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Associations of adult height and its components with mortality: a report from cohort studies of 135 000 Chinese women and men

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Background Although several studies have evaluated the relationship between adult height and mortality, their results have not been entirely consistent. Little is known about components of adult height in relation to mortality, particularly in developing countries.

Methods We examined the association of adult height and its components (leg and trunk length) with mortality using data from 74 869 Chinese women and 61 333 men in the Shanghai Women's (1996–2008) and Men's (2002–2008) Health Studies. Anthropometric measurements, including standing and sitting height and weight, were taken at baseline by trained interviewers according to a standard protocol. Deaths were ascertained by biennial home visits and linkage with the vital statistics registry. Cox regression models were used to evaluate the associations.

Results Neither height nor its components were associated with all-cause mortality. Height and, less consistently, its components were positively associated with cancer mortality, but inversely associated with cardiovascular disease (CVD) mortality. Hazard ratios (HRs) [95% confidence intervals (CIs)] for cancer mortality per 1-SD increment in height, trunk and leg length were 1.06 (1.01–1.12), 1.07 (1.01–1.12) and 1.03 (0.98–1.08), respectively, in women, and 1.13 (1.05–1.22), 1.09 (1.00–1.19) and 1.10 (1.03–1.16), respectively, in men. The corresponding HRs for CVD mortality were 0.89 (0.84–0.95), 0.93 (0.87–0.99) and 0.91 (0.86–0.98) in women, and 0.93 (0.86–1.02), 0.89 (0.81–0.98) and 0.99 (0.92–1.06) in men.

Conclusions Our results suggest that different mechanisms may be involved in linking height and its components with cancer and CVD mortality.

Keywords Body height, cancer, cardiovascular disease, Chinese, cohort study, mortality

Introduction

It has been suggested that poor nutrition, illness and adverse living circumstances experienced during early life may contribute to the development of chronic disease in later life.[1,2] Attained adult height is known to be influenced by these early life factors and has been widely used as a surrogate measure for early life exposures in epidemiologic studies. Short adult stature has been previously linked to increased risk of cardiovascular disease (CVD), but decreased risk of cancer, although the results have not been entirely consistent.[3–6] Potential mechanisms underlying the opposing associations of adult height with CVD and cancer are not fully understood. Elucidating components of adult height (leg and trunk length) in relation to disease risk may provide some insight into the relationship between early life exposures, height and adult health. It has been suggested that leg length is a sensitive marker of nutritional status and other exposures in childhood, and may be the component of adult height that is related to disease risk. Relatively few prospective studies,[7–10] however, have examined the associations of leg length and trunk length with disease risk. Furthermore, studies of adult height and disease risk published to date have been conducted largely in affluent Western countries,[3,8,11–16] and data from less-affluent developing countries are sparse;[17–19] it is unclear whether the associations of adult height and its components with health outcomes differ by the populations under study.

We evaluated the associations of adult height, leg length and trunk length with risk of all-cause and cause-specific mortality in two large cohort studies conducted in China, the Shanghai Women's Health Study (SWHS) and the Shanghai Men's Health Study (SMHS).

Methods

Study population

The SWHS and the SMHS are both population-based, prospective cohort studies. Details of the study methodologies have been reported previously.[20,21] Participants were identified through the Shanghai Resident Registry, which kept personal identification cards for all permanent residents in urban Shanghai. All women aged 40–70 years and men aged 40–74 years living in the study communities were approached for participation by trained interviewers and local community health workers. From 1996 to 2000, the SWHS recruited 74 942 women and from 2002 to 2006, the SMHS enrolled 61 500 men. The participation rates were 92.7% for SWHS and 74.1% for SMHS. At baseline, each subject completed an in-person interview to gather information on demographics, lifestyle habits, dietary intake, physical activity, occupational history, and menstrual and reproductive history (for women only). Anthropometric measurements were also taken for each subject at baseline. The study protocols were approved by the relevant institutional review boards of all institutes involved and written informed consent was obtained from all participants.

Anthropometry

Anthropometric measurements, including standing height (cm), sitting height (cm), weight (kg), and circumferences of the waist and hips (cm), were taken by trained health professionals according to a standard protocol. Each parameter was measured twice with a tolerance error of 1 cm for height and circumference measurements, and 1 kg for the weight measurement. If the difference between two measurements was greater than tolerance, a third measurement was then taken. All parameters were estimated as the mean value of the two closest measurements. The standing height was measured to the nearest 0.1 cm without shoes. The sitting height (trunk length) was measured to the nearest 0.1 cm with the participant seated on a stool against the wall. Leg length was calculated as the difference between standing height and trunk length. Weight was measured to the nearest 0.1 kg using a digital weight scale that was calibrated every 6 months. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in metres. Waist circumference was taken at 2.5 cm above the umbilicus and hip circumference at the level of maximum protrusion of the gluteal muscles. Waist–hip ratio (WHR) was then calculated as waist circumference divided by hip circumference.

Outcome ascertainment

All participants were followed-up for major chronic diseases and vital status through home visits conducted every 2 years and record linkage to the Shanghai Cancer Registry and the Shanghai Vital Statistics Registry. Information on newly diagnosed cancer cases in cohort members was obtained from the Shanghai Cancer Registry. For the SWHS, the in-person follow-up rates for the first (2000–2002), second (2002–2004) and third (2004–2007) surveys were 99.8, 98.7 and 95.0%, respectively. For the SMHS, the response rate for the first follow-up (2004–2008) was 97.6%. There were 34 cohort members who moved out of the study area and for whom vital status could not be determined via record linkage to the vital statistics registry; these subjects were treated as censored observations. The primary endpoint for this analysis was death from any cause that occurred after the baseline survey but before 31 December 2008. The underlying cause of death was determined on the basis of death certificates and coded according to the codes of the International Classification of Disease, 9th Revision (ICD-9). In addition to total mortality, we also examined deaths from cancer (ICD-9 codes 140–208) and CVD (ICD-9 codes 390–459). We further divided cancer deaths into deaths from female cancers, including breast (ICD-9 code 174), uterine (179, 182), cervical (180) and ovarian (183) cancers, and other cancer deaths for women, and smoking-related cancers, including cancers of the lip, oral cavity, pharynx (ICD-9 codes 140–149), oesophagus (150), pancreas (157), respiratory tract (160–163) and urinary tract (188–189), and smoking-unrelated cancers for men. We also examined deaths from stroke (ICD-9 codes 430–438), ischaemic heart disease (ICD codes 410–414), and other circulatory diseases in women and in men.

Statistical analysis

Participants with missing data on anthropometric measurements (65 women and 167 men) or who were lost to follow-up shortly after the study enrolment (8 women) were excluded, leaving 74 869 women and 61 333 men for analyses. Participants were categorized by sex-specific quintiles of height, leg length and trunk length, and the lowest quintiles were used as the reference categories. Hazard ratios (HRs) and 95% confidence intervals (95% CIs) were calculated using Cox proportional hazards models with age as the time metric. Entry time was defined as the age at enrolment and exit time was defined as the age at death or last date of follow-up, whichever came first. Birth calendar year (eight categories: 1926–1932, 1933–1937, 1938–1941, 1942–1945, 1946–1949, 1950–1953, 1954–1957 and after 1958) was treated as a strata variable in the Cox models. Multivariable models were further adjusted for education (four categories: up to elementary school, middle school, high school, beyond college), occupation (three categories: professional, clerical and manual workers), income (three categories: for men: monthly per capita income <1000 yuan, 1000–2000 yuan, and >2000 yuan; for women: annual family income <20 000, 20 000–30 000 yuan and >30 000 yuan), BMI (quintiles), WHR (quintiles), total physical activity [measured in metabolic equivalent (MET) hours/week, quintiles], cigarette smoking (never, former, current: 1–9, 10–19, ⩾20 cigarettes/day for men; never/ever for women), alcohol consumption (0, 0.1–1.0, 1.1–2.0 and >2.0 drinks/day for men; never/ever for women), daily intakes of total energy, red meat, fruit and vegetables (continuous), and menopausal status (pre-/post-menopausal for women). We also calculated HRs of mortality for per 1-standard deviation (SD) increment in height, trunk length and leg length. All analyses were performed by using SAS, version 9.1 software (SAS Institute, Inc., Cary, NC, USA), and all tests of statistical significance were based on two-sided probability.

Results

The average age and height of the study participants were 52.1 years and 157.5 cm for women and 54.9 years and 169.8 cm for men, respectively. Table 1 shows the age-adjusted baseline characteristics of participants according to height quintiles. Among both women and men, taller participants were younger and had a higher level of socioeconomic status (SES) as measured by education level, occupation and family income, as compared with shorter participants. They also appeared to have higher intakes of total energy, red meat, fruit and vegetables, higher WHR, and a lower level of physical activity, and were more likely to smoke cigarettes. There was little correlation between the number of cigarettes smoked and height among current smokers ($r = 0.018$) in men. Taller men were also more likely to drink alcohol than shorter men.

The correlation coefficients of age with height, leg length and trunk length in women were −0.38, −0.22 and −0.37, respectively. The corresponding coefficients in men were −0.33, −0.22 and −0.32.

In the SWHS cohort, we identified 3624 deaths, including 1018 from CVD [55.8% stroke, 21.8% coronary heart disease (CHD) and 22.4% other circulatory diseases] and 1653 from cancer (18.9% lung cancer, 14.3% colorectal cancer, 12.5% stomach cancer, 7.3% liver cancer, 10.1% breast cancer and 36.9% other cancers). In the SMHS cohort, we identified 1860 deaths, including 602 from CVD (49.0% stroke, 34.1% CHD and 16.9% other circulatory diseases) and 808 from cancer (30.9% lung cancer, 14.8% liver cancer, 13.0% stomach cancer, 7.7% colorectal cancer and 33.6% other cancers). Tables 2 and 3 show age- and multivariate-adjusted HRs of total and cause-specific mortality by quintiles of adult height in women and men. After adjustment for potential confounding factors, no significant association was found between height and total mortality in either women or men. However, greater height was related to significantly elevated risk of cancer mortality in both sexes. The multivariable-adjusted HRs (95% CIs) of cancer mortality for per 1-SD increment in height were 1.06 (1.01–1.12) for women and 1.13 (1.05–1.22) for men. In contrast, an inverse association between height and CVD mortality was found both in women and in men, with corresponding HRs of 0.89 (0.84–0.95) and 0.93 (0.86–1.02). The inverse association of height with CVD mortality was more evident for stroke than for ischaemic heart disease in both sexes.

Similar to height, trunk length showed a positive association with cancer mortality, an inverse association with CVD mortality and a null association with total mortality in women and men (Table 4). The results for leg length were less consistent (Table 5). A positive association between leg length and cancer mortality was more evident in men (HR for 1-SD increase: 1.10; 95% CI 1.03–1.16) than in women (HR: 1.03; 95% CI 0.98–1.08), whereas an inverse association with CVD was evident in women (HR for 1-SD increase: 0.91; 95% CI 0.86–0.98), but not in men (HR: 0.99; 95% CI 0.92–1.06).

Table 1 Baseline characteristics of participants according to quintiles of height,[a] the SWHS and SMHS

	Quintiles of height				
	Q1	Q2	Q3	Q4	Q5
Women (SWHS)					
Height (cm)	<153.0	153.0–155.8	156.0–158.9	159.0–161.9	⩾162.0
No. of subjects	13 825	12 652	16 415	14 385	17 592
Age at baseline (years)	58.2 ± 8.9	54.8 ± 9.1	52.6 ± 8.9	50.5 ± 8.2	48.4 ± 7.1
Low income[b] (%)	62.2	57.3	54.4	51.3	51.4
⩽Middle school (%)	67.7	62.1	58.4	55.8	52.0
Manual workers (%)	55.9	52.6	50.2	48.8	45.9
Ever smoked (%)	2.2	2.7	2.9	3.2	3.6
Ever drank (%)	2.3	2.2	2.1	2.3	2.4
Post-menopausal (%)	50.3	49.8	49.4	49.4	48.3
BMI (kg/m^2)	24.3 ± 3.5	24.1 ± 3.4	24.0 ± 3.3	23.9 ± 3.4	23.8 ± 3.3
WHR	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1
MET-hours/week	110.1 ± 46.9	108.7 ± 45.4	106.8 ± 45.1	105.2 ± 45.4	102.7 ± 46.4
Daily intake					
Energy (kcal/day)	1617.5 ± 419.0	1649.5 ± 405.4	1676.7 ± 403.0	1694.1 ± 405.4	1726.2 ± 414.9
Red meat (g/day)	47.9 ± 37.6	50.3 ± 36.4	51.3 ± 36.2	51.5 ± 36.4	53.0 ± 37.2
Fruit (g/day)	238.4 ± 182.8	257.4 ± 176.8	265.2 ± 175.8	273.3 ± 176.8	282.8 ± 181.0
Vegetables (g/day)	280.9 ± 176.9	290.9 ± 171.1	295.2 ± 170.1	303.0 ± 171.1	309.4 ± 175.1
Men (SMHS)					
Height (cm)	<165.0	165.0–168.4	168.5–170.9	171.0–174.9	⩾175.0
No. of subjects	11 148	13 162	10 143	14 358	12 522
Age at baseline (y)	60.6 ± 9.9	57.2 ± 9.8	54.9 ± 9.4	53.5 ± 8.9	51.2 ± 8.0
Low income[b] (%)	63.2	57.5	55.2	52.8	49.2
⩽Middle school (%)	48.9	43.9	40.6	38.8	34.2
Manual workers (%)	56.6	53.3	50.5	50.2	46.0
Ever smoked (%)	66.5	69.5	69.9	70.4	70.8
Ever drank (%)	33.2	33.8	33.7	33.5	34.7
BMI (kg/m^2)	23.8 ± 3.2	23.7 ± 3.1	23.7 ± 3.1	23.7 ± 3.1	23.7 ± 3.1
WHR	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1
MET-hours/week	62.4 ± 34.1	61.0 ± 33.2	59.7 ± 33.1	58.5 ± 33.2	57.2 ± 33.8
Daily intake					
Energy (kcal/day)	1855.8 ± 494.5	1884.2 ± 482.4	1901.4 ± 480.5	1928.9 ± 482.5	1966.3 ± 490.3
Red meat (g/day)	60.9 ± 45.3	61.9 ± 44.2	63.2 ± 44.0	63.7 ± 44.2	66.3 ± 44.9
Fruit (g/day)	139.2 ± 129.6	148.3 ± 126.4	150.9 ± 125.9	157.5 ± 126.5	160.1 ± 128.5
Vegetables (g/day)	330.3 ± 198.2	337.8 ± 193.3	344.5 ± 192.5	348.8 ± 193.4	356.3 ± 196.5

[a]For means: least-square means estimated through linear regression models, which included age as independent variable; for percentage: directly adjusted for age in 5-year categories; all tests for trend were significant ($P < 0.05$) expect for women and men who ever drank, and BMI for men.
[b]For men: monthly per capita income <1000 Chinese Yuan; for women: annual family income <20 000 Chinese Yuan.

Table 2 HRs and 95% CIs of total and cause-specific mortality according to quintiles of height,[a] the SWHS

	Quintiles of height (cm)					Per 1-SD increase
	<153.0	153.0–155.8	156.0–158.9	159.0–161.9	≥162.0	
All causes						
No. of deaths	1154	753	731	514	472	
Model 1[b]	1.00	0.95 (0.87–1.04)	0.88 (0.80–0.96)	0.89 (0.80–0.99)	0.90 (0.80–1.01)	0.94 (0.91–0.98)
Model 2[c]	1.00	0.99 (0.90–1.08)	0.93 (0.84–1.02)	0.95 (0.85–1.05)	0.97 (0.86–1.08)	0.97 (0.94–1.01)
Cancer						
No. of deaths	431	324	372	254	272	
Model 1	1.00	1.04 (0.90–1.21)	1.10 (0.95–1.27)	1.04 (0.89–1.22)	1.16 (0.98–1.36)	1.05 (1.00–1.10)
Model 2	1.00	1.06 (0.92–1.23)	1.13 (0.98–1.30)	1.08 (0.92–1.26)	1.21 (1.03–1.42)	1.06 (1.01–1.12)
Female cancers						
No. of deaths	52	53	58	48	73	
Model 1	1.00	1.33 (0.90–1.95)	1.27 (0.87–1.85)	1.36 (0.91–2.04)	1.98 (1.35–2.90)	1.21 (1.06–1.37)
Model 2	1.00	1.32 (0.90–1.95)	1.26 (0.86–1.85)	1.37 (0.91–2.05)	1.98 (1.35–2.90)	1.21 (1.06–1.37)
Other cancers						
No. of deaths	379	271	314	206	199	
Model 1	1.00	1.01 (0.86–1.18)	1.08 (0.93–1.26)	1.00 (0.84–1.19)	1.02 (0.85–1.22)	1.02 (0.96–1.08)
Model 2	1.00	1.02 (0.87–1.19)	1.11 (0.95–1.29)	1.03 (0.86–1.23)	1.07 (0.89–1.28)	1.04 (0.98–1.10)
CVD						
No. of deaths	387	215	187	139	90	
Model 1	1.00	0.86 (0.73–1.02)	0.75 (0.63–0.89)	0.85 (0.70–1.04)	0.67 (0.53–0.85)	0.86 (0.80–0.92)
Model 2	1.00	0.90 (0.76–1.07)	0.80 (0.67–0.95)	0.92 (0.76–1.12)	0.74 (0.58–0.94)	0.89 (0.84–0.95)
Stroke						
No. of deaths	208	129	105	82	44	
Model 1	1.00	0.96 (0.77–1.19)	0.77 (0.61–0.98)	0.93 (0.72–1.21)	0.61 (0.44–0.86)	0.86 (0.79–0.94)
Model 2	1.00	1.01 (0.81–1.26)	0.83 (0.66–1.06)	1.01 (0.77–1.31)	0.66 (0.47–0.93)	0.89 (0.82–0.97)
Ischaemic heart disease						
No. of deaths	90	42	40	25	25	
Model 1	1.00	0.74 (0.51–1.06)	0.71 (0.49–1.04)	0.70 (0.45–1.10)	0.91 (0.57–1.43)	0.88 (0.77–1.01)
Model 2	1.00	0.77 (0.53–1.12)	0.77 (0.53–1.12)	0.77 (0.49–1.20)	1.01 (0.64–1.61)	0.92 (0.80–1.06)
Other circulatory diseases						
No. of deaths	89	44	42	32	21	
Model 1	1.00	0.75 (0.52–1.07)	0.70 (0.48–1.01)	0.80 (0.53–1.21)	0.63 (0.38–1.03)	0.83 (0.73–0.96)
Model 2	1.00	0.79 (0.55–1.13)	0.74 (0.51–1.07)	0.86 (0.57–1.30)	0.67 (0.41–1.10)	0.87 (0.76–0.99)
Causes other than cancer or CVD						
No. of deaths	336	214	172	121	110	
Model 1	1.00	0.94 (0.79–1.11)	0.72 (0.60–0.87)	0.74 (0.60–0.92)	0.77 (0.61–0.96)	0.87 (0.81–0.93)
Model 2	1.00	1.00 (0.84–1.18)	0.79 (0.65–0.95)	0.82 (0.66–1.01)	0.83 (0.66–1.05)	0.91 (0.85–0.98)

[a]The total follow-up time for women in each quintile of height was 136 461, 126 248, 165 257, 145 366 and 178 132 person-years, respectively.
[b]Model 1: age adjusted only.
[c]Model 2: multivariate model: adjusted for birth calendar year, age, education, income, occupation, BMI, WHR, cigarette smoking, alcohol consumption, total physical activity (MET hours/week), daily intake of energy, red meat, fruit and vegetables and menopause status.

Table 3 HRs and 95% CIs of total and cause-specific mortality according to quintiles of height[a], the SMHS

	Quintiles of height (cm)					Per 1-SD increase
	<165.0	165.0–168.4	168.5–170.9	171.0–174.9	⩾175.0	
All causes						
No. of deaths	560	436	285	342	237	
Model 1[b]	1.00	0.88 (0.78–1.00)	0.93 (0.81–1.08)	0.92 (0.80–1.06)	0.98 (0.84–1.15)	0.97 (0.92–1.02)
Model 2[c]	1.00	0.93 (0.82–1.05)	1.00 (0.86–1.15)	0.99 (0.86–1.14)	1.06 (0.90–1.25)	1.00 (0.95–1.05)
Cancer						
No. of deaths	206	198	113	164	127	
Model 1	1.00	1.08 (0.89–1.31)	0.99 (0.78–1.25)	1.17 (0.95–1.45)	1.38 (1.09–1.74)	1.10 (1.02–1.18)
Model 2	1.00	1.11 (0.91–1.35)	1.03 (0.82–1.30)	1.24 (1.00–1.53)	1.47 (1.16–1.86)	1.13 (1.05–1.22)
Smoking-related cancers						
No. of deaths	92	94	58	76	62	
Model 1	1.00	1.19 (0.89–1.59)	1.22 (0.87–1.69)	1.33 (0.98–1.82)	1.74 (1.24–2.43)	1.16 (1.04–1.29)
Model 2	1.00	1.22 (0.91–1.62)	1.26 (0.90–1.76)	1.40 (1.02–1.92)	1.86 (1.32–2.62)	1.18 (1.06–1.32)
Other cancers						
No. of deaths	114	104	55	88	65	
Model 1	1.00	0.99 (0.76–1.29)	0.82 (0.59–1.13)	1.05 (0.79–1.39)	1.12 (0.81–1.55)	1.05 (0.95–1.16)
Model 2	1.00	1.02 (0.78–1.33)	0.86 (0.62–1.19)	1.10 (0.83–1.48)	1.20 (0.87–1.67)	1.08 (0.98–1.20)
CVD						
No. of deaths	203	136	100	104	59	
Model 1	1.00	0.79 (0.63–0.98)	0.96 (0.75–1.22)	0.84 (0.66–1.07)	0.77 (0.57–1.04)	0.90 (0.83–0.98)
Model 2	1.00	0.84 (0.67–1.04)	1.04 (0.82–1.33)	0.89 (0.70–1.14)	0.84 (0.62–1.14)	0.93 (0.86–1.02)
Stroke						
No. of deaths	104	66	50	52	23	
Model 1	1.00	0.72 (0.53–0.99)	0.89 (0.63–1.25)	0.76 (0.54–1.07)	0.52 (0.33–0.84)	0.84 (0.74–0.94)
Model 2	1.00	0.79 (0.58–1.08)	1.00 (0.71–1.41)	0.84 (0.60–1.19)	0.59 (0.37–0.95)	0.88 (0.78–1.00)
Ischaemic heart disease						
No. of deaths	63	53	35	34	20	
Model 1	1.00	1.02 (0.71–1.47)	1.16 (0.77–1.77)	0.98 (0.64–1.49)	0.98 (0.59–1.65)	0.97 (0.84–1.12)
Model 2	1.00	1.05 (0.73–1.52)	1.20 (0.79–1.83)	0.98 (0.64–1.51)	1.01 (0.60–1.72)	0.97 (0.84–1.13)
Other circulatory diseases						
No. of deaths	36	17	15	18	16	
Model 1	1.00	0.55 (0.31–0.98)	0.81 (0.44–1.50)	0.82 (0.46–1.47)	1.18 (0.64–2.19)	0.98 (0.80–1.20)
Model 2	1.00	0.59 (0.33–1.05)	0.90 (0.49–1.67)	0.89 (0.49–1.60)	1.29 (0.68–2.46)	1.01 (0.82–1.25)
Causes other than cancer or CVD						
No. of deaths	151	102	72	74	51	
Model 1	1.00	0.74 (0.58–0.96)	0.83 (0.62–1.10)	0.69 (0.52–0.91)	0.70 (0.50–0.97)	0.85(0.77–0.94)
Model 2	1.00	0.80 (0.62–1.03)	0.90 (0.68–1.20)	0.77 (0.57–1.02)	0.78 (0.55–1.09)	0.90(0.82–0.99)

[a]The total follow-up time for men in each quintile of height was 50 916, 59 714, 45 847, 64 861 and 56 308 person-years, respectively.

[b]Model 1: age adjusted only.

[c]Model 2: multivariate model: adjusted for birth calendar year, age, education, income, occupation, BMI, WHR, cigarette smoking, alcohol consumption, total physical activity (MET hours/week), daily intake of energy, red meat, fruit and vegetables.

Table 4 HRs and 95% CIs of total and cause-specific mortality according to quintiles of trunk length[a], the SWHS and SMHS

	Quintiles of trunk length					Per 1-SD increase
	Q1	Q2	Q3	Q4	Q5	
Women						
All causes						
No. of deaths	1218	807	753	520	326	
Model 1[b]	1.00	0.84 (0.77–0.92)	0.90 (0.82–0.98)	0.85 (0.76–0.94)	0.85 (0.75–0.97)	0.94 (0.90–0.97)
Model 2[c]	1.00	0.88 (0.81–0.96)	0.97 (0.88–1.06)	0.93 (0.84–1.04)	0.95 (0.84–1.09)	0.98 (0.95–1.01)
Cancer						
No. of deaths	441	363	391	262	196	
Model 1	1.00	0.98 (0.85–1.13)	1.15 (1.00–1.32)	1.01 (0.86–1.18)	1.15 (0.96–1.38)	1.05 (1.00–1.10)
Model 2	1.00	1.00 (0.87–1.16)	1.20 (1.04–1.38)	1.05 (0.90–1.24)	1.21 (1.01–1.45)	1.07 (1.01–1.12)
CVD						
No. of deaths	398	233	199	131	57	
Model 1	1.00	0.80 (0.68–0.94)	0.84 (0.71–1.00)	0.82 (0.67–1.00)	0.64 (0.48–0.85)	0.88 (0.83–0.94)
Model 2	1.00	0.84 (0.72–0.99)	0.91 (0.76–1.08)	0.90 (0.73–1.11)	0.71 (0.54–0.95)	0.93 (0.87–0.99)
Causes other than cancer or CVD						
No. of deaths	379	211	163	127	73	
Model 1	1.00	0.71 (0.60–0.84)	0.63 (0.52–0.76)	0.68 (0.55–0.84)	0.64 (0.49–0.84)	0.83 (0.78–0.89)
Model 2	1.00	0.78 (0.66–0.92)	0.73 (0.61–0.88)	0.82 (0.66–1.01)	0.79 (0.60–1.03)	0.91 (0.85–0.97)
Men						
All causes						
No. of deaths	583	412	371	265	229	
Model 1[b]	1.00	0.86 (0.76–0.98)	0.89 (0.78–1.02)	0.81 (0.70–0.94)	0.99 (0.84–1.16)	0.91 (0.86–0.96)
Model 2[c]	1.00	0.92 (0.81–1.05)	0.98 (0.86–1.13)	0.93 (0.80–1.09)	1.13 (0.96–1.33)	0.97 (0.92–1.03)
Cancer						
No. of deaths	230	174	163	118	123	
Model 1	1.00	0.91 (0.75–1.11)	0.97 (0.79–1.19)	0.89 (0.71–1.12)	1.29 (1.02–1.63)	1.03 (0.95–1.13)
Model 2	1.00	0.97 (0.79–1.18)	1.04 (0.85–1.28)	1.00 (0.79–1.25)	1.44 (1.14–1.83)	1.09 (1.00–1.19)
CVD						
No. of deaths	202	134	132	78	56	
Model 1	1.00	0.84 (0.67–1.04)	0.99 (0.79–1.23)	0.76 (0.58–0.99)	0.81 (0.59–1.10)	0.84 (0.76–0.93)
Model 2	1.00	0.88 (0.71–1.10)	1.07 (0.85–1.34)	0.84 (0.64–1.11)	0.87 (0.64–1.20)	0.89 (0.81–0.98)
Causes other than cancer or CVD						
No. of deaths	151	104	76	69	50	
Model 1	1.00	0.82 (0.64–1.05)	0.67 (0.50–0.88)	0.75 (0.56–1.01)	0.74 (0.53–1.03)	0.80 (0.71–0.89)
Model 2	1.00	0.92 (0.71–1.18)	0.79 (0.60–1.05)	0.96 (0.71–1.29)	0.92 (0.65–1.30)	0.90 (0.81–1.01)

[a]The range for each quintile: for women: <82.0, 82.0–83.9, 84.0–85.0, 85.1–87.0 and ⩾87.1 cm; for men: <88.0, 88.0–89.0, 90.0–91.0, 91.1–93.0 and ⩾93.1 cm. The total follow-up time in each quintile of trunk length was 133 962, 150 649, 172 654, 161 064 and 131 065 person-years, respectively, in women and 51 417, 55 091, 62 397, 56 329 and 52 413 person-years, respectively, in men.

[b]Model 1: age adjusted only.

[c]Model 2: multivariate model: adjusted for birth calendar year, age, education, income, occupation, BMI, WHR, cigarette smoking, alcohol consumption, total physical activity (MET hours/week), daily intake of energy, red meat, fruit and vegetables and menopause status (for women only).

Table 5 HRs and 95% CIs of total and cause-specific mortality according to quintiles of leg length[a], the SWHS and SMHS

	Quintiles of leg length					Per 1-SD increase
	Q1	Increase	Q3	Q4	Q5	
Women						
All causes						
No. of deaths	816	737	790	609	672	
Model 1[b]	1.00	0.97 (0.88–1.08)	1.02 (0.92–1.13)	0.98 (0.88–1.09)	0.96 (0.87–1.06)	0.98 (0.95–1.01)
Model 2[c]	1.00	0.98 (0.89–1.08)	1.03 (0.94–1.14)	0.99 (0.89–1.10)	0.96 (0.86–1.06)	0.98 (0.94–1.01)
Cancer						
No. of deaths	335	316	370	295	337	
Model 1	1.00	1.00 (0.86–1.17)	1.13 (0.97–1.31)	1.09 (0.94–1.28)	1.08 (0.93–1.26)	1.02 (0.97–1.08)
Model 2	1.00	1.01 (0.87–1.18)	1.14 (0.98–1.32)	1.11 (0.95–1.30)	1.10 (0.94–1.28)	1.03 (0.98–1.08)
CVD						
No. of deaths	274	217	208	154	165	
Model 1	1.00	0.87 (0.73–1.04)	0.83 (0.70–1.00)	0.79 (0.65–0.96)	0.78 (0.64–0.95)	0.91 (0.85–0.97)
Model 2	1.00	0.88 (0.74–1.05)	0.86 (0.72–1.03)	0.82 (0.67–0.99)	0.80 (0.65–0.97)	0.91 (0.86–0.98)
Causes other than cancer or CVD						
No. of deaths	207	204	212	160	170	
Model 1	1.00	1.07 (0.88–1.30)	1.10 (0.91–1.33)	1.04 (0.85–1.28)	1.00 (0.82–1.23)	0.98 (0.91–1.04)
Model 2	1.00	1.06 (0.87–1.28)	1.09 (0.89–1.32)	1.03 (0.83–1.26)	0.93 (0.76–1.15)	0.96 (0.90–1.03)
Men						
All causes						
No. of deaths	392	466	420	329	253	
Model 1[b]	1.00	1.06 (0.93–1.22)	1.14 (0.99–1.31)	1.14 (0.98–1.32)	1.04 (0.89–1.27)	1.02 (0.98–1.06)
Model 2[c]	1.00	1.07 (0.94–1.23)	1.15 (1.00–1.32)	1.12 (0.97–1.30)	1.03 (0.88–1.22)	1.02 (0.98–1.06)
Cancer						
No. of deaths	146	207	176	155	124	
Model 1	1.00	1.26 (1.02–1.55)	1.26 (1.01–1.57)	1.41 (1.12–1.77)	1.32 (1.04–1.68)	1.09 (1.03–1.16)
Model 2	1.00	1.25 (1.01–1.55)	1.26 (1.01–1.57)	1.40 (1.11–1.76)	1.32 (1.04–1.69)	1.10 (1.03–1.16)
CVD						
No. of deaths	139	148	141	97	77	
Model 1	1.00	0.97 (0.77–1.23)	1.12 (0.89–1.42)	1.00 (0.77–1.30)	0.97 (0.73–1.28)	0.98 (0.92–1.05)
Model 2	1.00	0.99 (0.79–1.26)	1.17 (0.92–1.48)	1.00 (0.77–1.31)	1.00 (0.75–1.33)	0.99 (0.92–1.06)
Causes other than cancer or CVD						
No. of deaths	107	111	103	77	52	
Model 1	1.00	0.92 (0.70–1.19)	1.00 (0.76–1.31)	0.94 (0.70–1.27)	0.74 (0.53–1.04)	0.95 (0.87–1.03)
Model 2	1.00	0.94 (0.72–1.22)	1.01 (0.77–1.33)	0.90 (0.67–1.22)	0.72 (0.51–1.02)	0.94 (0.86–1.02)

[a]The range for each quintile: for women: <70.0, 70.0–71.9, 72.0–73.9, 74.0–75.9 and ⩾76.0 cm; for men: <76.0, 76.0–78.4, 78.5–80.0, 80.1–82.5 and ⩾82.6 cm. The total follow-up time in each quintile of leg length was 129 724, 135 219, 155 764, 141 460 and 189 298 person-years, respectively, in women, and 46 738, 63 667, 60 807, 53 728 and 52 706 person-years, respectively, in men.

[b]Model 1: age adjusted only.

[c]Model 2: multivariate model: adjusted for birth calendar year, age, education, income, occupation, BMI, WHR, cigarette smoking, alcohol consumption, total physical activity (MET hours/week), daily intake of energy, red meat, fruit and vegetables and menopause status (for women only).

To address the concern of over-adjustment, we repeated analyses without adjusting for BMI and found similar results. For example, the HRs for cancer mortality per 1-SD increment in height, trunk and leg length were 1.06, 1.06 and 1.03, respectively, in women and 1.13, 1.08 and 1.11, respectively, in men.

We also conducted sensitivity analyses excluding subjects exposed to the Chinese famine during prenatal and childhood periods (born in 1950–1962) and found no material changes in the results. The multivariate-adjusted HRs for cancer mortality per 1-SD increase in height, trunk and leg length were 1.06, 1.06 and 1.03, respectively, in women, and 1.13, 1.09 and 1.09 in men. The corresponding HRs for CVD mortality were 0.89, 0.93 and 0.91 in women, and 0.92, 0.87 and 0.98 in men.

We conducted additional analyses stratified by pre-existing comorbidities and age. Among individuals without pre-existing comorbidities, the fully adjusted HRs (95% CIs) for cancer and CVD mortality per 1-SD increase in height were 1.08 (1.02–1.15) and 0.88 (0.82–0.96), respectively, in women, and 1.15 (1.04–1.27) and 0.92 (0.81–1.04), respectively, in men. Among individuals with pre-existing comorbidities, the corresponding HRs were 1.03 (0.93–1.13) and 0.90 (0.81–1.00) in women, and 1.10 (0.98–1.23) and 0.93 (0.83–1.04) in men. Among women aged $\leqslant$55 years, the HRs for cancer and CVD mortality per 1-SD increment in height were 1.16 (1.06–1.28) and 0.92 (0.77–1.10), whereas among women aged >55, the HRs were 1.02 (0.96–1.09) and 0.89 (0.83–0.96). For younger men, the corresponding HRs were 1.25 (1.07–1.46) and 0.88 (0.72–1.09), whereas for older men, the HRs were 1.09 (1.00–1.19) and 0.93 (0.85–1.03).

Discussion

In these two large cohort studies of Chinese women and men, we found that adult height was positively associated with cancer mortality, but was inversely associated with CVD mortality. These findings were generally consistent across sex and independent of SES and lifestyle risk factors.

The findings of our studies of Chinese women and men are in general agreement with those of previous studies conducted in Western populations.[8,11–14] The first US National Health and Nutrition Examination Survey (NHANES) and follow-up study[8] reported a positive association between adult height and total cancer incidence and found that the association was particularly evident in men, similar to our finding of a stronger association with cancer mortality in men than in women. Likewise, in the Health Professionals Follow-Up Study[12] and the Physicians' Health Study,[13] greater adult height was associated with an elevated risk of cancer, particularly cancers of the colon, pancreas, kidney and prostate. A positive association between adult height and post-menopausal breast cancer was found in a pooled analysis of seven major prospective cohort studies conducted in Western countries.[22] The association for pre-menopausal breast cancer, however, was less clear in the pooled analysis. No association between height and total cancer mortality was reported in a Finland study, in which the risk ratios of cancer mortality for per 5-cm increase in height were 0.98 in women and 1.02 in men.[3] The positive association between height and cancer mortality has also been reported in studies conducted in Asia Pacific region. By including 39 cohort studies from the Asia Pacific Cohort Studies Collaboration, Lee *et al.*[17] found that for each standard-deviation greater height, the risk of cancer mortality was increased by 5% in men and 9% in women. Similar associations were also observed in middle-aged Korean men[23] and women.[24] Overall, the evidence supports a positive association between height and cancer risk.[25]

In contrast to the positive association with cancer, height was inversely associated with CVD outcomes in our study and many previous studies.[3,15,16] A recent meta-analysis involving 52 studies[26] revealed that individuals in the shortest height category had an ~50% higher risk of CHD morbidity and mortality than those in the highest category. An inverse association of height with stroke was also reported in some studies,[17,23,24] but not in others.[15,16,27,28]

Studies of height in relation to incidence and mortality of cancer and CVD are generally consistent, suggesting that factors associated with adult height may affect both the risk of developing cancer or CVD and the risk of dying from these diseases. Potential mechanisms linking height with health outcomes in adult life remain to be elucidated.[25] The divergent findings on the associations with cancer and CVD suggest that adult height may be linked to these diseases through different pathways. Attained adult height is known to be related to early nutrition,[2] particularly energy intake,[2] and levels of insulin and insulin-like growth factor-1 (IGF-1),[12,29,30] which may in turn affect risk of certain types of cancer. Adult height is also related to coronary artery lumen diameter and lung function, which may mediate some of the observed association with CVD.[31–34] However, the inverse association between height and CHD was found to persist in studies that accounted for lung function, as measured by forced expiratory volume in 1 s.[7] In addition, it is plausible that hereditary factors which determine adult height may play a role in the development of cancer or CVD. A prospective study of twin pairs,[35] however, found a significant inverse association between height and CHD mortality within monozygotic discordant twin pairs, suggesting that environmental factors, rather than genetic factors, may account for the association.[35] It has been suggested that leg length may be a better measure than overall height of nutritional exposures during childhood and possibly a better predictor of health outcomes in later life. Relatively few prospective studies have evaluated components of adult height in relation to cancer or CVD.[7–9] Compared with trunk length, leg length showed a stronger association with cancer mortality in the NHANES Study,[8] and the Boyd–Orr study.[14] Moreover, the Boyd–Orr cohort study[9] found that childhood leg length, but not trunk length, was inversely associated CVD mortality both in men and women. Similar results were observed in the Caerphilly study.[7] Leg length also showed a closer inverse association with diabetes and atherosclerosis than trunk length in the Atherosclerosis Risk in Communities Study.[10,32] The Whitehall study[36] conducted in the UK, however, suggested that although leg length might underlie the inverse association between height and CHD risk factors, trunk length was more closely associated with CHD events. Rogers[30] first related childhood IGF-1 to components of height and found no sufficient evidence for the hypothesis that leg length is a better biomarker of childhood IGF-1, whereas trunk length might be even better for females.[30] Trunk length appeared to be the component of height that contributed to the associations of height with cancer and CVD mortality in our study.

Overall, our findings in both women and men provide no evidence suggesting that components of height are better predictors of mortality than height. Stroke was the main cause of CVD-related deaths in our study and contributed largely to the inverse association of height with CVD mortality in both women and men. In women, the positive association of height with cancer mortality was more evident for female cancers than for other cancers, whereas in men, the positive association was more evident for smoking-related cancers than for cancers unrelated to smoking. The latter finding appears to contradict previous studies, which showed a positive association for mortality from smoking-unrelated cancers but not smoking-related cancers. Although this discrepancy could not be readily explained, differences in socio-demographic and lifestyle factors among study populations could be a contributor. Adult height was positively related to SES in our and previous studies. Higher SES has been associated with a less healthy lifestyle in China, but a healthy lifestyle in the USA.

Data from historic records and national surveys over the period 1950–2005 in China have demonstrated a strong secular trend toward an increase in stature.[37] This trend likely reflects improved socio-economic development. The potential influence of this trend on health, however, remains uncertain, given the complex relationship of adult height with cancer and CVD. Further research is needed to address this issue.

The strengths of our study include the large sample size, the directly measured height and weight, the ability to adjust for SES and other potential confounding variables, and the nearly complete follow-up on outcomes. Our study also has several limitations. We did not collect any information on nutrition, disease history and other environmental factors during early life, and had limited information on birth weight (<10% cohort members provided birth weight information by self-report). We did not have any information on artery lumen diameter or lung function. Therefore, we were unable to evaluate whether these factors may explain the observed associations. In addition, we did not have repeated measures of height over time and were unable to directly address the potential influence of shrinkage due to aging or chronic illness on study results. However, the correlations between age and height and its components in our study population were modest. Furthermore, in stratified analyses, we found similar results among subgroups with and without pre-existing disease. These findings provide no evidence suggesting that failure to account for shrinkage in height might have introduced a serious bias in our main results. However, we could not exclude the possibility that reverse causation bias might account for a much weaker positive association between height and cancer mortality in older women and men compared with their younger counterparts in our study. Finally, findings of our study conducted in urban Shanghai may not be applicable to other populations.

In conclusion, our study found that adult height and, less consistently, its components were positively associated with cancer mortality and inversely associated with CVD mortality in Chinese women and men, suggesting different pathways are involved in linking height to different disease outcomes.

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Conflict of interest: None declared.

KEY MESSAGES

- Adult height and, less consistently, trunk and leg length are positively associated with cancer mortality and inversely associated with CVD mortality in Chinese women and men.
- Different mechanisms may be involved in linking height and its components with cancer and CVD mortality.

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