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CARDIOVASCULAR DISEASE

Adult height and the risks of cardiovascular disease and major causes of death in the Asia-Pacific region: 21 000 deaths in 510 000 men and women

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Background In Caucasian populations, adult height is inversely associated with cardiovascular disease (CVD) risk and positively related to some cancers. However, there are few data from Asian populations and from women. We sought to determine the sex- and region-specific associations between height and cardiovascular outcomes, and deaths due to cancer, respiratory and injury in populations from the Asia-Pacific region.

Methods Thirty-nine studies from the Asia Pacific Cohort Studies Collaboration database were included. We used Cox proportional hazard regression models to estimate the associations between height and pre-specified outcomes.

Results A total of 510 800 participants with 21 623 deaths were included. Amongst men, inverse linear associations were observed between height and coronary heart disease (CHD), stroke, CVD, injury and total mortality. The hazard ratios [95% confidence intervals, (CI)] for a 1-SD (= 6 cm) increment in height ranged from 0.85 (0.80–0.91) for injury to 0.97 (0.95–0.98) for total mortality. Similar trends were found between height and CHD, haemorrhagic stroke and CVD in women. A positive linear association was observed between height and cancer mortality. For each standard deviation greater height, the risk of cancer was increased by 5% (2–8%) and 9% (5–14%) in men and women, respectively. No regional difference was observed between Asian and Australasian cohorts. Adjusting for markers of education did not alter the results.

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Conclusions The opposing relationships of height with CVD and cancer suggest that care is required in setting national policies on childhood nutrition lest they have unintended consequences on the incidence of major non-communicable diseases.

Keywords Body height, cardiovascular disease, cancer, respiratory disease, injury, mortality

Introduction

Findings from observational studies indicate that impaired fetal growth[1] and psychosocial stress, sub-optimal nutrition and socioeconomic disadvantage[2] during childhood are linked with short adult stature. Adult stature itself has been reported to be negatively associated with coronary heart disease (CHD) and stroke, with some studies suggesting a 10-cm increment in height to be associated with an ~12–25% reduction in risk of CHD and 20–24% reduction in risk of stroke.[3–5] In some studies, statistical evidence is lost, particularly after adjustment for age and socio-economic status.[6–8] In contrast, height is reported to be positively associated with risk of cancer, with 20–60% higher risk of certain cancers for taller persons.[9] Further, in other populations, there is some suggestion of a sex differential in the reported association between height and mortality, although to what extent this is a reflection of insufficient statistical power rather than any real gender difference is unknown.[10,11] If real, these opposing relationships could provide insights regarding aetiological pathways for cancer and cardiovascular disease (CVD).

A major limitation of these earlier analyses is the lack of representativeness of the study populations since most of the data were derived from Caucasians, with comparatively few data from Asian populations, in whom the relationships between body stature with health outcomes have been inconsistently reported.[12–14] By pooling data from a series of cohort studies from the Asia-Pacific region, we quantify the relationships between height with a range of morbidity and mortality outcomes, from chronic disease to external causes, to clarify the pattern of these associations. Presenting the associations between height and a range of mortality and morbidity outcomes, rather than a disease single outcome, provides improved insights into aetiology of particular diseases.[15]

Methods

The Asia Pacific Cohort Studies Collaboration (APCSC) is a large collaborative project consisting of over 600 000 participants from 44 cohort studies in the Asia-Pacific region. Details of the collaboration have been published elsewhere.[16] Briefly, studies were eligible for inclusion if they met the following criteria: (i) a study population from the Asia Pacific region; (ii) prospective cohort study design; (iii) at least 5000 person-years of follow-up; (iv) date of birth (or age), sex and blood pressure recorded at baseline; and (v) date of death or age at death recorded during follow-up. In this study, only those participants with baseline data on age, year of birth, sex, height, systolic blood pressure (SBP), smoking and fatal or non-fatal outcomes were included in analyses.

Disease outcomes

Outcomes were classified according to the ninth revision of the International Classification of Diseases (ICD-9): CHD (ICD-9, 410–414), stroke (ICD-9, 430–438), haemorrhagic stroke (ICD-9, 431.0–432.9), ischaemic stroke (ICD-9, 433.0–434.9), cancer (ICD-9, 140–208), respiratory disease (ICD-9, 010–019, 136.6, 137, 460–467, 479–519) and injury (ICD-9, 800–999). All studies recorded deaths. Of the 39 studies included in this analysis, 18 studies additionally reported non-fatal stroke, and 15 reported non-fatal CHD outcomes. Cardiovascular events were defined as fatal CVD, non-fatal myocardial infarction and non-fatal stroke; no non-fatal outcomes were recorded for cancer, respiratory disease or injury.

Statistical analyses

Separately for men and women, associations between height and each of the outcomes were obtained from Cox regression models with adjustment for age, year of birth and study. We computed hazard ratios (HRs) for height in four equal groups (sex-specific fourths) with 95% confidence intervals (CIs) obtained from floating absolute risks, and as continuous variables, obtaining the HR for a standard deviation (SD) increase. Subgroup analyses estimated the separate effects by region [Asia and Australasia (Australia and New Zealand)]. Sensitivity analysis by age group estimated the effect of possible shrinkage in stature with age. Participants were divided into age <60 years and $\geqslant 60$ years at baseline to form approximately equal numbers per group. We tested for effect modification of age or region by adding an interaction term between height and age and between height and region to the Cox model, whilst a test for linear trend involved fitting a Cox model with an ordinal variable

defined by the fourths of height. In addition, non-linearity on the height–outcome relationships were also tested by comparing, using a likelihood ratio chi-square, the Cox model fitting the four height groups as a categorical variable with the Cox model fitting the height groups as an ordinal variable. The analyses were repeated with further adjustments made for SBP and cigarette smoking. Results were also adjusted for total cholesterol (TC) in a subgroup analysis of those studies with data for this variable. Given that stature is socioeconomically patterned, we also controlled for education, which was available in selected studies. Educational attainment levels were classified into three groups [none/not completed primary, completed primary (age 10 years), completed secondary (age 17/18 years) or completed tertiary]. All analyses were based on data from individual participants aged $\geqslant$20 years at the time of the baseline survey. All statistical analyses were performed using SAS 9.1 for Windows (SAS Institute Inc., USA).

Results

A total of 510 800 participants (81% Asian; 35% female) comprised the analytical sample. At baseline, the mean (SD) age was 48 years (11 years) and the mean (SD) height was 169 cm (6 cm) and 157 cm (6 cm) in men and women, respectively (Table 1). Compared with individuals from Asian cohorts, those from Australasia were generally older, taller, had higher mean SBP and TC, were less likely to have reported being a smoker and more likely to have completed tertiary education (24% Australasian vs 13% Asian) at study baseline. During the 3 284 397 person-years of follow-up, there were 21 623 fatal events and 9259 non-fatal events (for CHD and stroke); 11 023 CVD, 7497 cancers, 5389 strokes (37% ischaemic, 28% haemorrhagic, 6% subarachnoid haemorrhages and 29% unknown subtype), 3933 CHD, 1597 respiratory and 1443 deaths due to injury (Table 2). Subgroup analyses were performed using 352 827 participants (69%; 76% Asian) with TC values and 245 251 participants (48%; 65% Asian) with data on educational attainment. Participants from the Asian cohort were distributed evenly across four height groups. In contrast, participants from the Australasian cohort tended to be in the taller height groups.

Height and risk of CHD

An inverse linear association between height and CHD was observed for both sexes after allowing for age, study and year of birth (Figure 1). Further adjustment for SBP and smoking did not alter the association (results available from authors on request). A 1-SD increase in height was associated with an 8% (95% CI: 4–11%) decrease in subsequent CHD for men. Evidence of such association was weak with a 4% (95% CI: −1 to 10%) decrease for women (Table 3). No regional difference was observed for either sex (P-value for interaction = 0.31 for men, $P = 0.32$ for women). There was no difference in the strength of the association between the two age groups for either sex (Table 4). Further adjustment for TC or education level did not materially alter the results (data not shown).

Height and risk of stroke

For men, there was evidence of an inverse association between height and risk of all strokes such that a 1-SD increment in height was associated with a 7% (95% CI: 4–10%; $P_{trend} = 0.002$) lower risk (Figure 1). A similar association was observed for women [HR 0.94 (95% CI: 0.89–0.98)] but the evidence of a trend across strata was weak ($P_{trend} = 0.11$). In subgroup analyses, height was inversely associated with haemorrhagic stroke in women [HR 0.87 (95% CI: 0.79–0.96); $P_{trend} = 0.03$]. No evidence of an association between height and ischaemic stroke was observed in either sex or between cohorts from Asia and Australasia (Table 3). For each SD increase in height, the reduction in risk of any stroke in women aged <60 years and women aged $\geqslant$60 years was 14 and 2%, respectively (Table 4; P-value for age interaction = 0.01). For haemorrhagic stroke the corresponding reduction in risk was 25 and 3% (P-value for age interaction = 0.008). Further adjustment for TC or education level did not materially alter the results (data not shown).

Height and risk of CVD

Consistent with CHD, an inverse linear association between height and CVD was observed for both sexes and the association persisted after adjustment for age, study and year of birth (Figure 1). For each 1-SD increment in height, there was a 7% (95% CI: 5–9%) and 6% (95% CI: 3–9%) decrease in risk of CVD for men and women, respectively (Table 3). As with stroke, further adjustment for TC or education level did not impact on the results (data not shown).

Height and cancer mortality

A positive linear association between height and mortality from cancer was observed for both sexes after adjustment for age, study and year of birth (Figure 1). For men, a 1-SD increment in height was associated with a 5% (95% CI: 2–8%) increase in mortality from cancer (Table 3). For women, the respective increase in risk was 9% (95% CI: 5–14%) with no evidence to suggest regional heterogeneity in either sex (Table 3). Compared with persons aged $\geqslant$60 years, the relationship between height and cancer was weaker for younger persons (Table 4). Adjustment for TC or education level did not alter the results (data not shown).

Table 1 Summary of studies by region (Australasia and Asia)

Study name	*N*	Baseline year range	Median follow-up (year)	Female (%)	Current smoker (%)	Percentage of education		Age (year)	SBP (mmHg)	Cholesterol (mmol/l)	Height (cm)	
						None/non-completed primary	Tertiary	Mean (SD)	Mean (SD)	Mean (SD)	Male Mean (SD)	Female Mean (SD)
ALSA	1566	1992–93	4.7	48	8	0.4	96.9	78 (6)	148 (22)	5.8 (1.2)	169 (7)	156 (6)
ANHF	9271	1989–90	8.3	51	24	0.3	28	43 (13)	126 (18)	5.5 (1.1)	175 (7)	162 (6)
Busselton	7463	1966–81	26.5	52	34	–	–	45 (17)	138 (25)	5.9 (1.3)	173 (7)	161 (6)
Fletcher Challenge	10 344	1992–94	5.8	28	23	0	37.4	44 (15)	126 (17)	5.4 (1.2)	176 (7)	163 (7)
Melbourne	41 267	1990–94	8.5	59	11	7.1	21.8	55 (9)	138 (20)	5.5 (1.1)	172 (7)	160 (7)
Newcastle	5927	1983–94	8.9	50	23	0.3	23.4	52 (10)	132 (20)	5.9 (1.1)	173 (7)	161 (6)
Perth	10 226	1978–94	14.4	48	25	0.3	19.9	45 (13)	130 (20)	5.8 (1.2)	175 (7)	162 (6)
WA AAA Screenees	12 203	1996–99	3.2	0	11	0.8	15.9	72 (4)	157 (21)	–	171 (7)	–
Australasia	**98 267**	**1966–99**		**45**	**18**	**3.6**	**23.9**	**53 (14)**	**137 (22)**	**5.6 (1.1)**	**179 (7)**	**161 (7)**
Aito Town	1711	1980–83	15.2	57	19	–	–	51 (9)	136 (21)	4.6 (0.9)	163 (7)	151 (6)
Akabane	1834	1985–86	11.0	56	28	0	8.4	54 (8)	125 (19)	5.0 (0.9)	161 (6)	149 (5)
Anzhen	8377	1991	4.3	55	28	14.8	19.7	54 (13)	129 (24)	4.7 (0.9)	169 (6)	157 (6)
Anzhen02	4152	1992–93	3.0	51	21	0.1	74.8	47 (8)	122 (18)	–	170 (6)	159 (5)
Beijing Aging	2085	1992	4.8	51	30	51.9	6.7	70 (9)	141 (25)	4.4 (1.0)	165 (7)	153 (6)
Capital Iron & Steel Company	5132	1974–80	12.5	0	72	–	–	45 (8)	123 (19)	4.9 (1.0)	169 (6)	–
CISCH	2166	1992–93	3.3	51	27	0.3	62.1	44 (7)	118 (17)	–	170 (6)	159 (6)
Civil Service Workers	9316	1990–92	6.7	33	38	–	–	47 (5)	126 (18)	5.2 (0.9)	166 (6)	154 (5)
CVDFACTS	5716	1988–96	6.0	55	22	14.0	14.6	47 (15)	118 (19)	5.0 (1.2)	166 (6)	155 (6)
East Beijing	1087	1977–94	17.1	52	30	12.7	13.8	43 (15)	124 (22)		171 (7)	160 (6)
EGAT	3492	1985	11.4	23	43	–	–	43 (5)	121 (16)	5.8 (1.1)	165 (6)	155 (5)
Fangshan	2608	1991–92	3.6	67	39	32.0	0.9	47 (10)	136 (26)	4.6 (1.1)	168 (7)	156 (6)
Guangzhou Occupational	106 180	1985–97	7.1	11	51	0.1	12.1	41 (6)	117 (14)	5.3 (1.2)	169 (5)	158 (5)
Hisayama	1569	1961	24.6	56	43	–	–	56 (11)	135 (26)	4.1 (0.9)	157 (6)	146 (6)
Hong Kong	2881	1985–91	2.5	57	19	78.7	3.9	78 (7)	150 (25)	5.3 (0.9)	162 (7)	148 (7)
Huashan	1859	1990–92	2.8	52	0	–	–	53 (12)	126 (21)	4.6 (0.9)	168 (7)	156 (6)
Kinmen	1268	1993–96	2.9	47	28	79.7	1.6	63 (9)	139 (23)	–	166 (7)	154 (6)
KMIC	183 391	1992	4.0	37	34	–	–	44 (7)	122 (15)	5.0 (0.9)	169 (5)	157 (4)

(continued)

Table 1 Continued

Study name	*N*	Baseline year range	Median follow-up (year)	Female (%)	Current smoker (%)	Percentage of education		Age (year)	SBP (mmHg)	Cholesterol (mmol/l)	Height (cm)	
						None/non-completed primary	Tertiary	Mean (SD)	Mean (SD)	Mean (SD)	Male Mean (SD)	Female Mean (SD)
Konan	1194	1987–95	6.4	55	30	–	–	52 (16)	130 (19)	4.9 (0.9)	165 (8)	152 (7)
Miyama	1034	1988–90	6.6	55	29	0.4	4.0	60 (9)	132 (22)	–	160 (6)	149 (6)
Ohasama	2196	1992–93	4.1	63	20	–	–	59 (11)	128 (17)	5.0 (0.9)	161 (7)	149 (6)
Saitama	3602	1986–90	11.0	62	28	–	–	54 (12)	135 (20)	5.0 (1.0)	161 (7)	150 (6)
Seven Cities Cohorts	10 791	1987	2.7	55	35	0	0	54 (12)	130 (24)	5.1 (1.5)	167 (6)	156 (6)
Shibata	2335	1977	20.0	58	33	–	–	57 (11)	131 (21)	4.6 (1.2)	159 (6)	147 (7)
Shigaraki Town	3738	1991–97	4.4	59	29	–	–	57 (14)	132 (19)	5.0 (0.9)	164 (7)	151 (7)
Singapore Heart	2312	1982–97	14.6	49	22	–	–	41 (13)	123 (22)	5.9 (1.3)	166 (6)	154 (6)
Singapore NHS92	3304	1992	6.2	52	18	30.4	6.7	39 (12)	118 (19)	5.4 (1.1)	168 (6)	155 (6)
Six Cohorts	19 367	1982–86	9.0	47	46	–	–	45 (7)	119 (18)	4.2 (0.9)	165 (6)	154 (6)
Tanno/Soubetsu	1983	1977	16.4	53	39	–	–	51 (7)	133 (20)	4.9 (0.9)	162 (6)	151 (5)
Tianjin	9273	1984	6.1	51	51	–	–	55 (12)	136 (27)	–	168 (7)	156 (7)
Yunnan	6580	1992	4.5	3	68	59.8	4.0	56 (9)	124 (21)	4.3 (0.8)	162 (6)	154 (5)
Asia	**412 533**	**1961–97**		**33**	**39**	**7.8**	**13.0**	**45 (10)**	**122 (17)**	**4.9 (1.0)**	**168 (6)**	**156 (6)**
Overall	**510 800**	**1961–99**		**35**	**35**	**6.3**	**16.9**	**48 (11)**	**125 (19)**	**5.1 (1.0)**	**169 (6)**	**157 (6)**

ALSA = Australian Longitudinal Study of Aging; ANHF = Australian National Heart Foundation; WA AAA Screenees = Western Australian AAA Screenees; CISCH = Capital Iron and Steel Company Hospital; EGAT = Electricity Generating Authority of Thailand; KMIC = Korean Medical Insurance Corporation; NHS92 = National Health Study 1992; CVDFACTS = Cardiovascular Disease Risk Factors Tow-Township Study.

Table 2 Number of cardiovascular events and deaths due to cancer, respiratory disease, injury and all cause by study

Study name	CHD	Stroke	HS	IS	CVD	Cancer death	RD death	Injury death	Total death
ALSA	75	47	8	6	196	67	85	2	451
ANHF	77	17	–	2	115	154	21	36	373
Busselton	1203	898	92	229	2059	689	222	98	2799
Fletcher challenge	270	191	9	67	464	134	23	18	369
Melbourne	323	99	35	11	550	1112	95	72	2078
Newcastle	137	34	9	3	204	215	31	15	515
Perth	194	63	10	4	312	311	46	39	817
WA AAA screenees	322	227	31	113	602	400	69	28	975
Australasia	**2601**	**1576**	**194**	**435**	**4502**	**3082**	**592**	**308**	**8377**
Aito Town	15	25	5	–	58	62	14	24	180
Akabane	27	37	5	15	77	57	5	–	136
Anzhen	65	179	63	106	273	66	11	12	322
Anzhen02	1	16	1	14	17	–	–	–	19
Beijing Aging	–	85	–	–	202	48	29	13	423
Capital Iron & Steel Company	87	160	65	90	243	113	–	–	341
CISCH	14	9	–	–	23	3	–	3	7
Civil Service Workers	1	2	1	–	12	61	2	17	99
CVDFACTS	13	29	8	7	60	65	25	26	227
East Beijing	15	19	7	10	46	15	2	–	86
EGAT	33	16	–	–	51	43	–	37	164
Fangshan	5	34	8	20	50	8	1	7	46
Guangzhou Occupational	85	96	65	–	227	546	35	74	1116
Hisayama	88	325	69	229	448	199	162	55	814
Hong Kong	71	67	15	5	178	125	199	4	596
Huashan	3	16	6	10	22	4	1	1	26
Kinmen	8	9	–	–	35	32	6	3	86
KMIC	315	1221	380	493	1650	1232	54	558	2908
Konan	2	11	3	6	23	25	9	10	78
Miyama	2	6	–	4	18	35	5	12	80
Ohasama	5	50	10	34	66	30	9	8	85
Saitama	24	54	15	26	118	145	38	22	361
Seven Cities Cohorts	84	300	181	117	618	175	60	13	880

(continued)

Table 2 Continued

Study name	CHD	Stroke	HS	IS	CVD	Cancer death	RD death	Injury death	Total death
Shibata	66	204	36	75	338	207	95	56	819
Shigaraki Town	3	13	2	4	29	55	8	8	116
Singapore Heart	66	72	7	22	134	35	17	4	168
Singapore NHS92	33	44	4	14	78	22	2	5	71
Six Cohorts	47	206	91	104	393	381	47	89	915
Tanno/Soubetsu	24	33	16	10	73	90	–	–	255
Tianjin	112	369	184	121	739	297	105	40	1191
Yunnan	18	106	93	12	222	239	64	34	631
Asia	**1332**	**3813**	**1340**	**1548**	**6521**	**4415**	**1005**	**1135**	**13 246**
Overall	**3933**	**5389**	**1534**	**1983**	**11023**	**7497**	**1597**	**1443**	**21 623**

HS = haemorrhagic stroke; IS = ischaemic stroke; RD = respiratory disease.

Height and injury mortality

An inverse linear association was observed between height and risk of mortality from injury for men ($P_{trend} < 0.001$), but not for women ($P_{trend} = 0.79$) after adjusting for age, study and year of birth (Figure 1). Additional adjustment for SBP and smoking did not alter the results. For each 1-SD increase in height, there was a 15% (95% CI: 9–20%) decrease in injury mortality for men (Table 3). No evidence for difference between regions or by age was observed for either sex. Adjustment for TC or education level did not alter the results.

Height and respiratory disease mortality

When respiratory disease was the outcome of interest, there was no association with height in either men or women in any analysis.

Height and risk of all-cause mortality

As with injury, an inverse linear association between height and total mortality was observed for men ($P_{trend} = 0.002$) but not for women ($P_{trend} = 0.76$) (Figure 1). However, for each 1-SD increase in height, the reduction in total mortality was similar for both sexes ($P_{sex} = 0.5$). Additional adjustment for SBP and smoking did not alter the estimates. For each 1-SD increase, there was a 3% (95% CI: 2–5%) reduction in total mortality risk for men, with no evidence of regional heterogeneity (Table 3). For each 1-SD increment in height, men aged <60 years had a 7% decrease risk for total mortality whereas no change in risk was observed in men aged ⩾60 years (Table 4). Identical results were obtained when TC or education level were included in the analyses.

Discussion

Our analysis of a group of prospective cohorts comprising data on more than 21 000 deaths and 9000 non-fatal cardiovascular events is several orders of magnitude greater than previous studies that have examined the relationships of adult height to chronic disease endpoints. Hence, it should provide more reliable estimates of effect than any previous individual study. Consistent with earlier observations, inverse linear associations with height were apparent for CHD and CVD in both sexes. However, consistent with other studies, the associations were relatively small in magnitude such that an ~6 cm (1 SD) increment in height was associated with a 5–10% reduction in risk.[17,18] In contrast, but again in agreement with earlier reports, height was positively associated with an increased risk of cancer, the association being of the same size as that for CVD.[19]

While an inverse association between height and CHD has been widely documented, reports of a relationship between height and risk of ischaemic stroke have been inconsistent, with some studies observing

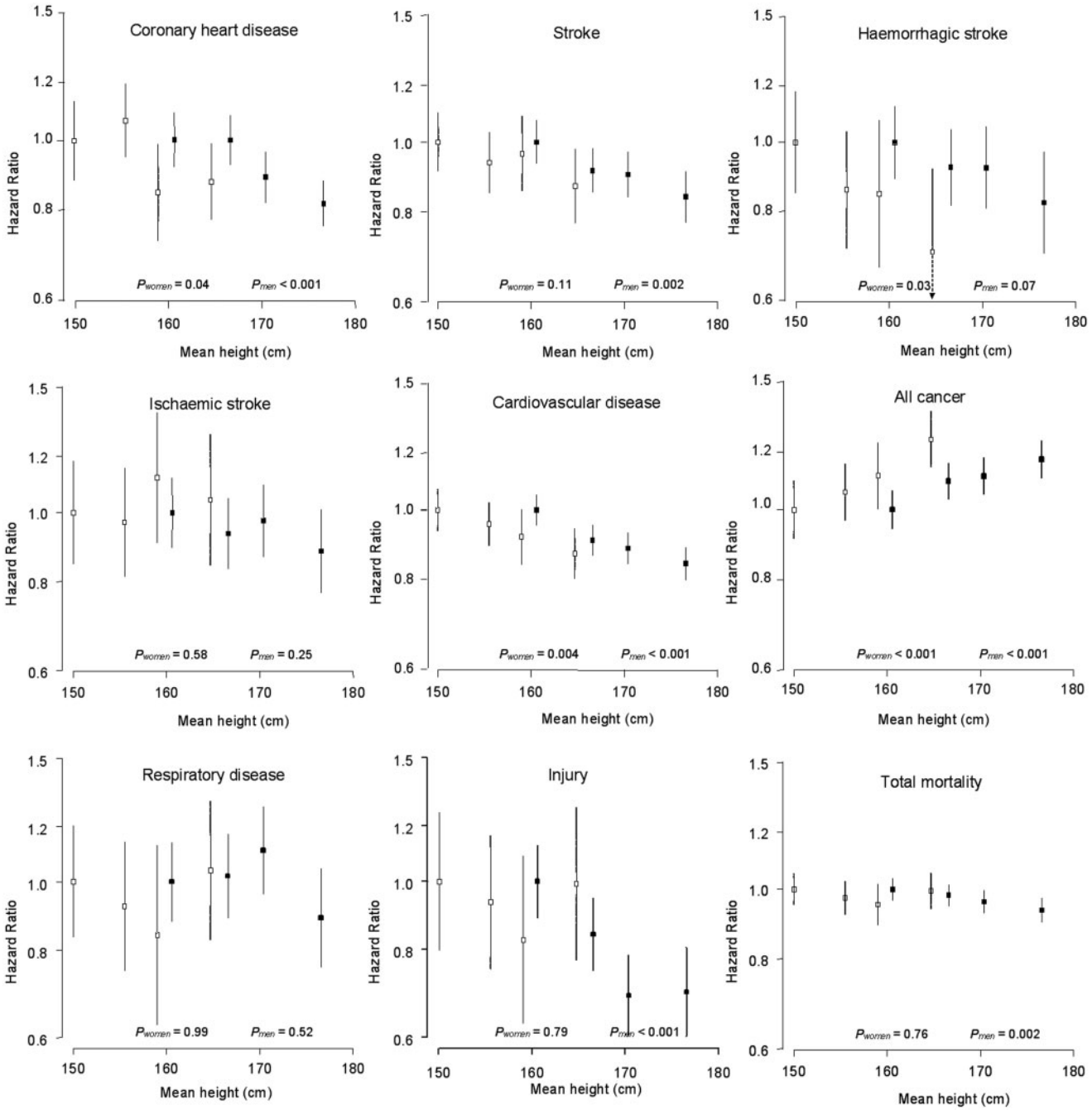

Figure 1 Age, study and year of birth adjusted HRs (95% CIs) for each outcome by height quarters in all participants. Black boxes represent male and white boxes represent female. *P*-values are test of linear trend by sex

an inverse relationship[4,14] and others (including the current study with the exception of men in Australasia) no relationship.[6,17,20] Estimates from our current analyses do support an inverse relationship with haemorrhagic stroke, mainly due to the strong association in the Asian cohort, which is likely to at least partially account for the inverse trend between height and total strokes reported here. As there was no evidence of a difference in the magnitude of this association between Asia and Australasia, the relationships with height may be related to other factors such as childhood and adult socio-economic status. A Korean study showed a 2–5% change in HRs for stroke and stroke sub-types after adjusting for socio-economic indicators.[12] Importantly, there was no evidence of marked attenuation when we included education level as a socio-economic indicator in our multivariable models.

Few studies have reported on association between height and mortality from all cancers combined,

Table 3 Age, study and year of birth adjusted HR (95% CIs) per 1-SD increase in height stratified by region

Outcome	Sex	No. of events	Overall[a]	Australasia	Asia	*P*-value for interaction
Coronary heart disease	M	2780	0.92 (0.89–0.96)	0.91 (0.88–0.95)	0.95 (0.89–1.01)	0.31
	F	1153	0.96 (0.90–1.01)	0.94 (0.87–1.00)	1.00 (0.90–1.10)	0.32
Stroke	M	3473	0.93 (0.90–0.96)	0.93 (0.87–0.98)	0.93 (0.90–0.97)	0.82
	F	1916	0.94 (0.89–0.98)	0.95 (0.88–1.03)	0.93 (0.88–0.98)	0.56
Haemorrhagic stroke	M	1050	0.91 (0.85–0.96)	0.95 (0.80–1.11)	0.90 (0.84–0.96)	0.58
	F	484	0.87 (0.79–0.96)	0.95 (0.77–1.19)	0.86 (0.78–0.95)	0.38
Ischaemic stroke	M	1334	0.95 (0.90–1.01)	0.88 (0.79–0.98)	0.98 (0.92–1.04)	0.10
	F	649	0.98 (0.90–1.06)	0.98 (0.84–1.15)	0.98 (0.89–1.07)	0.95
Cardiovascular disease	M	7293	0.93 (0.91–0.95)	0.93 (0.90–0.96)	0.93 (0.91–0.96)	0.88
	F	3730	0.94 (0.91–0.97)	0.95 (0.90–0.99)	0.94 (0.90–0.98)	0.85
All-cancer mortality	M	5232	1.05 (1.02–1.08)	1.06 (1.02–1.10)	1.04 (1.00–1.08)	0.41
	F	2265	1.09 (1.05–1.14)	1.11 (1.05–1.17)	1.08 (1.01–1.14)	0.47
Respiratory disease	M	1038	0.95 (0.90–1.01)	0.92 (0.84–1.00)	0.98 (0.91–1.06)	0.27
	F	559	0.93 (0.86–1.01)	0.96 (0.84–1.10)	0.92 (0.83–1.01)	0.58
Injury	M	1086	0.85 (0.80–0.91)	0.94 (0.84–1.07)	0.82 (0.77–0.88)	0.06
	F	357	0.98 (0.88–1.10)	1.05 (0.88–1.26)	0.95 (0.83–1.09)	0.35
Total mortality	M	14 628	0.97 (0.95–0.98)	0.97 (0.95–0.99)	0.96 (0.94–0.98)	0.64
	F	6995	0.98 (0.96–1.01)	0.99 (0.95–1.02)	0.98 (0.95–1.01)	0.78

[a]Including SBP and smoking in the model did not alter the results.

Table 4 Age, study and year of birth adjusted HR (95% CIs) per 1-SD increase in height stratified by age group

Outcome	Sex	No. of events	Overall	Age <60 years	Age ⩾60 years	*P*-value for interaction
Coronary heart disease	M	2780	0.92 (0.89–0.96)	0.92 (0.87–0.97)	0.93 (0.88–0.97)	0.76
	F	1153	0.96 (0.90–1.01)	0.97 (0.88–1.08)	0.94 (0.87–1.00)	0.52
Stroke	M	3473	0.93 (0.90–0.96)	0.90 (0.86–0.95)	0.96 (0.92–1.01)	0.07
	F	1916	0.94 (0.89–0.98)	0.86 (0.80–0.93)	0.98 (0.93–1.04)	0.01
Haemorrhagic stroke	M	1050	0.91 (0.85–0.96)	0.87 (0.80–0.95)	0.96 (0.87–1.05)	0.16
	F	484	0.87 (0.79–0.96)	0.75 (0.66–0.87)	0.97 (0.85–1.09)	<0.01
Ischaemic stroke	M	1334	0.95 (0.90–1.01)	0.93 (0.86–1.00)	0.98 (0.90–1.07)	0.31
	F	649	0.98 (0.90–1.06)	0.95 (0.84–1.08)	1.00 (0.90–1.11)	0.53
Cardiovascular disease	M	7293	0.93 (0.91–0.95)	0.91 (0.88–0.94)	0.95 (0.92–0.98)	0.06
	F	3730	0.94 (0.91–0.97)	0.90 (0.85–0.95)	0.96 (0.92–1.00)	0.06
All-cancer mortality	M	5232	1.05 (1.02–1.08)	0.99 (0.96–1.03)	1.11 (1.06–1.15)	<0.01
	F	2265	1.09 (1.05–1.14)	1.10 (1.04–1.17)	1.08 (1.02–1.15)	0.65
Respiratory disease	M	1038	0.95 (0.90–1.01)	0.95 (0.85–1.07)	0.96 (0.90–1.02)	0.94
	F	559	0.93 (0.86–1.01)	0.94 (0.78–1.14)	0.93 (0.85–1.01)	0.89
Injury	M	1086	0.85 (0.80–0.91)	0.85 (0.79–0.91)	0.88 (0.77–1.01)	0.63
	F	357	0.98 (0.88–1.10)	0.97 (0.84–1.13)	1.07 (0.90–1.27)	0.39
Total mortality	M	14628	0.97 (0.95–0.98)	0.93 (0.91–0.96)	1.00 (0.98–1.02)	<0.01
	F	6995	0.98 (0.96–1.01)	1.01 (0.97–1.05)	0.97 (0.94–1.00)	0.14

focusing instead on its relationship with specific cancers, but the findings have been conflicting. While a Finnish study reported no association between height and cancer for either sex,[21] the Renfrew and Paisley study reported a positive but weak association between height and cancers not related to smoking.[3] Similar to our finding, the age-adjusted relative risk for cancer for men from the Whitehall study was 1.03 (95% CI: 1.00–1.05) for each 5-cm increase in height.[19] The apparent lack of an association between height and cancer for men aged <60 years could be due to different cancer patterns. It has been shown that the increased cancer risk in tall relative to shorter people differs by cancer type ranging from 10 to 60%.[9]

Findings from the current study suggest an inverse association between height and risk of fatal injury, although the relationship was only observed for men. This may be a chance finding due to the large number of comparisons performed. However, it is consistent with the results from a Swedish study[22] that reported a 9% decrease in suicide risk for each 5-cm increase in height although not all studies have observed such an association.[23]

The apparent opposing associations between CVD and cancer for height might have resulted in the lack of an association between height and total mortality for women. The small inverse association observed in our analysis between height and total mortality in men might be influenced by the large weighting of the KMIC study, which contributed 36% of the participants in the APCSC and that KMIC participants were aged 35–59 years at baseline. However, the association we observed remained evident in sensitivity analyses that tested the effects of the KMIC study on the regional and age estimates.

Although adult height has been reported to be associated with cardiorespiratory disease and certain types of cancer, it is uncertain whether height is the causal factor. Height is possibly a surrogate marker of risk factors such as insulin-like growth factor (IGF) levels. For example, case-control studies of CHD have reported lower levels of IGF-I for cases.[24,25] In regard to cancer, attained height has been hypothesized to increase risk because of the greater number of cells available for malignant transformation.[26] Height may also usefully capture pre-adult environmental exposures such as socio-economic position,[27] nutrition and possibly, psychosocial stress.[28]

There are limitations to this study. First, socio-economic status, especially childhood socio-economic status, has been shown to be positively associated with adult height and negatively associated with cardiovascular risks.[29–32] The APCSC only had data on education level to use in this study as an indicator of socio-economic status. The higher percentage of participants completing secondary education or above in the Asian cohort might be due to selection bias since some studies were based on occupational cohorts. Nevertheless, other studies have shown changes in estimates of cardiovascular risk of <10% change after adjustment for socio-economic status.[5,12,33] Secondly, as intergenerational increase in height is becoming more rapid in Asian countries due to the recent nutrition transition in this region, our results might have been confounded by birth cohort effects. We have included year of birth in the models and, given that 90% of members of our cohorts were born between 1930 and 1960, any effect caused by the intergenerational increase in height should have been minimal. Thirdly, leg length has been reported to be associated with CHD and cancer.[9,33] As Asians tend to have shorter legs relative to body height than Caucasians, associations between leg length and study outcome might differ between Asians and Australasians. In any case, these associations could not be investigated as data on leg length were not available in the APCSC. Fourthly, we did not compare the absolute risk for a particular level of height between Asians and Australasians because, *a priori*, background rates of many of the endpoints of interest are very different. Further, as Asians are rapidly catching up with Caucasians in height, the difference in mean height between them will become smaller over the next few decades. Fifthly, physical activity and diet are potential confounders, which were not included in the model due to the lack of such data in APCSC.

Given that smoking, obesity and lack of physical activity overlap as risk factors for both CVD and several common cancers, the opposing relationships between CVD and mortality from cancer reported here underline the need for more research into the aetiological pathways of major non-communicable diseases as residual confounding may have resulted from the lack of detailed data on socio-economic status. Until this is done, policies such as those intended to increase nutritional intake in children to promote vertical growth cannot be recommended, lest they contribute to the growing tide of obesity in the Asia-Pacific region and around the world. Such an unintended consequence would have important adverse effects on the incidence of all of diabetes, CVD and certain cancers.

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KEY MESSAGE

- Inverse linear associations with height were apparent for CHD and CVD in both sexes with an estimate of 5–10% reduction in risk for each 6 cm greater height. On the contrary, a positive linear association was observed between height and risk of cancer.

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