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Complete List of Authors:	Liew, Seaw Jia; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System Lee, Tayu, John; Nossal Institute for Global Health, School of Population and Global Health, University of Melbourne Tan, Chuen Seng; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore Koh, Choon Huat, Gerald; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore Van Dam, Rob; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore Müller-Riemenschneider, Falk; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore
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Socio-demographic Factors in Relation to Hypertension Prevalence, Awareness, Treatment and Control in a Multi-ethnic Asian Population: A Cross-sectional Study

Seaw Jia LIEW[1], John Tayu LEE[2], Chuen Seng TAN[1,3], Gerald Choon Huat KOH[1,3], Rob Martinus VAN DAM[1,3,4], Falk MÜLLER-RIEMENSCHNEIDER[1,3,5]

[1] Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore
[2] Nossal Institute for Global Health, School of Population and Global Health, University of Melbourne
[3] Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore
[4] Harvard T.H. Chan School of Public Health, Boston, MA, USA
[5] Institute of Social Medicine, Epidemiology and Health Economics, Charité - Universitätsmedizin, Berlin, Germany

Corresponding author:

Falk Mueller-Riemenschneider, MBBS, MSc, MD
Assistant Professor
Leader Physical Activity and Nutrition Determinants in Asia (PANDA) Research Programme,
Deputy Leader Tele-Health Innovations (THOR) Research Programme,
Saw Swee Hock School of Public Health and Department of Medicine, Yong Loo Lin School of Medicine, National University of Singapore
Tahir Foundation Building (Block MD1), 12 Science Drive 2, #09-01v, Singapore 117549

Email: ephmf@nus.edu.sg

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Asian, awareness, control, hypertension, multi-ethnic, prevalence, socio-demographic

ABBREVIATIONS:

BP, blood pressure;

MEC, Multi-ethnic Cohort;

AOR, adjusted odds ratio.

ABSTRACTS

Background Literature suggested that multi-ethnic Western populations experienced differential hypertension outcomes, but evidence is limited in Asia. This study aimed to determine socio-demographic correlates of hypertension and its awareness, treatment and control among a multi-ethnic Asian population living in Singapore.

Methods We used cross-sectional data of the Multi-Ethnic Cohort (MEC) Study (n=14,530), recruited between 2004 and 2010. Participants who completed questionnaire and attended health examination, without cardiovascular diseases, cancer, asthma and mental illnesses were included in the study (n=10,215). Multivariable logistic regression models were used to determine socio-demographics factors associated with hypertension, unawareness of having hypertension, untreated and uncontrolled hypertension.

Results Among 10,215 participants (47.2% Chinese, 26.0% Malay and 26.8% Indian), hypertension prevalence was estimated to be 31.1%. Older age, Malay ethnicity, male, lower educational level, and being homemaker or retired/unemployed were factors significantly associated with hypertension. Stratified analysis suggested that age and education were consistently associated with hypertension across all ethnic groups. The proportions of being unaware, untreated and uncontrolled were 49.0%, 25.2% and 62.4%, respectively. Ethnicity and younger age were associated with unawareness; younger age, male and lower educational level were associated with untreated hypertension; and older age was associated with uncontrolled hypertension.

Conclusions Ethnic differences in relation to hypertension were associated with socio-demographic variability in ethnic groups. Age and educational level were consistent correlates of hypertension in all ethnic groups. Unawareness and uncontrolled hypertension were common in this Asian population and associated with socio-demographic factors. More targeted strategies may be required to overcome the observed disparities.

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STRENGTHS AND LIMITATIONS OF THIS STUDY

1. This a large population-based study of multi-ethnic Asian (Chinese, Malay, Indian) population living in an urban city state with relatively homogeneous living environment.
2. The minority ethnic groups (Malay and Indian) were purposively over-sampled to increase their representativeness in the study. In addition, this study recruited a large number of participants in the community to cover a wider age range and diverse socio-demographic profile.
3. The study used standardized and comprehensive methodologies to capture exposure and outcome data. The findings of this study were robust after adjustment for potential socio-demographic confounders.
4. The study design is cross-sectional, we cannot infer causality and determine the risk of hypertension.
5. Blood pressures of participants were measured on only one occasion during the health examination. However, standard BP measurement protocols were used, and multiple BP measurements were taken to minimize measurement error.

INTRODUCTION

Hypertension is a major risk factor of cardiovascular disease (CVD) and one of the leading causes of deaths from non-communicable diseases (NCD).[1 2] Hypertension is modifiable, yet there are a billion of individuals living with the condition worldwide and are at risk of hypertension-related complications.[3] The current evidence suggests that the public awareness and control of BP remains challenging,[4 5] and that gaps in hypertension management were attributable to broader social and economic determinants.[6-9]

In most Western countries, the impact of ethnic and socio-economic disparities on hypertension outcomes has been well established. [10] Literature suggested that racial difference in hypertension prevalence was determined by demographics and lifestyle variables.[11] A study reported that racial disparities observed in BP were determined by differences in educational level.[12] Educational level and family income are socio-economic variables that have been well examined in relation with hypertension but the findings in the literature are rather mixed.[11-13]

In Asia, the relationship between socio-demographic and hypertension is understudied. Singapore has a rapidly ageing, urbanized and multi-ethnic Asian population (Chinese, Malays and Indians). Previous studies have emphasized the importance to better understand awareness, treatment and control in order to improve hypertension management in the community.[14 15] To address existing gaps in the evidence, we examined socio-demographic determinants of hypertension, unawareness of having hypertension, untreated and uncontrolled hypertension in the multi-ethnic Asian population in Singapore.

METHODS

Patient and public involvement

The Multi-Ethnic Cohort Study (MEC) is a population-based study in Singapore (n=14,530) with recruitment conducted between 2004 and 2010. The detailed study methodology has been published elsewhere.[16] Briefly, MEC recruited Singaporeans or permanent residents aged ≥21 years who were free from cardiovascular diseases, stroke, heart diseases, transient ischemic attack, cancer, asthma and mental illnesses. The study included 10,215 individuals who had completed questionnaires and attended health examination. The minority ethnicity groups, Malays and Indians, were purposively over-sampled. Study procedures were approved by the National University of Singapore Institutional Review Board and SingHealth Centralised Institutional Review Board.

All participants who provided consent to participate in this study were visited at home and completed an interview-administered questionnaire in English, Chinese or Malay languages. Subsequently, they underwent a health examination including repeated BP measurements. The interview questionnaires collected self-reported socio-demographic information, hypertension diagnosis, medical history and anti-hypertensive medication use.

Participants were asked to rest for 5 minutes, then systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice using an automated digital monitor (Dinamap Carescape V100, General Electric). If the difference between these two readings of SBP or DBP exceeded 10 mmHg or 5 mmHg, respectively, SBP and DBP were measured again and recorded as the third set of readings. For the small number of participants whose BP exceeded the range of the digital monitor, a sphygmomanometer (Accoson, United Kingdom) was used.[16] Mean values of the SBP and the DBP were computed for every participant and used in subsequent analyses.

Variables

Outcome variables

Hypertension (among all participants) was defined as either (i) the participant answering 'yes' to the survey question '*has a physician (western trained) or other professional told you that you have high blood pressure?*' or (ii) having mean SBP ≥140 mmHg or mean DBP ≥90 mmHg during the health examination.

Unawareness of hypertension (among hypertensives) was defined as the participant answering 'no' or 'do not know' to the survey question '*has a physician (western trained) or other professional told you that you have high blood pressure?*' but having mean SBP ≥140 mmHg or mean DBP ≥90 mmHg during the health examination.

Untreated hypertension (among hypertensives who were aware) referred to participants who were aware of having hypertension but were not taking any anti-hypertensive medication (identified from interviewer recorded lists of drug names and brand names).

Uncontrolled hypertension (among hypertensives who were treated) was defined as participants on anti-hypertension medication who were found to have a mean SBP ≥140 mmHg or mean DBP ≥90 mmHg during the health examination.

Explanatory variables

The explanatory variables included self-reported socio-demographic factors (i.e. age, gender, ethnicity, highest educational level obtained, marital status, work status during the past 12 months and average monthly household income). Age at interview was derived from the date of birth. Ethnicity was obtained from participant's identity card and classified into Chinese, Malay and Indian. Highest education level was categorized into three levels: (i) primary school education or lower, (ii) secondary school education/ITE (Institute of Technical Education)/NTC (National Technical Certificate), and (iii) tertiary education or higher. Marital status was dichotomized into currently married or not married (single, divorced, widowed or married but separated from spouse). Work status was classified into three categories: (i) employed (working adults or full-time studying), (ii) homemaker (housewife or non-working individual who manages a home), and (iii) retired/unemployed. Participants were asked to provide average monthly household income in Singapore Dollars (1 Singapore Dollars approximates 0.74 U.S. Dollars) by choosing one of the following options: <$2,000, $2,000-3,999, $4,000-5,999, or ≥$6,000. An 'unknown' income category was created for participants who refused to report household income.

Statistical analyses

Counts and percentages were presented for categorical variables. Bivariate logistic regression analysis was performed to assess the association of each socio-demographic factor with hypertension, unawareness of hypertension, and untreated and uncontrolled hypertension, respectively. Multivariable logistic regression analysis was performed to include all socio-demographic variables into the model. To investigate whether the relationship between socio-demographic factors and hypertension was moderated by ethnicity, interaction effects between ethnicity and socio-demographic factors on hypertension were examined by adding the interaction terms to the multivariable model. A stratified analysis by ethnic group was conducted to explore whether differences in socio-demographics contribute in part to ethnic differences in hypertension. Odds Ratios (ORs) and Adjusted Odds Ratios (AORs) were reported with the corresponding 95% confidence intervals (95% CI). A p-value of <0.05 was considered statistically significant. All statistical analyses were conducted using STATA 14.0 for Windows (Stata Corporation, College Station, Texas, USA).

RESULTS

Among 14,530 participants enrolled in the MEC study, 11,101 individuals completed survey questionnaires and attended the health examination. After excluding participants with major diseases (i.e. cardiovascular diseases, stroke, transient ischemic attack, cancer, asthma and mental illnesses), duplicated records and 'Others' ethnic group, our final study population was 10,215 individuals of three main Asian ethnic groups, i.e. Chinese, Malay and Indian (online-only supplementary).

Participant characteristics

Table 1 lists the socio-demographic characteristics of our study population. The participants comprised 47.2% Chinese, 26.0% Malay and 26.8% Indian. The majority of the participants were aged ≥40 years (68.1%), females (56.7%), had secondary school or higher educational level (73.0%), married (76.0%), and were working or studying full-time (68.6%). The average monthly household income was less than $4,000 in 48.0% of the participants.

Factors associated with hypertension

Of the 10,215 participants included in our analysis (Table 1), 31.1% were hypertensives. The estimated prevalence of hypertension was higher among Malays (33.1%), adults aged ≥60 years old (72.8%), males (33.9%), participants with lower educational level (primary school or lower) (48.3%), married (32.9%), retired/unemployed (54.9%), and those with lower household income level, i.e. <$2,000 (35.1%).

In the multivariable analysis (Table 1), most of the socio-demographic factors remained significant, except marital status and household income. Compared with Chinese, the odds of hypertension were higher in Malays (p=0.007), whereas no significant difference was observed between Indian and Chinese (p=0.165). Older age was strongly associated with increased odds of hypertension (overall p<0.001). Adjustment for all other socio-demographic factors greatly increased the odds of hypertension in males. Compared to females, males were more likely to have hypertension (AOR=1.65, 95% CI=1.47-1.85). Decreased educational level was associated with higher odds of hypertension (overall p<0.001). Compared to working, being homemaker or retired/unemployed significantly increased the odds of hypertension (overall p<0.001). The originally significant relationship between household income and hypertension was eliminated after adjustment for age and educational level.

Significant interactions (p<0.050) were observed between ethnicity and age (p=0.025), gender (p<0.001), work status (p=0.034), and household income (p<0.001). After including these significant interaction terms into the final logistic model, interaction effects remained significant (p<0.050) between ethnicity and age, gender and household income. The addition of ethnicity affected the association between socio-demographic factors and the odds of hypertension.

Factors associated with hypertension stratified by ethnicity

In stratified analysis (Table 2), hypertension was present in 31.5% of Chinese, 33.1% of Malay and 28.5% of Indian. The association between socio-demographic factors and the odds of hypertension in each ethnic group was moderated by the interaction effects between ethnicity and age, gender, work status and household income. The adjusted odds ratios for each age-group were much higher in Malay and Indian ethnic groups when compared with Chinese ethnic. Males had significantly higher odds of hypertension only in Chinese and Indian but not in Malay ethnic. No significant interaction was found between ethnicity and educational level. Educational level was related to hypertension independently of ethnicity. Lower

Table 1: Association of socio-demographic factors and hypertension (n=10,215)

Socio-demographic factor		Total		Hypertension		Hypertension							
						Unadjusted				Adjusted			
		n	(%)	n	(%)	COR	(95% CI)		p-value	AOR	(95% CI)		p-value
Ethnicity													
	Chinese	4817	47.2	1519	31.5	1 [Ref.]			**0.001***	1 [Ref.]			**<0.001***
	Malay	2659	26.0	879	33.1	1.07	(0.97,	1.19)	0.177	**1.18**	(**1.05,**	**1.34**)	**0.007**
	Indian	2738	26.8	780	28.5	**0.86**	(**0.78,**	**0.96**)	**0.006**	0.92	(0.81,	1.04)	0.165
Age													
	<40	3258	31.9	292	9.0	1 [Ref.]			**<0.001***	1 [Ref.]			**<0.001***
	40-49	3187	31.2	798	25.0	**3.39**	(**2.94,**	**3.92**)	**<0.001**	**3.18**	(**2.73,**	**3.71**)	**<0.001**
	50-59	2420	23.7	1106	45.7	**8.55**	(**7.40,**	**9.88**)	**<0.001**	**7.54**	(**6.44,**	**8.82**)	**<0.001**
	>=60	1349	13.2	982	72.8	**27.18**	(**22.93,**	**32.21**)	**<0.001**	**19.97**	(**16.47,**	**24.23**)	**<0.001**
Gender													
	Female	5795	56.7	1682	29.0	1 [Ref.]				1 [Ref.]			
	Male	4419	43.3	1496	33.9	**1.25**	(**1.15,**	**1.36**)	**<0.001**	**1.65**	(**1.47,**	**1.85**)	**<0.001**
Highest education level													
	Primary or lower	2763	27.1	1334	48.3	1 [Ref.]			**<0.001***	1 [Ref.]			**<0.001***
	Secondary	4346	42.6	1271	29.2	**0.44**	(**0.40,**	**0.49**)	**<0.001**	**0.70**	(**0.62,**	**0.78**)	**<0.001**
	Tertiary or higher	3100	30.4	573	18.5	**0.24**	(**0.22,**	**0.27**)	**<0.001**	**0.59**	(**0.50,**	**0.69**)	**<0.001**
Marital status													
	Currently married	7757	76.0	2555	32.9	1 [Ref.]				1 [Ref.]			
	Not currently married	2452	24.0	623	25.4	**0.69**	(**0.63,**	**0.77**)	**<0.001**	1.11	(0.97,	1.26)	0.126
Work status													
	Working/Studying full-time	6972	68.6	1766	25.3	1 [Ref.]			**<0.001***	1 [Ref.]			**<0.001***
	Homemaker	2264	22.3	886	39.1	**1.90**	(**1.71,**	**2.10**)	**<0.001**	**1.36**	(**1.19,**	**1.56**)	**<0.001**
	Retired/Unemployed	930	9.2	511	54.9	**3.60**	(**3.13,**	**4.14**)	**<0.001**	**1.20**	(**1.01,**	**1.43**)	**0.042**
Monthly household income (SGD)^													
	<2,000	2277	22.3	800	35.1	1 [Ref.]			**<0.001***	1 [Ref.]			0.172*
	2,000-3,999	2619	25.7	740	28.3	**0.73**	(**0.64,**	**0.82**)	**<0.001**	1.07	(0.93,	1.23)	0.343
	4,000-5,999	1664	16.3	411	24.7	**0.61**	(**0.53,**	**0.70**)	**<0.001**	1.03	(0.88,	1.22)	0.691
	>=6,000	1462	14.3	349	23.9	**0.58**	(**0.50,**	**0.67**)	**<0.001**	1.13	(0.94,	1.36)	0.202

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis.
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05 (statistical significance); CI: Confidence interval; *overall p-value*

Table 2:Association of socio-demographic factors and hypertension by ethnic groups, i.e. Chinese (n=4,817), Malay (n=2,659) and Indian (n=2,739)

Socio-demographic factor	Ethnicity: Chinese AOR	(95% CI)		p-value	Malay AOR	(95% CI)		p-value	Indian AOR	(95% CI)		p-value
Age												
<40	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***
40-49	**2.50**	(**1.99,**	**3.15**)	**<0.001**	**4.04**	(**3.03,**	**5.38**)	**<0.001**	**3.44**	(**2.53,**	**4.68**)	**<0.001**
50-59	**6.44**	(**5.10,**	**8.15**)	**<0.001**	**8.38**	(**6.20,**	**11.33**)	**<0.001**	**8.26**	(**6.07,**	**11.25**)	**<0.001**
>=60	**14.37**	(**10.82,**	**19.06**)	**<0.001**	**30.53**	(**20.30,**	**45.92**)	**<0.001**	**23.81**	(**16.40,**	**34.56**)	**<0.001**
Gender												
Female	1 [Ref]				1 [Ref]				1 [Ref]			
Male	**1.85**	(**1.58,**	**2.17**)	**<0.001**	1.08	(0.85,	1.37)	0.527	**1.97**	(**1.56,**	**2.50**)	**<0.001**
Highest education level												
Primary or lower	1 [Ref]			**<0.001***	1 [Ref]			**0.017***	1 [Ref]			**<0.001***
Secondary	**0.65**	(**0.54,**	**0.77**)	**<0.001**	**0.73**	(**0.59,**	**0.91**)	**0.005**	**0.71**	(**0.57,**	**0.88**)	**0.002**
Tertiary or higher	**0.54**	(**0.43,**	**0.67**)	**<0.001**	0.73	(0.52,	1.04)	0.086	**0.50**	(**0.36,**	**0.68**)	**<0.001**
Marital status												
Currently married	1 [Ref]				1 [Ref]				1 [Ref]			
Not currently married	1.05	(0.87,	1.27)	0.616	1.00	(0.77,	1.31)	0.972	1.25	(0.98,	1.59)	0.074
Work status												
Working/Studying full-time	1 [Ref]			**0.0078***	1 [Ref]			0.126*	1 [Ref]			0.066*
Homemaker	**1.30**	(**1.05,**	**1.61**)	**0.015**	**1.29**	(**1.00,**	**1.67**)	**0.048**	**1.37**	(**1.05,**	**1.79**)	**0.021**
Retired/Unemployed	**1.38**	(**1.06,**	**1.78**)	**0.015**	0.97	(0.67,	1.43)	0.894	1.15	(0.83,	1.60)	0.398
Monthly household income (SGD)^												
<2,000	1 [Ref]			0.391*	1 [Ref]			**<0.001***	1 [Ref]			0.137*
2,000-3,999	0.88	(0.69,	1.12)	0.306	1.07	(0.84,	1.37)	0.593	**1.28**	(**1.00,**	**1.64**)	**0.046**
4,000-5,999	1.04	(0.80,	1.36)	0.764	1.02	(0.76,	1.37)	0.879	0.92	(0.67,	1.25)	0.579
>=6,000	1.12	(0.86,	1.46)	0.401	0.72	(0.47,	1.11)	0.133	1.20	(0.83,	1.75)	0.334

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis.
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05 (statistical significance); CI: Confidence interval; *overall p-value*

education was consistently associated with higher odds of hypertension in all ethnic groups, and the adjusted odds ratios were almost comparable with the non-stratified analysis (Table 1). In terms of work status, the odds of hypertension in homemaker were consistently significant for all ethnic groups and higher for Indians but relatively lower for Chinese and Malays. Significantly higher odds of hypertension in retired/unemployed persisted only among Chinese but not among minorities Malay and Indian ethnic groups. Income-hypertension relationship was not found in Chinese and Malay ethnic groups, but Indians having lower income (between $2,000 and $3,999) were significantly associated with hypertension.

Factors associated with unawareness of hypertension

Among hypertensives, 49.0% were unaware of having hypertension (i.e. 48.9% of Chinese, 53.4% of Malay and 44.4% of Indian). In the multivariable analysis (Table 3), significant associations of ethnicity and age with unawareness persisted. Indians were less likely to be unaware of having hypertension (AOR = 0.80, 95%CI: 0.67-0.96) when compared with Chinese while no significant association was observed for Malays. Additionally, participants from older age groups, i.e. 50-59 years (AOR = 0.58, 95%CI: 0.44-0.77) and ≥60 years (AOR = 0.53, 95%CI: 0.39-0.72), were less likely to be unaware of having hypertension when compared with adults aged below 40 years.

Factors associated with untreated hypertension

Among participants who were aware of having hypertension, 25.2% were untreated for hypertension (i.e. 24.7% of Chinese, 23.4% of Malay and 27.7% of Indian). In the multivariable analysis (Table 3), older age was associated with much reduced odds of untreated hypertension when compared with age below 40 years, i.e. 40-49 years (AOR = 0.39, 95%CI: 0.25-0.61), 50-59 years (AOR = 0.22, 95%CI: 0.14-0.34), and ≥60 years (AOR = 0.13, 95%CI: 0.08-0.21). Males remained to have a significantly higher odds of untreated hypertension (AOR = 1.51, 95%CI: 1.12-2.04) when compared with females. With regards to educational level, the direction of the association with untreated hypertension changed in the multi-variable analysis, i.e. higher educational level was associated with lower odds of being untreated, but only secondary school education was a significant factor (AOR = 0.69, 95%CI: 0.52-0.91) when compared with primary school education.

Factors associated with uncontrolled hypertension

Among participants who were treated for hypertension, 62.4% did not have their hypertension controlled (i.e. 65.5% of Chinese, 63.1% of Malay and 56.7% of Indian). In the multivariable analysis (Table 4), only older age and being retired/unemployed remained as significant factors. Higher odds of uncontrolled hypertension were associated with older age. Participants from older age groups, i.e. 50-59 years (AOR = 2.54, 95%CI: 1.33-4.87) and ≥60 years (AOR = 3.98, 95%CI: 2.01-7.91) were more likely to experience uncontrolled hypertension when compared with participants aged <40 years. The majority of the retirees and unemployed participants were older adults aged ≥60 years (53.0%). Compared with adults who were working or studying full-time, participants who were retired or unemployed (AOR = 1.51, 95%CI: 1.02-2.24) were more likely to have uncontrolled hypertension.

Table 3: Association of socio-demographic factors and unawareness among hypertensives (n=3,175), untreated among those who were aware of hypertension (n=1,618)

	Unawareness among hypertensives								Untreated among aware							
	COR	(95% CI)		p-value	AOR	(95% CI)		p-value	COR	(95% CI)		p-value	AOR	(95% CI)		p-value
Ethnicity																
Chinese	1 [Ref]			**0.001***	1 [Ref]			**0.0046***	1 [Ref]			0.335*	1 [Ref]			0.520*
Malay	**1.19**	(**1.01,**	**1.41**)	**0.037**	1.11	(0.93,	1.32)	0.258	0.93	(0.70,	1.24)	0.630	0.87	(0.64,	1.20)	0.398
Indian	**0.83**	(**0.70,**	**0.99**)	**0.037**	**0.80**	(**0.67,**	**0.96**)	**0.018**	1.17	(0.89,	1.52)	0.257	1.05	(0.78,	1.42)	0.731
Age																
<40	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***
40-49	0.89	(0.67,	1.16)	0.383	0.89	(0.67,	1.18)	0.403	**0.37**	(**0.24,**	**0.57**)	**<0.001**	**0.39**	(**0.25,**	**0.61**)	**<0.001**
50-59	**0.58**	(**0.44,**	**0.75**)	**<0.001**	**0.58**	(**0.44,**	**0.77**)	**<0.001**	**0.20**	(**0.13,**	**0.31**)	**<0.001**	**0.22**	(**0.14,**	**0.34**)	**<0.001**
>=60	**0.50**	(**0.39,**	**0.66**)	**<0.001**	**0.53**	(**0.39,**	**0.72**)	**<0.001**	**0.12**	(**0.08,**	**0.19**)	**<0.001**	**0.13**	(**0.08,**	**0.21**)	**<0.001**
Gender																
Female	1 [Ref]				1 [Ref]				1 [Ref]				1 [Ref]			
Male	1.08	(0.94,	1.25)	0.259	1.15	(0.96,	1.37)	0.140	**1.68**	(**1.34,**	**2.11**)	**<0.001**	**1.51**	(**1.12,**	**2.04**)	**0.007**
Highest education level																
Primary or lower	1 [Ref]			**0.007***	1 [Ref]			0.310*	1 [Ref]			**0.007***	1 [Ref]			**0.033***
Secondary	**1.27**	(**1.09,**	**1.48**)	**0.002**	1.13	(0.95,	1.33)	0.162	1.02	(0.80,	1.32)	0.849	**0.69**	(**0.52,**	**0.91**)	**0.010**
Tertiary or higher	1.21	(1.00,	1.48)	0.054	1.01	(0.80,	1.28)	0.937	**1.59**	(**1.17,**	**2.15**)	**0.003**	0.83	(0.56,	1.23)	0.362
Marital status																
Currently married	1 [Ref]				1 [Ref]				1 [Ref]				1 [Ref]			
Not currently married	1.02	(0.85,	1.21)	0.860	1.09	(0.91,	1.32)	0.356	0.88	(0.66,	1.17)	0.367	1.05	(0.76,	1.45)	0.781
Work status																
Working/Studying full-time	1 [Ref]			**0.002***	1 [Ref]			0.139*	1 [Ref]			**<0.001***	1 [Ref]			0.557*
Homemaker	0.91	(0.77,	1.07)	0.254	1.12	(0.91,	1.39)	0.275	**0.47**	(**0.35,**	**0.62**)	**<0.001**	0.83	(0.58,	1.19)	0.316
Retired/Unemployed	**0.70**	(**0.58,**	**0.86**)	**0.001**	0.86	(0.69,	1.08)	0.203	**0.49**	(**0.35,**	**0.68**)	**<0.001**	0.88	(0.60,	1.30)	0.511
Monthly household income (SGD)^																
<2,000	1 [Ref]			0.845*	1 [Ref]			0.837*	1 [Ref]			**0.001***	1 [Ref]			0.147*
2,000-3,999	1.00	(0.82,	1.22)	0.996	0.91	(0.74,	1.12)	0.391	1.09	(0.80,	1.48)	0.600	0.87	(0.62,	1.22)	0.425
4,000-5,999	1.08	(0.85,	1.37)	0.530	0.97	(0.75,	1.25)	0.802	0.79	(0.54,	1.18)	0.249	**0.62**	(**0.40,**	**0.96**)	**0.031**
>=6,000	0.95	(0.74,	1.22)	0.680	0.86	(0.65,	1.14)	0.296	1.07	(0.73,	1.58)	0.732	0.76	(0.48,	1.21)	0.242

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis.
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05 (statistical significance); CI: Confidence interval; *overall p-value*

Table 4: Association of socio-demographic factors and uncontrolled hypertension among treated (n=1,211)

		Uncontrolled among treated							
		Crude OR				Adjusted OR			
		COR	95% CI		p-value	AOR	95% CI		p-value
Ethnicity									
	Chinese	1 [Ref]			**0.042***	1 [Ref]			0.174*
	Malay	0.91	(0.69,	1.21)	0.526	0.99	(0.72,	1.35)	0.949
	Indian	**0.70**	(**0.53,**	**0.93**)	**0.013**	0.76	(0.56,	1.04)	0.084
Age									
	<40	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***
	40-49	1.78	(0.93,	3.43)	0.084	1.61	(0.82,	3.15)	0.163
	50-59	**2.89**	(**1.54,**	**5.41**)	**0.001**	**2.54**	(**1.33,**	**4.87**)	**0.005**
	>=60	**6.28**	(**3.32,**	**11.86**)	**<0.001**	**3.98**	(**2.01,**	**7.91**)	**<0.001**
Gender									
	Female	1 [Ref]				1 [Ref]			
	Male	1.16	(0.91,	1.46)	0.231	1.35	(0.99,	1.85)	0.061
Highest education level									
	Primary or lower	1 [Ref]			**<0.001***	1 [Ref]			0.239*
	Secondary	**0.66**	(**0.51,**	**0.86**)	**0.002**	0.81	(0.61,	1.08)	0.150
	Tertiary or higher	**0.54**	(**0.38,**	**0.75**)	**<0.001**	0.74	(0.49,	1.12)	0.153
Marital status									
	Currently married	1 [Ref]				1 [Ref]			
	Not currently married	1.12	(0.83,	1.50)	0.465	1.04	(0.75,	1.44)	0.811
Work status									
	Working/Studying full-time	1 [Ref]			**<0.001***	1 [Ref]			0.068*
	Homemaker	**1.65**	(**1.26,**	**2.16**)	**<0.001**	1.34	(0.94,	1.89)	0.101
	Retired/Unemployed	**2.93**	(**2.08,**	**4.13**)	**<0.001**	**1.51**	(**1.02,**	**2.24**)	**0.041**
Monthly household income (SGD)^									
	<2,000	1 [Ref]			**<0.001***	1 [Ref]			**0.028***
	2,000-3,999	0.86	(0.61,	1.20)	0.372	0.95	(0.66,	1.35)	0.762
	4,000-5,999	0.77	(0.52,	1.14)	0.193	0.94	(0.61,	1.44)	0.767
	>=6,000	**0.65**	(**0.43,**	**0.99**)	**0.045**	0.85	(0.53,	1.36)	0.506

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis;
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05 (statistical significance); CI: Confidence interval; *overall p-value*

DISCUSSION

This large multi-ethnic Asian cohort study provides valuable insights into socio-demographic determinants of hypertension within relatively homogeneous living environment and access to health care. We estimated that approximately 1 in 3 participants had hypertension. The strength of the association between socio-demographic factors and hypertension differed across ethnic groups. In addition to the established socio-demographic risk factors (i.e. age and gender), our study adds new evidence about the importance of ethnicity in relation to hypertension. Our stratified analysis suggested that the observed ethnic differences in relation to hypertension was partly attributed to the variability in socio-demographic characteristics of each ethnic group. Educational level rather than household income was an important socio-economic indicator consistently associated with hypertension within all ethnic groups. Almost half of the hypertensives in our study were unaware of having hypertension and 25% of those who were aware of having hypertension remained untreated. Adults under 40 years of age were more likely to be undetected and untreated than older individuals. Male participants were more likely to be untreated than females, and participants with low educational level were more likely to be untreated when compared with those with higher educational level. Among treated participants, more than half did not achieve optimal BP levels and older age was strongly associated with worse BP control.

In agreement with similar studies conducted in other Asian countries[17-20] and Singapore,[14 15] our study further demonstrated that older age is a strong factor associated with hypertension. Ethnic differences in relation to hypertension were observed in our study, consistent with the current literature which was largely conducted in the Western countries.[10 21 22] While the association between Indian ethnicity and hypertension ceased to be significant after the addition of socio-demographic factors, the association between Malay ethnicity and hypertension was statistically significant. The ethnic differences observed in our study were partly explained by the variability in socio-demographic profile within each ethnic group, an interesting finding revealed from the stratified analysis. For instance, Malays and Indians had higher odds ratio than Chinese for every increase in age group. Further, strong associations between gender and hypertension was observed among Chinese and Indian, but not Malay. Higher educational level has been found to be associated with lower prevalence of hypertension in earlier studies,[23 24] and our finding demonstrates that this association was consistent for all ethnic groups. No association between marital status and hypertension was observed in our study. The association between retired/unemployed status and hypertension was significant only among Chinese but not in other ethnic groups. In general, the income-hypertension association was not significant in our study after accounting for age and educational level.

Older participants were more likely to be aware of having hypertension because it is common among the age groups and health policies may have offered screening opportunity to this subgroup. The literature suggested that minority ethnic groups who were hypertensive were more likely to be aware of their hypertension.[9 21] However, our study observed that Malay ethnic who had greater odds of hypertension did not seem to be sufficiently aware of their condition. Conversely, Indians were relatively more aware of having hypertension compared to Chinese. The observed ethnic differences in hypertension awareness may be attributable to variations in lifestyle and cultural factors, and perceived benefit of hypertension prevention and control.[25-27]

Although older age was significantly related to hypertension, older participants in our study were more likely to be aware of having hypertension and treated for the condition. But, younger age, male gender and low educational level were significant determinants for untreated hypertension. Other study demonstrated that the measures of education can better explain variation in hypertension and health inequalities.[12] Low educational attainment may directly or indirectly influence the treatment and control of hypertension through lack of understanding about disease prevention, healthy lifestyle, perceived discrimination, among others.[23] Evidence suggested that education is a critical component of health and it is important to incorporate educational element in public health promotion and reducing health

disparities.[28 29] Older age was significantly associated with uncontrolled hypertension in our study. This finding is consistent with the current evidence[30 31] but also contrasts with other findings which suggest that older adults had better control of BP.[4 18] Lack of control of BP among older adults in our population could due to aging-related physiological changes, comorbidity and variation in response to treatment among older adults.[32] Social factors such as living in social exclusion, limited peer support, and not having sufficient knowledge to cope with their hypertension condition may also affect their BP control.[33]

Strength and Limitation

This study has a number of strengths. First, it is based on a large population-based study of a multi-ethnic Asian population living in an urban city state. Second, the study used standardized and comprehensive methodologies to capture exposure and outcome data. Third, we had purposively over-sampled minority ethnic groups and recruited a large number of study participants to cover a wider age range and diverse socio-demographic profile. Fourth, the findings of this study were robust after adjustment for potential socio-demographic confounders. However, we noted that the study has several important limitations. First, because the study design is cross-sectional, we cannot infer causality and determine the risk of hypertension. Second, BP of participants were measured on only one occasion during the health examination. However, standard BP measurement protocols were used, and multiple BP measurements were taken to minimize measurement error. Third, some participants did not provide information about average monthly household income. To overcome this limitation, we had classified them as a separate category (i.e. 'unknown income' group) and included them for analyses. Unmeasured confounding cannot be adjusted for in our study. Although the results are not generalizable to the Singapore population, our findings contributed new insights to the study of hypertension in multi-ethnic urban Asian population. Future more in-depth prospective studies may be useful to examine underlying mechanisms that contribute to differential hypertension outcomes, and uncover the segments of population who may benefit from active prevention and early treatment strategies.

CONCLUSION

Ethnic differences observed in hypertension were associated with socio-demographic variability within ethnic groups. Age and educational level were consistent correlates of hypertension in all ethnic groups. Unawareness and uncontrolled hypertension were common in this Asian population and associated with socio-demographic factors. More targeted strategies may be required to overcome the observed disparities.

WHAT IS ALREADY KNOWN ON THIS SUBJECT?

Ethnicity and socio-economic factors contribute to differences in hypertension prevalence, awareness, treatment and control in Western populations. However, there is a lack of evidence regarding the role of ethnicity and other socio-demographic factors on hypertension related outcomes in multi-ethnic Asian population.

WHAT THIS STUDY ADDS?

Our study demonstrated that hypertension status differed by ethnicity (Chinese, Malay and Indian) and that these differences were associated with socio-demographic variability in ethnic groups. Educational level rather than household income was a significant socioeconomic indicator of hypertension status and appeared consistent across ethnic groups.

The estimated prevalence of unawareness of hypertension status and uncontrolled blood pressure was high in this study. Younger participants in particular were less aware of their hypertension. Older participants on the other hand were more likely to be aware of being hypertensive and had their condition treated but the control of their BP levels remained challenging.

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CONTRIBUTORS

LSJ, JLTY and FMR contributed to the study design and development of the study objectives. LSJ acquired the data, conducted analyses and drafted the manuscript. LSJ and RMVD contributed to study methodological strategy; LSJ, JLTY and TCS contributed to the analytic strategies; GKCH and FMR contributed medical insights to guide the analysis and interpretation of results; FMR provided supervision and monitored study progress; All authors reviewed and revised the manuscript.

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COMPETING INTERESTS

None declared

ETHICS APPROVAL

The MEC study was approved by the National University of Singapore Institutional Review Board and SingHealth Centralised Institutional Review Board.

DATA SHARING STATEMENT

The Singapore Population Health Studies Scientific Committee reviews requests for data. The request form is available at https://blog.nus.edu.sg/sphs/.

REFERENCES

1. Organization WH. Noncommunicable diseases. 2017
2. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. (1474-547X (Electronic))
3. Organization WH. Global Health Observatory (GHO) data: NCD mortality and morbidity, 2015.
4. Chow CK, Teo KK, Rangarajan S, et al. Prevalence, awareness, treatment, and control of hypertension in rural and urban communities in high-, middle-, and low-income countries. *JAMA* 2013;310(9):959-68. doi: 10.1001/jama.2013.184182
5. Rahimi K, Emdin CA, MacMahon S. The Epidemiology of Blood Pressure and Its Worldwide Management. *Circulation Research* 2015;116(6):925-36. doi: 10.1161/circresaha.116.304723
6. Hunte HER, Mentz G, House JS, et al. Variations in Hypertension-Related Outcomes Among Blacks, Whites and Hispanics in Two Large Urban Areas and in the United States. *Ethnicity & disease* 2012;22(4):391-97.
7. Marshall A, Nazroo J, Feeney K, et al. Comparison of hypertension healthcare outcomes among older people in the USA and England. *J Epidemiol Community Health* 2016;70(3):264-70.
8. Joffres M, Falaschetti E, Gillespie C, et al. Hypertension prevalence, awareness, treatment and control in national surveys from England, the USA and Canada, and correlation with stroke and ischaemic heart disease mortality: a cross-sectional study. *BMJ open* 2013;3(8):e003423.
9. Thorpe RJ, Bowie JV, Smolen JR, et al. Racial disparities in hypertension awareness and management: Are there differences among African Americans and Whites living in similar social and healthcare resource environments? *Ethnicity & disease* 2014;24(3):269-75.
10. Kramer H, Han C, Post W, et al. Racial/Ethnic differences in hypertension and hypertension treatment and control in the multi-ethnic study of atherosclerosis (MESA)*. *American Journal of Hypertension* 2004;17(10):963-70. doi: 10.1016/j.amjhyper.2004.06.001
11. Holmes L, Hossain J, Ward D, et al. Racial/Ethnic Variability in Hypertension Prevalence and Risk Factors in National Health Interview Survey. *ISRN Hypertension* 2013;2013:8. doi: 10.5402/2013/257842
12. Non AL, Gravlee CC, Mulligan CJ. Education, Genetic Ancestry, and Blood Pressure in African Americans and Whites. *American Journal of Public Health* 2012;102(8):1559-65. doi: 10.2105/AJPH.2011.300448
13. Kaplan MS, Huguet N, Feeny DH, et al. Self-reported hypertension prevalence and income among older adults in Canada and the United States. *Social Science & Medicine* 2010;70(6):844-49. doi: https://doi.org/10.1016/j.socscimed.2009.11.019
14. Malhotra R, Chan A, Malhotra C, et al. Prevalence, awareness, treatment and control of hypertension in the elderly population of Singapore. *Hypertension Research* 2010;33:1223. doi: 10.1038/hr.2010.177
15. Wu Y, Tai ES, Heng D, et al. Risk factors associated with hypertension awareness, treatment, and control in a multi-ethnic Asian population. *Journal of Hypertension* 2009;27(1):190-97. doi: 10.1097/HJH.0b013e328317c8c3
16. Tan KHX, Tan LWL, Sim X, et al. Cohort Profile: The Singapore Multi-Ethnic Cohort (MEC) study. *International Journal of Epidemiology* 2018;47(3):699-99j. doi: 10.1093/ije/dyy014
17. Li W, Gu H, Teo KK, et al. Hypertension prevalence, awareness, treatment, and control in 115 rural and urban communities involving 47 000 people from China. *Journal of Hypertension* 2016;34(1):39-46. doi: 10.1097/hjh.0000000000000745
18. Liu X, Gu W, Li Z, et al. Hypertension prevalence, awareness, treatment, control, and associated factors in Southwest China: an update. *Journal of Hypertension* 2017;35(3):637-44. doi: 10.1097/hjh.0000000000001203
19. Abdul-Razak S, Daher AM, Ramli AS, et al. Prevalence, awareness, treatment, control and socio demographic determinants of hypertension in Malaysian adults. *BMC Public Health* 2016;16(1):351. doi: 10.1186/s12889-016-3008-y

20. B Bjertness M, Htet A, E Meyer H, et al. Prevalence and determinants of hypertension in Myanmar - A nationwide cross-sectional study2016.
21. Balfour PC, Rodriguez CJ, Ferdinand KC. The Role of Hypertension in Race-Ethnic Disparities in Cardiovascular Disease. *Current cardiovascular risk reports* 2015;9(4):18. doi: 10.1007/s12170-015-0446-5
22. Modesti PA, Reboldi G, Cappuccio FP, et al. Panethnic Differences in Blood Pressure in Europe: A Systematic Review and Meta-Analysis. *PLOS ONE* 2016;11(1):e0147601. doi: 10.1371/journal.pone.0147601
23. Alves RFS, Faerstein E. Educational inequalities in hypertension: complex patterns in intersections with gender and race in Brazil. *International Journal for Equity in Health* 2016;15:146. doi: 10.1186/s12939-016-0441-6
24. Lee H-Y. Socioeconomic Disparities in the Prevalence, Diagnosis, and Control of Hypertension in the Context of a Universal Health Insurance System. *Journal of Korean Medical Science* 2017;32(4):561-67. doi: 10.3346/jkms.2017.32.4.561
25. Okonofua EC, Cutler NE, Lackland DT, et al. Ethnic Differences in Older Americans: Awareness, Knowledge, and Beliefs About Hypertension*. *American Journal of Hypertension* 2005;18(7):972-79. doi: 10.1016/j.amjhyper.2005.02.019
26. Pettey CM, McSweeney JC, Stewart KE, et al. African Americans' Perceptions of Adherence to Medications and Lifestyle Changes Prescribed to Treat Hypertension. *SAGE open* 2016;6(1):10.1177/2158244015623595.
27. Peters RM, Aroian KJ, Flack JM. African American Culture and Hypertension Prevention. *Western journal of nursing research* 2006;28(7):831-63. doi: 10.1177/0193945906289332
28. Hahn RA, Truman BI. Education Improves Public Health and Promotes Health Equity. *International journal of health services : planning, administration, evaluation* 2015;45(4):657-78. doi: 10.1177/0020731415585986
29. Zajacova A, Lawrence EM. The Relationship Between Education and Health: Reducing Disparities Through a Contextual Approach. *Annual Review of Public Health* 2018;39(1):273-89. doi: 10.1146/annurev-publhealth-031816-044628
30. Seow LSE, Subramaniam M, Abdin E, et al. Hypertension and its associated risks among Singapore elderly residential population. *Journal of Clinical Gerontology and Geriatrics* 2015;6(4):125-32. doi: https://doi.org/10.1016/j.jcgg.2015.05.002
31. Doulougou B, Gomez F, Alvarado B, et al. Factors associated with hypertension prevalence, awareness, treatment and control among participants in the International Mobility in Aging Study (IMIAS). *Journal Of Human Hypertension* 2015;30:112. doi: 10.1038/jhh.2015.30

https://www.nature.com/articles/jhh201530#supplementary-information
32. Lionakis N, Mendrinos D, Sanidas E, et al. Hypertension in the elderly. *World Journal of Cardiology* 2012;4(5):135-47. doi: 10.4330/wjc.v4.i5.135
33. Coyle CE. The Effects of Loneliness and Social Isolation on Hypertension in Later Life: Including Risk, Diagnosis and Management of the Chronic Condition. *Graduate Doctoral Dissertations* 2014;174

Online-only Supplementary

Table S-1: Characteristics of participants by ethnic group

Socio-demographic factors	Chinese						Malay						Indian					
	n	Normotensive		Hypertensive		p-value	n	Normotensive		Hypertensive		p-value	n	Normotensive		Hypertensive		p-value
Age (years), mean (SD)	4,817	42.22	(11.28)	54.71	(11.42)	<0.001	2,659	40.13	(11.10)	53.04	(10.93)	<0.001	2,739	41.17	(11.20)	53.77	(11.09)	<0.001
Gender, n (%)						<0.001						0.181						0.004
Female	2727	1,921	(72.4)	734	(27.6)		1,630	1,031	(65.9)	533	(34.1)		1,650	1,161	(73.7)	415	(26.3)	
Male	2226	1,377	(63.7)	785	(36.3)		1,163	749	(68.4)	346	(31.6)		1,231	797	(68.6)	365	(31.4)	
Blood pressure, mean (SD)																		
SBP, mean (SD)	4,814	116.74	(11.97)	149.09	(16.80)	<0.001	2,659	118.03	(12.02)	150.04	(17.33)	<0.001	2,739	114.49	(12.91)	147.24	(18.70)	<0.001
DBP, mean (SD)	4,814	70.40	(8.48)	84.40	(10.57)	<0.001	2,659	69.78	(8.33)	83.32	(11.07)	<0.001	2,739	69.14	(8.64)	82.18	(11.40)	<0.001
Highest education level, n (%)						<0.001						<0.001						<0.001
Primary or lower	1119	499	(46.5)	573	(53.5)		870	419	(51.2)	400	(48.8)		931	511	(58.6)	361	(41.4)	
Secondary	1858	1,228	(68.6)	561	(31.4)		1,503	1,027	(71.8)	404	(28.2)		1,199	820	(72.8)	306	(27.2)	
Tertiary or higher	2034	1,569	(80.3)	385	(19.7)		489	332	(81.6)	75	(18.4)		824	626	(84.7)	113	(15.3)	
Marital status, n (%)						<0.001						0.001						0.832
Currently married	3674	2,366	(65.6)	1,242	(34.4)		2,145	1,359	(65.3)	721	(34.7)		2,140	1,477	(71.4)	592	(28.6)	
Not married/divorced/separated	1284	930	(77.1)	277	(22.9)		651	420	(72.7)	158	(27.3)		739	479	(71.8)	188	(28.2)	
Work status, n (%)						<0.001						<0.001						<0.001
Working/Studying full-time	3635	2,642	(74.2)	919	(25.8)		1,702	1,209	(74.3)	419	(25.7)		1,859	1,355	(76.0)	428	(24.0)	
Homemaker	856	475	(59.7)	321	(40.3)		862	467	(58.1)	337	(41.9)		730	436	(65.7)	228	(34.3)	
Retired/Unemployed	470	162	(37.4)	271	(62.6)		263	99	(45.6)	118	(54.4)		336	158	(56.4)	122	(43.6)	
Monthly household income (SGD)^, n (%)						<0.001						<0.001						<0.001
<2,000	715	379	(57.7)	278	(42.3)		869	543	(67.8)	258	(32.2)		887	555	(67.8)	264	(32.2)	
2,000-3,999	1046	713	(73.3)	260	(26.7)		865	563	(70.9)	231	(29.1)		923	603	(70.8)	249	(29.2)	
4,000-5,999	812	554	(75.2)	183	(24.8)		519	317	(70.8)	131	(29.2)		559	382	(79.7)	97	(20.3)	
≥6,000	1015	707	(75.2)	233	(24.8)		285	162	(78.6)	44	(21.4)		393	244	(77.2)	72	(22.8)	

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis;
n refers to number, SD refers to standard deviation
For categorical variables, we reported the counts and percentages, and used the chi-square test to assess association between each categorical variable and hypertension status. For continuous variables, we reported the mean and standard deviation and used the 2-sample independent t-test to assess association between the continuous variable and hypertension status.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,7
Bias	9	Describe any efforts to address potential sources of bias	*6,7*
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, 10 (Table 1)
		(b) Indicate number of participants with missing data for each variable of interest	10 (Table 1)
Outcome data	15*	Report numbers of outcome events or summary measures	9-14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11, 13-14
		(*b*) Report category boundaries when continuous variables were categorized	10-11, 13-14
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Socio-demographic Factors in Relation to Hypertension Prevalence, Awareness, Treatment and Control in a Multi-ethnic Asian Population: A Cross-sectional Study

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Complete List of Authors:	Liew, Seaw Jia; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System Lee, Tayu, John; Nossal Institute for Global Health, School of Population and Global Health, University of Melbourne Tan, Chuen Seng; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore Koh, Choon Huat, Gerald; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore Van Dam, Rob; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore Müller-Riemenschneider, Falk; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore
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Socio-demographic Factors in Relation to Hypertension Prevalence, Awareness, Treatment and Control in a Multi-ethnic Asian Population: A Cross-sectional Study

Seaw Jia LIEW[1], John Tayu LEE[2], Chuen Seng TAN[1,3], Gerald Choon Huat KOH[1,3], Rob Martinus VAN DAM[1,3,4], Falk MÜLLER-RIEMENSCHNEIDER[1,3,5]

[1] Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore
[2] Nossal Institute for Global Health, School of Population and Global Health, University of Melbourne
[3] Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore
[4] Harvard T.H. Chan School of Public Health, Boston, MA, USA
[5] Institute of Social Medicine, Epidemiology and Health Economics, Charité - Universitätsmedizin, Berlin, Germany

Corresponding author:

Falk Mueller-Riemenschneider, MBBS, MSc, MD
Associate Professor
Leader Physical Activity and Nutrition Determinants in Asia (PANDA) Research Programme,
Deputy Leader Tele-Health Innovations (THOR) Research Programme,
Saw Swee Hock School of Public Health and Department of Medicine, Yong Loo Lin School of Medicine, National University of Singapore
Tahir Foundation Building (Block MD1), 12 Science Drive 2, #09-01v, Singapore 117549

Email: ephmf@nus.edu.sg

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Asian, awareness, control, hypertension, multi-ethnic, prevalence, socio-demographic

ABBREVIATIONS:

BP, blood pressure;

MEC, Multi-ethnic Cohort;

COR, crude odds ratio;

AOR, adjusted odds ratio.

ABSTRACTS

Objectives: Literature suggested that multi-ethnic Western populations experienced differential hypertension outcomes, but evidence is limited in Asia. This study aimed to determine socio-demographic correlates of hypertension and its awareness, treatment and control among a multi-ethnic Asian population living in Singapore.

Setting: We used cross-sectional data of participants from the Multi-Ethnic Cohort (MEC) (n=14,530) recruited in Singapore between 2004 and 2010.

Participants: Participants who completed questionnaire and attended health examination, without cardiovascular diseases, cancer, asthma and mental illnesses were included in the study (n=10,215). Multivariable logistic regression models were used to determine socio-demographics factors associated with hypertension, unawareness of having hypertension, untreated and uncontrolled hypertension.

Results: Among 10,215 participants (47.2% Chinese, 26.0% Malay and 26.8% Indian), hypertension prevalence was estimated to be 31.1%. Older age, Malay ethnicity, male, lower educational level, and being homemaker or retired/unemployed were factors significantly associated with hypertension. Stratified analysis suggested that age and education were consistently associated with hypertension across all ethnic groups. The proportions of being unaware, untreated and uncontrolled were 49.0%, 25.2% and 62.4%, respectively. Ethnicity and younger age were associated with unawareness; younger age, male and lower educational level were associated with untreated hypertension; and older age was associated with uncontrolled hypertension.

Conclusions: In this study, ethnic differences in relation to hypertension were associated with socio-demographic variability in ethnic groups. Age and educational level were consistent correlates of hypertension in all ethnic groups. Unawareness and uncontrolled hypertension were common in this Asian population and associated with socio-demographic factors. More targeted strategies may be required to overcome the observed disparities.

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STRENGTHS AND LIMITATIONS OF THIS STUDY

1. This a large population-based study of multi-ethnic Asian (Chinese, Malay, Indian) population living in an urban city state with relatively homogeneous living environment.
2. The minority ethnic groups (Malay and Indian) were purposively over-sampled to increase their representativeness in the study. In addition, this study recruited a large number of participants in the community to cover a wider age range and diverse socio-demographic profile.
3. The study used standardized and comprehensive methodologies to capture exposure and outcome data. The findings of this study were robust after adjustment for potential socio-demographic confounders.
4. The study design is cross-sectional, we cannot infer causality and determine the risk of hypertension. Treatment for hypertension was based on self-reported intake of antihypertensive medication and a participant's compliance to medication was not assessed.
5. Participants were advised to fast for 8-12 hours before the health examination, however, a participant's exposure to caffeine and alcohol prior to blood pressure measurement was not assessed. Blood pressure of participants was only measured during the health examination. However, standard BP measurement protocols were used, and multiple BP measurements were taken to minimize measurement error.

INTRODUCTION

Hypertension is a major risk factor of cardiovascular disease (CVD) and one of the leading causes of deaths from non-communicable diseases (NCD).[1 2] Hypertension is modifiable, yet there are a billion of individuals living with the condition worldwide and are at risk of hypertension-related complications.[3] The current evidence suggests that the public awareness and control of blood pressure (BP) remains challenging,[4 5] and that gaps in hypertension management were attributable to broader social and economic determinants.[6-9]

In most Western countries, the impact of ethnic and socio-economic disparities on hypertension outcomes has been well established. [10] Literature suggested that racial difference in hypertension prevalence was determined by demographics and lifestyle variables.[11] A study reported that racial disparities observed in BP were determined by differences in educational level.[12] Educational level and family income are socio-economic variables that have been well examined in relation with hypertension but the findings in the literature are rather mixed.[11-13]

In Asia, the relationship between socio-demographic and hypertension is understudied. Singapore has a rapidly ageing, urbanized and multi-ethnic Asian population (Chinese, Malays and Indians). Previous studies have emphasized the importance to better understand awareness, treatment and control in order to improve hypertension management in the community.[14 15] To address existing gaps in the evidence, we examined socio-demographic determinants of hypertension, unawareness of having hypertension, untreated and uncontrolled hypertension in the multi-ethnic Asian population in Singapore.

METHODS

Patient and public involvement

The Multi-Ethnic Cohort Study (MEC) is a population-based study in Singapore (n=14,530) with recruitment conducted between 2004 and 2010. The MEC participants were mainly recruited from the existing cohorts, i.e. Singapore Prospective Study Program (SP2) and Singapore Cardiovascular Cohort Study (SCCS2), and the detailed study methodology has been published elsewhere.[16] Briefly, MEC recruited Singaporeans or permanent residents aged ≥21 years who were free from cardiovascular diseases, stroke, heart diseases, transient ischemic attack, cancer, asthma and mental illnesses. The minority ethnic groups, Malays and Indians, were purposively over-sampled through public outreach at community events, mosques and temples as well as referrals from existing cohort members in addition to household visitation. The study included 10,215 individuals who had completed questionnaires and attended health examination. Study procedures were approved by the National University of Singapore Institutional Review Board and SingHealth Centralised Institutional Review Board.

All participants who provided consent to participate in this study were visited at home and completed an interview-administered questionnaire in English, Chinese or Malay languages. Subsequently, they underwent a health examination including repeated BP measurements. The interview questionnaires collected self-reported socio-demographic information, hypertension diagnosis, medical history and anti-hypertensive medication use.

Participants were asked to rest for 5 minutes, then systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice using an automated digital monitor (Dinamap Carescape V100, General Electric). If the difference between these two readings of SBP or DBP exceeded 10 mmHg or 5 mmHg, respectively, SBP and DBP were measured again and recorded as the third set of readings. For the small number of participants whose BP exceeded the range of the digital monitor, a sphygmomanometer (Accoson, United Kingdom) was used.[16] Mean values of the SBP and the DBP were computed for every participant and used in subsequent analyses.

Variables

Outcome variables

Hypertension (among all participants) was defined as either (i) the participant answering 'yes' to the survey question '*has a physician (western trained) or other professional told you that you have high blood pressure?*' or (ii) having mean SBP ≥140 mmHg or mean DBP ≥90 mmHg during the health examination.

Unawareness of hypertension (among hypertensives) was defined as the participant answering 'no' or 'do not know' to the survey question '*has a physician (western trained) or other professional told you that you have high blood pressure?*' but having mean SBP ≥140 mmHg or mean DBP ≥90 mmHg during the health examination.

Untreated hypertension (among hypertensives who were aware) referred to participants who were aware of having hypertension but were not taking any anti-hypertensive medication (identified from interviewer recorded lists of drug names and brand names).

Uncontrolled hypertension (among hypertensives who were treated) was defined as participants on anti-hypertension medication who were found to have a mean SBP ≥140 mmHg or mean DBP ≥90 mmHg during the health examination.

Explanatory variables

The explanatory variables included self-reported socio-demographic factors (i.e. age, gender, ethnicity, highest educational level obtained, marital status, work status during the past 12 months and average monthly household income). Age at interview was derived from the date of birth. Ethnicity was obtained from participant's identity card and classified into Chinese, Malay and Indian. Highest education level was categorized into three levels: (i) primary school education or lower, (ii) secondary school education/ITE (Institute of Technical Education)/NTC (National Technical Certificate), and (iii) tertiary education or higher. Marital status was dichotomized into currently married or not married (single, divorced, widowed or married but separated from spouse). Work status was classified into three categories: (i) employed (working adults or full-time studying), (ii) homemaker (housewife or non-working individual who manages a home), and (iii) retired/unemployed. Participants were asked to provide average monthly household income in Singapore Dollars (1 Singapore Dollars approximates 0.74 U.S. Dollars) by choosing one of the following options: <$2,000, $2,000-3,999, $4,000-5,999, or ≥$6,000. An 'unknown' income category was created for participants who refused to report household income.

Statistical analyses

Counts and percentages were presented for categorical variables. Bivariate and multivariable logistic regression analyses were performed to assess the association of each socio-demographic factor with hypertension, unawareness of hypertension, and untreated and uncontrolled hypertension, respectively. Multivariable logistic regression analyses were performed by mutually adjusting for all other socio-demographic variables (i.e. age, gender, ethnicity, highest educational level attained, marital status, work status during the past 12 months and average monthly household income) excluding the main variable under each investigation. To investigate whether the relationship between socio-demographic factors and hypertension was moderated by ethnicity, interaction effects between ethnicity and socio-demographic factors on hypertension were examined by adding the interaction terms to the multivariable model. A stratified analysis by ethnic group was conducted to explore whether differences in socio-demographics contribute in part to ethnic differences in hypertension. Odds Ratios (ORs) and Adjusted Odds Ratios (AORs) were reported with the corresponding 95% confidence intervals (95% CI). A p-value of <0.05 was considered statistically significant. All statistical analyses were conducted using STATA 14.0 for Windows (Stata Corporation, College Station, Texas, USA).

RESULTS

Among 14,530 participants enrolled in the MEC study, 11,101 individuals completed survey questionnaires and attended the health examination. After excluding participants with major diseases (i.e. cardiovascular diseases, stroke, transient ischemic attack, cancer, asthma and mental illnesses), duplicated records and 'Others' ethnic group, our final study population was 10,215 individuals of three main Asian ethnic groups, i.e. Chinese, Malay and Indian (online-only supplementary).

Participant characteristics

Table 1 lists the socio-demographic characteristics of our study population. The participants comprised 47.2% Chinese, 26.0% Malay and 26.8% Indian. The majority of the participants were aged ≥40 years (68.1%), females (56.7%), had secondary school or higher educational level (73.0%), married (76.0%), and were working or studying full-time (68.6%). The average monthly household income was less than $4,000 in 48.0% of the participants.

Factors associated with hypertension

Of the 10,215 participants included in our analysis (Table 1), 31.1% were hypertensives. In this study population, the estimated prevalence of hypertension varied across socio-demographic factors: ethnic group (Malay: 33.1%; Chinese: 31.5%; Indian: 28.5%), age (≥60 years: 72.8%; 50-59 years: 45.7%; 40-49 years: 25.0%; <40 years: 9.0%), gender (male: 33.9%; female: 29.0%), educational level (primary school or lower: 48.3%; secondary: 29.2%; tertiary or higher: 18.5%), marital status (married: 32.9%; not currently married: 25.4%), work status (retired/unemployed: 54.9%; homemaker: 39.1%; working/studying: 25.3%), and monthly household income level (<$2,000: 35.1%; $2000-3,999: 28.3%; $4,000-5,999: 24.7%; >=$6,000: 23.9%).

In the multivariable analysis (Table 1), most of the socio-demographic factors remained significant, except marital status and household income. Compared with Chinese, the odds of hypertension were higher in Malays (p=0.007), whereas no significant difference was observed between Indian and Chinese (p=0.165). Older age was strongly associated with increased odds of hypertension (overall p<0.001). Multivariable analysis demonstrated that the adjusted odds of hypertension in males compared to females was higher than the unadjusted odds ratio (AOR=1.65 vs. COR=1.25). Compared to females, males were more likely to have hypertension (AOR=1.65, 95% CI=1.47-1.85). Decreased educational level was associated with higher odds of hypertension (overall p<0.001). Compared to working or studying full-time, being homemaker or retired/unemployed significantly increased the odds of hypertension (overall p<0.001). The originally significant relationship between household income and hypertension was eliminated after adjustment for age and educational level.

Significant interactions (p<0.050) were observed between ethnicity and age (p=0.025), gender (p<0.001), work status (p=0.034), and household income (p<0.001). After including these significant interaction terms into the final logistic model, interaction effects remained significant (p<0.050) between ethnicity and age, gender and household income. The addition of ethnicity affected the association between socio-demographic factors and the odds of hypertension.

Factors associated with hypertension stratified by ethnicity

In stratified analysis (Table 2), hypertension was present in 31.5% of Chinese, 33.1% of Malay and 28.5% of Indian. The association between socio-demographic factors and the odds of hypertension in each ethnic group was moderated by the interaction effects between ethnicity and age, gender, work status and

Table 1: Association of socio-demographic factors and hypertension (n=10,215)

Socio-demographic factor		Total	Hypertension		Hypertension: Unadjusted				Hypertension: Adjusted			
		n	n	(%)	COR	(95% CI)		p-value	AOR	(95% CI)		p-value
Ethnicity												
	Chinese	4817	1519	31.5	1 [Ref.]			**0.001***	1 [Ref.]			**<0.001***
	Malay	2659	879	33.1	1.07	(0.97,	1.19)	0.177	**1.18**	**(1.05,**	**1.34)**	**0.007**
	Indian	2739	780	28.5	**0.86**	**(0.78,**	**0.96)**	**0.006**	0.92	(0.81,	1.04)	0.165
Age												
	<40	3258	292	9.0	1 [Ref.]			**<0.001***	1 [Ref.]			**<0.001***
	40-49	3187	798	25.0	**3.39**	**(2.94,**	**3.92)**	**<0.001**	**3.18**	**(2.73,**	**3.71)**	**<0.001**
	50-59	2420	1106	45.7	**8.55**	**(7.40,**	**9.88)**	**<0.001**	**7.54**	**(6.44,**	**8.82)**	**<0.001**
	>=60	1349	982	72.8	**27.18**	**(22.93,**	**32.21)**	**<0.001**	**19.97**	**(16.47,**	**24.23)**	**<0.001**
Gender												
	Female	5795	1682	29.0	1 [Ref.]				1 [Ref.]			
	Male	4419	1496	33.9	**1.25**	**(1.15,**	**1.36)**	**<0.001**	**1.65**	**(1.47,**	**1.85)**	**<0.001**
Highest education level												
	Primary or lower	2763	1334	48.3	1 [Ref.]			**<0.001***	1 [Ref.]			**<0.001***
	Secondary	4346	1271	29.2	**0.44**	**(0.40,**	**0.49)**	**<0.001**	**0.70**	**(0.62,**	**0.78)**	**<0.001**
	Tertiary or higher	3100	573	18.5	**0.24**	**(0.22,**	**0.27)**	**<0.001**	**0.59**	**(0.50,**	**0.69)**	**<0.001**
Marital status												
	Currently married	7757	2555	32.9	1 [Ref.]				1 [Ref.]			
	Not currently married	2452	623	25.4	**0.69**	**(0.63,**	**0.77)**	**<0.001**	1.11	(0.97,	1.26)	0.126
Work status												
	Working/Studying full-time	6972	1766	25.3	1 [Ref.]			**<0.001***	1 [Ref.]			**<0.001***
	Homemaker	2264	886	39.1	**1.90**	**(1.71,**	**2.10)**	**<0.001**	**1.36**	**(1.19,**	**1.56)**	**<0.001**
	Retired/Unemployed	930	511	54.9	**3.60**	**(3.13,**	**4.14)**	**<0.001**	**1.20**	**(1.01,**	**1.43)**	**0.042**
Monthly household income (SGD)^												
	<2,000	2277	800	35.1	1 [Ref.]			**<0.001***	1 [Ref.]			0.172*
	2,000-3,999	2619	740	28.3	**0.73**	**(0.64,**	**0.82)**	**<0.001**	1.07	(0.93,	1.23)	0.343
	4,000-5,999	1664	411	24.7	**0.61**	**(0.53,**	**0.70)**	**<0.001**	1.03	(0.88,	1.22)	0.691
	>=6,000	1462	349	23.9	**0.58**	**(0.50,**	**0.67)**	**<0.001**	1.13	(0.94,	1.36)	0.202

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis.
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05; CI: Confidence interval; *overall p-value*

Table 2:Association of socio-demographic factors and hypertension by ethnic groups, i.e. Chinese (n=4,817), Malay (n=2,659) and Indian (n=2,739)

Socio-demographic factor	Ethnicity: Chinese AOR	Chinese (95% CI)	Chinese p-value	Malay AOR	Malay (95% CI)	Malay p-value	Indian AOR	Indian (95% CI)	Indian p-value
Age									
<40	1 [Ref]		**<0.001***	1 [Ref]		**<0.001***	1 [Ref]		**<0.001***
40-49	**2.50**	(**1.99, 3.15**)	**<0.001**	**4.04**	(**3.03, 5.38**)	**<0.001**	**3.44**	(**2.53, 4.68**)	**<0.001**
50-59	**6.44**	(**5.10, 8.15**)	**<0.001**	**8.38**	(**6.20, 11.33**)	**<0.001**	**8.26**	(**6.07, 11.25**)	**<0.001**
>=60	**14.37**	(**10.82, 19.06**)	**<0.001**	**30.53**	(**20.30, 45.92**)	**<0.001**	**23.81**	(**16.40, 34.56**)	**<0.001**
Gender									
Female	1 [Ref]			1 [Ref]			1 [Ref]		
Male	**1.85**	(**1.58, 2.17**)	**<0.001**	1.08	(0.85, 1.37)	0.527	**1.97**	(**1.56, 2.50**)	**<0.001**
Highest education level									
Primary or lower	1 [Ref]		**<0.001***	1 [Ref]		**0.017***	1 [Ref]		**<0.001***
Secondary	**0.65**	(**0.54, 0.77**)	**<0.001**	**0.73**	(**0.59, 0.91**)	**0.005**	**0.71**	(**0.57, 0.88**)	**0.002**
Tertiary or higher	**0.54**	(**0.43, 0.67**)	**<0.001**	0.73	(0.52, 1.04)	0.086	**0.50**	(**0.36, 0.68**)	**<0.001**
Marital status									
Currently married	1 [Ref]			1 [Ref]			1 [Ref]		
Not currently married	1.05	(0.87, 1.27)	0.616	1.00	(0.77, 1.31)	0.972	1.25	(0.98, 1.59)	0.074
Work status									
Working/Studying full-time	1 [Ref]		**0.0078***	1 [Ref]		0.126*	1 [Ref]		0.066*
Homemaker	**1.30**	(**1.05, 1.61**)	**0.015**	**1.29**	(**1.00, 1.67**)	**0.048**	**1.37**	(**1.05, 1.79**)	**0.021**
Retired/Unemployed	**1.38**	(**1.06, 1.78**)	**0.015**	0.97	(0.67, 1.43)	0.894	1.15	(0.83, 1.60)	0.398
Monthly household income (SGD)^									
<2,000	1 [Ref]		0.391*	1 [Ref]		**<0.001***	1 [Ref]		0.137*
2,000-3,999	0.88	(0.69, 1.12)	0.306	1.07	(0.84, 1.37)	0.593	**1.28**	(**1.00, 1.64**)	**0.046**
4,000-5,999	1.04	(0.80, 1.36)	0.764	1.02	(0.76, 1.37)	0.879	0.92	(0.67, 1.25)	0.579
>=6,000	1.12	(0.86, 1.46)	0.401	0.72	(0.47, 1.11)	0.133	1.20	(0.83, 1.75)	0.334

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis.
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05; CI: Confidence interval; *overall p-value*

household income. The adjusted odds ratios of hypertension were higher in older age categories compared to age below 40 years, and similar pattern was observed in each ethnic group. Males had significantly higher odds of hypertension only in Chinese and Indian but not in Malay ethnic. No significant interaction was found between ethnicity and educational level. Educational level was related to hypertension independently of ethnicity. Lower education was consistently associated with higher odds of hypertension in all ethnic groups, and the adjusted odds ratios were almost comparable with the non-stratified analysis (Table 1). In terms of work status, the odds of hypertension in homemaker were consistently significant for all ethnic groups and higher for Indians but relatively lower for Chinese and Malays. Significantly higher odds of hypertension in retired/unemployed persisted only among Chinese but not among minorities Malay and Indian ethnic groups. Income-hypertension relationship was not found in Chinese and Malay ethnic groups, but Indians having lower income (between $2,000 and $3,999) were significantly associated with hypertension.

Factors associated with unawareness of hypertension

Among hypertensives, 49.0% were unaware of having hypertension (i.e. 48.9% of Chinese, 53.4% of Malay and 44.4% of Indian). In the multivariable analysis (Table 3), significant associations of ethnicity and age with unawareness persisted. Indians were less likely to be unaware of having hypertension (AOR = 0.80, 95%CI: 0.67-0.96) when compared with Chinese while no significant association was observed for Malays. Additionally, participants from older age groups, i.e. 50-59 years (AOR = 0.58, 95%CI: 0.44-0.77) and ≥60 years (AOR = 0.53, 95%CI: 0.39-0.72), were less likely to be unaware of having hypertension when compared with adults aged below 40 years.

Factors associated with untreated hypertension

Among participants who were aware of having hypertension, 25.2% were untreated for hypertension (i.e. 24.7% of Chinese, 23.4% of Malay and 27.7% of Indian). In the multivariable analysis (Table 3), older age was associated with much reduced odds of untreated hypertension when compared with age below 40 years, i.e. 40-49 years (AOR = 0.39, 95%CI: 0.25-0.61), 50-59 years (AOR = 0.22, 95%CI: 0.14-0.34), and ≥60 years (AOR = 0.13, 95%CI: 0.08-0.21). Males remained to have a significantly higher odds of untreated hypertension (AOR = 1.51, 95%CI: 1.12-2.04) when compared with females. With regards to educational level, the direction of the association with untreated hypertension changed in the multivariable analysis, i.e. higher educational level was associated with lower odds of being untreated, but only secondary school education was a significant factor (AOR = 0.69, 95%CI: 0.52-0.91) when compared with primary school education.

Factors associated with uncontrolled hypertension

Among participants who were treated for hypertension, 62.4% did not have their hypertension controlled (i.e. 65.5% of Chinese, 63.1% of Malay and 56.7% of Indian). In the multivariable analysis (Table 4), only older age and being retired/unemployed remained as significant factors. Higher odds of uncontrolled hypertension were associated with older age. Participants from older age groups, i.e. 50-59 years (AOR = 2.54, 95%CI: 1.33-4.87) and ≥60 years (AOR = 3.98, 95%CI: 2.01-7.91) were more likely to experience uncontrolled hypertension when compared with participants aged <40 years. The majority of the retirees and unemployed participants were older adults aged ≥60 years (53.0%). Compared with adults who were working or studying full-time, participants who were retired or unemployed (AOR = 1.51, 95%CI: 1.02-2.24) were more likely to have uncontrolled hypertension.

Table 3: Association of socio-demographic factors and unawareness among hypertensives (n=3,175), untreated among those who were aware of hypertension (n=1,618)

Socio-demographic factor	Unawareness among hypertensives								Untreated among aware							
	COR	(95% CI)		p-value	AOR	(95% CI)		p-value	COR	(95% CI)		p-value	AOR	(95% CI)		p-value
Ethnicity																
Chinese	1 [Ref]			**0.001***	1 [Ref]			**0.0046***	1 [Ref]			0.335*	1 [Ref]			0.520*
Malay	**1.19**	(**1.01,**	**1.41**)	**0.037**	1.11	(0.93,	1.32)	0.258	0.93	(0.70,	1.24)	0.630	0.87	(0.64,	1.20)	0.398
Indian	**0.83**	(**0.70,**	**0.99**)	**0.037**	**0.80**	(**0.67,**	**0.96**)	**0.018**	1.17	(0.89,	1.52)	0.257	1.05	(0.78,	1.42)	0.731
Age																
<40	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***
40-49	0.89	(0.67,	1.16)	0.383	0.89	(0.67,	1.18)	0.403	**0.37**	(**0.24,**	**0.57**)	**<0.001**	**0.39**	(**0.25,**	**0.61**)	**<0.001**
50-59	**0.58**	(**0.44,**	**0.75**)	**<0.001**	**0.58**	(**0.44,**	**0.77**)	**<0.001**	**0.20**	(**0.13,**	**0.31**)	**<0.001**	**0.22**	(**0.14,**	**0.34**)	**<0.001**
>=60	**0.50**	(**0.39,**	**0.66**)	**<0.001**	**0.53**	(**0.39,**	**0.72**)	**<0.001**	**0.12**	(**0.08,**	**0.19**)	**<0.001**	**0.13**	(**0.08,**	**0.21**)	**<0.001**
Gender																
Female	1 [Ref]				1 [Ref]				1 [Ref]				1 [Ref]			
Male	1.08	(0.94,	1.25)	0.259	1.15	(0.96,	1.37)	0.140	**1.68**	(**1.34,**	**2.11**)	**<0.001**	**1.51**	(**1.12,**	**2.04**)	**0.007**
Highest education level																
Primary or lower	1 [Ref]			**0.007***	1 [Ref]			0.310*	1 [Ref]			**0.007***	1 [Ref]			**0.033***
Secondary	**1.27**	(**1.09,**	**1.48**)	**0.002**	1.13	(0.95,	1.33)	0.162	1.02	(0.80,	1.32)	0.849	**0.69**	(**0.52,**	**0.91**)	**0.010**
Tertiary or higher	1.21	(1.00,	1.48)	0.054	1.01	(0.80,	1.28)	0.937	**1.59**	(**1.17,**	**2.15**)	**0.003**	0.83	(0.56,	1.23)	0.362
Marital status																
Currently married	1 [Ref]				1 [Ref]				1 [Ref]				1 [Ref]			
Not currently married	1.02	(0.85,	1.21)	0.860	1.09	(0.91,	1.32)	0.356	0.88	(0.66,	1.17)	0.367	1.05	(0.76,	1.45)	0.781
Work status																
Working/Studying full-time	1 [Ref]			**0.002***	1 [Ref]			0.139*	1 [Ref]			**<0.001***	1 [Ref]			0.557*
Homemaker	0.91	(0.77,	1.07)	0.254	1.12	(0.91,	1.39)	0.275	**0.47**	(**0.35,**	**0.62**)	**<0.001**	0.83	(0.58,	1.19)	0.316
Retired/Unemployed	**0.70**	(**0.58,**	**0.86**)	**0.001**	0.86	(0.69,	1.08)	0.203	**0.49**	(**0.35,**	**0.68**)	**<0.001**	0.88	(0.60,	1.30)	0.511
Monthly household income (SGD)^																
<2,000	1 [Ref]			0.845*	1 [Ref]			0.837*	1 [Ref]			**0.001***	1 [Ref]			0.147*
2,000-3,999	1.00	(0.82,	1.22)	0.996	0.91	(0.74,	1.12)	0.391	1.09	(0.80,	1.48)	0.600	0.87	(0.62,	1.22)	0.425
4,000-5,999	1.08	(0.85,	1.37)	0.530	0.97	(0.75,	1.25)	0.802	0.79	(0.54,	1.18)	0.249	**0.62**	(**0.40,**	**0.96**)	**0.031**
>=6,000	0.95	(0.74,	1.22)	0.680	0.86	(0.65,	1.14)	0.296	1.07	(0.73,	1.58)	0.732	0.76	(0.48,	1.21)	0.242

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis.
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05; CI: Confidence interval; *overall p-value*

Table 4: Association of socio-demographic factors and uncontrolled hypertension among treated (n=1,211)

Socio-demographic factor		Uncontrolled among treated							
		COR	95% CI		p-value	AOR	95% CI		p-value
Ethnicity									
	Chinese	1 [Ref]			**0.042***	1 [Ref]			0.174*
	Malay	0.91	(0.69,	1.21)	0.526	0.99	(0.72,	1.35)	0.949
	Indian	**0.70**	**(0.53,**	**0.93)**	**0.013**	0.76	(0.56,	1.04)	0.084
Age									
	<40	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***
	40-49	1.78	(0.93,	3.43)	0.084	1.61	(0.82,	3.15)	0.163
	50-59	**2.89**	**(1.54,**	**5.41)**	**0.001**	**2.54**	**(1.33,**	**4.87)**	**0.005**
	>=60	**6.28**	**(3.32,**	**11.86)**	**<0.001**	**3.98**	**(2.01,**	**7.91)**	**<0.001**
Gender									
	Female	1 [Ref]				1 [Ref]			
	Male	1.16	(0.91,	1.46)	0.231	1.35	(0.99,	1.85)	0.061
Highest education level									
	Primary or lower	1 [Ref]			**<0.001***	1 [Ref]			0.239*
	Secondary	**0.66**	**(0.51,**	**0.86)**	**0.002**	0.81	(0.61,	1.08)	0.150
	Tertiary or higher	**0.54**	**(0.38,**	**0.75)**	**<0.001**	0.74	(0.49,	1.12)	0.153
Marital status									
	Currently married	1 [Ref]				1 [Ref]			
	Not currently married	1.12	(0.83,	1.50)	0.465	1.04	(0.75,	1.44)	0.811
Work status									
	Working/Studying full-time	1 [Ref]			**<0.001***	1 [Ref]			0.068*
	Homemaker	**1.65**	**(1.26,**	**2.16)**	**<0.001**	1.34	(0.94,	1.89)	0.101
	Retired/Unemployed	**2.93**	**(2.08,**	**4.13)**	**<0.001**	**1.51**	**(1.02,**	**2.24)**	**0.041**
Monthly household income (SGD)^									
	<2,000	1 [Ref]			**<0.001***	1 [Ref]			**0.028***
	2,000-3,999	0.86	(0.61,	1.20)	0.372	0.95	(0.66,	1.35)	0.762
	4,000-5,999	0.77	(0.52,	1.14)	0.193	0.94	(0.61,	1.44)	0.767
	>=6,000	**0.65**	**(0.43,**	**0.99)**	**0.045**	0.85	(0.53,	1.36)	0.506

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis;
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05; CI: Confidence interval; *overall p-value*

DISCUSSION

This large multi-ethnic Asian cohort study provides valuable insights into socio-demographic determinants of hypertension within relatively homogeneous living environment and access to health care. We estimated that approximately 1 in 3 participants had hypertension. The strength of the association between socio-demographic factors and hypertension differed across ethnic groups. In addition to the established socio-demographic risk factors (i.e. age and gender), our study adds new evidence about the importance of ethnicity in relation to hypertension. Our stratified analysis suggested that the observed ethnic differences in relation to hypertension was partly attributed to the variability in socio-demographic characteristics of each ethnic group. Educational level rather than household income was an important socio-economic indicator consistently associated with hypertension within all ethnic groups. Almost half of the hypertensives in our study were unaware of having hypertension and 25% of those who were aware of having hypertension remained untreated. Adults under 40 years of age were more likely to be undetected and untreated than older individuals. Male participants were more likely to be untreated than females, and participants with low educational level were more likely to be untreated when compared with those with higher educational level. Among treated participants, more than half did not achieve optimal BP levels and older age was strongly associated with worse BP control.

In agreement with similar studies conducted in other Asian countries[17-20] and Singapore,[14 15] our study further demonstrated that older age is a strong factor associated with hypertension. Ethnic differences in relation to hypertension were observed in our study, consistent with the current literature which was largely conducted in the Western countries.[10 21 22] While the association between Indian ethnicity and hypertension ceased to be significant after the addition of socio-demographic factors, the association between Malay ethnicity and hypertension was statistically significant. The ethnic differences observed in our study were partly explained by the variability in socio-demographic profile within each ethnic group, an interesting finding revealed from the stratified analysis. For instance, Malays and Indians had higher odds ratio than Chinese for every increase in age group. Further, strong associations between gender and hypertension was observed among Chinese and Indian, but not Malay. Higher educational level had been found to be associated with lower prevalence of hypertension in earlier studies,[23 24] and our finding demonstrated that this association was consistent for all ethnic groups. No association between marital status and hypertension was observed in our study. The association between retired/unemployed status and hypertension was significant only among Chinese but not in other ethnic groups. In general, the income-hypertension association was not significant in our study after accounting for age and educational level.

Older participants were more likely to be aware of having hypertension because it is common among the age groups and health policies may have offered screening opportunity to this subgroup. The literature suggested that minority ethnic groups who were hypertensive were more likely to be aware of their hypertension.[9 21] However, our study observed that Malay ethnic who had greater odds of hypertension did not seem to be sufficiently aware of their condition. Conversely, Indians were relatively more aware of having hypertension compared to Chinese. The observed ethnic differences in hypertension awareness may be attributable to variations in lifestyle and cultural factors, and perceived benefit of hypertension prevention and control.[25-27]

Although older age was significantly related to hypertension, older participants in our study were more likely to be aware of having hypertension and treated for the condition. But, younger age, male gender and low educational level were significant determinants for untreated hypertension. Other study demonstrated that the measures of education can better explain variation in hypertension and health inequalities.[12] Low educational attainment may directly or indirectly influence the treatment and control of hypertension through lack of understanding about disease prevention, healthy lifestyle, perceived discrimination, among others.[23] Evidence suggested that education is a critical component of health and it is important to

incorporate educational element in public health promotion and reducing health disparities.[28 29] Older age was significantly associated with uncontrolled hypertension in our study. This finding is consistent with the current evidence[30 31] but also contrasts with other findings which suggested that older adults had better control of BP.[4 18] Lack of control of BP among older adults in our population could due to aging-related physiological changes, comorbidity and variation in response to treatment among older adult.[32] Social factors such as living in social exclusion, limited peer support, and not having sufficient knowledge to cope with their hypertension condition may also affect their BP control.[33]

Strength and Limitation

This study has a number of strengths. First, it is based on a large population-based study of a multi-ethnic Asian population living in an urban city state. Second, the study used standardized and comprehensive methodologies to capture exposure and outcome data. Third, we had purposively over-sampled minority ethnic groups and recruited a large number of study participants to cover a wider age range and diverse socio-demographic profile. Fourth, the findings of this study were robust after adjustment for potential socio-demographic confounders. However, we noted that the study has several important limitations. First, because the study design is cross-sectional, we cannot infer causality and determine the risk of hypertension. Second, the classification of participants as being treated for hypertension was based on self-reported intake of antihypertensive medication and a participant's compliance to medication was not determined. Third, participants were advised to fast for 8-12 hours before attending health examination. However, assessment on participants' exposures to caffeine and alcohol prior to BP measurements were not carried out, hence this study was not able to rule out that some participants may have been exposed to them. Fourth, BP of participants were measured on only one occasion during the health examination. However, standard BP measurement protocols were used, and multiple BP measurements were taken to minimize measurement error. Fourth, some participants did not provide information about average monthly household income. To overcome this limitation, we had classified them as a separate category (i.e. 'unknown income' group) and included them for analyses. Unmeasured confounding cannot be adjusted for in our study. Although the results are not generalizable to the Singapore population, our findings contributed new insights to the study of hypertension in multi-ethnic urban Asian population. Future more in-depth prospective studies may be useful to examine underlying mechanisms that contribute to differential hypertension outcomes, and uncover the segments of population who may benefit from active prevention and early treatment strategies.

CONCLUSION

In this study, ethnic differences observed in hypertension were associated with socio-demographic variability within ethnic groups. Age and educational level were consistent correlates of hypertension in all ethnic groups. Unawareness and uncontrolled hypertension were common in this Asian population and associated with socio-demographic factors. More targeted strategies may be required to overcome the observed disparities.

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CONTRIBUTORS

LSJ, JLTY and FMR contributed to the study design and development of the study objectives. LSJ acquired the data, conducted analyses and drafted the manuscript. LSJ and RMVD contributed to study methodological strategy; LSJ, JLTY and TCS contributed to the analytic strategies; GKCH and FMR contributed medical insights to guide the analysis and interpretation of results; FMR provided supervision and monitored study progress; All authors reviewed and revised the manuscript.

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COMPETING INTERESTS

None declared

ETHICS APPROVAL

The MEC study was approved by the National University of Singapore Institutional Review Board and SingHealth Centralised Institutional Review Board.

DATA SHARING STATEMENT

The Singapore Population Health Studies Scientific Committee reviews requests for data. The request form is available at https://blog.nus.edu.sg/sphs/.

REFERENCES

1. Organization WH. Noncommunicable diseases. 2017
2. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. (1474-547X (Electronic))
3. Organization WH. Global Health Observatory (GHO) data: NCD mortality and morbidity, 2015.
4. Chow CK, Teo KK, Rangarajan S, et al. Prevalence, awareness, treatment, and control of hypertension in rural and urban communities in high-, middle-, and low-income countries. *JAMA* 2013;310(9):959-68. doi: 10.1001/jama.2013.184182
5. Rahimi K, Emdin CA, MacMahon S. The Epidemiology of Blood Pressure and Its Worldwide Management. *Circulation Research* 2015;116(6):925-36. doi: 10.1161/circresaha.116.304723
6. Hunte HER, Mentz G, House JS, et al. Variations in Hypertension-Related Outcomes Among Blacks, Whites and Hispanics in Two Large Urban Areas and in the United States. *Ethnicity & disease* 2012;22(4):391-97.
7. Marshall A, Nazroo J, Feeney K, et al. Comparison of hypertension healthcare outcomes among older people in the USA and England. *J Epidemiol Community Health* 2016;70(3):264-70.
8. Joffres M, Falaschetti E, Gillespie C, et al. Hypertension prevalence, awareness, treatment and control in national surveys from England, the USA and Canada, and correlation with stroke and ischaemic heart disease mortality: a cross-sectional study. *BMJ open* 2013;3(8):e003423.
9. Thorpe RJ, Bowie JV, Smolen JR, et al. Racial disparities in hypertension awareness and management: Are there differences among African Americans and Whites living in similar social and healthcare resource environments? *Ethnicity & disease* 2014;24(3):269-75.
10. Kramer H, Han C, Post W, et al. Racial/Ethnic differences in hypertension and hypertension treatment and control in the multi-ethnic study of atherosclerosis (MESA)*. *American Journal of Hypertension* 2004;17(10):963-70. doi: 10.1016/j.amjhyper.2004.06.001
11. Holmes L, Hossain J, Ward D, et al. Racial/Ethnic Variability in Hypertension Prevalence and Risk Factors in National Health Interview Survey. *ISRN Hypertension* 2013;2013:8. doi: 10.5402/2013/257842
12. Non AL, Gravlee CC, Mulligan CJ. Education, Genetic Ancestry, and Blood Pressure in African Americans and Whites. *American Journal of Public Health* 2012;102(8):1559-65. doi: 10.2105/AJPH.2011.300448
13. Kaplan MS, Huguet N, Feeny DH, et al. Self-reported hypertension prevalence and income among older adults in Canada and the United States. *Social Science & Medicine* 2010;70(6):844-49. doi: https://doi.org/10.1016/j.socscimed.2009.11.019
14. Malhotra R, Chan A, Malhotra C, et al. Prevalence, awareness, treatment and control of hypertension in the elderly population of Singapore. *Hypertension Research* 2010;33:1223. doi: 10.1038/hr.2010.177
15. Wu Y, Tai ES, Heng D, et al. Risk factors associated with hypertension awareness, treatment, and control in a multi-ethnic Asian population. *Journal of Hypertension* 2009;27(1):190-97. doi: 10.1097/HJH.0b013e328317c8c3
16. Tan KHX, Tan LWL, Sim X, et al. Cohort Profile: The Singapore Multi-Ethnic Cohort (MEC) study. *International Journal of Epidemiology* 2018;47(3):699-99j. doi: 10.1093/ije/dyy014
17. Li W, Gu H, Teo KK, et al. Hypertension prevalence, awareness, treatment, and control in 115 rural and urban communities involving 47 000 people from China. *Journal of Hypertension* 2016;34(1):39-46. doi: 10.1097/hjh.0000000000000745

18. Liu X, Gu W, Li Z, et al. Hypertension prevalence, awareness, treatment, control, and associated factors in Southwest China: an update. *Journal of Hypertension* 2017;35(3):637-44. doi: 10.1097/hjh.0000000000001203
19. Abdul-Razak S, Daher AM, Ramli AS, et al. Prevalence, awareness, treatment, control and socio demographic determinants of hypertension in Malaysian adults. *BMC Public Health* 2016;16(1):351. doi: 10.1186/s12889-016-3008-y
20. B Bjertness M, Htet A, E Meyer H, et al. Prevalence and determinants of hypertension in Myanmar - A nationwide cross-sectional study2016.
21. Balfour PC, Rodriguez CJ, Ferdinand KC. The Role of Hypertension in Race-Ethnic Disparities in Cardiovascular Disease. *Current cardiovascular risk reports* 2015;9(4):18. doi: 10.1007/s12170-015-0446-5
22. Modesti PA, Reboldi G, Cappuccio FP, et al. Panethnic Differences in Blood Pressure in Europe: A Systematic Review and Meta-Analysis. *PLOS ONE* 2016;11(1):e0147601. doi: 10.1371/journal.pone.0147601
23. Alves RFS, Faerstein E. Educational inequalities in hypertension: complex patterns in intersections with gender and race in Brazil. *International Journal for Equity in Health* 2016;15:146. doi: 10.1186/s12939-016-0441-6
24. Lee H-Y. Socioeconomic Disparities in the Prevalence, Diagnosis, and Control of Hypertension in the Context of a Universal Health Insurance System. *Journal of Korean Medical Science* 2017;32(4):561-67. doi: 10.3346/jkms.2017.32.4.561
25. Okonofua EC, Cutler NE, Lackland DT, et al. Ethnic Differences in Older Americans: Awareness, Knowledge, and Beliefs About Hypertension*. *American Journal of Hypertension* 2005;18(7):972-79. doi: 10.1016/j.amjhyper.2005.02.019
26. Pettey CM, McSweeney JC, Stewart KE, et al. African Americans' Perceptions of Adherence to Medications and Lifestyle Changes Prescribed to Treat Hypertension. *SAGE open* 2016;6(1):10.1177/2158244015623595.
27. Peters RM, Aroian KJ, Flack JM. African American Culture and Hypertension Prevention. *Western journal of nursing research* 2006;28(7):831-63. doi: 10.1177/0193945906289332
28. Hahn RA, Truman BI. Education Improves Public Health and Promotes Health Equity. *International journal of health services : planning, administration, evaluation* 2015;45(4):657-78. doi: 10.1177/0020731415585986
29. Zajacova A, Lawrence EM. The Relationship Between Education and Health: Reducing Disparities Through a Contextual Approach. *Annual Review of Public Health* 2018;39(1):273-89. doi: 10.1146/annurev-publhealth-031816-044628
30. Seow LSE, Subramaniam M, Abdin E, et al. Hypertension and its associated risks among Singapore elderly residential population. *Journal of Clinical Gerontology and Geriatrics* 2015;6(4):125-32. doi: https://doi.org/10.1016/j.jcgg.2015.05.002
31. Doulougou B, Gomez F, Alvarado B, et al. Factors associated with hypertension prevalence, awareness, treatment and control among participants in the International Mobility in Aging Study (IMIAS). *Journal Of Human Hypertension* 2015;30:112. doi: 10.1038/jhh.2015.30
32. Lionakis N, Mendrinos D, Sanidas E, et al. Hypertension in the elderly. *World Journal of Cardiology* 2012;4(5):135-47. doi: 10.4330/wjc.v4.i5.135
33. Coyle CE. The Effects of Loneliness and Social Isolation on Hypertension in Later Life: Including Risk, Diagnosis and Management of the Chronic Condition. *Graduate Doctoral Dissertations* 2014;174

Online-only Supplementary

Table S-1: Characteristics of participants by ethnic group

Socio-demographic factors	Chinese					Malay					Indian				
	Normotensive		Hypertensive		p-value	Normotensive		Hypertensive		p-value	Normotensive		Hypertensive		p-value
	n	(%)	n	(%)		n	(%)	n	(%)		n	(%)	n	(%)	
Age (years), mean (SD)	42.22	(11.28)	54.71	(11.42)	<0.001	40.13	(11.10)	53.04	(10.93)	<0.001	41.17	(11.20)	53.77	(11.09)	<0.001
Gender, n (%)					<0.001					0.181					0.004
Female	1,921	(72.4)	734	(27.6)		1,031	(65.9)	533	(34.1)		1,161	(73.7)	415	(26.3)	
Male	1,377	(63.7)	785	(36.3)		749	(68.4)	346	(31.6)		797	(68.6)	365	(31.4)	
Blood pressure, mean (SD)															
Systolic blood pressure	116.74	(11.97)	149.09	(16.80)	<0.001	118.03	(12.02)	150.04	(17.33)	<0.001	114.49	(12.91)	147.24	(18.70)	<0.001
Diastolic blood pressure	70.40	(8.48)	84.40	(10.57)	<0.001	69.78	(8.33)	83.32	(11.07)	<0.001	69.14	(8.64)	82.18	(11.40)	<0.001
Highest education level, n (%)					<0.001					<0.001					<0.001
Primary or lower	499	(46.5)	573	(53.5)		419	(51.2)	400	(48.8)		511	(58.6)	361	(41.4)	
Secondary	1,228	(68.6)	561	(31.4)		1,027	(71.8)	404	(28.2)		820	(72.8)	306	(27.2)	
Tertiary or higher	1,569	(80.3)	385	(19.7)		332	(81.6)	75	(18.4)		626	(84.7)	113	(15.3)	
Marital status, n (%)					<0.001					0.001					0.832
Currently married	2,366	(65.6)	1,242	(34.4)		1,359	(65.3)	721	(34.7)		1,477	(71.4)	592	(28.6)	
Not married/divorced/separated	930	(77.1)	277	(22.9)		420	(72.7)	158	(27.3)		479	(71.8)	188	(28.2)	
Work status, n (%)					<0.001					<0.001					<0.001
Working/Studying full-time	2,642	(74.2)	919	(25.8)		1,209	(74.3)	419	(25.7)		1,355	(76.0)	428	(24.0)	
Homemaker	475	(59.7)	321	(40.3)		467	(58.1)	337	(41.9)		436	(65.7)	228	(34.3)	
Retired/Unemployed	162	(37.4)	271	(62.6)		99	(45.6)	118	(54.4)		158	(56.4)	122	(43.6)	
Monthly household income (SGD)^, n (%)					<0.001					<0.001					<0.001
<2,000	379	(57.7)	278	(42.3)		543	(67.8)	258	(32.2)		555	(67.8)	264	(32.2)	
2,000-3,999	713	(73.3)	260	(26.7)		563	(70.9)	231	(29.1)		603	(70.8)	249	(29.2)	
4,000-5,999	554	(75.2)	183	(24.8)		317	(70.8)	131	(29.2)		382	(79.7)	97	(20.3)	
≥6,000	707	(75.2)	233	(24.8)		162	(78.6)	44	(21.4)		244	(77.2)	72	(22.8)	

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis;
n refers to number, SD refers to standard deviation
SGD refers to Singapore Dollars
For categorical variables, we reported the counts and percentages, and used the chi-square test to assess association between each categorical variable and hypertension status. For continuous variables, we reported the mean and standard deviation and used the 2-sample independent t-test to assess association between the continuous variable and hypertension status.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,7
Bias	9	Describe any efforts to address potential sources of bias	*6,7*
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, 10 (Table 1)
		(b) Indicate number of participants with missing data for each variable of interest	10 (Table 1)
Outcome data	15*	Report numbers of outcome events or summary measures	9-14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11, 13-14
		(*b*) Report category boundaries when continuous variables were categorized	10-11, 13-14
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Socio-demographic Factors in Relation to Hypertension Prevalence, Awareness, Treatment and Control in a Multi-ethnic Asian Population: A Cross-sectional Study

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Complete List of Authors:	Liew, Seaw Jia; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System Lee, Tayu, John; Nossal Institute for Global Health, School of Population and Global Health, University of Melbourne Tan, Chuen Seng; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore Koh, Choon Huat, Gerald; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore Van Dam, Rob; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore Müller-Riemenschneider, Falk; Saw Swee Hock School of Public Health, National University of Singapore and National University Health System; Yong Loo Lin School of Medicine, National University of Singapore
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Socio-demographic Factors in Relation to Hypertension Prevalence, Awareness, Treatment and Control in a Multi-ethnic Asian Population: A Cross-sectional Study

Seaw Jia LIEW[1], John Tayu LEE[2], Chuen Seng TAN[1,3], Gerald Choon Huat KOH[1,3], Rob Martinus VAN DAM[1,3,4], Falk MÜLLER-RIEMENSCHNEIDER[1,3,5]

[1] Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore
[2] Nossal Institute for Global Health, School of Population and Global Health, University of Melbourne
[3] Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore
[4] Harvard T.H. Chan School of Public Health, Boston, MA, USA
[5] Institute of Social Medicine, Epidemiology and Health Economics, Charité - Universitätsmedizin, Berlin, Germany

Corresponding author:

Falk Mueller-Riemenschneider, MBBS, MSc, MD
Associate Professor
Leader Physical Activity and Nutrition Determinants in Asia (PANDA) Research Programme,
Deputy Leader Tele-Health Innovations (THOR) Research Programme,
Saw Swee Hock School of Public Health and Department of Medicine, Yong Loo Lin School of Medicine, National University of Singapore
Tahir Foundation Building (Block MD1), 12 Science Drive 2, #09-01v, Singapore 117549

Email: ephmf@nus.edu.sg

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Asian, awareness, control, hypertension, multi-ethnic, prevalence, socio-demographic

ABBREVIATIONS:

BP, blood pressure;

MEC, Multi-ethnic Cohort;

COR, crude odds ratio;

AOR, adjusted odds ratio.

ABSTRACTS

Objectives: Literature suggested that multi-ethnic Western populations experienced differential hypertension outcomes, but evidence is limited in Asia. This study aimed to determine socio-demographic correlates of hypertension and its awareness, treatment and control among a multi-ethnic Asian population living in Singapore.

Setting: We used cross-sectional data of participants from the Multi-Ethnic Cohort (MEC) (n=14,530) recruited in Singapore between 2004 and 2010.

Participants: Participants who completed questionnaire and attended health examination, without cardiovascular diseases, cancer, stroke, renal failure, asthma and mental illnesses were included in the study. Multivariable logistic regression models were used to determine socio-demographics factors associated with hypertension, unawareness of having hypertension, untreated and uncontrolled hypertension.

Results: Among 10,215 participants (47.2% Chinese, 26.0% Malay and 26.8% Indian), hypertension prevalence was estimated to be 31.1%. Older age, Malay ethnicity, male, lower educational level, and being homemaker or retired/unemployed were factors significantly associated with hypertension. Stratified analysis suggested that age and education were consistently associated with hypertension across all ethnic groups. The proportions of being unaware, untreated and uncontrolled were 49.0%, 25.2% and 62.4%, respectively. Ethnicity and younger age were associated with unawareness; younger age, male and lower educational level were associated with untreated hypertension; and older age was associated with uncontrolled hypertension.

Conclusions: In this study, ethnic differences in relation to hypertension were associated with socio-demographic variability in ethnic groups. Age and educational level were consistent correlates of hypertension in all ethnic groups. Unawareness and uncontrolled hypertension were common in this Asian population and associated with socio-demographic factors. More targeted strategies may be required to overcome the observed disparities.

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STRENGTHS AND LIMITATIONS OF THIS STUDY

1. This is a large population-based study of a multi-ethnic Asian (Chinese, Malay, Indian) population living in an urban city state with relatively homogeneous living environment.
2. The minority ethnic groups (Malay and Indian) were purposively over-sampled to increase their representativeness in the study.
3. The study used standardized and comprehensive methodologies to capture exposure and outcome data, and the findings were robust after adjustment for potential socio-demographic confounders.
4. Due to the cross-sectional design, this study cannot infer causality and the estimated prevalence of hypertension reported in this study may not be generalizable due to the sampling methodology.
5. Participant's exposure to caffeine and alcohol prior to blood pressure measurement was not assessed and treatment for hypertension was based on self-reported intake of antihypertensive medication.

INTRODUCTION

Hypertension is a major risk factor of cardiovascular disease (CVD) and one of the leading causes of deaths from non-communicable diseases (NCD).[1 2] Hypertension is modifiable, yet there are a billion of individuals living with the condition worldwide and are at risk of hypertension-related complications.[3] The current evidence suggests that the public awareness and control of blood pressure (BP) remains challenging,[4 5] and that gaps in hypertension management were attributable to broader social and economic determinants.[6-9]

In most Western countries, the impact of ethnic and socio-economic disparities on hypertension outcomes has been well established. [10] Literature suggested that racial difference in hypertension prevalence was determined by demographics and lifestyle variables.[11] A study reported that racial disparities observed in BP were determined by differences in educational level.[12] Educational level and family income are socio-economic variables that have been well examined in relation with hypertension but the findings in the literature are rather mixed.[11-13]

In Asia, the relationship between socio-demographic and hypertension is understudied. Singapore has a rapidly ageing, urbanized and multi-ethnic Asian population (Chinese, Malays and Indians). Previous studies have emphasized the importance to better understand awareness, treatment and control in order to improve hypertension management in the community.[14 15] To address existing gaps in the evidence, we examined socio-demographic determinants of hypertension, unawareness of having hypertension, untreated and uncontrolled hypertension in the multi-ethnic Asian population in Singapore.

METHODS

Patient and public involvement

The Multi-Ethnic Cohort Study (MEC) is a population-based study in Singapore (n=14,530) with recruitment conducted between 2004 and 2010. The MEC participants were mainly recruited from the existing cohorts between 2004 and 2007, i.e. Singapore Prospective Study Program (SP2) and Singapore Cardiovascular Cohort Study (SCCS2),[16 17] with additional participants recruited between 2007 and 2010. The detailed study methodology can be found on the study webpage http://blog.nus.edu.sg/sphs/ and the MEC Cohort Profile.[18] Essentially, the study participants were Singaporeans or permanent residents of three ethnic groups (i.e. Chinese, Malay and Indian), aged ≥21 years and free from cancer, heart disease, stroke, renal failure, asthma and mental illness. In the recruitment of additional participants, the minority ethnic groups, Malays and Indians, were recruited following a convenience sampling methodology and purposively over-sampled through public outreach at community events, mosques and temples as well as referrals from existing cohort members in addition to household visitation. In general, the sample population had a relatively homogenous living condition, i.e. all participants were living in Singapore, a city state, where government policies had led to relatively even distributions of public housing, ethnic groups, and provision of various health related infrastructure across the country. The study included individuals who had completed questionnaires and attended health examination. Study procedures were approved by the National University of Singapore Institutional Review Board and SingHealth Centralised Institutional Review Board.

All participants who provided consent to participate in this study were visited at home and completed an interview-administered questionnaire in English, Chinese or Malay languages. Subsequently, they underwent a health examination including repeated BP measurements. The interview questionnaires collected self-reported socio-demographic information, hypertension diagnosis, medical history and anti-hypertensive medication use.

Participants were asked to rest for 5 minutes, then systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice using an automated digital monitor (Dinamap Carescape V100, General Electric). If the difference between these two readings of SBP or DBP exceeded 10 mmHg or 5 mmHg, respectively, SBP and DBP were measured again and recorded as the third set of readings. For the small number of participants whose BP exceeded the range of the digital monitor, a sphygmomanometer (Accoson, United Kingdom) was used.[18] Mean values of the SBP and the DBP were computed for every participant and used in subsequent analyses.

Variables

Outcome variables

Hypertension (among all participants) was defined as either (i) the participant answering 'yes' to the survey question '*has a physician (western trained) or other professional told you that you have high blood pressure?*' or (ii) having mean SBP ≥140 mmHg or mean DBP ≥90 mmHg during the health examination.

Unawareness of hypertension (among hypertensives) was defined as the participant answering 'no' or 'do not know' to the survey question '*has a physician (western trained) or other professional told you that you have high blood pressure?*' but having mean SBP ≥140 mmHg or mean DBP ≥90 mmHg during the health examination.

Untreated hypertension (among hypertensives who were aware) referred to participants who were aware of having hypertension but were not taking any anti-hypertensive medication (identified from interviewer recorded lists of drug names and brand names).

Uncontrolled hypertension (among hypertensives who were treated) was defined as participants on anti-hypertension medication who were found to have a mean SBP ≥140 mmHg or mean DBP ≥90 mmHg during the health examination.

Explanatory variables

The explanatory variables included self-reported socio-demographic factors (i.e. age, gender, ethnicity, highest educational level obtained, marital status, work status during the past 12 months and average monthly household income). Age at interview was derived from the date of birth. Ethnicity was obtained from participant's identity card and classified into Chinese, Malay and Indian. Highest education level was categorized into three levels: (i) primary school education or lower, (ii) secondary school education/ITE (Institute of Technical Education)/NTC (National Technical Certificate), and (iii) tertiary education or higher. Marital status was dichotomized into currently married or not married (single, divorced, widowed or married but separated from spouse). Work status was classified into three categories: (i) employed (working adults or full-time studying), (ii) homemaker (housewife or non-working individual who manages a home), and (iii) retired/unemployed. Participants were asked to provide average monthly household income in Singapore Dollars (1 Singapore Dollars approximates 0.74 U.S. Dollars) by choosing one of the following options: <$2,000, $2,000-3,999, $4,000-5,999, or ≥$6,000. An 'unknown' income category was created for participants who refused to report household income.

Statistical analyses

Counts and percentages were presented for categorical variables. Bivariate and multivariable logistic regression analyses were performed to assess the association of each socio-demographic factor with hypertension, unawareness of hypertension, and untreated and uncontrolled hypertension, respectively. Multivariable logistic regression analyses were performed by mutually adjusting for all other socio-demographic variables (i.e. age, gender, ethnicity, highest educational level attained, marital status, work status during the past 12 months and average monthly household income) excluding the main variable under each investigation. To investigate whether the relationship between socio-demographic factors and hypertension was moderated by ethnicity, interaction effects between ethnicity and socio-demographic factors on hypertension were examined by adding the interaction terms to the multivariable model. A stratified analysis by ethnic group was conducted to explore whether differences in socio-demographics contribute in part to ethnic differences in hypertension. Odds Ratios (ORs) and Adjusted Odds Ratios (AORs) were reported with the corresponding 95% confidence intervals (95% CI). A p-value of <0.05 was considered statistically significant. All statistical analyses were conducted using STATA 14.0 for Windows (Stata Corporation, College Station, Texas, USA).

RESULTS

Among 14,530 participants enrolled in the MEC study, 11,101 individuals completed survey questionnaires and attended the health examination. After excluding participants with major diseases (i.e. cardiovascular diseases, stroke, transient ischemic attack, cancer, asthma and mental illnesses), duplicated records and 'Others' ethnic group, our final study population was 10,215 individuals of three main Asian ethnic groups, i.e. Chinese, Malay and Indian (online-only supplementary).

Participant characteristics

Table 1 lists the socio-demographic characteristics of our study population. The participants comprised 47.2% Chinese, 26.0% Malay and 26.8% Indian. The majority of the participants were aged ≥40 years (68.1%), females (56.7%), had secondary school or higher educational level (73.0%), married (76.0%), and were working or studying full-time (68.6%). The average monthly household income was less than $4,000 in 48.0% of the participants.

Factors associated with hypertension

Of the 10,215 participants included in our analysis (Table 1), 31.1% were hypertensives. In this study population, the estimated prevalence of hypertension varied across socio-demographic factors: ethnic group (Malay: 33.1%; Chinese: 31.5%; Indian: 28.5%), age (≥60 years: 72.8%; 50-59 years: 45.7%; 40-49 years: 25.0%; <40 years: 9.0%), gender (male: 33.9%; female: 29.0%), educational level (primary school or lower: 48.3%; secondary: 29.2%; tertiary or higher: 18.5%), marital status (married: 32.9%; not currently married: 25.4%), work status (retired/unemployed: 54.9%; homemaker: 39.1%; working/studying: 25.3%), and monthly household income level (<$2,000: 35.1%; $2000-3,999: 28.3%; $4,000-5,999: 24.7%; >=$6,000: 23.9%).

In the multivariable analysis (Table 1), most of the socio-demographic factors remained significant, except marital status and household income. Compared with Chinese, the odds of hypertension were higher in Malays (p=0.007), whereas no significant difference was observed between Indian and Chinese (p=0.165). Older age was strongly associated with increased odds of hypertension (overall p<0.001). Multivariable analysis demonstrated that the adjusted odds of hypertension in males compared to females was higher than the unadjusted odds ratio (AOR=1.65 vs. COR=1.25). Compared to females, males were more likely to have hypertension (AOR=1.65, 95% CI=1.47-1.85). Decreased educational level was associated with higher odds of hypertension (overall p<0.001). Compared to working or studying full-time, being homemaker or retired/unemployed significantly increased the odds of hypertension (overall p<0.001). The originally significant relationship between household income and hypertension was eliminated after adjustment for age and educational level.

Significant interactions (p<0.050) were observed between ethnicity and age (p=0.025), gender (p<0.001), work status (p=0.034), and household income (p<0.001). After including these significant interaction terms into the final logistic model, interaction effects remained significant (p<0.050) between ethnicity and age, gender and household income. The addition of ethnicity affected the association between socio-demographic factors and the odds of hypertension.

Factors associated with hypertension stratified by ethnicity

In stratified analysis (Table 2), hypertension was present in 31.5% of Chinese, 33.1% of Malay and 28.5% of Indian. The association between socio-demographic factors and the odds of hypertension in each ethnic group was moderated by the interaction effects between ethnicity and age, gender, work status and

Table 1: Association of socio-demographic factors and hypertension (n=10,215)

Socio-demographic factor		Total	Hypertension		Hypertension: Unadjusted				Hypertension: Adjusted			
		n	n	(%)	COR	(95% CI)		p-value	AOR	(95% CI)		p-value
Ethnicity												
	Chinese	4817	1519	31.5	1 [Ref.]			**0.001***	1 [Ref.]			**<0.001***
	Malay	2659	879	33.1	1.07	(0.97,	1.19)	0.177	**1.18**	**(1.05,**	**1.34)**	**0.007**
	Indian	2739	780	28.5	**0.86**	**(0.78,**	**0.96)**	**0.006**	0.92	(0.81,	1.04)	0.165
Age												
	<40	3258	292	9.0	1 [Ref.]			**<0.001***	1 [Ref.]			**<0.001***
	40-49	3187	798	25.0	**3.39**	**(2.94,**	**3.92)**	**<0.001**	**3.18**	**(2.73,**	**3.71)**	**<0.001**
	50-59	2420	1106	45.7	**8.55**	**(7.40,**	**9.88)**	**<0.001**	**7.54**	**(6.44,**	**8.82)**	**<0.001**
	>=60	1349	982	72.8	**27.18**	**(22.93,**	**32.21)**	**<0.001**	**19.97**	**(16.47,**	**24.23)**	**<0.001**
Gender												
	Female	5795	1682	29.0	1 [Ref.]				1 [Ref.]			
	Male	4419	1496	33.9	**1.25**	**(1.15,**	**1.36)**	**<0.001**	**1.65**	**(1.47,**	**1.85)**	**<0.001**
Highest education level												
	Primary or lower	2763	1334	48.3	1 [Ref.]			**<0.001***	1 [Ref.]			**<0.001***
	Secondary	4346	1271	29.2	**0.44**	**(0.40,**	**0.49)**	**<0.001**	**0.70**	**(0.62,**	**0.78)**	**<0.001**
	Tertiary or higher	3100	573	18.5	**0.24**	**(0.22,**	**0.27)**	**<0.001**	**0.59**	**(0.50,**	**0.69)**	**<0.001**
Marital status												
	Currently married	7757	2555	32.9	1 [Ref.]				1 [Ref.]			
	Not currently married	2452	623	25.4	**0.69**	**(0.63,**	**0.77)**	**<0.001**	1.11	(0.97,	1.26)	0.126
Work status												
	Working/Studying full-time	6972	1766	25.3	1 [Ref.]			**<0.001***	1 [Ref.]			**<0.001***
	Homemaker	2264	886	39.1	**1.90**	**(1.71,**	**2.10)**	**<0.001**	**1.36**	**(1.19,**	**1.56)**	**<0.001**
	Retired/Unemployed	930	511	54.9	**3.60**	**(3.13,**	**4.14)**	**<0.001**	**1.20**	**(1.01,**	**1.43)**	**0.042**
Monthly household income (SGD)^												
	<2,000	2277	800	35.1	1 [Ref.]			**<0.001***	1 [Ref.]			0.172*
	2,000-3,999	2619	740	28.3	**0.73**	**(0.64,**	**0.82)**	**<0.001**	1.07	(0.93,	1.23)	0.343
	4,000-5,999	1664	411	24.7	**0.61**	**(0.53,**	**0.70)**	**<0.001**	1.03	(0.88,	1.22)	0.691
	>=6,000	1462	349	23.9	**0.58**	**(0.50,**	**0.67)**	**<0.001**	1.13	(0.94,	1.36)	0.202

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis.
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05; CI: Confidence interval; *overall p-value*

Table 2:Association of socio-demographic factors and hypertension by ethnic groups, i.e. Chinese (n=4,817), Malay (n=2,659) and Indian (n=2,739)

Socio-demographic factor	Ethnicity: Chinese AOR	Chinese (95% CI)	Chinese p-value	Malay AOR	Malay (95% CI)	Malay p-value	Indian AOR	Indian (95% CI)	Indian p-value
Age									
<40	1 [Ref]		**<0.001***	1 [Ref]		**<0.001***	1 [Ref]		**<0.001***
40-49	**2.50**	(**1.99, 3.15**)	**<0.001**	**4.04**	(**3.03, 5.38**)	**<0.001**	**3.44**	(**2.53, 4.68**)	**<0.001**
50-59	**6.44**	(**5.10, 8.15**)	**<0.001**	**8.38**	(**6.20, 11.33**)	**<0.001**	**8.26**	(**6.07, 11.25**)	**<0.001**
>=60	**14.37**	(**10.82, 19.06**)	**<0.001**	**30.53**	(**20.30, 45.92**)	**<0.001**	**23.81**	(**16.40, 34.56**)	**<0.001**
Gender									
Female	1 [Ref]			1 [Ref]			1 [Ref]		
Male	**1.85**	(**1.58, 2.17**)	**<0.001**	1.08	(0.85, 1.37)	0.527	**1.97**	(**1.56, 2.50**)	**<0.001**
Highest education level									
Primary or lower	1 [Ref]		**<0.001***	1 [Ref]		**0.017***	1 [Ref]		**<0.001***
Secondary	**0.65**	(**0.54, 0.77**)	**<0.001**	**0.73**	(**0.59, 0.91**)	**0.005**	**0.71**	(**0.57, 0.88**)	**0.002**
Tertiary or higher	**0.54**	(**0.43, 0.67**)	**<0.001**	0.73	(0.52, 1.04)	0.086	**0.50**	(**0.36, 0.68**)	**<0.001**
Marital status									
Currently married	1 [Ref]			1 [Ref]			1 [Ref]		
Not currently married	1.05	(0.87, 1.27)	0.616	1.00	(0.77, 1.31)	0.972	1.25	(0.98, 1.59)	0.074
Work status									
Working/Studying full-time	1 [Ref]		**0.0078***	1 [Ref]		0.126*	1 [Ref]		0.066*
Homemaker	**1.30**	(**1.05, 1.61**)	**0.015**	**1.29**	(**1.00, 1.67**)	**0.048**	**1.37**	(**1.05, 1.79**)	**0.021**
Retired/Unemployed	**1.38**	(**1.06, 1.78**)	**0.015**	0.97	(0.67, 1.43)	0.894	1.15	(0.83, 1.60)	0.398
Monthly household income (SGD)^									
<2,000	1 [Ref]		0.391*	1 [Ref]		**<0.001***	1 [Ref]		0.137*
2,000-3,999	0.88	(0.69, 1.12)	0.306	1.07	(0.84, 1.37)	0.593	**1.28**	(**1.00, 1.64**)	**0.046**
4,000-5,999	1.04	(0.80, 1.36)	0.764	1.02	(0.76, 1.37)	0.879	0.92	(0.67, 1.25)	0.579
>=6,000	1.12	(0.86, 1.46)	0.401	0.72	(0.47, 1.11)	0.133	1.20	(0.83, 1.75)	0.334

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis.
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05; CI: Confidence interval; *overall p-value*

household income. The adjusted odds ratios of hypertension were higher in older age categories compared to age below 40 years, and similar pattern was observed in each ethnic group. Males had significantly higher odds of hypertension only in Chinese and Indian but not in Malay ethnic. No significant interaction was found between ethnicity and educational level. Educational level was related to hypertension independently of ethnicity. Lower education was consistently associated with higher odds of hypertension in all ethnic groups, and the adjusted odds ratios were almost comparable with the non-stratified analysis (Table 1). In terms of work status, the odds of hypertension in homemaker were consistently significant for all ethnic groups and higher for Indians but relatively lower for Chinese and Malays. Significantly higher odds of hypertension in retired/unemployed persisted only among Chinese but not among minorities Malay and Indian ethnic groups. Income-hypertension relationship was not found in Chinese and Malay ethnic groups, but Indians having lower income (between $2,000 and $3,999) were significantly associated with hypertension.

Factors associated with unawareness of hypertension

Among hypertensives, 49.0% were unaware of having hypertension (i.e. 48.9% of Chinese, 53.4% of Malay and 44.4% of Indian). In the multivariable analysis (Table 3), significant associations of ethnicity and age with unawareness persisted. Indians were less likely to be unaware of having hypertension (AOR = 0.80, 95%CI: 0.67-0.96) when compared with Chinese while no significant association was observed for Malays. Additionally, participants from older age groups, i.e. 50-59 years (AOR = 0.58, 95%CI: 0.44-0.77) and ≥60 years (AOR = 0.53, 95%CI: 0.39-0.72), were less likely to be unaware of having hypertension when compared with adults aged below 40 years.

Factors associated with untreated hypertension

Among participants who were aware of having hypertension, 25.2% were untreated for hypertension (i.e. 24.7% of Chinese, 23.4% of Malay and 27.7% of Indian). In the multivariable analysis (Table 3), older age was associated with much reduced odds of untreated hypertension when compared with age below 40 years, i.e. 40-49 years (AOR = 0.39, 95%CI: 0.25-0.61), 50-59 years (AOR = 0.22, 95%CI: 0.14-0.34), and ≥60 years (AOR = 0.13, 95%CI: 0.08-0.21). Males remained to have a significantly higher odds of untreated hypertension (AOR = 1.51, 95%CI: 1.12-2.04) when compared with females. With regards to educational level, the direction of the association with untreated hypertension changed in the multivariable analysis, i.e. higher educational level was associated with lower odds of being untreated, but only secondary school education was a significant factor (AOR = 0.69, 95%CI: 0.52-0.91) when compared with primary school education.

Factors associated with uncontrolled hypertension

Among participants who were treated for hypertension, 62.4% did not have their hypertension controlled (i.e. 65.5% of Chinese, 63.1% of Malay and 56.7% of Indian). In the multivariable analysis (Table 4), only older age and being retired/unemployed remained as significant factors. Higher odds of uncontrolled hypertension were associated with older age. Participants from older age groups, i.e. 50-59 years (AOR = 2.54, 95%CI: 1.33-4.87) and ≥60 years (AOR = 3.98, 95%CI: 2.01-7.91) were more likely to experience uncontrolled hypertension when compared with participants aged <40 years. The majority of the retirees and unemployed participants were older adults aged ≥60 years (53.0%). Compared with adults who were working or studying full-time, participants who were retired or unemployed (AOR = 1.51, 95%CI: 1.02-2.24) were more likely to have uncontrolled hypertension.

Table 3: Association of socio-demographic factors and unawareness among hypertensives (n=3,175), untreated among those who were aware of hypertension (n=1,618)

Socio-demographic factor	Unawareness among hypertensives								Untreated among aware							
	COR	(95% CI)		p-value	AOR	(95% CI)		p-value	COR	(95% CI)		p-value	AOR	(95% CI)		p-value
Ethnicity																
Chinese	1 [Ref]			**0.001***	1 [Ref]			**0.0046***	1 [Ref]			0.335*	1 [Ref]			0.520*
Malay	**1.19**	(**1.01,**	**1.41**)	**0.037**	1.11	(0.93,	1.32)	0.258	0.93	(0.70,	1.24)	0.630	0.87	(0.64,	1.20)	0.398
Indian	**0.83**	(**0.70,**	**0.99**)	**0.037**	**0.80**	(**0.67,**	**0.96**)	**0.018**	1.17	(0.89,	1.52)	0.257	1.05	(0.78,	1.42)	0.731
Age																
<40	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***
40-49	0.89	(0.67,	1.16)	0.383	0.89	(0.67,	1.18)	0.403	**0.37**	(**0.24,**	**0.57**)	**<0.001**	**0.39**	(**0.25,**	**0.61**)	**<0.001**
50-59	**0.58**	(**0.44,**	**0.75**)	**<0.001**	**0.58**	(**0.44,**	**0.77**)	**<0.001**	**0.20**	(**0.13,**	**0.31**)	**<0.001**	**0.22**	(**0.14,**	**0.34**)	**<0.001**
>=60	**0.50**	(**0.39,**	**0.66**)	**<0.001**	**0.53**	(**0.39,**	**0.72**)	**<0.001**	**0.12**	(**0.08,**	**0.19**)	**<0.001**	**0.13**	(**0.08,**	**0.21**)	**<0.001**
Gender																
Female	1 [Ref]				1 [Ref]				1 [Ref]				1 [Ref]			
Male	1.08	(0.94,	1.25)	0.259	1.15	(0.96,	1.37)	0.140	**1.68**	(**1.34,**	**2.11**)	**<0.001**	**1.51**	(**1.12,**	**2.04**)	**0.007**
Highest education level																
Primary or lower	1 [Ref]			**0.007***	1 [Ref]			0.310*	1 [Ref]			**0.007***	1 [Ref]			**0.033***
Secondary	**1.27**	(**1.09,**	**1.48**)	**0.002**	1.13	(0.95,	1.33)	0.162	1.02	(0.80,	1.32)	0.849	**0.69**	(**0.52,**	**0.91**)	**0.010**
Tertiary or higher	1.21	(1.00,	1.48)	0.054	1.01	(0.80,	1.28)	0.937	**1.59**	(**1.17,**	**2.15**)	**0.003**	0.83	(0.56,	1.23)	0.362
Marital status																
Currently married	1 [Ref]				1 [Ref]				1 [Ref]				1 [Ref]			
Not currently married	1.02	(0.85,	1.21)	0.860	1.09	(0.91,	1.32)	0.356	0.88	(0.66,	1.17)	0.367	1.05	(0.76,	1.45)	0.781
Work status																
Working/Studying full-time	1 [Ref]			**0.002***	1 [Ref]			0.139*	1 [Ref]			**<0.001***	1 [Ref]			0.557*
Homemaker	0.91	(0.77,	1.07)	0.254	1.12	(0.91,	1.39)	0.275	**0.47**	(**0.35,**	**0.62**)	**<0.001**	0.83	(0.58,	1.19)	0.316
Retired/Unemployed	**0.70**	(**0.58,**	**0.86**)	**0.001**	0.86	(0.69,	1.08)	0.203	**0.49**	(**0.35,**	**0.68**)	**<0.001**	0.88	(0.60,	1.30)	0.511
Monthly household income (SGD)^																
<2,000	1 [Ref]			0.845*	1 [Ref]			0.837*	1 [Ref]			**0.001***	1 [Ref]			0.147*
2,000-3,999	1.00	(0.82,	1.22)	0.996	0.91	(0.74,	1.12)	0.391	1.09	(0.80,	1.48)	0.600	0.87	(0.62,	1.22)	0.425
4,000-5,999	1.08	(0.85,	1.37)	0.530	0.97	(0.75,	1.25)	0.802	0.79	(0.54,	1.18)	0.249	**0.62**	(**0.40,**	**0.96**)	**0.031**
>=6,000	0.95	(0.74,	1.22)	0.680	0.86	(0.65,	1.14)	0.296	1.07	(0.73,	1.58)	0.732	0.76	(0.48,	1.21)	0.242

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis.
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05; CI: Confidence interval; *overall p-value*

Table 4: Association of socio-demographic factors and uncontrolled hypertension among treated (n=1,211)

Socio-demographic factor		Uncontrolled among treated							
		COR	95% CI		p-value	AOR	95% CI		p-value
Ethnicity									
	Chinese	1 [Ref]			**0.042***	1 [Ref]			0.174*
	Malay	0.91	(0.69,	1.21)	0.526	0.99	(0.72,	1.35)	0.949
	Indian	**0.70**	**(0.53,**	**0.93)**	**0.013**	0.76	(0.56,	1.04)	0.084
Age									
	<40	1 [Ref]			**<0.001***	1 [Ref]			**<0.001***
	40-49	1.78	(0.93,	3.43)	0.084	1.61	(0.82,	3.15)	0.163
	50-59	**2.89**	**(1.54,**	**5.41)**	**0.001**	**2.54**	**(1.33,**	**4.87)**	**0.005**
	>=60	**6.28**	**(3.32,**	**11.86)**	**<0.001**	**3.98**	**(2.01,**	**7.91)**	**<0.001**
Gender									
	Female	1 [Ref]				1 [Ref]			
	Male	1.16	(0.91,	1.46)	0.231	1.35	(0.99,	1.85)	0.061
Highest education level									
	Primary or lower	1 [Ref]			**<0.001***	1 [Ref]			0.239*
	Secondary	**0.66**	**(0.51,**	**0.86)**	**0.002**	0.81	(0.61,	1.08)	0.150
	Tertiary or higher	**0.54**	**(0.38,**	**0.75)**	**<0.001**	0.74	(0.49,	1.12)	0.153
Marital status									
	Currently married	1 [Ref]				1 [Ref]			
	Not currently married	1.12	(0.83,	1.50)	0.465	1.04	(0.75,	1.44)	0.811
Work status									
	Working/Studying full-time	1 [Ref]			**<0.001***	1 [Ref]			0.068*
	Homemaker	**1.65**	**(1.26,**	**2.16)**	**<0.001**	1.34	(0.94,	1.89)	0.101
	Retired/Unemployed	**2.93**	**(2.08,**	**4.13)**	**<0.001**	**1.51**	**(1.02,**	**2.24)**	**0.041**
Monthly household income (SGD)^									
	<2,000	1 [Ref]			**<0.001***	1 [Ref]			**0.028***
	2,000-3,999	0.86	(0.61,	1.20)	0.372	0.95	(0.66,	1.35)	0.762
	4,000-5,999	0.77	(0.52,	1.14)	0.193	0.94	(0.61,	1.44)	0.767
	>=6,000	**0.65**	**(0.43,**	**0.99)**	**0.045**	0.85	(0.53,	1.36)	0.506

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis;
SGD referred to Singapore Dollar
Crude OR (COR) was derived from bivariate logistic regression model
Adjusted OR (AOR) was derived from multivariable logistic regression model mutually adjusted for all other socio-demographic factors
*Bolded values are 2-sided p-values <0.05; CI: Confidence interval; *overall p-value*

DISCUSSION

This large multi-ethnic Asian cohort study provides valuable insights into socio-demographic determinants of hypertension within relatively homogeneous living environment and access to health care. We estimated that approximately 1 in 3 participants had hypertension. The strength of the association between socio-demographic factors and hypertension differed across ethnic groups. In addition to the established socio-demographic risk factors (i.e. age and gender), our study adds new evidence about the importance of ethnicity in relation to hypertension. Our stratified analysis suggested that the observed ethnic differences in relation to hypertension was partly attributed to the variability in socio-demographic characteristics of each ethnic group. Educational level rather than household income was an important socio-economic indicator consistently associated with hypertension within all ethnic groups. Almost half of the hypertensives in our study were unaware of having hypertension and 25% of those who were aware of having hypertension remained untreated. Adults under 40 years of age were more likely to be undetected and untreated than older individuals. Male participants were more likely to be untreated than females, and participants with low educational level were more likely to be untreated when compared with those with higher educational level. Among treated participants, more than half did not achieve optimal BP levels and older age was strongly associated with worse BP control.

In agreement with similar studies conducted in other Asian countries[19-22] and Singapore,[14 15] our study further demonstrated that older age is a strong factor associated with hypertension. Ethnic differences in relation to hypertension were observed in our study, consistent with the current literature which was largely conducted in the Western countries.[10 23 24] While the association between Indian ethnicity and hypertension ceased to be significant after the addition of socio-demographic factors, the association between Malay ethnicity and hypertension was statistically significant. The ethnic differences observed in our study were partly explained by the variability in socio-demographic profile within each ethnic group, an interesting finding revealed from the stratified analysis. For instance, Malays and Indians had higher odds ratio than Chinese for every increase in age group. Further, strong associations between gender and hypertension was observed among Chinese and Indian, but not Malay. Higher educational level had been found to be associated with lower prevalence of hypertension in earlier studies,[25 26] and our finding demonstrated that this association was consistent for all ethnic groups. No association between marital status and hypertension was observed in our study. The association between retired/unemployed status and hypertension was significant only among Chinese but not in other ethnic groups. In general, the income-hypertension association was not significant in our study after accounting for age and educational level.

Older participants were more likely to be aware of having hypertension because it is common among the age groups and health policies may have offered screening opportunity to this subgroup. The literature suggested that minority ethnic groups who were hypertensive were more likely to be aware of their hypertension.[9 23] However, our study observed that Malay ethnic who had greater odds of hypertension did not seem to be sufficiently aware of their condition. Conversely, Indians were relatively more aware of having hypertension compared to Chinese. The observed ethnic differences in hypertension awareness may be attributable to variations in lifestyle and cultural factors, and perceived benefit of hypertension prevention and control.[27-29]

Although older age was significantly related to hypertension, older participants in our study were more likely to be aware of having hypertension and treated for the condition. But, younger age, male gender and low educational level were significant determinants for untreated hypertension. Other study demonstrated that the measures of education can better explain variation in hypertension and health inequalities.[12] Low educational attainment may directly or indirectly influence the treatment and control of hypertension through lack of understanding about disease prevention, healthy lifestyle, perceived discrimination, among others.[25] Evidence suggested that education is a critical component of health and it is important to

incorporate educational element in public health promotion and reducing health disparities.[30 31] Older age was significantly associated with uncontrolled hypertension in our study. This finding is consistent with the current evidence[32 33] but also contrasts with other findings which suggested that older adults had better control of BP.[4 20] Lack of control of BP among older adults in our population could due to aging-related physiological changes, comorbidity and variation in response to treatment among older adults.[34] Social factors such as living in social exclusion, limited peer support, and not having sufficient knowledge to cope with their hypertension condition may also affect their BP control.[35]

Strengths and limitations

This study has a number of strengths. First, it is based on a large population-based study of a multi-ethnic Asian population living in an urban city state. Second, the study used standardized and comprehensive methodologies to capture exposure and outcome data. Third, we had purposively over-sampled minority ethnic groups and recruited a large number of study participants to cover a wider age range and diverse socio-demographic profile. Fourth, the findings of this study were robust after adjustment for potential socio-demographic confounders. However, we noted that the study has several important limitations. First, because the study design is cross-sectional, we cannot infer causality and determine the risk of hypertension. Further, this study adopted a convenience sampling methodology. Hence, the ethnic differences observed in this study may not be representative of the general Singapore population . In addition, we excluded individuals with established cardiovascular or cerebrovascular diseases, which are known outcomes of hypertension, to avoid influences on hypertension medication intake and adherence. Thus, the estimated prevalence of hypertension reported in this study would probably have under-estimated the true population prevalence. Despite these limitations with regards to the generalizability of our findings, this study provides important and novel real-life information related to awareness, treatment and control of hypertension in a multi-ethnic Asian population residing in a relatively homogenous living condition. Second, the classification of participants as being treated for hypertension was based on self-reported intake of antihypertensive medication and a participant's compliance to medication was not determined. Third, participants were advised to fast for 8-12 hours before attending health examination. However, assessment on participants' exposures to caffeine and alcohol prior to BP measurements were not carried out, hence this study was not able to rule out that some participants may have been exposed to them. Fourth, BP of participants were measured on only one occasion during the health examination. However, standard BP measurement protocols were used, and multiple BP measurements were taken to minimize measurement error. Fifth, some participants did not provide information about average monthly household income. To overcome this limitation, we had classified them as a separate category (i.e. 'unknown income' group) and included them for analyses. Unmeasured confounding cannot be adjusted for in our study. Although the results are not generalizable to the Singapore population, our findings contributed new insights to the study of hypertension in multi-ethnic urban Asian population. Future more in-depth prospective studies may be useful to examine underlying mechanisms that contribute to differential hypertension outcomes, and uncover the segments of population who may benefit from active prevention and early treatment strategies.

CONCLUSION

In this study, ethnic differences observed in hypertension were associated with socio-demographic variability within ethnic groups. Age and educational level were consistent correlates of hypertension in all ethnic groups. Unawareness and uncontrolled hypertension were common in this Asian population and associated with socio-demographic factors. More targeted strategies may be required to overcome the observed disparities.

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CONTRIBUTORS

LSJ, JLTY and FMR contributed to the study design and development of the study objectives. LSJ acquired the data, conducted analyses and drafted the manuscript. LSJ and RMVD contributed to study methodological strategy; LSJ, JLTY and TCS contributed to the analytic strategies; GKCH and FMR contributed medical insights to guide the analysis and interpretation of results; FMR provided supervision and monitored study progress; All authors reviewed and revised the manuscript.

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COMPETING INTERESTS

None declared

ETHICS APPROVAL

The MEC study was approved by the National University of Singapore Institutional Review Board and SingHealth Centralised Institutional Review Board.

DATA SHARING STATEMENT

The Singapore Population Health Studies Scientific Committee reviews requests for data. The request form is available at https://blog.nus.edu.sg/sphs/.

REFERENCES

1. Organization WH. Noncommunicable diseases. 2017
2. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. (1474-547X (Electronic))
3. Organization WH. Global Health Observatory (GHO) data: NCD mortality and morbidity, 2015.
4. Chow CK, Teo KK, Rangarajan S, et al. Prevalence, awareness, treatment, and control of hypertension in rural and urban communities in high-, middle-, and low-income countries. *JAMA* 2013;310(9):959-68. doi: 10.1001/jama.2013.184182
5. Rahimi K, Emdin CA, MacMahon S. The Epidemiology of Blood Pressure and Its Worldwide Management. *Circulation Research* 2015;116(6):925-36. doi: 10.1161/circresaha.116.304723
6. Hunte HER, Mentz G, House JS, et al. Variations in Hypertension-Related Outcomes Among Blacks, Whites and Hispanics in Two Large Urban Areas and in the United States. *Ethnicity & disease* 2012;22(4):391-97.
7. Marshall A, Nazroo J, Feeney K, et al. Comparison of hypertension healthcare outcomes among older people in the USA and England. *J Epidemiol Community Health* 2016;70(3):264-70.
8. Joffres M, Falaschetti E, Gillespie C, et al. Hypertension prevalence, awareness, treatment and control in national surveys from England, the USA and Canada, and correlation with stroke and ischaemic heart disease mortality: a cross-sectional study. *BMJ open* 2013;3(8):e003423.
9. Thorpe RJ, Bowie JV, Smolen JR, et al. Racial disparities in hypertension awareness and management: Are there differences among African Americans and Whites living in similar social and healthcare resource environments? *Ethnicity & disease* 2014;24(3):269-75.
10. Kramer H, Han C, Post W, et al. Racial/Ethnic differences in hypertension and hypertension treatment and control in the multi-ethnic study of atherosclerosis (MESA)*. *American Journal of Hypertension* 2004;17(10):963-70. doi: 10.1016/j.amjhyper.2004.06.001
11. Holmes L, Hossain J, Ward D, et al. Racial/Ethnic Variability in Hypertension Prevalence and Risk Factors in National Health Interview Survey. *ISRN Hypertension* 2013;2013:8. doi: 10.5402/2013/257842
12. Non AL, Gravlee CC, Mulligan CJ. Education, Genetic Ancestry, and Blood Pressure in African Americans and Whites. *American Journal of Public Health* 2012;102(8):1559-65. doi: 10.2105/AJPH.2011.300448
13. Kaplan MS, Huguet N, Feeny DH, et al. Self-reported hypertension prevalence and income among older adults in Canada and the United States. *Social Science & Medicine* 2010;70(6):844-49. doi: https://doi.org/10.1016/j.socscimed.2009.11.019
14. Malhotra R, Chan A, Malhotra C, et al. Prevalence, awareness, treatment and control of hypertension in the elderly population of Singapore. *Hypertension Research* 2010;33:1223. doi: 10.1038/hr.2010.177
15. Wu Y, Tai ES, Heng D, et al. Risk factors associated with hypertension awareness, treatment, and control in a multi-ethnic Asian population. *Journal of Hypertension* 2009;27(1):190-97. doi: 10.1097/HJH.0b013e328317c8c3
16. Khoo CM, Heng D, Tai ES, et al. Is There a Clear Threshold for Fasting Plasma Glucose That Differentiates Between Those With and Without Neuropathy and Chronic Kidney Disease?: The Singapore Prospective Study Program. *American Journal of Epidemiology* 2009;169(12):1454-62. doi: 10.1093/aje/kwp076
17. Yeo KK, Tai BC, Heng D, et al. Ethnicity modifies the association between diabetes mellitus and ischaemic heart disease in Chinese, Malays and Asian Indians living in Singapore. *Diabetologia* 2006;49(12):2866-73. doi: 10.1007/s00125-006-0469-z

18. Tan KHX, Tan LWL, Sim X, et al. Cohort Profile: The Singapore Multi-Ethnic Cohort (MEC) study. *International Journal of Epidemiology* 2018;47(3):699-99j. doi: 10.1093/ije/dyy014
19. Li W, Gu H, Teo KK, et al. Hypertension prevalence, awareness, treatment, and control in 115 rural and urban communities involving 47 000 people from China. *Journal of Hypertension* 2016;34(1):39-46. doi: 10.1097/hjh.0000000000000745
20. Liu X, Gu W, Li Z, et al. Hypertension prevalence, awareness, treatment, control, and associated factors in Southwest China: an update. *Journal of Hypertension* 2017;35(3):637-44. doi: 10.1097/hjh.0000000000001203
21. Abdul-Razak S, Daher AM, Ramli AS, et al. Prevalence, awareness, treatment, control and socio demographic determinants of hypertension in Malaysian adults. *BMC Public Health* 2016;16(1):351. doi: 10.1186/s12889-016-3008-y
22. B Bjertness M, Htet A, E Meyer H, et al. Prevalence and determinants of hypertension in Myanmar - A nationwide cross-sectional study2016.
23. Balfour PC, Rodriguez CJ, Ferdinand KC. The Role of Hypertension in Race-Ethnic Disparities in Cardiovascular Disease. *Current cardiovascular risk reports* 2015;9(4):18. doi: 10.1007/s12170-015-0446-5
24. Modesti PA, Reboldi G, Cappuccio FP, et al. Panethnic Differences in Blood Pressure in Europe: A Systematic Review and Meta-Analysis. *PLOS ONE* 2016;11(1):e0147601. doi: 10.1371/journal.pone.0147601
25. Alves RFS, Faerstein E. Educational inequalities in hypertension: complex patterns in intersections with gender and race in Brazil. *International Journal for Equity in Health* 2016;15:146. doi: 10.1186/s12939-016-0441-6
26. Lee H-Y. Socioeconomic Disparities in the Prevalence, Diagnosis, and Control of Hypertension in the Context of a Universal Health Insurance System. *Journal of Korean Medical Science* 2017;32(4):561-67. doi: 10.3346/jkms.2017.32.4.561
27. Okonofua EC, Cutler NE, Lackland DT, et al. Ethnic Differences in Older Americans: Awareness, Knowledge, and Beliefs About Hypertension*. *American Journal of Hypertension* 2005;18(7):972-79. doi: 10.1016/j.amjhyper.2005.02.019
28. Pettey CM, McSweeney JC, Stewart KE, et al. African Americans' Perceptions of Adherence to Medications and Lifestyle Changes Prescribed to Treat Hypertension. *SAGE open* 2016;6(1):10.1177/2158244015623595.
29. Peters RM, Aroian KJ, Flack JM. African American Culture and Hypertension Prevention. *Western journal of nursing research* 2006;28(7):831-63. doi: 10.1177/0193945906289332
30. Hahn RA, Truman BI. Education Improves Public Health and Promotes Health Equity. *International journal of health services : planning, administration, evaluation* 2015;45(4):657-78. doi: 10.1177/0020731415585986
31. Zajacova A, Lawrence EM. The Relationship Between Education and Health: Reducing Disparities Through a Contextual Approach. *Annual Review of Public Health* 2018;39(1):273-89. doi: 10.1146/annurev-publhealth-031816-044628
32. Seow LSE, Subramaniam M, Abdin E, et al. Hypertension and its associated risks among Singapore elderly residential population. *Journal of Clinical Gerontology and Geriatrics* 2015;6(4):125-32. doi: https://doi.org/10.1016/j.jcgg.2015.05.002
33. Doulougou B, Gomez F, Alvarado B, et al. Factors associated with hypertension prevalence, awareness, treatment and control among participants in the International Mobility in Aging Study (IMIAS). *Journal Of Human Hypertension* 2015;30:112. doi: 10.1038/jhh.2015.30 https://www.nature.com/articles/jhh201530#supplementary-information
34. Lionakis N, Mendrinos D, Sanidas E, et al. Hypertension in the elderly. *World Journal of Cardiology* 2012;4(5):135-47. doi: 10.4330/wjc.v4.i5.135
35. Coyle CE. The Effects of Loneliness and Social Isolation on Hypertension in Later Life: Including Risk, Diagnosis and Management of the Chronic Condition. *Graduate Doctoral Dissertations* 2014;174

Online-only Supplementary

Table S-1: Characteristics of participants by ethnic group

Socio-demographic factors	Chinese					Malay					Indian				
	Normotensive		Hypertensive		p-value	Normotensive		Hypertensive		p-value	Normotensive		Hypertensive		p-value
	n	(%)	n	(%)		n	(%)	n	(%)		n	(%)	n	(%)	
Age (years), mean (SD)	42.22	(11.28)	54.71	(11.42)	<0.001	40.13	(11.10)	53.04	(10.93)	<0.001	41.17	(11.20)	53.77	(11.09)	<0.001
Gender, n (%)					<0.001					0.181					0.004
Female	1,921	(72.4)	734	(27.6)		1,031	(65.9)	533	(34.1)		1,161	(73.7)	415	(26.3)	
Male	1,377	(63.7)	785	(36.3)		749	(68.4)	346	(31.6)		797	(68.6)	365	(31.4)	
Blood pressure, mean (SD)															
Systolic blood pressure	116.74	(11.97)	149.09	(16.80)	<0.001	118.03	(12.02)	150.04	(17.33)	<0.001	114.49	(12.91)	147.24	(18.70)	<0.001
Diastolic blood pressure	70.40	(8.48)	84.40	(10.57)	<0.001	69.78	(8.33)	83.32	(11.07)	<0.001	69.14	(8.64)	82.18	(11.40)	<0.001
Highest education level, n (%)					<0.001					<0.001					<0.001
Primary or lower	499	(46.5)	573	(53.5)		419	(51.2)	400	(48.8)		511	(58.6)	361	(41.4)	
Secondary	1,228	(68.6)	561	(31.4)		1,027	(71.8)	404	(28.2)		820	(72.8)	306	(27.2)	
Tertiary or higher	1,569	(80.3)	385	(19.7)		332	(81.6)	75	(18.4)		626	(84.7)	113	(15.3)	
Marital status, n (%)					<0.001					0.001					0.832
Currently married	2,366	(65.6)	1,242	(34.4)		1,359	(65.3)	721	(34.7)		1,477	(71.4)	592	(28.6)	
Not married/divorced/separated	930	(77.1)	277	(22.9)		420	(72.7)	158	(27.3)		479	(71.8)	188	(28.2)	
Work status, n (%)					<0.001					<0.001					<0.001
Working/Studying full-time	2,642	(74.2)	919	(25.8)		1,209	(74.3)	419	(25.7)		1,355	(76.0)	428	(24.0)	
Homemaker	475	(59.7)	321	(40.3)		467	(58.1)	337	(41.9)		436	(65.7)	228	(34.3)	
Retired/Unemployed	162	(37.4)	271	(62.6)		99	(45.6)	118	(54.4)		158	(56.4)	122	(43.6)	
Monthly household income (SGD)^, n (%)					<0.001					<0.001					<0.001
<2,000	379	(57.7)	278	(42.3)		543	(67.8)	258	(32.2)		555	(67.8)	264	(32.2)	
2,000-3,999	713	(73.3)	260	(26.7)		563	(70.9)	231	(29.1)		603	(70.8)	249	(29.2)	
4,000-5,999	554	(75.2)	183	(24.8)		317	(70.8)	131	(29.2)		382	(79.7)	97	(20.3)	
≥6,000	707	(75.2)	233	(24.8)		162	(78.6)	44	(21.4)		244	(77.2)	72	(22.8)	

^Of all participants, 21.5% did not provide information on their averaged monthly household income. They have been categorized as 'unknown income' and included for analysis;
n refers to number, SD refers to standard deviation
SGD refers to Singapore Dollars
For categorical variables, we reported the counts and percentages, and used the chi-square test to assess association between each categorical variable and hypertension status. For continuous variables, we reported the mean and standard deviation and used the 2-sample independent t-test to assess association between the continuous variable and hypertension status.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,7
Bias	9	Describe any efforts to address potential sources of bias	*6,7*
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, 10 (Table 1)
		(b) Indicate number of participants with missing data for each variable of interest	10 (Table 1)
Outcome data	15*	Report numbers of outcome events or summary measures	9-14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11, 13-14
		(*b*) Report category boundaries when continuous variables were categorized	10-11, 13-14
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.