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Asia Pac J Public Health 2011 23: 936 originally published online 10 May 2010
DOI: 10.1177/1010539510361637

The online version of this article can be found at:
http://aph.sagepub.com/content/23/6/936
Hypertension, Hypertension Control, and Chronic Kidney Disease in a Malay Population in Singapore

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Abstract
Studies conducted in Western populations demonstrate that blood pressure (BP) is a major risk factor for chronic kidney disease (CKD). The authors examined the cross-sectional association between BP and CKD in 3280 adults of Malay ethnicity aged 40 to 80 years living in Singapore. CKD was defined as (1) estimated glomerular filtration rate (eGFR) of < 60 mL/min/1.73 m² and (2) presence of microalbuminuria/macroalbuminuria. They observed a dose-dependent positive association between BP and CKD (P trend < .0001). In multivariable-adjusted analysis, compared with participants with normal BP, the odds ratio (OR; 95% confidence interval [CI]) of eGFR < 60 mL/min/1.73 m² was 1.85 (0.95-3.62), 2.95 (1.55-5.64), and 4.96 (2.63-9.37) for prehypertension, and stage 1 and stage 2 hypertension, respectively. Similar results were obtained for microalbuminuria/macroalbuminuria. Stage 2 hypertension had the greatest population-attributable risk of CKD (23%). The strong positive association of hypertension with CKD emphasizes the need to control BP in Asian populations to reduce the burden of kidney disease.

Keywords
blood pressure, chronic kidney disease, glomerular filtration rate, microalbuminuria, macroalbuminuria, Malay, Singapore

Introduction
Chronic kidney disease (CKD), a risk factor for end-stage renal disease (ESRD), is a major public health problem.1,2 Blood pressure (BP) has been shown to be a risk factor for CKD and for adverse

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cardiovascular outcomes.\textsuperscript{3,4} Intervention trials have shown that effective control of hypertension leads to reduced proteinuria and slower progression of CKD,\textsuperscript{5,6} and the Seventh Report of the Joint National Committee (JNC 7) on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure\textsuperscript{7} recommends a tight BP control for individuals with CKD to prevent adverse outcomes. Recent studies in Western populations suggest that hypertension at all ranges, even in “high normal levels,” are associated with CKD.\textsuperscript{8-10} However, there are few studies that examine the association between BP and CKD in Asia. In this study, we examined the relationship between ranges of BP and CKD among a Malay adult population in Singapore.

**Methods**

**Study Population**

The Singapore Malay Eye Study was a population-based, cross-sectional study designed to study the prevalence and risk factors for major eye diseases affecting urban Malays living in Singapore. Details of the study participants and methods have been published previously.\textsuperscript{11} In brief, 5600 individuals aged 40 to 80 years were selected by an age-stratified random sampling method from the computer-generated random list of 16 069 Malay names provided by the Ministry of Home Affairs. Of the 4168 eligible individuals, 3280 participated in the study (78.7\% response rate). A potential participant was considered to be ineligible if the person had moved from the residential address, had not lived there in the past 6 months, was deceased, or was terminally ill.

**Exposure Measurement**

Information on participants’ demographic characteristics, educational attainment, cigarette smoking, alcohol consumption, and medical history were obtained using a standardized questionnaire administered by trained personnel. BP measurement was taken with a digital automatic BP monitor (Dinamap model Pro Series DP110X-RW, 100V2; GE Medical Systems Information Technologies, Inc, USA) on 2 occasions 5 minutes apart, after the participants were seated for at least 5 minutes. If the BPs differed by more than 10 mm Hg systolic and 5 mm Hg diastolic, a third measurement was taken, and the BP of the individual was taken as the average of the 2 closest readings. Hypertension was defined as systolic BP $\geq 140$ mm Hg or diastolic BP $\geq 90$ mm Hg or self-reported previously diagnosed hypertension. BP was categorized according to the JNC 7 categories\textsuperscript{7} as follows: (1) normal BP ($<120$ mm Hg systolic and $<80$ mm Hg diastolic); (2) prehypertension (120 to 139 mm Hg systolic or 80 to 89 mm Hg diastolic); (3) stage 1 hypertension (140 to 159 mm Hg systolic and 90 to 99 mm Hg diastolic); and (4) stage 2 hypertension ($\geq 160$ mm Hg systolic or $\geq 100$ mm Hg diastolic). Undiagnosed hypertension (unaware) was defined as a self-report of no prior diagnosis of hypertension. Treatment of hypertension was defined as a participant answering “yes” to the question “Are you currently taking any medication for high BP?” Control of hypertension was defined as systolic BP $<140$ mm Hg and diastolic BP $<90$ mm Hg and poorly controlled hypertension as systolic BP $>140$ mm Hg and diastolic BP $>90$ mm Hg in the context of pharmacological treatment of hypertension.

**Measurement of Outcome**

Our outcome of interest was CKD defined as (1) an estimated glomerular filtration rate (eGFR) of $<60$ mL/min/1.73 m$^2$ based on the US National Kidney Foundation Kidney Disease Outcome Quality Initiative working group definition\textsuperscript{12} and (2) microalbuminuria/macroalbuminuria
defined as a urinary albumin-to-creatinine ratio (ACR) ≥ 17 mg/g for men and ≥ 25 mg/g for women. We also defined CKD using an alternate definition—that is, as the presence of either eGFR < 60 mL/min/1.73 m² or microalbuminuria/macroalbuminuria (combined end points). GFR was estimated from serum creatinine concentration using the modification of diet in renal disease equation, defined as follows: eGFR = 186.3 × (Serum creatinine in mg/dL)⁻¹.154 × Age⁻⁰.²⁰³ × (0.742 for women). Serum creatinine measurement was carried out at the National University Hospital Reference Laboratory and was reported in μmol/L. ACR was calculated from urinary albumin (mg/L) and creatinine (mmol/L) using spot untimed urine samples and was reported in μg/mg.

Of the 3280 participants, we excluded 176 individuals with missing information on serum creatinine (n = 132), self-reported BP (n = 35), and other relevant covariates (n = 9), leaving 3104 participants for the eGFR < 60 mL/min/1.73 m² analysis. For the microalbuminuria/macroalbuminuria analysis, we included 931 participants who had information on ACR and other relevant covariates.

**Definition of Other Variables**

Age was defined as the age at the time of examination and was categorized into 4 groups: 40 to 49, 50 to 59, 60 to 69, and 70 to 80. Education was categorized into (1) primary and below (≤6 years) and (2) high school and above (>6 years). Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m²). Diabetes mellitus was defined as a casual plasma glucose ≥ 200 mg/dL (11.1 mmol/L) or self-reported physician-diagnosed diabetes or use of glucose-lowering medication. Cigarette smokers were categorized as current, former, and never smokers and those who consumed alcohol into drinkers and nondrinkers.

**Statistical Analysis**

Means and standard deviations were reported for continuous variables and proportions for categorical variables. We examined the association of BP with the prevalence of both eGFR < 60 mL/min/1.73 m² (n = 660) and microalbuminuria/macroalbuminuria (n = 349). For this, first, we categorized BP according to JNC 7 BP categories. Second, we categorized BP using quartiles of systolic and diastolic BP. Finally, we categorized BP according to hypertension awareness, treatment, and control. Logistic regression models were used to calculate the ORs and 95% CIs of eGFR < 60 mL/min/1.73 m² and microalbuminuria/macroalbuminuria across BP categories using the JNC 7 normal BP category, lowest quartiles of systolic and diastolic BP, and the absence of hypertension as reference categories in 2 separate models. In the first model, we adjusted for age (years) and sex and in the multivariable model we additionally adjusted for categories of education, cigarette smoking, alcohol consumption, diabetes mellitus, and BMI (kg/m²). Tests for trend were performed using the categories and quartiles of BP as ordinal variables in multivariable logistic regression models. We also analyzed the association between JNC 7 BP categories and CKD using the combined end points. Finally, we calculated the population attributable risk (PAR) of CKD using the combined end points. The PAR estimates were derived using the formula Pd [RR – (1/RR)], where Pd is the proportion of cases exposed to the risk factor, and RR is the adjusted relative risk estimated using the observed OR.

We performed several sets of supplementary analyses. First, we analyzed systolic and diastolic BP as continuous variables in the multivariable model for both eGFR < 60 mL/min/1.73 m² and microalbuminuria/macroalbuminuria. Second, we excluded participants with diabetes mellitus and examined whether exclusion of participants with diabetes mellitus changed the effect estimates.
Third, we used the likelihood-ratio tests to determine whether prediction models that included BP measurements and their quadratic terms provided a better fit than did models limited to BP measurements alone for the combined CKD outcome. Finally, we examined the association between JNC-7 BP categories and microalbuminuria/macroalbuminuria using the ACR cutoff as defined by the European Hypertension Society Clinical Guidelines (ACR ≥ 22 mg/g for men and ≥ 31 mg/g for women). All statistical analyses were performed using SAS version 9.1.

### Results

Selected baseline characteristics of the study population are shown in Table 1. The prevalence of eGFR < 60 mL/min/1.73 m² was 21.3% (95% CI = 19.8%-22.7%), and the prevalence of microalbuminuria/macroalbuminuria was 37.5% (95% CI = 34.4%-40.7%). The majority of those with hypertension belonged to the stage 2 hypertension group. Of the 3104 participants included for eGFR < 60 mL/min/1.73 m² analysis, 69% (n = 2134) had hypertension.

Table 2 shows the association between BP categories and eGFR < 60 mL/min/1.73 m². The prevalence of eGFR < 60 mL/min/1.73 m² increased with increasing JNC 7 BP categories in a dose-dependent manner (P trend < .0001). In the multivariable models, stage 1 and 2 hypertension showed significant positive association with eGFR < 60 mL/min/1.73 m². The association of prehypertension with eGFR < 60 mL/min/1.73 m² neared statistical significance. The multivariable-adjusted OR of eGFR < 60 mL/min/1.73 m² was 2.5 in participants with hypertension compared with those without hypertension. When BP was analyzed in quartiles, a significant graded association was observed between increasing quartiles of systolic and diastolic BP and eGFR < 60 mL/min/1.73 m² (P trend < .0001). In the multivariable models, systolic BP > 143 mm Hg and diastolic BP > 86 mm Hg was significantly associated with eGFR < 60 mL/min/1.73 m² compared with systolic BP ≤ 129 mm Hg and diastolic BP ≤ 70 mm Hg.

Table 3 shows the association between BP categories and microalbuminuria/macroalbuminuria. Similar to the results for eGFR < 60 mL/min/1.73 m² as the outcome, the prevalence of...
Microalbuminuria/macroalbuminuria increased significantly across JNC 7 BP categories (P trend < .0001). In the multivariable models, stage 1 and 2 hypertension showed significant positive association with microalbuminuria/macroalbuminuria. The multivariable-adjusted OR of microalbuminuria/macroalbuminuria was 2.5 in participants with hypertension as compared with those without hypertension. When BP was analyzed in quartiles, both systolic and diastolic BP quartiles were positively associated with microalbuminuria/macroalbuminuria. Systolic BP > 130 mm Hg and diastolic BP > 80 mm Hg was significantly associated with microalbuminuria/macroalbuminuria, compared with systolic BP ≤ 130 mm Hg and diastolic BP ≤ 72 mm Hg.

We also analyzed the association between JNC 7 BP categories and CKD using an alternate definition (combined end point of either eGFR < 60 mL/min/1.73 m² or microalbuminuria/macroalbuminuria), and the results were essentially similar (data not shown). For example, compared with participants with normal BP, the ORs (95% CIs) of CKD using the combined end points were 2.33 (1.34-4.07) for prehypertension, 3.63 (2.11-6.24) for stage 1 hypertension, and 6.48 (3.80-11.05) for stage 2 hypertension. The PAR of hypertension for CKD using the combined end points is estimated to be 7% among individuals with stage 1 hypertension and 23% among individuals with stage 2 hypertension.

Table 4 shows the association between hypertension awareness, treatment, and control and CKD. Of the 2134 participants with hypertension, 43% were unaware (undiagnosed) of their hypertension, 24% were aware but not on treatment, 24% were being treated, but their
hypertension remained poorly controlled, and only 9% had their hypertension controlled with medications. Compared with treated, controlled hypertension, poorly controlled hypertension was positively associated with eGFR < 60 mL/min/1.73 m²; however, the association fell short of statistical significance in the multivariable model. Undetected or untreated hypertension was negatively associated with eGFR < 60 mL/min/1.73 m². Compared with treated, controlled hypertension, poorly controlled hypertension was significantly associated with microalbuminuria/macroalbuminuria; undetected or untreated hypertension was also associated with microalbuminuria/macroalbuminuria, though the association failed to reach statistical significance.

The positive association between BP and eGFR < 60 mL/min/1.73 m² and microalbuminuria/macroalbuminuria persisted when systolic and diastolic BP were analyzed as continuous variables (data not shown). The multivariable-adjusted OR (95% CI) of eGFR < 60 mL/min/1.73 m² increased by 1.12 (1.11-1.13) for every 10-unit increase in systolic BP and by 1.15 (1.14-1.16) for every 10-unit increase in diastolic BP; the multivariable-adjusted OR (95% CI) of microalbuminuria/macroalbuminuria increased by 1.33 (1.32-1.34) for every 10-unit increase in systolic BP and by 1.59 (1.58-1.61) for every 10-unit increase in diastolic BP. When we repeated the main analysis

### Table 3. Association Between BP Categories and Microalbuminuria/Macroalbuminuria

<table>
<thead>
<tr>
<th>BP Categories</th>
<th>No. at Risk (Cases)</th>
<th>Prevalence of Microalbuminuria/Macroalbuminuria (%)</th>
<th>Age, Sex-Adjusted OR</th>
<th>Multivariable&lt;sup&gt;a&lt;/sup&gt; OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JNC-7 BP category&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>71 (7)</td>
<td>9.9</td>
<td>1.00 (referent)</td>
<td>1.00 (referent)</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>226 (47)</td>
<td>20.8</td>
<td>2.23 (0.96-5.21)</td>
<td>2.22 (0.93-5.27)</td>
</tr>
<tr>
<td>Stage 1 hypertension</td>
<td>224 (69)</td>
<td>30.8</td>
<td>3.32 (1.43-7.67)</td>
<td>3.02 (1.28-7.15)</td>
</tr>
<tr>
<td>Stage 2 hypertension</td>
<td>410 (226)</td>
<td>55.1</td>
<td>8.25 (3.64-18.70)</td>
<td>6.70 (2.89-15.60)</td>
</tr>
<tr>
<td>P trend</td>
<td></td>
<td></td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Hypertensive status&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normotensive</td>
<td>297 (54)</td>
<td>18.2</td>
<td>1.00 (referent)</td>
<td>1.00 (referent)</td>
</tr>
<tr>
<td>Hypertensive</td>
<td>634 (295)</td>
<td>46.5</td>
<td>3.02 (2.13-4.29)</td>
<td>2.53 (1.75-3.66)</td>
</tr>
<tr>
<td>Systolic BP quartiles</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Quartile 1 (84-130 mm Hg)</td>
<td>229 (38)</td>
<td>16.6</td>
<td>1.00 (referent)</td>
<td>1.00 (referent)</td>
</tr>
<tr>
<td>Quartile 2 (131-145 mm Hg)</td>
<td>239 (67)</td>
<td>28.0</td>
<td>1.81 (1.15-2.85)</td>
<td>1.64 (1.02-2.63)</td>
</tr>
<tr>
<td>Quartile 3 (146-164 mm Hg)</td>
<td>224 (97)</td>
<td>43.3</td>
<td>3.28 (2.10-5.14)</td>
<td>2.82 (1.76-4.52)</td>
</tr>
<tr>
<td>Quartile 4 (165-275 mm Hg)</td>
<td>239 (147)</td>
<td>61.5</td>
<td>6.14 (3.88-9.72)</td>
<td>5.39 (3.34-8.71)</td>
</tr>
<tr>
<td>P trend</td>
<td></td>
<td></td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Diastolic BP quartiles</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Quartile 1 (48-72 mm Hg)</td>
<td>225 (58)</td>
<td>25.8</td>
<td>1.00 (referent)</td>
<td>1.00 (referent)</td>
</tr>
<tr>
<td>Quartile 2 (73-80 mm Hg)</td>
<td>248 (77)</td>
<td>31.1</td>
<td>1.30 (0.86-1.98)</td>
<td>1.30 (0.84-2.03)</td>
</tr>
<tr>
<td>Quartile 3 (81-89 mm Hg)</td>
<td>234 (96)</td>
<td>41.0</td>
<td>2.25 (1.49-3.41)</td>
<td>2.18 (1.40-3.40)</td>
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<tr>
<td>Quartile 4 (90-131 mm Hg)</td>
<td>224 (118)</td>
<td>52.7</td>
<td>3.36 (2.22-5.11)</td>
<td>3.53 (2.26-5.52)</td>
</tr>
<tr>
<td>P trend</td>
<td></td>
<td></td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

Abbreviations: BP, blood pressure; eGFR, estimated glomerular filtration rate; OR, odds ratio; CI, confidence interval.

<sup>a</sup>Adjusted for age (years), gender, education (primary and below, high school and above), body mass index (kg/m²), smoking (current, former, never), alcohol intake (present, absent), and diabetes status (present, absent).

<sup>b</sup>BP classified according to Seventh Report of the Joint National Committee (JNC 7) on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure criteria (normal, systolic BP < 120 mm Hg and diastolic BP < 80 mm Hg; prehypertension, systolic BP = 120-139 or diastolic BP = 80-89 mm Hg; stage 1 hypertension, systolic BP ≥ 140 or diastolic BP = 90-99 mm Hg; stage 2 hypertension, systolic BP ≥ 160 or diastolic BP ≥ 100 mm Hg).

<sup>c</sup>Hypertension was defined as a self-reported history or systolic BP ≥ 140 mm Hg or diastolic BP ≥ 90 mm Hg.
with nondiabetic participants, the results were essentially similar. For example, the multivariable-adjusted ORs for higher JNC 7 categories compared with normal BP (BP < 120/80 mm Hg) were 2.47, 4.02, and 6.36 for eGFR < 60 mL/min/m² and 2.82, 4.31, and 8.37 for microalbuminuria/macroalbuminuria. When we compared the models with and without an additional quadratic term, adding the quadratic term did not improve the model prediction (P = .22 for the model with systolic BP variables and P = .4 for the model with diastolic BP variables) for the combined CKD outcome. Finally, when we examined the association between JNC-7 BP category and microalbuminuria/macroalbuminuria using the ACR cutoff as defined by the European Hypertension Society Clinical Guidelines, the results were essentially similar; for example, compared with normal BP, the multivariable-adjusted ORs (95% CI) for higher JNC categories were 1.63 (0.68-3.93), 2.11 (0.88-5.06), and 4.99 (2.13-11.66) with a significant trend (P < .0001).

### Discussion

The results of this population-based study in the Malay population in Singapore demonstrated that BP was strongly associated with CKD, defined as an eGFR of <60 mL/min/1.73 m² or the presence of microalbuminuria/macroalbuminuria. This association was found to be independent of age, sex, education, cigarette smoking, alcohol consumption, diabetes mellitus, and BMI. Compared with people with treated, controlled hypertension, those with poorly controlled hypertension were >2.5 times more likely to have microalbuminuria/macroalbuminuria. Stage 2 hypertension had the greatest PAR of CKD (23%) among the JNC 7 BP categories.

The prevalence of CKD in our study population based on decreased kidney function (eGFR < 60 mL/min/1.73 m²) was 21.3%, and based on kidney damage (microalbuminuria/macroalbuminuria), it was 37.5%. In the recent National Health and Nutrition Examination survey (NHANES 1999-2004) the prevalence of eGFR < 60 mL/min/1.73 m² was 8.1%, and
the prevalence of microalbuminuria/macroalbuminuria was 9.5% among adults aged ≥20 years.\textsuperscript{17} The prevalence of CKD is reported to be 10.2% in Singapore,\textsuperscript{18} 9.8% in Taiwan,\textsuperscript{19} 13.7% in Korea,\textsuperscript{20} and 15.1% in the Japanese general population.\textsuperscript{21} The higher prevalence of both types of CKD observed in our study could be attributed to the older age and the higher prevalence of hypertension in the study population.

The mechanism by which hypertension leads to kidney disease has been well established.\textsuperscript{22,23} Higher BP is a strong predictor of progressive renal dysfunction\textsuperscript{3,4} and promotes faster decline of GFR.\textsuperscript{12} Also, aggressive control of BP with antihypertensive agents delays the progression of kidney disease.\textsuperscript{24,25} Diabetes mellitus is an important risk factor for kidney disease.\textsuperscript{26,27} In this study, the association between BP and CKD remained significant, even after excluding participants with diabetes mellitus from the analysis, suggesting that high BP is associated with CKD independent of diabetes.

Our finding of a positive association between increasing JNC 7 BP categories and CKD was consistent with results from previous studies. In the CLUE study conducted among 23,534 adult volunteers in Maryland, Haroun et al\textsuperscript{28} reported a positive, linear association between JNC 6 BP categories and CKD. Coresh et al\textsuperscript{29} showed that elevated serum creatinine level was positively associated with higher BP categories among US NHANES III participants. Similar associations between all stages of hypertension and ESRD were reported by several cohort studies conducted in Western countries.\textsuperscript{3,10,30} In the current study, both systolic and diastolic BP were independently associated with CKD. The data presented suggested a continuous, linear association between BP and CKD. Greater odds of CKD were observed at systolic BP > 143 mm Hg and diastolic BP > 86 mm Hg for eGFR < 60 mL/min/1.73 m\textsuperscript{2} and systolic BP > 130 mm Hg and diastolic BP > 80 mm Hg for microalbuminuria/macroalbuminuria. These findings indirectly support the JNC 7 recommended target BP of <130/80 mm Hg for individuals with CKD in order to reduce the associated cardiovascular morbidity and mortality.\textsuperscript{7} We have shown in a previous study that both systolic and diastolic BP were associated with CKD in a multiethnic Asian population, including Chinese, Malay, and Indian populations in Singapore.\textsuperscript{31} Similar to our finding, elevated levels of systolic and diastolic BP were associated with earlier stages of kidney disease defined by dipstick positive proteinuria in a large screening program conducted among the Southeast Asian population.\textsuperscript{18} In another Japanese cohort, both systolic and diastolic BPs were reported to be independent risk factors for ESRD.\textsuperscript{30} However, evidence from observational studies and a meta-analysis show that systolic BP is a stronger predictor of ESRD than diastolic BP.\textsuperscript{22,32}

We found that those with poorly controlled hypertension were >2.5 times more likely to have microalbuminuria/macroalbuminuria compared with those with treated, controlled hypertension. Surprisingly, in our study sample, we found that the prevalence of eGFR < 60 mL/min/1.73 m\textsuperscript{2} was low among those with undetected or untreated hypertension (prevalence = 22.3%) compared with those with treated, controlled hypertension (prevalence = 30.1%). There are several possible explanations for this unexpected finding. First, it could be because of the similar lower prevalence of diabetes among those with undetected or untreated hypertension (prevalence = 23%), compared with those with treated, controlled hypertension (prevalence = 31%) in our study. Diabetes mellitus is a well-recognized risk factor for CKD. Second, it is also possible that those with undetected or untreated hypertension may have hypertension that is of a more recent onset (ie, for a shorter duration) compared with treated, controlled hypertension. However, there is no significant difference in the mean age between the 2 groups. Finally, this could also be a chance finding.

The strengths of our study include its population-based sample; confinement of the study sample to Malay race-ethnicity, thus reducing confounding by race-ethnicity; the use a of a measure of kidney function (eGFR) as well as a marker of kidney damage (albuminuria) to define CKD; and the availability of information on potential confounding factors. Several limitations of
our study have to be noted. Because of the cross-sectional nature of the study, we are not in a position to interpret the association to be only one directional and imply that hypertension causes CKD. It is also possible that kidney dysfunction can cause secondary hypertension. Microalbuminuria/macroalbuminuria was defined based on a single spot urinary ACR measurement, which could have overestimated its prevalence. NHANES III reported that only 63.2% of the individuals had persistent microalbuminuria on repeat measurement. Despite these limitations, we believe that our study findings may have important public health implications in Asia in devising strategies for the prevention of hypertension and improving BP control among those with hypertension so as to reduce the burden of kidney disease.

In conclusion, higher BP levels, even moderate elevations of BP in the “high normal range” were found to be associated with CKD among Malay adults aged 40 to 80 years in Singapore. Our study results extend the current evidence on the association of higher BP with CKD reported from several previous Western studies to an Asian population. Therefore, early detection of high BP and aggressive control may help prevent CKD in Asian populations.

Declaration of Conflicting Interests
The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding
This study was funded by the National Medical Research Council (NMRC), 0796/2003, and the Biomedical Research Council (BMRC), 501/1/25-5, with support from the Singapore Prospective Study Program and the Singapore Tissue Network, A*STAR.

References


