with obesity, dyslipidaemia, hypertension and insulin resistance. Moreover, Ford and colleagues [44] found that the WHO definition of MetS yielded higher prevalence estimates and ORs for self-reported heart attack and congestive heart failure than those from the ATP III definition of MetS. Based on these findings, and our results, subjects with microalbuminuria, along with other components of MetS, may be at increased risk of cardiovascular morbidity and mortality. Subjects with hypertension took different antihypertensive agents, which could largely influence the appearance of microalbuminuria. However, in our study, we didn't have the details of antihypertensive agents in hypertensive subjects. It is one of the limitations of our study. Also, the study is a cross-sectional study and only associations between microalbuminuria and MetS could be estimated. Further cohort study is necessary to clarify the causal relation.

In conclusion, we demonstrated that microalbuminuria is strongly associated with MetS, as defined by the AHA/NHLBI and the IDF, and their individual components. After concurrently adjusting for the components of MetS, as well as age and gender, microalbuminuria was still associated with all the individual components of MetS. We should therefore consider the possibility of MetS if subjects present with microalbuminuria.

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