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Original Contribution

Height and Site-specific Cancer Risk: A Cohort Study of a Korean Adult Population

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To evaluate the association between height and risk of cancer in an East Asian, middle-income population, the authors followed up a cohort of 788,789 Koreans (449,214 men and 339,575 women) aged 40–64 years for cancer incidence between 1994 and 2003. Cox proportional hazards regression analysis was used to evaluate the association. Each 5-cm increment in height was associated with 5% and 7% higher risk of all-sites cancer in men and women, respectively, after adjustment for age, body mass index, and behavioral and socioeconomic factors. When the associations were evaluated for site-specific cancers, a positive association was observed for cancer of the colon and thyroid in both men and women. Among gender-specific cancers, prostate cancer was positively associated with height in men. In women, there was a positive association between height and cancers of the breast and ovary, which did not change even after additional adjustment for reproductive factors. Although more clarification is needed for some site-specific cancers, the same positive association of height with cancer in a middle-income Korean population as found in high-income Western populations supports the influence of early life environment on cancer development in adulthood.

body height; Korea; neoplasms

Abbreviations: IGF, insulin-like growth factor; KCCR, Korea Central Cancer Registry.

Several previous studies have found positive associations between adult height and risk of cancer (1, 2). The underlying mechanism for this association is unclear, but there is evidence that the association, at least in part, represents prepubertal environmental exposures that influence both skeletal growth and later risk of cancer.

These environmental influences include infant and childhood diet and might act via intermediate biologic pathways, including insulin, insulin-like growth factors, and sex steroid hormones (3). Because adult height is also influenced by genetic variants (4), it is possible that genetic variation influencing both skeletal growth and cancer risk underlies the association. Finally, it has been suggested that size might increase cancer risk simply by increasing the amount of tissue available to undergo neoplastic change (5).

With only a few exceptions (6, 7), studies that were well designed and took account of probable confounding factors consistently show a positive association with height (3), especially for cancers of the breast (8, 9), prostate (1, 10), and colorectum (11, 12). However, for other cancers, in particular for stomach cancer (6, 13, 14) and lung cancer (6, 15), evidence is mixed.

Furthermore, most of the studies evaluating an association between height and cancer to date have been conducted in Western populations (1, 2, 6, 12, 16) or Asian populations residing in Western countries (17), and only a few studies have been conducted in low- or middle-income countries (18, 19). If the findings of studies outside of Western countries are consistent with those of studies from Western countries, the association between height and cancer would more likely reflect fundamental biologic determinants of height than environmental influences that are likely to vary from one population to another.

A study in the Asia-Pacific region (19) showed that the risk of colorectal cancer mortality increased with increasing height and that the magnitude of this association was similar

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Table 1. Distribution of Age and Age-adjusted Risk Factors of Study Participants at Baseline Examination by Height, Korea, 1994–2003

Characteristics	Men					Women				
	Total No. Available	Height Quartile, cm				Total No. Available	Height Quartile, cm			
		≤164.5	164.6–168.0	168.1–171.0	>171.0		≤151.0	151.1–155.0	155.1–158.0	>158.0
No. of participants	449,214	112,442	125,637	99,223	111,912	339,575	91,555	98,337	70,688	78,995
No. of person-years	3,887,559	964,575	1,085,897	862,819	974,268	2,993,598	803,595	866,703	624,533	698,767
Mean age, years (SD)	449,214	51.5 (6.7)	50.2 (6.5)	49.1 (6.3)	48.8 (6.3)	339,575	53.7 (6.9)	50.8 (6.9)	49.4 (6.6)	47.8 (6.1)
Body mass index, %										
<18.5 kg/m^2		2.5	2.5	2.2	2.2		2.2	2.3	2.5	2.6
18.5–24.9 kg/m^2		73.4	70.6	70.2	68.2		59.2	60.9	63.9	65.4
25.0–29.9 kg/m^2		23.2	26.0	26.7	28.5		34.6	33.6	30.4	29.4
≥30.0 kg/m^2		0.9	0.9	0.9	1.1		4.0	3.2	3.3	2.7
Cigarette smoking, %	443,795					304,845	5.2	4.8	4.5	4.6
Never smoker		23.8	22.3	21.4	20.7					
Former smoker		22.1	24.6	25.3	26.4					
Current smoker										
1–19 cigarettes/day		38.5	37.7	37.3	36.7					
≥20 cigarettes/day		15.6	15.4	16.0	16.2					
Alcohol consumption, %	447,165					320,208	14.7	13.9	13.6	13.0
<30 g/week		46.0	42.5	41.4	40.1					
30–104 g/week		25.8	27.9	28.2	28.4					
105–209 g/week		14.3	15.3	15.9	16.1					
≥210 g/week		14.0	14.3	14.6	15.4					
Engaging in regular exercise, %	440,815	34.9	37.8	39.2	40.7	326,789	15.9	18.4	20.1	22.1
Pay level, %	421,292					309,226				
Quartile 1 (highest)		24.2	28.2	30.2	32.3		22.6	30.4	34.0	37.4
Quartile 2		22.7	26.0	27.7	28.6		20.9	22.5	23.6	24.0
Quartile 3		18.7	22.0	23.4	23.0		23.9	22.2	21.1	20.0
Quartile 4 (lowest)		34.4	23.8	18.8	16.2		32.6	24.8	21.3	18.6
Occupation, %[a]	445,116					339,087				
"High" occupational group		43.6	51.6	55.0	58.6		6.5	11.9	15.5	20.0
"Low" occupational group		38.2	35.4	33.8	31.7		3.4	3.2	3.1	3.1
Unemployed		18.2	13.1	11.2	9.7		90.1	84.9	81.4	76.9
Area or residence, %	439,671					312,852				
Capital		23.3	22.9	23.8	23.9		21.7	23.7	25.1	27.8
Large city		23.4	25.7	27.8	28.2		23.9	26.2	27.5	28.4
Other area		53.3	51.5	48.4	47.9		54.4	50.1	47.4	43.9

Table continues

to those from other studies conducted largely in Western populations. However, the relations between height and other cancers were not investigated.

Recently, we reported a robust positive association between height and mortality from all-sites-combined cancer in a Korean male cohort study, which persisted even after adjusting for health risk factors and socioeconomic position (18). However, no robust association was found for cancers at individual sites. Moreover, we were unable to examine associations with nonfatal cancer risk, as opposed to death from cancer. Because early detection can delay or prevent death from some cancers (20), it is possible that the association of height with morbidity will differ from that with mortality.

The aim of this study was to evaluate the associations between height and risk of any and site-specific cancers in a large cohort of Korean men and women.

MATERIALS AND METHODS

Study participants

Study participants were Korean men and women 40–64 years of age at baseline, who underwent a health examination

Table 1. Continued

Characteristics	Men: Total No. Available	Men: ≤164.5	Men: 164.6–168.0	Men: 168.1–171.0	Men: >171.0	Women: Total No. Available	Women: ≤151.0	Women: 151.1–155.0	Women: 155.1–158.0	Women: >158.0
Age at menarche, %						304,379				
<12 years							0.7	0.7	0.8	0.8
12–13 years							11.8	13.4	14.3	15.4
14–15 years							38.9	41.1	42.1	42.5
≥16 years							48.6	44.8	42.8	41.3
Age at first childbirth, %						336,406				
<22 years							12.0	11.1	10.2	9.0
22–24 years							24.8	24.4	24.4	23.7
25–27 years							25.2	27.5	28.8	29.8
28–30 years							11.2	12.2	12.9	13.8
≥31 years							3.4	3.7	3.6	3.3
Not applicable[b]							23.2	21.0	20.0	19.4
Duration of breastfeeding, %						260,602				
1–12 months							11.5	13.4	14.6	15.7
13–24 months							16.0	17.5	18.2	19.6
25–36 months							17.3	18.4	19.3	19.8
37–48 months							12.8	12.6	12.3	11.4
≥49 months							12.2	11.0	9.8	8.7
Never or not applicable[b]							30.2	27.1	25.8	24.9
Postmenopausal status, %						339,575	51.6	50.5	49.9	49.5
Estrogen replacement, ever, %						339,575	3.1	3.5	3.7	4.1
Oral birth control pill, ever, %						339,575	23.3	23.1	23.0	22.2

Abbreviation: SD, standard deviation.

[a] Occupations were categorized into 3 groups: 1) housewife for unemployed female dependents; 2) a "high" occupational group for educational, administrative, professional, and executive jobs; and 3) a "low" occupational group for manual, semiskilled, and unskilled jobs and police work.

[b] Women who did not report experiencing childbirth.

between 1993 and 1994 provided to public servants and their unemployed dependents by the Korea Medical Insurance Corporation, one of the major institutions of the Korea National Health Insurance System. Ninety-five percent of public servants in 1994 and 49.6% of all the invited dependents who were 40–64 years of age in 1993 underwent the health examination.

Among the 800,507 health examinees between 1993 and 1994, 10,805 persons who died from any cause or were ever diagnosed with cancer prior to October 1994 when the prospective follow-up started and 913 persons whose height data were missing or within the upper or lower 0.05% of the height distribution were excluded. A total of 449,214 men and 339,575 women were included in the analysis.

Measurements

Weight (kg) and height (cm) were measured in light clothing by use of standardized scales and stadiometers, respectively, by registered nursing staff. The average height of the study participants was 167.9 cm (standard deviation, 5.2 cm; range, 148.0–185.0 cm) for men and 154.6 cm (standard deviation, 5.2 cm; range, 136.0–170.5 cm) for women. Study participants were divided into 4 groups according to the quartiles of height distribution for each sex (≤164.5, 164.6–168.0, 168.1–171.0, >171.0 cm for men; ≤151.0, 151.1–155.0, 155.1–158.0, >158.0 cm for women).

Body mass index (weight (kg)/height (m)^2) was calculated as the weight divided by the height squared and categorized into 4 groups according to World Health Organization criteria: <18.5, 18.5–24.9, 25–29.9, and ≥30 (21).

Information on the health-related behaviors of all participants and on female reproductive factors was obtained in 1993 and 1994 by a self-administered questionnaire.

Two categories were constructed for physical exercise (engage in regular exercise or not), because more detailed information was unavailable. For alcohol consumption and smoking habits, different categories were applied according to the gender of participants. For women, 2 categories were constructed for alcohol consumption (nondrinker or drinker) and cigarette-smoking habits (never smoked or past/current smoker), because the proportions of alcohol consumers

(13.0%) and cigarette smokers (4.8%) were small. Male participants were categorized into 4 groups based on weekly alcohol consumption (<30, 30–104, 105–209, ≥210 g/week). The amount of ethanol ingested per week for men was calculated by using the drinking frequency per week and the usual amount consumed at each sitting and then estimating ethanol quantity based on the gram weight of the most popular Korean liquor, *Soju*. Four categories were constructed for smoking habits in men (never smoker, former smoker, currently smoking fewer than 20 cigarettes per day, currently smoking at least 20 cigarettes per day).

Area of residence was grouped into capital, large city, and other region according to the categorization of the administrative jurisdiction. Occupations were categorized into 3 groups: unemployed dependents; a high occupational group for educational, administrative, professional, and executive jobs; and a low occupational group for manual, semiskilled, and unskilled jobs and police work. Economic status was classified into 4 groups on the basis of the quartile distribution of the monthly salary level of the public servants or the public servants who support unemployed dependents (first = lowest quartile and fourth = highest quartile).

For women, we took account of reproductive factors, because some of the cancers in women evaluated in this study (i.e., cancers of the breast, ovary, and uterine corpus) are reported to have an association with those factors (20). Age at menarche was categorized into 4 groups (≤11, 12–13, 14–15, and ≥16 years). Age at first childbirth was categorized into 6 groups (≤21, 22–24, 25–27, 28–30, ≥31 years, and not applicable). Lifetime duration of breastfeeding across all pregnancies was categorized into 6 groups (1–12, 13–24, 25–36, 37–48, ≥49 months, and never/not applicable). Menopausal status was defined on the basis of self-report of natural menopause, hormone replacement therapy, or age (>55 years) at baseline examination. The cutoff level of age at menopause was selected on the basis of a nationwide Korean study reporting that 95% of Korean women undergo menopause before 55 years of age (22). Previous use of estrogen replacement and the oral birth control pill was categorized into 2 groups (never used, past/current use).

Outcome measurement

Cancer occurring between October 1, 1994, and December 31, 2003, was the main outcome event. Codes C00–C99 in the *International Classification of Diseases*, Tenth Revision, were used to identify cancers. Cancer cases were identified through data linkage with Korea Central Cancer Registry (KCCR) data by using a unique personal identification number. KCCR is a hospital-based cancer registration system that began in 1978. Approximately 80% of all hospitals in Korea participate in the KCCR (23). To increase the completeness of identified cancer cases, we additionally used death report data of the Korean National Statistical Office and Serious Disease Registry data of the Korea National Health Insurance System, a nationwide registry for persons with serious diseases such as cancer. With this, 1,664 cancer cases (4.36% of all identified cancer cases) were additionally identified.

Analytical methods

Prospective follow-up started in October 1994, and the endpoint of the follow-up was the date of the first diagnosis of cancer, date of death for those who died of noncancer causes, or the end of follow-up at December 2003, whichever came first.

To examine the distribution of covariates according to height category, we did direct gender-specific age standardization using the Korean population structure in 1993 as the standard population (Table 1).

The risk for cancers at all sites and individual sites associated with each 5-cm increment in height, as well as with quartile categories of height distribution among study participants, was estimated by using Cox proportional hazards regression analysis in participants for whom data on behavioral and socioeconomic factors were complete. The individual cancer sites presented in this study were selected on the basis of prevalence among participants (more than 300 cases in men and 200 cases in women). The adjustment for covariates was performed in several steps to examine the effect of potential confounders on the association between height and cancer. Age was adjusted in the first model. Body mass index, smoking habit, alcohol consumption, and engagement in regular exercise were additionally adjusted for in the second model. Socioeconomic factors (level of monthly salary, occupation, and area of residence) were additionally adjusted for in the third model. For liver cancer, additional adjustment for hepatitis B viral surface antigenicity, the most important risk factor for liver cancer in Korea (24), was performed in a subgroup of participants who had available information. For women, reproductive factors were additionally adjusted for, to evaluate the associations between height and cancers of the breast, ovary, and uterine corpus, in women who had complete data for all of these covariates.

All analyses were performed by using the SAS statistical package (SAS Institute, Inc., Cary, North Carolina). The Samsung Medical Center Institutional Review Board approved this study.

RESULTS

A total of 26,380 men (contributing 3,887,559 person-years) and 11,789 women (contributing 2,993,598 person-years) experienced a cancer event during the average 8.72 years of follow-up.

Table 1 shows the age-adjusted distribution of risk factors of study participants according to height quartile. Among men, taller individuals consumed more alcohol, were more likely to have smoked, and had a higher prevalence of obesity while, among women, the reverse was true. In both men and women, the taller group tended to have a higher pay level, to be more likely to be living in the capital or a large city, and to be more likely to report engaging in regular exercise. For reproductive factors, taller women were more likely to have experienced menarche at an earlier age, to have had their first childbirth at a later age, and to have ever used estrogen replacement, while they were less likely to be at postmenopausal status at study entry and to have used the oral birth

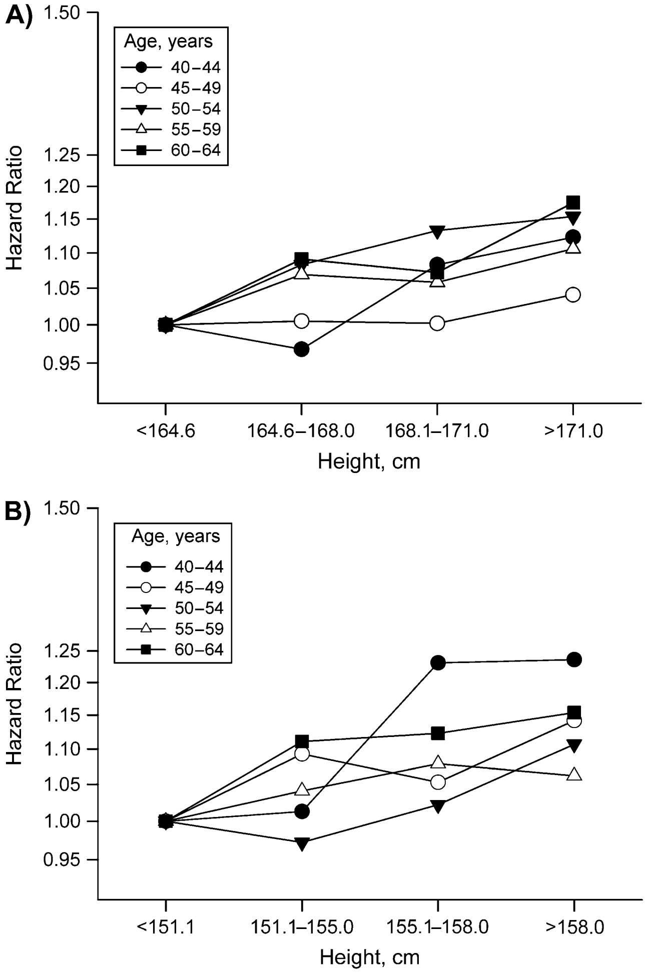

Figure 1. Association between height and combined all-sites cancer by strata for each 5 years of age among men (A) and women (B), Korea, 1994–2003. Hazard ratios were obtained by a Cox proportional hazards model with adjustment for age, body mass index, cigarette smoking, alcohol consumption, engagement in regular exercise, level of monthly salary, occupation, and area of residence. The P_{trend} in each age stratum was significant (< 0.05) across all age strata in men except for men aged between 45 and 49 years. The P_{trend} was significant (< 0.05) across all age strata in women.

control pill. The total lifetime duration of breastfeeding was shorter among taller women than among shorter women.

Figure 1 shows the association between height and all-sites-combined cancer by 5-year age strata. In both men and women, the risk of cancer tended to increase with increasing height across all age strata.

Table 2 shows the association between height and cancer risk in men. Each 5-cm increment in height was associated with a 3% higher risk of any cancer in age-adjusted analyses. With additional adjustment for potential confounding factors, an independent positive association remained, with each 5-cm increment in height being associated with a 5% higher risk of any cancer. When the associations were evaluated for cancers at individual sites, a positive trend was observed for cancers of the colon, rectum, liver, biliary tract, lung, urinary tract, prostate, and thyroid and for lymphoma. Despite very large numbers of cancers, there was clearly no association of height with stomach cancer and pancreatic cancer.

Table 3 shows the association between height and cancer risk in women. Each 5-cm increment in height was associated with an 8% higher risk of any cancer in age-adjusted analyses. With additional adjustment for potential confounding factors, an independent positive association remained, with each 5-cm increment in height being associated with a 7% higher risk of cancer. When the associations were evaluated for cancers at individual sites, a positive trend was observed for cancers of the colon, liver, thyroid, leukemia, breast, and ovary. The positive trend for cancers of the breast and ovary did not change even with an additional adjustment for reproductive factors.

When we undertook age-adjusted analyses in the whole cohort of 449,214 men and 339,575 women regardless of available information on probable confounders, the results were essentially the same as those presented in Tables 2 and 3.

An additional adjustment for hepatitis B viral antigenicity in a subgroup with available information was done, and the positive association between height and liver cancer was attenuated markedly in both men and women (the full set of results with all models is available in Appendix Table 1).

DISCUSSION

In this cohort study of Korean men and women, we found that taller persons were at increased risk of all-sites cancer compared with shorter persons in a dose-response pattern. Generally, the findings in men are consistent with those of other studies that have largely been conducted on high-income Western male populations. A study with American male physicians reported a positive association between height and risk of cancer at all sites in a dose-response pattern (1). A follow-up study among participants of the US National Health and Nutrition Examination Survey also showed approximately 60% higher risk of all-sites cancer among taller men compared with men in the shortest categories (2). However, the study on the association between height and all-sites cancer was seldom conducted among women, and a positive association has not been clearly shown (2). In this regard, the findings of our study showing a positive association between height and cancer risk in both men and women support the notion that fundamental biologic mechanisms might underlie the association between height and cancer.

Given that there was a trend that taller men and women were younger than shorter persons, it is possible that the increased risk of cancer among taller persons simply reflects the fact that the younger generation may have a greater risk of cancer than the older generation. However, we observed that a positive association between height and cancer was consistent in all 5-year age strata for both men and women (Figure 1). Thus, the association between height and cancer is unlikely to have been caused by a birth cohort effect on height.

A positive association of height with cancers of the prostate in men, female breast and ovarian cancers in women, and cancers of the colon and thyroid in both genders was

Table 2. Associations Between Height and Cancers at All Sites Combined and Individual Sites for 412,494 Korean Men, 1994–2003[a]

Individual Sites (ICD-10 Code)	Height Categories, cm[b]							
	164.6–168.0		168.1–171.0		>171.0		5-cm Increment	
	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval
All sites (C00–C97) (n = 23,725)								
Age adjusted	1.04	1.00, 1.08	1.05	1.01, 1.09	1.09	1.05, 1.13	1.03	1.02, 1.04
Multivariable adjusted[c]	1.05	1.01, 1.08	1.06	1.02, 1.10	1.10	1.06, 1.14	1.03	1.02, 1.05
Fully adjusted[d]	1.06	1.03, 1.10	1.09	1.04, 1.13	1.13	1.09, 1.18	1.05	1.03, 1.06
Esophagus (C15) (n = 877)								
Age adjusted	0.97	0.81, 1.15	0.98	0.81, 1.19	0.97	0.80, 1.17	0.98	0.92, 1.05
Multivariable adjusted[c]	0.99	0.83, 1.18	1.01	0.83, 1.22	0.99	0.82, 1.20	0.99	0.93, 1.06
Fully adjusted[d]	1.07	0.90, 1.28	1.14	0.94, 1.38	1.15	0.95, 1.40	1.05	0.99, 1.12
Stomach (C16) (n = 8,777)								
Age adjusted	0.98	0.93, 1.04	0.96	0.90, 1.02	0.99	0.94, 1.05	1.00	0.98, 1.02
Multivariable adjusted[c]	0.98	0.93, 1.04	0.96	0.90, 1.02	0.99	0.93, 1.05	0.99	0.97, 1.02
Fully adjusted[d]	1.00	0.94, 1.06	0.98	0.93, 1.05	1.03	0.97, 1.09	1.01	0.99, 1.03
Colon (C18) (n = 2,499)								
Age adjusted	1.11	1.00, 1.24	1.23	1.09, 1.38	1.23	1.10, 1.38	1.09	1.05, 1.13
Multivariable adjusted[c]	1.09	1.98, 1.22	1.20	1.07, 1.35	1.20	1.07, 1.34	1.08	1.04, 1.12
Fully adjusted[d]	1.04	0.93, 1.16	1.12	1.00, 1.26	1.10	0.98, 1.24	1.04	1.00, 1.08
Rectum (C19–C21) (n = 2,281)								
Age adjusted	1.15	1.03, 1.29	1.20	1.06, 1.35	1.20	1.07, 1.36	1.07	1.03, 1.11
Multivariable adjusted[c]	1.14	1.02, 1.28	1.19	1.05, 1.34	1.18	1.05, 1.33	1.06	1.02, 1.11
Fully adjusted[d]	1.12	1.00, 1.26	1.16	1.03, 1.32	1.16	1.03, 1.31	1.06	1.01, 1.10
Liver (C22) (n = 5,809)								
Age adjusted	1.04	0.97, 1.12	1.02	0.94, 1.10	1.10	1.02, 1.19	1.03	1.00, 1.05
Multivariable adjusted[c]	1.05	0.98, 1.13	1.03	0.95, 1.11	1.12	1.04, 1.20	1.03	1.01, 1.06
Fully adjusted[d]	1.07	1.00, 1.15	1.07	0.99, 1.16	1.17	1.09, 1.26	1.05	1.03, 1.08
Biliary tract (C23, C24) (n = 941)								
Age adjusted	1.09	0.92, 1.30	1.08	0.89, 1.31	1.22	1.02, 1.46	1.07	1.01, 1.14
Multivariable adjusted[c]	1.09	0.91, 1.30	1.07	0.88, 1.30	1.21	1.01, 1.45	1.07	1.01, 1.14
Fully adjusted[d]	1.10	0.92, 1.31	1.09	0.90, 1.32	1.24	1.03, 1.49	1.08	1.01, 1.15
Pancreas (C25) (n = 920)								
Age adjusted	1.05	0.88, 1.25	1.07	0.89, 1.30	0.99	0.82, 1.20	1.00	1.94, 1.06
Multivariable adjusted[c]	1.05	0.88, 1.25	1.06	0.88, 1.28	0.98	0.81, 1.18	0.99	0.93, 1.05
Fully adjusted[d]	1.04	0.88, 1.24	1.06	0.88, 1.29	0.98	0.81, 1.19	0.99	0.93, 1.06

Table continues

found in our study. An increased risk of prostate cancer among taller men has been commonly reported from Western (1, 10) and Asian (25) populations. For breast and ovarian cancer, a positive association is consistently observed in very different populations with a diverse range of height, such as American (26, 27), Norwegian (8, 28), Netherlands (9, 29), Asian-American (17), and Japanese (1, 6, 8–12, 27–34) women with very few exceptions (7). A pooled analysis (31) of studies worldwide, including Asian populations and studies in Norwegian (32) and multiethnic Asian (33) populations, has reported an increased risk of thyroid cancer for the tallest members compared with the shortest members in both genders. Although exceptions exist (1, 6), colon cancer has also been more commonly reported as being positively associated with height in many studies in Western (11, 12) and Asian (19) populations. Although specific etiologic processes have been suggested for each of these cancers by some investigators, findings of positive associations of height with these site-specific cancers observed in many populations of diverse ethnicity and diverse range of population height suggest that a common mechanism links each of these associations.

Findings from previous studies of the association of height with lung cancer have been inconsistent, with

Table 2. Continued

Individual Sites (ICD-10 Code)	Height Categories, cm[b]							
	164.6–168.0		168.1–171.0		>171.0		5-cm Increment	
	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval
Lung (C33, C34) (n = 4,453)								
Age adjusted	0.97	0.89, 1.05	1.00	0.92, 1.09	1.04	0.96, 1.13	1.02	0.99, 1.05
Multivariable adjusted[c]	1.00	0.93, 1.09	1.04	0.95, 1.13	1.09	1.01, 1.19	1.03	1.01, 1.06
Fully adjusted[d]	1.05	0.97, 1.13	1.10	1.01, 1.21	1.18	1.09, 1.29	1.07	1.04, 1.10
Urinary tract (C64–C68) (n = 2,006)								
Age adjusted	1.17	1.03, 1.32	1.25	1.09, 1.42	1.45	1.28, 1.64	1.14	1.10, 1.19
Multivariable adjusted[c]	1.16	1.03, 1.32	1.24	1.08, 1.41	1.43	1.26, 1.62	1.14	1.09, 1.19
Fully adjusted[d]	1.12	0.99, 1.27	1.18	1.03, 1.35	1.35	1.19, 1.54	1.12	1.07, 1.17
Prostate (C61) (n = 1,612)								
Age adjusted	1.20	1.05, 1.38	1.40	1.21, 1.61	1.30	1.13, 1.50	1.14	1.09, 1.20
Multivariable adjusted[c]	1.18	1.03, 1.36	1.37	1.19, 1.58	1.27	1.10, 1.47	1.13	1.08, 1.19
Fully adjusted[d]	1.10	0.96, 1.26	1.23	1.07, 1.42	1.11	0.96, 1.29	1.08	1.03, 1.13
Central nervous system (C70–C72) (n = 282)								
Age adjusted	0.90	0.66, 1.24	0.90	0.64, 1.28	1.04	0.75, 1.44	1.03	1.92, 1.15
Multivariable adjusted[c]	0.91	0.66, 1.25	0.92	0.65, 1.29	1.05	0.76, 1.46	1.04	0.93, 1.16
Fully adjusted[d]	0.91	0.66, 1.26	0.91	0.64, 1.29	1.04	0.75, 1.45	1.03	0.92, 1.16
Thyroid (C73) (n = 43)								
Age adjusted	1.51	1.12, 2.02	1.75	1.30, 2.36	1.86	1.39, 2.48	1.21	1.11, 1.33
Multivariable adjusted[c]	1.47	1.10, 1.97	1.71	1.26, 2.30	1.78	1.33, 2.39	1.20	1.09, 1.31
Fully adjusted[d]	1.40	1.04, 1.88	1.60	1.18, 2.16	1.64	1.23, 2.21	1.16	1.06, 1.28
Lymphoma (C81–C85) (n = 704)								
Age adjusted	1.06	0.86, 1.31	1.27	1.02, 1.58	1.30	1.05, 1.61	1.10	1.02, 1.18
Multivariable adjusted[c]	1.06	0.86, 1.31	1.27	1.02, 1.58	1.30	1.06, 1.61	1.10	1.02, 1.18
Fully adjusted[d]	1.08	0.87, 1.33	1.30	1.04, 1.62	1.34	1.08, 1.66	1.11	1.03, 1.19
Leukemia (C91–C95) (n = 384)								
Age adjusted	0.97	0.75, 1.27	0.83	0.61, 1.12	0.97	0.73, 1.28	1.00	0.91, 1.10
Multivariable adjusted[c]	0.98	0.75, 1.27	0.83	0.62, 1.13	0.97	0.73, 1.29	1.00	0.91, 1.10
Fully adjusted[d]	1.01	0.77, 1.31	0.86	0.63, 1.17	1.01	0.75, 1.34	1.02	0.92, 1.12
Skin (C43, C44) (n = 334)								
Age adjusted	1.03	0.76, 1.39	0.92	0.66, 1.29	1.40	1.05, 1.88	1.10	0.99, 1.22
Multivariable adjusted[c]	1.03	0.77, 1.40	0.93	0.66, 1.29	1.41	1.05, 1.89	1.10	0.99, 1.22
Fully adjusted[d]	1.04	0.77, 1.40	0.93	0.66, 1.30	1.41	1.05, 1.91	1.10	0.99, 1.22

Abbreviation: ICD-10, *International Statistical Classification of Diseases and Related Health Problems.*
[a] Men for whom information about body mass index and behavioral and socioeconomic factors was complete.
[b] Reference category: ≤164.5 cm.
[c] Adjusted for age, body mass index (<18.5, 18.5–24.9, 25.0–29.9, and ≥30 kg/m^2), cigarette smoking (never, past, current 1–19 cigarettes/day, current ≥20 cigarettes/day), alcohol consumption (<30, 30–104, 105–209, ≥210 g/week), and regular exercise (yes or no).
[d] Additionally adjusted for level of monthly salary (quartile), occupation (high group occupation, low group occupation, or unemployed), and area of residence (capital, large city, or other).

positive associations in some (6, 15), no association in others (1, 2, 6), and even an inverse association in 1 study (35). Tobacco is by far the strongest risk factor for lung cancer. The offspring of parents who smoke are more likely to become smokers themselves (36), and exposure to passive parental tobacco is associated with reduced childhood growth (37). Thus, a different prevalence of smoking between populations or between generations might be reflected in the various associations of height with lung cancer risk between the studies.

Alternatively, the inconsistent findings might reflect the influences of statistical chance and power, with the number

Table 3. Associations Between Height and Cancers at All Sites Combined and Individual Sites for 276,072 Korean Women, 1994–2004[a]

Individual Sites (ICD-10 Code)	Height Categories, cm[b]							
	151.1–155.0		155.1–158.0		>158.0		5-cm Increment	
	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval
All sites (C00–C97) (n = 9,443)								
Age adjusted	1.06	1.01, 1.12	1.13	1.06, 1.20	1.19	1.12, 1.26	1.08	1.06, 1.10
Multivariable adjusted[c]	1.06	1.01, 1.12	1.13	1.06, 1.20	1.20	1.13, 1.27	1.08	1.06, 1.10
Fully adjusted[d]	1.05	1.00, 1.11	1.11	1.04, 1.18	1.16	1.09, 1.23	1.07	1.05, 1.09
Stomach (C16) (n = 2,274)								
Age adjusted	0.95	0.86, 1.06	0.91	0.81, 1.03	0.98	0.87, 1.11	0.99	0.95, 1.03
Multivariable adjusted[c]	0.95	0.86, 1.06	0.91	0.81, 1.03	0.99	0.87, 1.11	0.99	0.95, 1.03
Fully adjusted[d]	0.96	0.86, 1.07	0.93	0.82, 1.05	1.01	0.89, 1.14	1.00	0.95, 1.04
Colon (C18) (n = 1,007)								
Age adjusted	1.05	0.89, 1.24	1.19	0.99, 1.42	1.31	1.10, 1.58	1.11	1.04, 1.18
Multivariable adjusted[c]	1.04	0.88, 1.23	1.19	0.99, 1.43	1.32	1.10, 1.58	1.11	1.04, 1.18
Fully adjusted[d]	1.00	0.85, 1.19	1.12	0.93, 1.35	1.21	1.01, 1.46	1.08	1.01, 1.15
Rectum (C19–C21) (n = 892)								
Age adjusted	1.01	0.85, 1.19	0.94	0.78, 1.15	0.92	0.75, 1.12	1.01	0.94, 1.07
Multivariable adjusted[c]	1.01	0.85, 1.19	0.95	0.78, 1.15	0.93	0.76, 1.13	1.01	0.94, 1.08
Fully adjusted[d]	1.00	0.84, 1.18	0.94	0.77, 1.14	0.92	0.75, 1.12	1.00	0.94, 1.08
Liver (C22) (n = 940)								
Age adjusted	0.96	0.81, 1.13	1.04	0.86, 1.26	1.09	0.91, 1.32	1.06	0.99, 1.13
Multivariable adjusted[c]	0.96	0.81, 1.13	1.06	0.88, 1.27	1.12	0.92, 1.35	1.07	1.00, 1.14
Fully adjusted[d]	0.98	0.83, 1.16	1.09	0.91, 1.32	1.18	0.97, 1.43	1.09	1.02, 1.16
Biliary tract (C23, C24) (n = 451)								
Age adjusted	1.14	0.90, 1.45	1.12	0.85, 1.47	1.19	0.90, 1.58	1.06	0.96, 1.16
Multivariable adjusted[c]	1.14	0.90, 1.50	1.13	0.86, 1.49	1.22	0.92, 1.61	1.06	0.97, 1.17
Fully adjusted[d]	1.14	0.90, 1.45	1.13	0.86, 1.49	1.22	0.92, 1.62	1.06	0.97, 1.17
Pancreas (C25) (n = 334)								
Age adjusted	1.21	0.93, 1.57	0.89	0.63, 1.25	1.14	0.82, 1.58	1.03	0.92, 1.15
Multivariable adjusted[c]	1.22	0.94, 1.59	0.90	0.64, 1.27	1.17	0.84, 1.63	1.04	0.93, 1.16
Fully adjusted[d]	1.21	0.93, 1.57	0.88	0.63, 1.24	1.12	0.80, 1.57	1.03	0.92, 1.14
Lung (C33, C34) (n = 943)								
Age adjusted	1.02	0.87, 1.21	1.11	0.93, 1.34	1.06	0.87, 1.29	1.05	0.98, 1.12
Multivariable adjusted[c]	1.03	0.87, 1.22	1.13	0.94, 1.36	1.07	0.88, 1.30	1.05	0.99, 1.12
Fully adjusted[d]	1.04	0.88, 1.22	1.14	0.94, 1.37	1.08	0.88, 1.31	1.05	0.99, 1.13
Urinary tract (C64–C68) (n = 379)								
Age adjusted	0.90	0.68, 1.18	1.17	0.88, 1.56	1.09	0.81, 1.47	1.10	0.99, 1.22
Multivariable adjusted[c]	0.90	0.68, 1.17	1.16	0.87, 1.55	1.08	0.80, 1.46	1.10	0.99, 1.22
Fully adjusted[d]	0.88	0.67, 1.16	1.14	0.86, 1.53	1.05	0.78, 1.43	1.09	0.98, 1.21
Central nervous system (C70–C72) (n = 866)								
Age adjusted	1.09	0.74, 1.62	1.23	0.80, 1.89	1.05	0.66, 1.66	1.06	0.91, 1.23
Multivariable adjusted[c]	1.09	0.74, 1.62	1.23	0.80, 1.90	1.05	0.67, 1.67	1.06	0.91, 1.23
Fully adjusted[d]	1.08	0.73, 1.61	1.21	0.78, 1.87	1.02	0.64, 1.63	1.05	0.90, 1.22
Thyroid (C73) (n = 1,550)								
Age adjusted	1.66	1.41, 1.94	1.65	1.39, 1.95	2.05	1.75, 2.42	1.28	1.21, 1.35
Multivariable adjusted[c]	1.64	1.40, 1.93	1.64	1.38, 1.95	2.05	1.74, 2.41	1.28	1.21, 1.34
Fully adjusted[d]	1.58	1.35, 1.86	1.55	1.31, 1.84	1.90	1.61, 2.24	1.24	1.18, 1.31

Table continues

Table 3. Continued

Individual Sites (ICD-10 Code)	Height Categories, cm[b]							
	151.1–155.0		155.1–158.0		>158.0		5-cm Increment	
	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval
Lymphoma (C81–C85) (n = 306)								
Age adjusted	1.04	0.76, 1.41	1.11	0.79, 1.55	1.32	0.95, 1.82	1.11	0.99, 1.24
Multivariable adjusted[c]	1.04	0.77, 1.41	1.11	0.79, 1.56	1.32	0.95, 1.83	1.11	0.99, 1.24
Fully adjusted[d]	1.02	0.75, 1.39	1.08	0.77, 1.51	1.26	0.90, 1.75	1.09	0.97, 1.22
Leukemia (C91–C95) (n = 158)								
Age adjusted	1.16	0.75, 1.80	1.08	0.66, 1.77	1.71	1.09, 2.67	1.22	1.04, 1.43
Multivariable adjusted[c]	1.18	0.76, 1.82	1.09	0.67, 1.80	1.75	1.12, 2.74	1.23	1.05, 1.44
Fully adjusted[d]	1.15	0.74, 1.78	1.05	0.64, 1.73	1.66	1.05, 2.62	1.21	1.03, 1.42
Skin (C43, C44) (n = 202)								
Age adjusted	0.91	0.63, 1.31	0.96	0.63, 1.46	1.39	0.94, 2.06	1.11	0.96, 1.27
Multivariable adjusted[c]	0.91	0.63, 1.30	0.97	0.64, 1.47	1.40	0.95, 2.07	1.11	0.97, 1.28
Fully adjusted[d]	0.91	0.63, 1.31	0.97	0.64, 1.48	1.42	0.96, 2.12	1.12	0.97, 1.29
Breast (C50) (n = 2,102)								
Age adjusted	1.24	1.09, 1.42	1.41	1.23, 1.62	1.65	1.45, 1.88	1.19	1.14, 1.25
Multivariable adjusted[c]	1.24	1.08, 1.41	1.40	1.22, 1.61	1.64	1.44, 1.87	1.19	1.14, 1.25
Fully adjusted[d]	1.16	1.02, 1.33	1.27	1.11, 1.46	1.43	1.25, 1.64	1.14	1.08, 1.19
Reproductive factor adjusted[e]	1.13	0.95, 1.36	1.45	1.21, 1.74	1.60	1.34, 1.90	1.18	1.11, 1.25
Cervix uteri (C53) (n = 866)								
Age adjusted	1.12	0.94, 1.34	1.11	0.91, 1.34	0.88	0.71, 1.08	1.00	0.94, 1.07
Multivariable adjusted[c]	1.12	0.94, 1.34	1.11	0.91, 1.35	0.88	0.72, 1.09	1.00	0.94, 1.07
Fully adjusted[d]	1.14	0.96, 1.36	1.14	0.93, 1.38	0.91	0.74, 1.13	1.02	0.95, 1.09
Reproductive factor adjusted[e]	1.21	0.95, 1.54	1.18	0.91, 1.54	0.94	0.71, 1.25	1.01	0.92, 1.11
Corpus uteri (C54) (n = 298)								
Age adjusted	1.06	0.76, 1.48	1.02	0.72, 1.46	1.26	0.90, 1.76	1.11	0.99, 1.25
Multivariable adjusted[c]	1.07	0.77, 1.48	1.03	0.72, 1.47	1.28	0.92, 1.79	1.12	0.99, 1.26
Fully adjusted[d]	1.06	0.76, 1.48	1.02	0.71, 1.46	1.27	0.90, 1.78	1.11	0.99, 1.25
Reproductive factor adjusted[e]	0.95	0.61, 1.49	0.83	0.51, 1.36	1.11	0.70, 1.73	1.04	0.88, 1.22
Ovary (C56, C57) (n = 398)								
Age adjusted	1.23	0.92, 1.65	1.44	1.06, 1.95	1.68	1.25, 2.26	1.23	1.11, 1.36
Multivariable adjusted[c]	1.23	0.92, 1.65	1.45	1.07, 1.97	1.71	1.27, 2.29	1.24	1.12, 1.37
Fully adjusted[d]	1.20	0.90, 1.61	1.39	1.02, 1.89	1.60	1.19, 2.16	1.21	1.09, 1.35
Reproductive factor adjusted[e]	1.14	0.78, 1.67	1.42	0.95, 2.11	1.68	1.14, 2.48	1.24	1.08, 1.41

Abbreviation: ICD-10, *International Statistical Classification of Diseases and Related Health Problems*.

[a] Women for whom information about body mass index and behavioral and socioeconomic factors was complete.

[b] Reference category: ≤151.0 cm.

[c] Adjusted for age, body mass index (<18.5, 18.5–24.9, 25.0–29.9, and ≥30), cigarette smoking (ever, never), alcohol consumption (drinker, nondrinker), and regular exercise (yes or no).

[d] Additionally adjusted for level of monthly salary (quartile), occupation (high group occupation, low group occupation, or unemployed), and area of residence (capital, large city, or other).

[e] Additionally adjusted for age at menarche (<12, 12–13, 14–15, ≥16 years), duration of breastfeeding (≤12, 13–24, 25–36, 37–48, 49–59, ≥60 months), age at first childbirth (≤21, 22–24, 25–27, 28–30, ≥31 years), menopausal status (yes, no), estrogen replacement (ever, never), and use of oral birth control pill (ever, never) in 159,006 women with complete data.

of lung cancer cases in previous studies ranging from 114 to 348. Ours is one of the very largest studies to date, having 4,454 lung cancer cases among the men. We found a clear, positive, independent association of height with lung cancer risk in men. We had far fewer cases in women (943 cases); nonetheless, this still represents 1 of the largest studies in women, and we found a positive association in women similar to that found in men, although with less statistical precision. Given this large sample size, together with the similar magnitudes of association in men and women in this study, despite the very marked differences in smoking prevalence by gender, we believe that our results provide very strong evidence for a positive association of height with lung cancer that is driven by genetic or environmental factors that influence both skeletal growth and neoplastic processes in lung cells.

Although it is commonly suggested that height may work as a surrogate marker for biologic mediators of cancer (3, 12, 13), the pathways through which height appears to be associated with cancer are not yet clarified (3).

One possible common mechanism is that taller individuals have larger organs and therefore a greater number of cells that can undergo neoplastic change at each of these sites. This has been proposed for the height–breast cancer association (5) and also for the height–colorectal cancer association, because taller persons have a longer intestinal tract and therefore increased epithelial cell proliferation (38–40) and because acromegaly has been associated with increased colorectal cancer (41). It is also plausible that taller individuals will have larger respiratory tracts and livers, but it is unlikely that height would be related to the size of the thyroid gland or ovaries.

It has also been suggested that the insulin-like growth factor (IGF) system, a major regulator of childhood growth (42), may be an important common mechanism linking taller height in adulthood to increased cancer risk for these sites. High levels of IGF-I or a low level of IGF-binding protein 3 has been found to be associated with an increased risk of cancer of the prostate (43, 44), premenopausal breast (45, 46), colorectum (47, 48), and lung (49), supporting the role of IGF-I in the association between height and these cancers.

The timing of puberty could play a role in the growth of a person, and early puberty was suggested to explain the association between height and cancer, especially breast cancer, through either longer or earlier exposure of sensitive tissue to carcinogens, such as sex hormones (50, 51). However, it is less likely given that early puberty and early age of reaching maximum height are associated with shorter stature in some populations. Furthermore, the association between height and breast cancer was not attenuated even when the age at menarche was adjusted for in our study, as well as in several previous studies (9, 52, 53).

Helicobacter pylori infection is a necessary factor in the development of stomach cancer (54). This bacterial infection is most commonly acquired in childhood and is associated with lower socioeconomic position, overcrowded conditions, and short stature (55, 56). In this regard, one might anticipate an inverse association mediated by *H. pylori*. However, we found no association between adulthood height and stomach cancer.

To our knowledge, our study is the largest and also the first study in an East Asian population to examine associations between height and the incidence of any cancer and a very wide range of site-specific cancers. Information on a range of potential confounding factors allowed us to evaluate whether the association between height and cancer risk was independent of smoking and other known risk factors of cancer.

There are, however, some limitations to our study. Measurement of height was for routine clinical purposes, rather than research purposes. However, measurement error is likely to be lower and less likely to be differential by this method than by self-reporting, which has been used in some previous studies relating height to cancer risk. DNA sampling was not done, and we did not have information on participants' parental height. Hence, we were unable to assess the possible influence of genetic factors on the association between height and cancer. Some probable confounders (i.e., family history of cancers, duration of smoking, menopausal age) were not fully controlled because of the lack of available information, which may have resulted in slightly biased results.

We identified incident cancer cases from KCCR in which approximately 80% of the registered hospitals participated in 2002. Despite that, as the registry covers all of the hospitals with residency training programs, underestimation of cancer cases is unlikely to be substantial. However, if hospitals located in more urban areas (where taller and more affluent people are more likely to live) have a higher chance of participation, the results may be biased.

In conclusion, in this cohort study involving Korean men and women, taller height was found to be associated with greater risk of all-sites cancer and cancers of the colon, thyroid, prostate, breast, and ovary even after body mass index, the behavioral and socioeconomic characteristics in adulthood, and female reproductive factors were taken into consideration. The consistencies in the associations between height and cancer in our study and previous studies in different populations support the likelihood of a common pathway that affects skeletal growth and cancer risk across these populations.

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Appendix Table 1. Associations Between Height and Liver Cancer (ICD-10 code C22) in Study Participants (314,979 Men and 88,118 Women) for Whom Information About Hepatitis B Viral Antigen and Covariates Was Complete, Korea, 1994–2003

	Height Categories, cm,[a] in Men (No. of Cases = 4,866)							
	164.6–168.0		168.1–171.0		>171.0		5-cm Increment	
	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval
Age adjusted	1.05	0.97, 1.14	1.04	0.95, 1.13	1.14	1.05, 1.23	1.04	1.01, 1.07
Multivariable adjusted[b]	1.06	0.98, 1.15	1.05	0.96, 1.14	1.15	1.06, 1.25	1.04	1.01, 1.07
Fully adjusted[c]	1.08	1.00, 1.17	1.08	0.99, 1.18	1.20	1.10, 1.30	1.06	1.03, 1.09
Hepatitis B viral antigenicity adjusted[d]	1.03	0.95, 1.11	0.99	0.91, 1.08	1.04	0.95, 1.12	1.00	0.97, 1.03
	Height Categories, cm,[e] in Women (No. of Cases = 165)							
	151.1–155.0		155.1–158.0		>158.0		5-cm Increment	
	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval	Hazard Ratio	95% Confidence Interval
Age adjusted	1.25	0.74, 2.11	1.25	0.73, 2.13	1.34	0.81, 2.23	1.10	0.93, 1.30
Multivariable adjusted[b]	1.26	0.75, 2.14	1.28	0.75, 2.18	1.38	0.83, 2.29	1.11	0.94, 1.31
Fully adjusted[c]	1.32	0.78, 2.24	1.36	0.79, 2.34	1.50	0.89, 2.51	1.15	0.97, 1.36
Hepatitis B viral antigenicity adjusted[d]	1.30	0.76, 2.21	1.26	0.74, 2.18	1.32	0.78, 2.22	1.07	0.90, 1.26

Abbreviation: ICD-10, *International Statistical Classification of Diseases and Related Health Problems*.

[a] Reference category: ≤164.5 cm.

[b] Adjusted for age, body mass index (<18.5, 18.5–24.9, 25.0–29.9, and ≥30), cigarette smoking (never, past, 1–19 cigarettes/day, and ≥20 cigarettes/day in men; ever, never in women), alcohol consumption (<30, 30–104, 105–209, and ≥210 g/week in men; drinker, nondrinker in women), and regular exercise (yes or no).

[c] Adjusted for the covariates in the above model and additionally for level of monthly salary (quartile), occupation (high group occupation, low group occupation, or unemployed), and area of residence (capital, large city, or other).

[d] Adjusted for the covariates in the above models and additionally for hepatitis B viral antigenicity.

[e] Reference category: ≤151.0 cm.