Public Health Nutrition: 24(13), 4245–4256 doi:10.1017/S1368980021002044

Differential educational patterning of cardiometabolic risks between women and men among community-dwelling Chinese adults in Hong Kong: the mediating role of obesity

Gary KK Chung[1,2], Francisco TT Lai[1,3], Heidi Hung[1], Eng-Kiong Yeoh[1,2] and Roger Y Chung[1,2,*]

[1]JC School of Public Health and Primary Care, Faculty of Medicine, The Chinese University of Hong Kong, 4/F, Shatin, New Territories, Hong Kong, People's Republic of China: [2]CUHK Institute of Health Equity, The Chinese University of Hong Kong, Hong Kong, People's Republic of China: [3]Department of Pharmacology and Pharmacy, The University of Hong Kong, Hong Kong, People's Republic of China

Submitted 7 September 2020: Final revision received 28 April 2021: Accepted 7 May 2021: First published online 26 May 2021

Abstract
Objectives: Educational inequalities in cardiometabolic diseases (CMD) are globally recognised; nonetheless, the evidence on potential explanatory mechanisms and effective strategies for CMD prevention and inequality reduction is relatively scarce in Asia. Therefore, the current study examined the extent and potential mediators of the association of education level with CMD conditions (i.e., hypertension and diabetes) in an advanced economy in Asia.
Design: A cross-sectional study.
Setting: This territory-wide cross-sectional Population Health Survey in 2014–2015 was performed in Hong Kong. Demographic, socio-economic and lifestyle factors were collected via questionnaire, while clinical data on blood pressure and glucose levels, lipid profiles and anthropometric measures were obtained during health examination. Hypertension and diabetes statuses were objectively defined by both clinical data and the use of relevant medications.
Participants: 2297 community-dwelling adults aged between 15–84 years recruited via systematic replicated sampling of living quarters.
Results: Multivariable binary logistic regression analysis showed that lower education level was significantly associated with hypertension among women but not men, whereas similar pattern was also observed for diabetes and other related clinical risk factors. Also, general and abdominal obesity were independently associated with hypertension and diabetes among both women and men, and substantially mediated the observed inequalities across education levels among women. Specifically, abdominal obesity was a particularly strong risk factor and mediator for diabetes.
Conclusion: Educational patterning of CMD was more apparent among women in Hong Kong. Obesity control appears to be important for both overall CMD prevention and reduction of educational inequalities in CMD among women.

Keywords
Cardiometabolic diseases
Obesity
Gender
Socio-economic
Chinese

Cardiometabolic diseases (CMD), including hypertension, diabetes and more advanced cardiovascular conditions, are increasingly prevalent across the globe[1]. Despite the growing national and international effort on CMD control, reducing the burden of CMD and associated inequalities across social groups has remained a long-standing public health challenge[1]. A large body of research in developed world regions suggested a greater prevalence or incidence of hypertension and diabetes among the less educated[2,3], leading to disproportionate burden of health and social care across education levels. Specifically, in the Asian settings, the extent of educational inequalities in CMD morbidity or mortality appears to be more apparent than many other developed settings including Australasia, America and some western European countries[4,5], suggesting the public health significance for addressing educational inequalities in CMD in Asia.

*Corresponding author: Email rychung@cuhk.edu.hk

Apart from the educational inequalities in CMD, research on the patterning across social groups and major explanatory mechanisms remained understudied among the Asian populations. In the past decade, a few studies in China and South Korea showed a more evident patterning of hypertension, diabetes and other CMD risk factors across education levels among women relative to men[6–12]. Also, while a range of clinical risk factors, including the levels of blood pressure and blood glucose, lipid profiles and obesity, have been proposed to explain the association between lower education level and CMD[13], these relevant studies were mainly conducted in the Western settings, limiting their generalisability to the Asian settings. To design cost-effective strategies to tackle the potential educational inequalities in CMD in Asia, it is necessary to consider the possible gender difference in the social patterning of CMD and to identify the key risk factors that may also be disproportionately distributed among the less educated when compared with the better educated in the Asian context.

Hong Kong serves as an ideal setting to investigate the educational inequality in CMD in Asia, since it had experienced rapid economic and epidemiologic transitions in the second half of the twentieth century[14] and could act as an exemplar to the rapidly developing China and other emerging Asian economies. Also, a re-examination of educational inequality in CMD in Hong Kong is warranted as the relevant evidence is rather outdated. Research in Hong Kong with the primary objective to assess socio-economic inequality in CMD was mostly based on data around or before the early 2000s[15–19], while more recent studies relied on self-reported data[20,21]. The latest relevant research in Hong Kong focused specifically on obesity rather than other CMD conditions and supported a greater burden of abdominal obesity among the socially deprived[22]. In light of this, the present study first examined the associations of education level with objectively measured hypertension and diabetes by women and men among Chinese adults in Hong Kong. Secondly, we assessed the associations of clinical risk factors, including general and abdominal obesity, blood pressure, blood glucose and lipid profiles, with hypertension and diabetes, respectively. Finally, we estimated the potential mediating effect of the significant clinical risk factors on any observed associations of education level with hypertension and diabetes.

Methods

Study population

In the current study, we used the data collected in the territory-wide cross-sectional Population Health Survey (PHS) conducted by the Department of Health of the Hong Kong Special Administrative Region Government in 2014–2015, which covered the land-based non-institutional population aged 15 years or above in Hong Kong, excluding foreign domestic helpers and visitors of Hong Kong. The PHS comprised two parts, a household survey for all recruited respondents and subsequently a health examination for a random subsample of eligible and consented respondents[23]. The household survey part adopted the Frame of Quarters maintained by the Census and Statistics Department of Hong Kong as the sampling frame. The Frame of Quarters consists of the Register of Quarters and the Register of Segments, of which the former contains records of all addresses of permanent quarters (i.e., dwellings in a residential building) in built-up areas, whereas the latter contains records of area segments (i.e., small districts) in non-built-up areas. Specifically, records in the Frame of Quarters were first stratified by geographical area and type of quarters (records in the Register of Segments were sorted by geographical area only as quarters in these area segments may not have clear addresses and thus cannot be identified individually). Then, systematic replicated sampling was applied in each stratum for sample selection. Living quarters were drawn systematically to form replicates according to fixed sampling interval by making use of non-repetitive random numbers. Hence, the Frame of Quarters was divided into a large number of replicates comprising about 500 quarters each (including both permanent quarters and quarters in segments). Each replicate could be deemed as a representative sample of domestic households in Hong Kong. These replicates of living quarters were then randomly sampled. All eligible individuals aged 15 years or above in the households of selected living quarters were enumerated individually. Eventually, 12 022 individuals from 5435 domestic households were successfully recruited, representing a household response rate of 75·4 %.

Upon completing a structured questionnaire administered by trained interviewers, all respondents aged between 15 and 84 years were further invited to sign a PHS consent form of health examination. For respondents under 18 years of age, their consent forms were signed by parents or guardians. Eligible and consented respondents were randomly selected to undergo a follow-up health examination. In total, 2347 respondents aged between 15 and 84 years had completed both the household survey and the health examination. After excluding the missing data, outliers and dubious clinical readings (n 50), 2297 respondents were eventually included in the final sample for complete case analyses.

Measurements

Demographic and socio-economic characteristics were obtained using questionnaire. Specifically, marital status was classified as 'married' and 'non-married' (including never married, divorced, separated and widowed). With reference to the International Standard Classification of Education proposed by the Organisation for Economic Co-operation and Development[24], the highest attained education level was grouped into 'primary or below' 'lower secondary' 'upper secondary' 'sub-degree' (i.e., post-secondary education below degree level including technical/vocational training, diploma programmes and other non-degree certificate courses) and 'degree or above'. The self-reported monthly household income, in Hong Kong dollars (HKD\$7·8 ≈ USD\$1), was categorised into '\$0–9999' '\$10000–29999' '\$30000–49999' and '≥ \$50 000'.

As for lifestyle factors, smoking status was categorised into 'currently smoking', 'previously smoking' and 'never smoking'. Based on data on the average volume and types of alcoholic beverages consumed in the 12 months preceding the survey, the consumption level of alcohol was classified as '0' '0·1–2' '2·1–4' and '> 4' alcohol units/d (1 alcohol unit = drink volume (ml) × alcohol content (% by volume) × 0·789/1000). As for the fruit and vegetable intake level, respondents were first asked about the intake frequency and then the serving on a typical day they consumed fruits and vegetables, respectively. One serving of fruit was defined as equivalent to half piece of large-sized fruit (e.g., banana) or one piece of medium-sized fruit (e.g., apple, orange and pear), whereas one serving of vegetables was defined as equivalent to a bowl of raw leafy vegetables or half a bowl of cooked vegetables. The fruit and vegetable intake level per day was estimated by taking the sum of the average daily servings of fruits and that of vegetables, and then grouped into '0–1·9'" '2–4·9' and '≥ 5' servings/d. The physical activity level of respondents was assessed using the Global Physical Activity Questionnaire developed by the WHO for physical activity surveillance[25]. Information on the respondent's physical activity participation in a typical week for work, travel between places and recreational activities, including the number of days and time spent in each setting, was collected. The average time spent across types of physical activities per week was assessed. Hence, the metabolic equivalent of task-min/week of respondents was calculated based on the analysis guide for Global Physical Activity Questionnaire[25] and then ranked by quartiles.

Regarding measurements on hypertension, diabetes and other clinical cardiometabolic risk factors, we collected data on blood pressure, blood glucose, general and abdominal obesity, lipid profiles and self-reported use of the medications and insulin therapy. During the health examination, anthropometric and blood pressure measurements, as well as blood tests for biochemical markers, were conducted by trained staff supervised by medical practitioners in designated health examination centres. Procedures of all physical and biochemical measurements complied with the WHO STEPwise approach to surveillance Manual[26]. In the current study, hypertension and diabetes were regarded as the primary CMD outcomes. Hypertension was defined as systolic blood pressure ≥ 140 mmHg, and/or diastolic blood pressure ≥ 90 mmHg, and/or use of anti-hypertensive medications[27], whereas diabetes was defined as $HbA_{1c} \geq 6{\cdot}5\,\%$, and/or fasting plasma glucose ≥ 7 mmol/l, and/or use of insulin, and/or use of anti-diabetic medications[28,29]. As for other clinical cardiometabolic risk factors, general obesity was defined as BMI ≥ 25 kg/m^2 according to the official classification of BMI adopted by the Hong Kong Government. As such a classification may not be the most up-to-date, sensitivity analyses using an alternative cut-off of BMI ≥ 27 kg/m^2 were performed to ensure the robustness of our results[30]. Abdominal obesity was defined as waist-to-hip ratio ≥ 0·85 for female or ≥ 0·9 for male[31,32]. Regarding the lipid profiles, LDL-cholesterol ≥ 160 mg/dl, HDL-cholesterol < 40 mg/dl, total cholesterol ≥ 240 mg/dl and total TAG ≥ 200 mg/dl were considered as unhealthy lipid profiles according to the National Cholesterol Education Program Adult Treatment Panel III classification[33].

Statistical analyses

Continuous variables were reported as mean and SD, while categorical variables were reported as percentages. The crude associations of sample characteristics with education levels were tested by Mantel–Haenszel test for trend or one-way ANOVA.

As for multivariable analyses, Fig. 1 displays the conceptual framework on the separate associations of education with both hypertension and diabetes, the possible mediating roles of clinical cardiometabolic risk factors and lifestyle factors, and the potential effect modification between women and men. As the current study aimed to explore the mediating roles of clinical cardiometabolic risk factors, we focused on the indirect pathway through these clinical risk factors while adjusting for the effects of lifestyle factors and other potential confounding factors for analyses in the current study. Multiple binary logistic regressions, stratified by women and men, were first employed to examine the associations of education level with hypertension, diabetes and related clinical risk factors, controlling for demographic, socio-economic and lifestyle factors. Interaction terms between education and gender were also included to test for the potential effect modification between women and men, with $P < 0{\cdot}2$ as the cut-off for statistical significance to avoid missing a true interaction effect due to inadequate statistical power[34]. Second, the associations of clinical risk factors with hypertension and diabetes were also examined. Finally, for the respective association of education with hypertension and that with diabetes, we performed two separate multiple mediation analyses according to the method proposed by Preacher and Hayes[35]. The mediating roles of clinical risk factors that were significantly associated with hypertension and diabetes (as identified in the second part of analysis) were simultaneously assessed in the mediation analyses. Specifically, we estimated the indirect effects and the resultant mediation ratios through these clinical risk factors in the multivariable binary logistic regression analyses for hypertension and diabetes, with adjustments for the same set of potential confounders. All data analyses were conducted using statistical software R 3.4.0 and Stata 14. OR and 95 % CI are presented, and all statistical tests were two-tailed with a significance level of $P < 0{\cdot}05$.

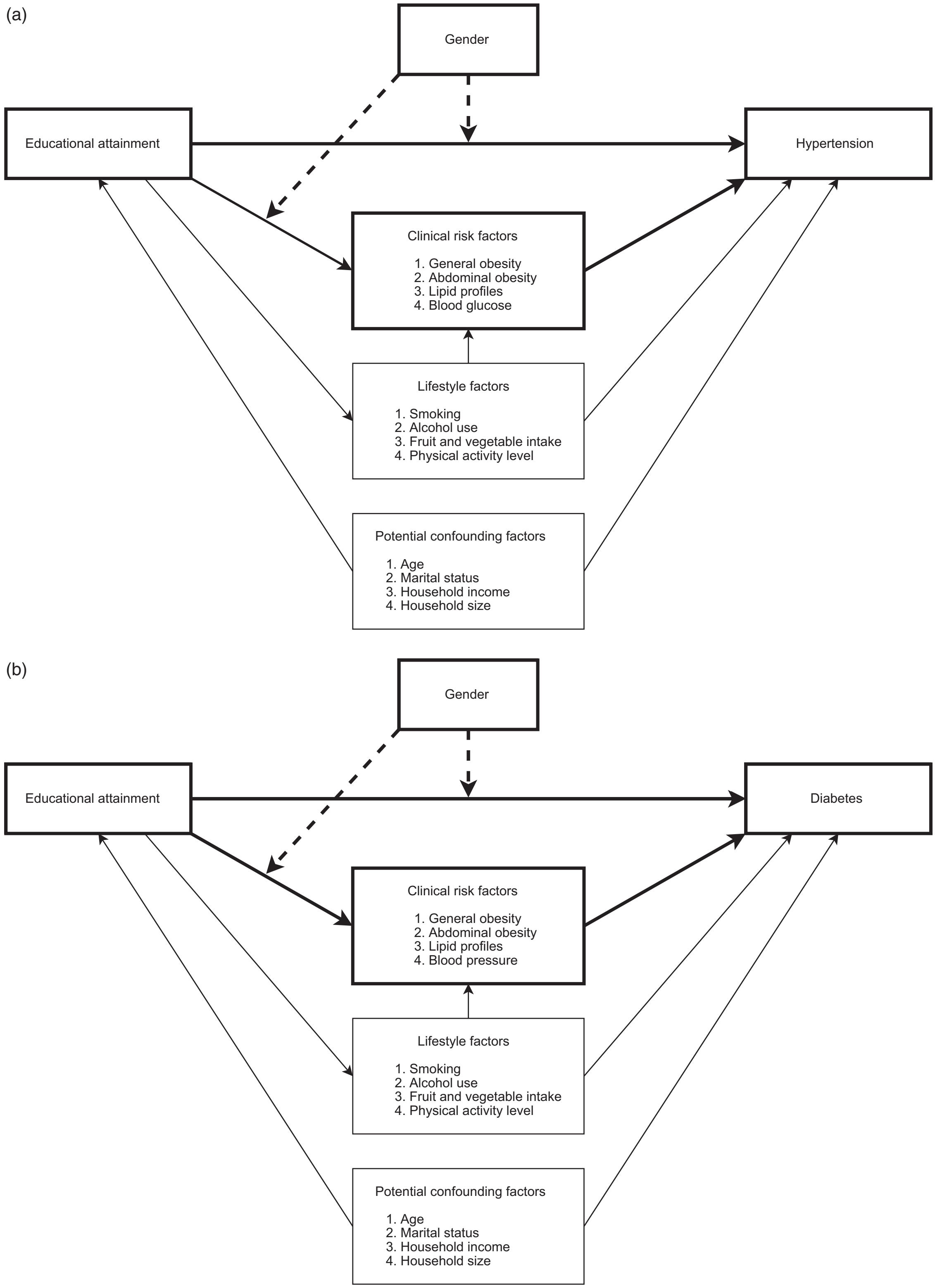

Fig. 1 Conceptual framework on the associations of education with (a) hypertension and (b) diabetes, the possible mediating roles of clinical cardiometabolic risk factors and the potential effect modification between women and men. Solid bold arrows represent main associations; solid thin arrows represent associations that were taken in account only for adjustment; dashed arrows represent effect modifications

https://doi.org/10.1017/S1368980021002044 Published online by Cambridge University Press

Table 1 Characteristics of respondents sampled in the Population Health Survey 2014–2015 of Hong Kong, stratified by education levels* (*n* 2297)

	Total (*n* 2297)		Education level: Primary or below (*n* 335)		Lower secondary (*n* 344)		Upper secondary (*n* 755)		Sub-degree (*n* 280)		Degree or above (*n* 583)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P*†
Demographic and socio-economic characteristics													
Age (years)	59·3	9·2	63·0	10·7	47·3	17·4	41·5	16·2	35·8	15·0	36·2	13·1	<0·001
% women	52·5		67·2		50·0		51·3		48·9		48·9		<0·001
Marital status (% married)	58·2		75·8		72·4		58·5		43·6		46·5		<0·001
Household size	3·1	1·2	3·2	1·4	3·5	1·2	3·4	1·3	3·3	1·1	3·2	1·2	0·008
Household income (%)													<0·001
HKD$0–9999	11·0		26·6		10·8		9·9		7·5		5·1		
HKD$10 000–29 999	35·0		34·9		51·2		41·6		32·5		18·2		
HKD$30 000–49 999	30·0		29·3		24·7		32·2		34·3		28·5		
≥ HKD$50 000	24·1		9·3		13·4		16·3		25·7		48·2		
Lifestyle factors													
Smoking (%)													<0·001
Currently smoking	10·8		9·6		19·8		13·9		7·1		4·1		
Previously smoking	12·7		15·8		17·7		12·3		13·9		7·9		
Never smoking	76·4		74·6		62·5		73·8		78·9		88·0		
Alcohol unit/d (%)													<0·001
0	34·6		47·8		42·2		37·0		26·1		23·5		
0·1–2	34·5		34·0		33·7		33·6		36·8		35·3		
2·1–4	21·7		14·0		17·7		19·2		27·5		28·8		
> 4	9·2		4·2		6·4		10·2		9·6		12·3		
Serving of fruit and vegetable intake (%)													0·003
0–1·9	62·6		53·7		64·8		62·5		65·0		65·5		
2–4·9	33·8		40·9		32·3		34·3		30·0		31·7		
≥ 5	3·6		5·4		2·9		3·2		5·0		2·7		
Physical activity level (%)													<0·001
1st quartile (≤ 618 MET-min/week)	25·2		23·6		20·3		23·0		27·5		30·7		
2nd quartile (961–1501 MET-min/week)	24·8		25·4		21·5		24·4		27·5		25·6		
3rd quartile (1502–2708 MET-min/week)	25·0		26·0		25·6		24·9		21·8		25·7		
4th quartile (≥ 2709 MET-min/week)	25·0		25·1		32·6		27·7		23·2		18·0		
Clinical risk factors													
BMI (% ≥ 25 kg/m^2)	28·7		39·7		30·5		26·8		30·7		23·0		<0·001
WHR (% ≥ 0·85 for female/≥ 0·9 for male)	37·5		66·3		47·1		36·2		25·0		23·0		<0·001
LDL-cholesterol (% ≥ 160 mg/dl)	12·5		18·2		15·1		11·5		9·3		10·5		<0·001
HDL-cholesterol (% < 40 mg/dl)	13·5		14·3		15·1		14·2		14·6		10·5		0·052
TC (% ≥ 240 mg/dl)	12·0		18·5		16·6		10·5		7·5		9·6		<0·001
TAG (% ≥ 200 mg/dl)	6·7		8·1		12·2		5·6		6·4		4·3		<0·001
FPG (% ≥ 7 mmol/l)	2·6		5·4		3·8		2·3		2·1		1·0		<0·001
HbA_{1c} (% ≥ 6·5 %)	6·5		15·8		8·4		4·8		5·0		3·1		<0·001
SBP (% ≥ 140 mmHg)	14·6		37·0		17·2		12·3		9·3		5·8		<0·001
DBP (% ≥ 90 mmHg)	12·9		16·4		13·7		14·0		9·6		10·6		0·005
Cardiometabolic disease conditions													
Hypertension (% yes)	25·0		52·8		29·1		22·3		16·8		14·2		<0·001
Diabetes (% yes)	7·6		17·3		9·9		5·8		5·7		3·8		<0·001

*Values are percentages for categorical variables and means (SD) for continuous variables.
†Mantel–Haenszel test for trend was used for categorical variables, while one-way ANOVA was used for continuous variables.

Results

Among the 2297 respondents, 335 (14·6 %) had their highest attained education of primary level or below, whereas 583 (25·4 %) held a degree or above (Table 1). Less educated respondents tended to be older, women, married, smoking, more physically active, as well as having lower household income, lower alcohol consumption but higher fruit and vegetable intake. Also, the less educated were prone to hypertension and diabetes and performed worse in terms of clinical risk factors.

The educational patterning of hypertension, diabetes and most clinical risk factors differed between women and men, given the statistically significant interaction terms between education level and gender (Table 2). Controlling for demographic, socio-economic and lifestyle factors, lower education level was significantly associated with hypertension among women (primary or below: OR = 2·33; 95 % CI (1·19, 4·59), lower secondary: OR = 2·92; 95 % CI (1·45, 5·87), when compared with degree holders or above) but not among men, indicating a gender difference in the association of education with

https://doi.org/10.1017/S1368980021002044 Published online by Cambridge University Press

Table 2 Binary logistic regression on the associations of education with cardiometabolic disease conditions and related risk factors among respondents sampled in the Health Survey 2014–2015 of Hong Kong, stratified by women and men (*n* 2297)

	Education level									Education × gender interaction
	Primary or below (*n* 335)		Lower secondary (*n* 344)		Upper secondary (*n* 755)		Sub-degree level (*n* 280)		Degree or above (*n* 583)	
	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI		Global *P*‡
Cardiometabolic disease outcomes										
Hypertension										0·008
Women†	2·33	1·19, 4·59*	2·92	1·45, 5·87**	1·78	0·96, 3·30	1·64	0·74, 3·62	Ref	
Men†	1·19	0·64, 2·23	0·92	0·51, 1·63	1·26	0·80, 1·97	1·24	0·71, 2·18	Ref	
P-values for education × gender interaction‡	0·005		0·003		0·245		0·492			
Diabetes										0·123
Women†	3·34	0·88, 12·71	3·26	0·82, 12·93	1·80	0·47, 6·91	3·93	0·90, 17·07	ref	
Men†	0·74	0·32, 1·71	0·81	0·35, 1·85	0·97	0·48, 1·93	1·09	0·46, 2·61	ref	
P-values for education × gender interaction‡	0·031		0·070		0·415		0·175			
Clinical risk factors										
BMI ≥ 25 kg/m^2										0·001
Women†	2·70	1·54, 4·71***	1·71	0·97, 3·00	1·61	1·01, 2·58*	2·33	1·35, 4·00**	ref	
Men†	0·74	0·42, 1·30	0·85	0·53, 1·37	0·86	0·59, 1·25	1·17	0·76, 1·82	ref	
P-values for education × gender interaction‡	<0·001		0·042		0·023		0·045			
WHR ≥ 0·85 (female)/≥ 0·9 (male)										0·015
Women†	2·69	1·59, 4·53***	1·86	1·11, 3·10*	1·44	0·94, 2·22	1·33	0·77, 2·28	ref	
Men†	1·01	0·56, 1·83	1·29	0·78, 2·14	1·31	0·88, 1·95	0·89	0·54, 1·46	ref	
P-values for education × gender interaction‡	0·001		0·092		0·388		0·196			
LDL-cholesterol ≥ 160 mg/dl										<0·001
Women†	2·11	0·96, 4·64	2·84	1·31, 6·17**	2·61	1·33, 5·13**	1·29	0·51, 3·24	ref	
Men†	0·74	0·32, 1·71	0·81	0·35, 1·85	0·97	0·48, 1·93	1·09	0·46, 2·61	ref	
P-values for education × gender interaction‡	0·001		0·002		<0·001		0·415			
HDL-cholesterol < 40 mg/dl										0·822
Women†	1·67	0·66, 4·25	1·16	0·46, 2·90	1·63	0·78, 3·40	1·35	0·55, 3·34	ref	
Men†	0·96	0·50, 1·84	0·89	0·51, 1·55	0·94	0·60, 1·47	1·36	0·81, 2·27	ref	
P-values for education × gender interaction‡	0·681		0·896		0·385		0·791			
TC ≥ 240 mg/dl										0·001
Women†	1·56	0·74, 3·29	2·22	1·06, 4·66*	1·92	1·00, 3·67*	1·00	0·40, 2·48	ref	
Men†	0·55	0·24, 1·25	0·85	0·43, 1·66	0·47	0·27, 0·84*	0·61	0·31, 1·22	ref	
P-values for education × gender interaction‡	0·001		0·015		<0·001		0·465			
TAG ≥ 200 mg/dl										0·035
Women†	1·96	0·63, 6·15	2·11	0·68, 6·56	2·19	0·81, 5·93	1·69	0·49, 5·88	ref	
Men†	0·58	0·21, 1·60	1·73	0·81, 3·69	0·55	0·27, 1·14	1·29	0·60, 2·79	ref	
P-values for education × gender interaction‡	0·048		0·966		0·056		0·955			
SBP ≥ 140 mmHg										0·143
Women†	1·97	0·85, 4·55	2·80	1·17, 6·69*	2·05	0·92, 4·58	1·60	0·58, 4·43	ref	
Men†	1·77	0·85, 3·68	0·89	0·42, 1·88	1·24	0·68, 2·27	1·68	0·80, 3·50	ref	
P-values for education × gender interaction‡	0·391		0·026		0·280		0·998			
DBP ≥ 90 mmHg										0·115
Women†	1·43	0·64, 3·19	2·22	1·00, 4·95	2·37	1·20, 4·70*	1·94	0·84, 4·47	ref	
Men†	0·74	0·36, 1·51	0·74	0·39, 1·39	0·98	0·61, 1·58	0·68	0·36, 1·29	ref	
P-values for education × gender interaction‡	0·023		0·023		0·033		0·057			
FPG ≥ 7 mmol/l										0·810
Women†	7·51	0·69, 81·28	5·47	0·51, 58·59	2·70	0·27, 26·84	4·66	0·40, 54·21	ref	
Men†	0·58	0·21, 1·60	1·73	0·81, 3·69	0·55	0·27, 1·14	1·29	0·60, 2·79	ref	
P-values for education × gender interaction‡	0·492		0·711		0·995		0·524			
HbA_{1c} ≥ 6·5 %										0·077
Women†	4·57	0·94, 22·15	3·78	0·75, 19·02	1·73	0·34, 8·74	5·81	1·09, 30·89*	ref	

Public Health Nutrition

https://doi.org/10.1017/S1368980021002044 Published online by Cambridge University Press

Table 2 *Continued*

	Education level									Education × gender interaction
	Primary or below (*n* 335)		Lower secondary (*n* 344)		Upper secondary (*n* 755)		Sub-degree level (*n* 280)		Degree or above (*n* 583)	
	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI		Global *P*‡
Men†	0·81	0·34, 1·95	0·83	0·35, 1·99	0·96	0·46, 2·00	0·99	0·39, 2·53	ref	
P-values for education × gender interaction‡	0·037		0·076		0·523		0·093			

DBP, diastolic blood pressure; FPG, fasting plasma glucose; HbA_{1c}, haemoglobin A_{1c}; SBP, systolic blood pressure; TC, total cholesterol; WHR, waist-to-hip ratio.
$^{*}P<0·05$, $^{**}P<0·01$, $^{***}P<0·001$.
†Adjusted for age, marital status, household income, household size, smoking, alcohol use, fruit and vegetable intake, and physical activity level for each cardiometabolic outcome or clinical risk factor.
‡Adjusted for age, gender, marital status, household income, household size, smoking, alcohol use, fruit and vegetable intake, physical activity level and the education × gender interaction terms in the total sample.

hypertension ($P=0·008$ for the interaction term between education and gender). Although no significant associations were found with diabetes, lower education level also tended to be associated with increased odds of diabetes among women but reduced odds among men ($P=0·123$ for the interaction term between education and gender). Similar gender-specific patterns were also observed for the association of education with other clinical risk factors, including general and abdominal obesity and higher LDL-cholesterol, total cholesterol, TAG, blood pressure and HbA_{1c} levels ($P<0·2$ for their corresponding interaction terms between education and gender). Sensitivity analysis using an alternative cut-off for general obesity yielded consistent results (see online supplementary material, Supplemental Table 1).

Among all the clinical risk factors, general and abdominal obesity were independently associated with hypertension and diabetes regardless of women and men (Table 3). After controlling for demographic, socio-economic, lifestyle factors and other clinical risk factors, respondents with general obesity showed increased odds of having hypertension (OR = 2·81; 95 % CI (1·91, 4·12) for women, OR = 2·19; 95 % CI (1·55, 3·09 for men) and diabetes (OR = 1·79; 95 % CI (1·01, 3·17) for women, OR = 2·45; 95 % CI (1·48, 4·05) for men). Sensitivity analysis using an alternative cut-off for general obesity showed comparable pattern despite a relatively stronger effect with hypertension among women (see online supplementary material, Supplemental Table 2). Abdominal obesity was also associated with hypertension among women (OR = 2·19; 95 % CI (1·55, 3·09) and diabetes (OR = 3·33; 95 % CI (1·67, 6·57) for women, OR = 1·91; 95 % CI (1·12, 3·25) for men). Nonetheless, no significant associations were observed for other clinical risk factors.

Given that general and abdominal obesity were the only significant clinical risk factors of hypertension and diabetes and that educational inequalities in both diseases were observed only among women, their mediating roles were simultaneously assessed in separate multiple mediation models with hypertension and diabetes (Fig. 2). Significant total indirect effects through both general obesity and abdominal obesity were observed for the associations of education level with hypertension (mediation ratio = 23·7 %; $P=0·001$) and diabetes (mediation ratio = 27·5 %; $P=0·005$), respectively. Specifically, for hypertension, the respective mediation ratios of general obesity and abdominal obesity were 17·3 % ($P=0·005$) and 6·4 % ($P=0·071$), while for diabetes, the corresponding mediation ratios were 10·2 % ($P=0·117$) and 17·4 % ($P=0·026$).

Discussion

Summary of findings

The present study provided solid evidence on the educational inequalities in objectively measured hypertension, diabetes and related clinical cardiometabolic risk factors in Hong Kong, a highly developed Asian setting. The educational inequalities in these CMD conditions appeared to be apparent only among women but not men. Obesity, including both general and abdominal obesity, did not only serve as an independent risk factor of hypertension and diabetes but also an important mediator of the observed disparities across education levels among women.

Interpretations of findings

Our findings clearly demonstrated a gender difference in the patterning of CMD conditions across education level in Hong Kong, which accords with studies conducted in other advanced economies in Asia[6–12] and across the globe[36–38]. Although the more educated women tended to have greater health awareness and motivation for preventive behaviours[39] and enjoy better material conditions[40], the associations of education level with hypertension and diabetes were not attenuated after adjustments for self-reported lifestyle factors and household income in our analyses, suggesting an independent role of education in the social patterning of CMD among Hong Kong women. The strong influence of educational attainment on CMD among women may be attributed to the more overt gender bias and the associated social roles of women in Asian societies in the past[41]. Taking Hong

https://doi.org/10.1017/S1368980021002044 Published online by Cambridge University Press

Table 3 Binary logistic regression on the associations of clinical risk factors with hypertension and diabetes among respondents sampled in the Population Health Survey 2014–2015 of Hong Kong, stratified by women and men (*n* 2297)

	Hypertension				Diabetes			
	Women (*n* 1206)		Men (*n* 1091)		Women (*n* 1206)		Men (*n* 1091)	
	OR	95 % CI†	OR	95 % CI†	OR	95 % CI†	OR	95 % CI†
Clinical risk factors								
BMI ≥ 25 kg/m^2	2·81	1·91, 4·12**	2·19	1·55, 3·09**	1·79	1·01, 3·17*	2·45	1·48, 4·05**
WHR ≥ 0·85 (female)/≥ 0·9 (male)	1·51	1·03, 2·22*	1·31	0·93, 1·85	3·33	1·69, 6·57**	1·91	1·12, 3·25*
LDL-cholesterol ≥ 160 mg/dl	1·06	0·48, 2·30	1·01	0·52, 1·97	0·65	0·13, 3·22	0·69	0·24, 1·94
HDL-cholesterol < 40 mg/dl	1·30	0·66, 2·56	0·83	0·56, 1·24	1·39	0·54, 3·60	1·27	0·75, 2·16
TC ≥ 240 mg/dl	0·98	0·46, 2·09	1·42	0·69, 2·95	0·29	0·06, 1·44	1·58	0·52, 4·83
TAG ≥ 200 mg/dl	0·75	0·38, 1·50	0·86	0·49, 1·51	0·97	0·36, 2·58	1·50	0·74, 3·06
FPG ≥ 7 mmol/l	1·24	0·34, 4·49	1·11	0·46, 2·67		N/A		N/A
HbA_{1c} ≥ 6·5 %	1·21	0·56, 2·62	0·77	0·41, 1·44		N/A		N/A
SBP ≥ 140 mmHg		N/A		N/A	0·72	0·36, 1·44	0·77	0·42, 1·43
DBP ≥ 90 mmHg		N/A		N/A	0·76	0·33, 1·75	0·56	0·28, 1·14

DBP, diastolic blood pressure; FPG, fasting plasma glucose; HbA_{1c}, haemoglobin A_{1c}; N/A, not applicable; SBP, systolic blood pressure; TC, total cholesterol; WHR, waist-to-hip ratio.
*P < 0·05, **P < 0·001.
†Model included age, marital status, education, household income, household size, smoking, alcohol use, fruit and vegetable intake, physical activity level and all the listed clinical risk factors.

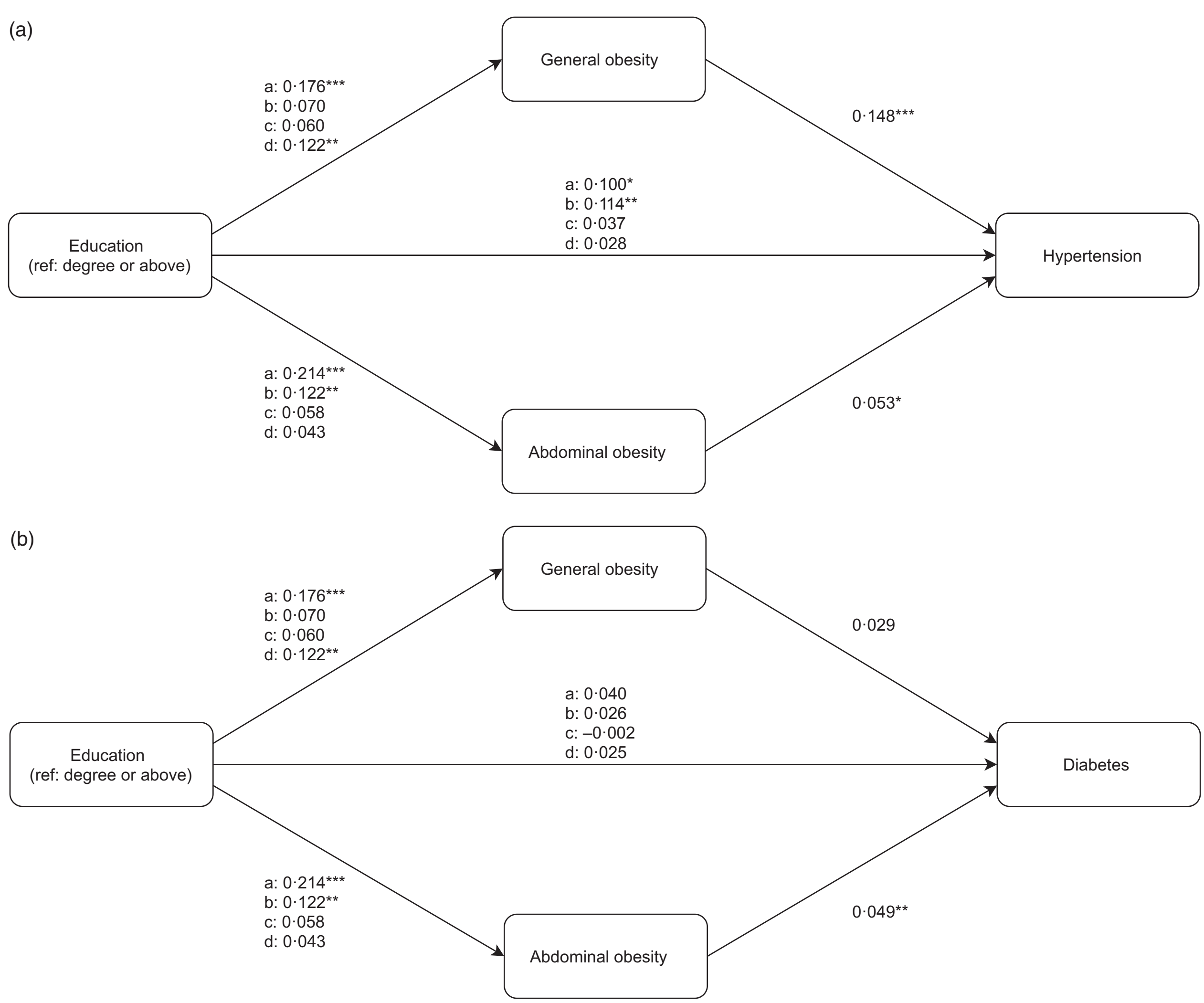

Fig. 2 Mediation analyses of general obesity and abdominal obesity on the associations of education with (A) hypertension and (B) diabetes among women sampled in the Population Health Survey 2014–2015 of Hong Kong (*n* 1206). a: Primary or below; b: lower secondary; c: upper secondary; d: sub-degree. *P < 0·05, **P < 0·01, ***P < 0·001. Model adjusted for age, marital status, education, household income, household size, smoking, alcohol use, fruit and vegetable intake, and physical activity level

Public Health Nutrition

Kong as an example, women generally had less opportunities for education before 1978 when universal free education was not guaranteed by the Government[42,43], and thus only those with a better socio-economic background could afford to receive higher education. In this sense, educational attainment, especially for women, does not only determine adulthood socio-economic positions but also reflects early-life circumstances during sensitive period of life[40] which could have exerted detrimental effect on adult CMD that might be independent of adulthood circumstances and exposures[44]. This proposed explanation via early-life exposures also echoed a previous study on a rapidly transitioning southern Chinese population which suggested that pre-adult adversities could be critical for the gender-specific effects of socio-economic positions on adulthood obesity[45]. Nonetheless, given the wider access to education in the younger generations in Hong Kong, future studies should explore the potential cohort effect and assess whether the observed educational inequalities in CMD among women were confined to the older generations who had less chance for higher education in general.

Apart from the gender-specific educational inequalities in CMD, obesity control in the general population appears to be important for CMD prevention in Hong Kong since general and abdominal obesity were the only clinical risk factors independently associated with hypertension and diabetes among both women and men as observed in the current study. In this particular setting, our finding is in line with the ever-increasing effect of obesity, alongside high blood pressure and high blood glucose, on the global CMD epidemic since 1980[46], and echoed previous research supporting a strong link of obesity with a wide range of CMD risk factors and subclinical vascular diseases even after comprehensive adjustments for traditional clinical risk factors[47]. As obesity is increasingly recognised as a state of chronic low-grade systemic inflammation, the independent and potentially more prominent role of obesity over other clinical risk factors implies the inadequacy of unfavourable lipid profiles, as reflected by concentrations of cholesterols and TAG, to explain the cardiometabolic risks of obesity. Rather, it may have operated through other mechanisms such as increased secretions of adipokines and inflammatory cytokines by adipocytes and decline in adiponectin levels associated with adiposity[48].

Another key message of the current study is that obesity control targeted to the less educated women may be most effective in the reduction of educational inequalities in CMD in Hong Kong, given the significant mediating role of both types of obesity among women. Our observed mediation ratios between education and CMD via general obesity (i.e., 17·3 % for hypertension and 10·2 % for diabetes) were largely comparable with those reported in other populations with 6·9–15·1 % of the association being mediated by BMI[49–51]; nonetheless, these studies did not assess the respective mediation ratios via abdominal obesity. As observed in the present study, despite a weaker contribution of abdominal obesity than general obesity to the educational inequality in hypertension (6·4 % *v.* 17·3 %), the mediating effect of abdominal obesity was substantially stronger on the association of education with diabetes (17·4 % *v.* 10·2 %). While abdominal obesity is generally deemed a critical risk factor of metabolic disorders and cardiovascular events[52,53], a more apparent socio-economic patterning of abdominal obesity as compared with that of general obesity in Hong Kong[22,54,55] may have also contributed to its stronger mediating role in the educational inequality in diabetes. Hence, our findings also highlighted the distinct role of abdominal obesity, in addition to general obesity, in both potential CMD prevention and inequality reduction.

Public health implications

To reduce both the obesity prevalence and its associated inequalities, a mix of population-wide and high-risk targeted strategies should be taken into considerations[56], especially on abdominal obesity which receives less attention from policymakers and the public in general. As recommended in the latest joint position statement from the International Atherosclerosis Society and the International Chair on Cardiometabolic Risk Working Group on Visceral Obesity[57], evidence-based public health messages focusing on abdominal fat distribution in addition to excess body weight are necessary to better combat the rising obesity epidemic. Therefore, public education programmes should include dissemination of knowledge on abdominal obesity as well as advocacy and training on anthropometric waist measurements (e.g., waist circumference and waist-to-hip ratio) beyond weight assessment to promote self-monitoring in the community. Apart from population-wide campaigns, high-risk targeted programmes are also recommended to narrow the educational inequality in obesity and related CMD. To this end, weight management programmes delivered in primary care settings may be more effective for the socio-economically disadvantaged[58]. Moreover, programmes leading to modest weight reduction, rather than a fast and substantial reduction, showed a preferential loss of visceral adipose tissues[59] and thus may be particularly useful for abdominal obesity control. Nonetheless, as the existing evidence on effective interventions primarily targeting abdominal obesity is scant[60], more specific research on innovative strategies for abdominal obesity control is therefore warranted. On the whole, community-based strategies or policies that aimed at structural changes to the environment with greater emphasis on community engagement appear to be an effective and equitable approach for obesity control, as they demand lower individual capacity to understand and respond to health messages, and meanwhile offer a better understanding of the underlying structural barriers faced by the socio-economically disadvantaged[61,62].

Limitations

Despite the strengths of the current study, there are several limitations. First, due to the cross-sectional nature of the

https://doi.org/10.1017/S1368980021002044 Published online by Cambridge University Press

current study, no temporal sequence could be established in the regression and mediation analyses. Second, the PHS adopted a systematic replicated sampling of living quarters, in which all eligible household members were enumerated. Nonetheless, as data at household level were not available in the PHS, we could not take into account the potential clustering effect among individuals within the same household in the analyses. Third, measurements on lifestyle behaviours and household income were based on self-reported data, which may be subject to reporting, recall and social desirability biases. Other potential biases may also be introduced as we excluded a small proportion (2·1 %) of respondents with missing, extreme or dubious measurements. Our results may also be subject to voluntary participation bias as only consented respondents were randomly sampled for the health examination. Fourth, regarding the mediation analyses, we focused on the indirect pathway through clinical cardiometabolic risk factors (as one of the objectives of the current study); nonetheless, the conceptual framework is indeed more complex with different levels of mediation (Fig. 1). While we have adjusted for the effect of lifestyle in the mediation analyses, our findings did not take into account the specific contributions of the other indirect pathways through lifestyle. Last, as data on genetic compositions, psychosocial factors, work conditions and dietary patterns other than fruit and vegetable intake were not available, residual confounding due to these unobserved characteristics may exist despite adjustments for demographic, socio-economic and lifestyle factors in our analysis.

Conclusion

Disparities in CMD conditions across education level were apparent only among women in Hong Kong. Both general obesity and abdominal obesity served as the key clinical risk factors of hypertension and diabetes, and substantially mediated the observed educational inequality in hypertension and diabetes among women. To tackle the overall CMD burden and associated inequalities, both the population-wide and high-risk targeted approaches of obesity management appear to be important, especially for abdominal obesity which deserves greater attention from both policymakers and the general public.

Acknowledgements

Acknowledgements: The data used in the current study were taken from the Population Health Survey 2014–2015 conducted by the Department of Health of the Government of Hong Kong Special Administrative Region. The role of the Department of Health was to conduct fieldwork to collect data for the Population Health Survey 2014–2015. All data analyses leading to findings in this publication were conducted by the authors but not by the Department of Health. The first author, Gary K.K. Chung, acknowledges the Research Grants Council for its support over his Postdoctoral Fellowship (Ref. no.: PDFS2122-4H02). The corresponding author, Roger Y. Chung, acknowledges the National Academy of Medicine for its support over his International Health Policy Fellowship. *Financial support:* This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors. *Conflict of interest:* There are no conflicts of interest. *Authorship:* G.K.C. conducted literature review, analysed and interpreted the data and substantially contributed to the manuscript write-up. F.T.T.L. and H.H. analysed and interpreted the data and assisted in the write-up. E.K.Y. interpreted the data and critically appraised the paper. R.Y.C. oversaw the study, analysed and interpreted the data, and critically appraised the paper. *Ethics of human subject participation:* The Population Health Survey 2014–2015 has been approved by the Ethics Committee of the Department of Health. Detailed information on the design and sampling methods of the PHS has been described elsewhere.

Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980021002044

References

1. Kones R & Rumana U (2017) Cardiometabolic diseases of civilization: history and maturation of an evolving global threat. An update and call to action. *Ann Med* **49**, 260–274.
2. Leng B, Jin Y, Li G *et al.* (2015) Socioeconomic status and hypertension: a meta-analysis. *J Hypertens* **33**, 221–229.
3. Agardh E, Allebeck P, Hallqvist J *et al.* (2011) Type 2 diabetes incidence and socio-economic position: a systematic review and meta-analysis. *Int J Epidemiol* **40**, 804–818.
4. Woodward M, Peters SA, Batty GD *et al.* (2015) Socioeconomic status in relation to cardiovascular disease and cause-specific mortality: a comparison of Asian and Australasian populations in a pooled analysis. *BMJ Open* **5**, e006408.
5. Vathesatogkit P, Batty GD & Woodward M (2014) Socioeconomic disadvantage and disease-specific mortality in Asia: systematic review with meta-analysis of population-based cohort studies. *J Epidemiol Community Health* **68**, 375–383.
6. Wu H, Meng X, Wild SH *et al.* (2017) Socioeconomic status and prevalence of type 2 diabetes in mainland China, Hong Kong and Taiwan: a systematic review. *J Glob Health* **7**, 011103.
7. Wu H, Bragg F, Yang L *et al.* (2019) Sex differences in the association between socioeconomic status and diabetes prevalence and incidence in China: cross-sectional and prospective studies of 0·5 million adults. *Diabetologia* **62**, 1420–1429.

8. Yoo S, Cho HJ & Khang YH (2010) General and abdominal obesity in South Korea, 1998–2007: gender and socioeconomic differences. *Prev Med* **51**, 460–465.
9. Ma YX, Zhang B, Jiang WB *et al.* (2013) The impact of socioeconomic status on the prevalence of hypertension among adults in 9 provinces of China, 1991–2009. *Zhonghua Liu Xing Bing Xue Za Zhi* **34**, 1051–1054.
10. Kim YJ, Lee JS, Park J *et al.* (2017) Trends in socioeconomic inequalities in five major risk factors for cardiovascular disease in the Korean population: a cross-sectional study using data from the Korea National Health and Nutrition Examination Survey, 2001–2014. *BMJ Open* **7**, e014070.
11. Hong SA, Kim K & Kim MK (2012) Trends in the inequality of fruit and vegetable consumption between education levels indicated by the Korea National Health and Nutrition Examination Surveys. *Eur J Clin Nutr* **66**, 942–949.
12. Chung GK, Lai FT, Yeoh EK *et al.* (2019) Educational inequality in physician-diagnosed hypertension widened and persisted among women from 1999 to 2014 in Hong Kong. *Sci Rep* **9**, 14361.
13. Schultz WM, Kelli HM, Lisko JC *et al.* (2018) Socioeconomic status and cardiovascular outcomes: challenges and interventions. *Circulation* **137**, 2166–2178.
14. Chung RY, Lai FT, Chung GK *et al.* (2018) Socioeconomic disparity in mortality risks widened across generations during rapid economic development in Hong Kong: an age-period-cohort analysis from 1976 to 2010. *Ann Epidemiol* **28**, 743–752.
15. Wong SL & Donnan SP (1992) Influence of socioeconomic status on cardiovascular diseases in Hong Kong. *J Epidemiol Community Health* **46**, 148–150.
16. Woo J, Leung SS, Ho SC *et al.* (1999) Influence of educational level and marital status on dietary intake, obesity and other cardiovascular risk factors in a Hong Kong Chinese population. *Eur J Clin Nutr* **53**, 461–467.
17. Woo J, Ho SC, Sham A *et al.* (2003) Diet and glucose tolerance in a Chinese population. *Eur J Clin Nutr* **57**, 523–530.
18. Yu TS & Wong TW (2004) Socioeconomic distribution of health and health care utilization in a new town in Hong Kong, China. *Biomed Environ Sci* **17**, 234–245.
19. Chou KL & Chi I (2005) Functional disability related to diabetes mellitus in older Hong Kong Chinese adults. *Gerontology* **51**, 334–339.
20. Wong MC, Leung MC, Tsang CS *et al.* (2013) The rising tide of diabetes mellitus in a Chinese population: a population-based household survey on 121,895 persons. *Int J Public Health* **58**, 269–276.
21. Wong MC, Wang HH, Leung MC *et al.* (2015) The rising prevalence of self-reported hypertension among Chinese subjects: a population-based study from 121 895 household interviews. *QJM* **108**, 9–17.
22. Chung GK, Chung RY, Chan DC *et al.* (2019) The independent role of deprivation in abdominal obesity beyond income poverty. A population-based household survey in Chinese adults. *J Public Health* **41**, 476–486.
23. Department of Health (2017) *Report of Population Health Survey 2014–2015*. Hong Kong: Department of Health.
24. OECD (1999) *Classifying Education Programmes: Manual for ISCED-97 Implementation in OECD Countries 1999 Organisation for Economic Co-operation and Development (OECD) 1999 Edition*. Paris: OECD Publishing.
25. World Health Organisation & Global Physical Activity Questionnaire (GPAQ) Analysis Guide. https://www.who.int/ncds/surveillance/steps/resources/GPAQ_Analysis_Guide.pdf?ua=1 (accessed April 2021).
26. World Health Organization (2005) *WHO STEPS Surveillance Manual: The WHO STEPwise Approach to Chronic Disease Risk Factor Surveillance*. Geneva: World Health Organization.
27. U.S. Department of Health and Human Services (2004) *The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure*. Bethesda (MD): National Institutes of Health.
28. International Expert Committee (2009) International expert committee report on the role of the A1C assay in the diagnosis of diabetes. *Diabetes Care* **32**, 1327–1334.
29. Expert Committee on the Diagnosis and Classification of Diabetes Mellitus (2003) Report of the expert committee on the diagnosis and classification of diabetes mellitus. *Diabetes Care* **26**, Suppl. 1, S5–S20.
30. Barba C, Cavalli-Sforza T, Cutter J *et al.* (2004) Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* **363**, 157–163.
31. WHO, IASO & IOTF (2000) *The Asia-Pacific Perspective: Redefining Obesity and Its Treatment*. Australia, Melbourne: Health Communications.
32. Alberti KG & Zimmet PZ (1998) Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. *Diabet Med* **15**, 539–553.
33. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (2001) Executive summary of the third report of the national cholesterol education program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). *JAMA* **285**, 2486–2497.
34. Selvin S (1996) *Statistical Analysis of Epidemiologic Data*. New York: Oxford University Press.
35. Preacher KJ & Hayes AF (2008) Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behav Res Methods* **40**, 879–891.
36. Cohen AK, Rai M, Rehkopf DH *et al.* (2013) Educational attainment and obesity: a systematic review. *Obes Rev* **14**, 989–1005.
37. Jaacks LM, Vandevijvere S, Pan A *et al.* (2019) The obesity transition: stages of the global epidemic. *Lancet Diabetes Endocrinol* **7**, 231–240.
38. Boissonnet C, Schargrodsky H, Pellegrini F *et al.* (2011) Educational inequalities in obesity, abdominal obesity, and metabolic syndrome in seven Latin American cities: the CARMELA Study. *Eur J Cardiovasc Prev Rehabil* **18**, 550–556.
39. Iversen AC & Kraft P (2006) Does socio-economic status and health consciousness influence how women respond to health related messages in media? *Health Educ Res* **21**, 601–610.
40. Galobardes B, Shaw M, Lawlor DA *et al.* (2006) Indicators of socioeconomic position (part 1). *J Epidemiol Community Health* **60**, 7–12.
41. Westwood R, Mehrain T & Cheung FM (1995) *Gender and Society in Hong Kong: A Statistical Profile*. Hong Kong: Hong Kong Institute of Asia-Pacific Studies, Chinese University of Hong Kong.
42. Education Bureau (1997) *Report on Review of 9-year Compulsory Education*. Hong Kong: Education Bureau.
43. Mak GC & Chung YP (1997) Education and labour force participation of women in Hong Kong. In *Engendering Hong Kong Society: A Gender Perspective of Women's Status*, pp. 13–39 [FM Cheung, editor]. Hong Kong: The Chinese University Press.
44. Barr DA (2017) The childhood roots of cardiovascular disease disparities. *Mayo Clin Proc* **92**, 1415–1421.
45. Kavikondala S, Schooling CM, Jiang CQ *et al.* (2009) Pathways to obesity in a developing population: the Guangzhou Biobank Cohort Study. *Int J Epidemiol* **38**, 72–82.
46. Danaei G, Lu Y, Singh GM *et al.* (2014) Cardiovascular disease, chronic kidney disease, and diabetes mortality burden of cardiometabolic risk factors from 1980 to 2010: a comparative risk assessment. *Lancet Diabetes Endocrinol* **2**, 634–647.

47. Burke GL, Bertoni AG, Shea S *et al.* (2008) The impact of obesity on cardiovascular disease risk factors and subclinical vascular disease: the multi-ethnic study of atherosclerosis. *Arch Intern Med* **168**, 928–935.
48. Coelho M, Oliveira T & Fernandes R (2013) Biochemistry of adipose tissue: an endocrine organ. *Arch Med Sci* **9**, 191–200.
49. Kershaw KN, Droomers M, Robinson WR *et al.* (2013) Quantifying the contributions of behavioral and biological risk factors to socioeconomic disparities in coronary heart disease incidence: the MORGEN study. *Eur J Epidemiol* **28**, 807–814.
50. Degano IR, Marrugat J, Grau M *et al.* (2017) The association between education and cardiovascular disease incidence is mediated by hypertension, diabetes, and body mass index. *Sci Rep* **7**, 12370.
51. Carter AR, Gill D, Davies NM *et al.* (2019) Understanding the consequences of education inequality on cardiovascular disease: mendelian randomisation study. *BMJ* **365**, l1855.
52. Despres JP (2012) Body fat distribution and risk of cardiovascular disease: an update. *Circulation* **126**, 1301–1313.
53. Chung GK, Yu RHY, Ho SS *et al.* (2020) Prospective association of obesity patterns with subclinical carotid plaque development in early postmenopausal Chinese women. *Obesity* **28**, 1342–1350.
54. Chung GK, Yu RHY, Woo J *et al.* (2020) Accelerated progression of waist-to-hip ratio but not body mass index associated with lower socioeconomic positions: a cohort study of non-obese early postmenopausal Chinese women. *Menopause* **27**, 550–558.
55. Chung GK, Lai FTT, Chan DC *et al.* (2020) Socioeconomic disadvantages over the lifecourse and their influence on obesity among older Hong Kong Chinese adults. *Eur J Public Health* **30**, 1013–1018.
56. Rose G (1985) Sick individuals and sick populations. *Int J Epidemiol* **14**, 32–38.
57. Neeland IJ, Ross R, Despres JP *et al.* (2019) Visceral and ectopic fat, atherosclerosis, and cardiometabolic disease: a position statement. *Lancet Diabetes Endocrinol* **7**, 715–725.
58. Hillier-Brown FC, Bambra CL, Cairns JM *et al.* (2014) A systematic review of the effectiveness of individual, community and societal-level interventions at reducing socio-economic inequalities in obesity among adults. *Int J Obes* **38**, 1483–1490.
59. Chaston TB & Dixon JB (2008) Factors associated with percent change in visceral versus subcutaneous abdominal fat during weight loss: findings from a systematic review. *Int J Obes* **32**, 619–628.
60. Kesztyus D, Erhardt J, Schonsteiner D *et al.* (2018) Therapeutic treatment for abdominal obesity in adults. *Dtsch Arztebl Int* **115**, 487–493.
61. Beauchamp A, Backholer K, Magliano D *et al.* (2014) The effect of obesity prevention interventions according to socioeconomic position: a systematic review. *Obes Rev* **15**, 541–554.
62. Boelsen-Robinson T, Peeters A, Beauchamp A *et al.* (2015) A systematic review of the effectiveness of whole-of-community interventions by socioeconomic position. *Obes Rev* **16**, 806–816.

https://doi.org/10.1017/S1368980021002044 Published online by Cambridge University Press