To evaluate the association between adult height as a surrogate marker of childhood circumstances and the risk of mortality, 344,519 South Korean women aged 40–64 years categorized into six height groups were prospectively followed for mortality between 1994 and 2004. In Cox proportional hazards regression with adjustment for behavioral and biologic risk factors, there was an inverse association between height and total mortality; mortality risk decreased 7% for each 5-cm increment in height. The association did not materially change after adjustment for behavioral factors and adulthood socioeconomic factors or after full adjustment for all available covariates. When height-associated risks of death from specific causes were evaluated in a fully adjusted analysis, a 5-cm increment in height was associated with lower risks of death from respiratory diseases, stroke, diabetes mellitus, and external causes (hazard ratios were 0.84 (95% confidence interval (CI): 0.74, 0.96), 0.84 (95% CI: 0.80, 0.88), 0.87 (95% CI: 0.80, 0.96), and 0.88 (95% CI: 0.83, 0.94), respectively) and with a higher risk of death from cancer (hazard ratio = 1.05, 95% CI: 1.02, 1.09). Given that adult height reflects early-life conditions, the independent associations between height and mortality from all causes and specific causes support the view that early-life circumstances significantly influence health outcomes in adulthood.

A person’s adult height is determined by both genetic and environmental factors. Among the environmental factors, health status and socioeconomic conditions in early life are considered to have an important influence (1, 2) and have long been hypothesized to be associated with health status in adulthood (3). In this regard, many investigators evaluating the impact of early-life conditions on health outcomes in adulthood have used adult height as a surrogate marker of early-life environment (4–13). On the basis of these studies, short stature is generally associated with an increased risk of total mortality, providing evidence for the impact of childhood conditions on adult health (7, 13–16).

However, the associations between height and some specific causes of death, such as stroke (4, 17), coronary heart disease (9, 13, 16), and cancer (7, 18), have been inconsistent between studies. Previous studies evaluating the association between height and health outcomes were mostly conducted in Western populations (6, 8, 14, 19). There have been only two prospective studies conducted outside Western countries; one was carried out in Japan (4) and one in South Korea (16). These studies had some limitations, however. Specifically, in the Japanese study, Hozawa et al. (4) evaluated the association between height and stroke mortality only, while the South Korean study (16) was limited to males. Although Song et al. (16) reported associations between height and mortality from a range of specific causes in the South Korean study, a study carried out in a population of Asian women would be valuable, given that the association between height and cause-specific mortality may differ between men and women (4, 7) and that data on males...
cannot provide information about female sex-specific cancers such as cancers of the breast, ovary, and uterus.

In this cohort study, we evaluated the association between height and mortality from all causes and specific causes in a large cohort of South Korean women. Our study included a large number of participants and an adequate number of death events, which provided strength in terms of statistical power to resolve some of the inconsistent results of other studies, especially for the association between height and mortality from specific causes. Available information on a range of risk factors allowed us to examine the relation between height and mortality independently of behavioral and biologic factors and adulthood socioeconomic position.

**MATERIALS AND METHODS**

**Study participants**

The study participants were South Korean women aged 40–64 years who underwent a health examination provided by the Korea Medical Insurance Corporation between 1993 and 1994. The Korea Medical Insurance Corporation is one of the major institutions of the Korea National Health Insurance System and has provided a biennial health examination to all public servants since 1980 and to their unemployed dependants aged 40 years or older since 1993. Ninety-five percent of public servants in 1994 and 52 percent of all of the invited female dependants in 1993 underwent the health examination. Among 345,238 female examinees aged 40–64 years, those who died during the health examination period \(n = 533\), whose height data were not available \(n = 117\), and those within the upper or lower 0.01 percent of the height distribution \(n = 69\) were excluded. Thus, 344,519 women were included in the study.

**Measurements**

All of the medical facilities performing health examinations were equipped with standardized measuring devices and high-quality laboratories authorized by the Korea Association of Clinical Pathology and the Korea Association of Quality Control over Clinical Laboratory Examination. Weight (kg) and height (cm) were measured in light clothing using standardized scales and stadiometers, respectively, by registered nursing staff. Otherwise, no specific guidelines were used. The average height of the study participants was 154.5 cm (standard deviation, 5.2; range, 131.5–173.5 cm). Study participants were divided into six height groups: <149, 149–151, 152–154, 155–157, 158–160, and ≥161 cm. Body mass index was calculated as weight divided by the square of height \((\text{weight (kg)/height (m)}^2)\) and was categorized into four groups: <18.5, 18.5–24.9, 25–29.9, and ≥30 (20). Fasting venous blood samples were obtained and used to assess total cholesterol and glucose levels. A single measurement of blood pressure in the seated position was made by the registered nursing staff using a standard sphygmomanometer.

Information on the health-related behaviors of participants was obtained from a self-administered questionnaire in 1993 and 1994. Closed-ended questions on cigarette smoking habits, alcohol consumption, and engagement in regular exercise were presented with several categories of responses. Two categories were constructed for alcohol consumption (nondrinker or drinker) and cigarette smoking (never smoker or ever smoker) because the proportions of alcohol drinkers (13.0 percent) and cigarette smokers (4.8 percent) were small. For physical exercise, two categories were used—engaging or not engaging in regular exercise—because more detailed information was unavailable. Area of residence was grouped into three categories: Seoul, another large city, or another region (i.e., medium-sized city, small city, or rural area) according to the categorization of the administrative jurisdiction. Occupations were categorized into three groups: housewife, for unemployed female dependants; 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 four groups based on the quartile distribution of the monthly salary level of the public servants or the public servants who supported female dependants, with the first quartile being the lowest.

**Mortality follow-up**

All deaths which occurred between October 1, 1994, and December 31, 2004, were determined using data linkage with the death report data from the Korean National Statistical Office. Codes from the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, were used to identify cause-specific deaths in the following categories: cancer (C00–C97), circulatory diseases (I00–I99), ischemic heart disease (I20–I25), stroke (I60–I69), diabetes mellitus (E10–E14), respiratory diseases (J00–J99), and external causes (V01–Y98).

**Statistical methods**

Follow-up began in October 1994, and the participants were censored on the date of death or on December 31, 2004, if they were still alive at the end of the follow-up period. We calculated age-standardized mortality rates (per 100,000 person-years) in each height group by direct standardization, with the population structure of South Korean women in 1993 used as the standard. Hazard ratios and 95 percent confidence intervals for mortality from all causes and specific causes for the six height groups were estimated in Cox proportional hazards regression analysis, using three different models to examine the effect of potential confounders on the association between height and mortality. In the first model, results were adjusted for age, conventional behavioral factors (alcohol consumption, cigarette smoking, and physical exercise), and biologic health risk factors (blood pressure, cholesterol level, fasting blood glucose level, and body mass index). In the second model, results were adjusted for age, behavioral factors, and socioeconomic factors (pay level, area of residence, and occupation). Then, in the third model, the analysis was repeated with adjustment for all covariates.
This study was approved by the internal review board of Samsung Medical Center in Seoul, South Korea.

RESULTS

During an average of 9.86 years of follow-up, 12,016 women (in 3,398,444 person-years) died. Cancer was the most common cause of death (4,901 cases; 40.8 percent), and death from circulatory diseases accounted for 26.8 percent of deaths (3,218 cases), with 2,004 deaths being due to stroke and 543 deaths resulting from ischemic heart disease. Deaths from endocrine diseases, respiratory diseases, and external causes accounted for 5.7 percent, 2.5 percent, and 10.0 percent of all deaths, respectively.

Table 1 shows the age-adjusted distribution of risk factors among study participants by height. Compared with the shorter group, the taller group was more likely to have higher blood pressure and higher fasting blood glucose levels and tended to be less obese. Lifestyle tended to be healthier in the taller group, with a lower prevalence of ever smoking and alcohol consumption and a higher prevalence...
of regular exercise. Socioeconomic position, as measured by occupation and pay level, increased with increasing level of height. The proportion of women living in Seoul or another large city was higher in the taller group.

Figure 1 shows age-adjusted mortality from all causes and from specific causes in each height group. Age-adjusted mortality from all causes, stroke, respiratory diseases, and external causes decreased with increasing height.

Table 2 shows the multivariable-adjusted hazard ratio for mortality in each height group for deaths from all causes and specific causes. There was an inverse association between height and all-cause mortality, and the risk of mortality decreased by 7 percent with each 5-cm increment in height when results were adjusted for conventional health risk factors. This association was slightly attenuated but remained statistically significant when results were adjusted for only the socioeconomic and behavioral confounders without biologic factors (i.e., cholesterol, blood pressure, glucose, and body mass index), and even when results were adjusted for all of the available covariates.

When the risks associated with height were evaluated for deaths from specific causes, the risks of death from stroke, diabetes mellitus, respiratory diseases, and external causes were inversely associated with height. When results were adjusted only for socioeconomic and behavioral confounders (without biologic factors), the inverse association between height and death from diabetes mellitus lost statistical significance. The same loss of statistical significance was also observed when results were adjusted only for socioeconomic and behavioral confounders without biologic factors and when results were adjusted for all of the covariates.

There was no difference in the direction of the association across stroke subtypes (i.e., ischemic stroke and hemorrhagic stroke). There was no association between ischemic heart disease and height.

A positive association was observed between height and risk of death from all cancers combined. However, the associations between height and cancers at individual sites varied site-specifically. The risks of death from cancers of the ovary and hepatobiliary tract were positively associated with height, while there was a negative association between cervical cancer mortality and height. No specific association was found between height and death from cancers of the stomach, colorectum, pancreas, respiratory tract, brain, and hematopoietic system. A positive association was found between height and breast cancer mortality in the analysis adjusted for biologic and behavioral risk factors. However, the association did not exist when results were adjusted for only socioeconomic and behavioral confounders without biologic factors or when the results were adjusted for all covariates.

**DISCUSSION**

In this cohort study of South Korean women, lower height was associated with an increased risk of mortality, as reported in previous studies of Western populations (7, 8, 15) and South Korean men (16). The consistency in the height-mortality association between the studies of various populations is strong evidence for an impact of early-life conditions on health outcomes in adulthood.

Lower socioeconomic position in adulthood tends to be closely related to exposure to an adverse childhood environment and also to poor health outcomes, based on previous studies (21–23); therefore, adult socioeconomic position may have seriously confounded the association between height and mortality. However, it is less likely given that the association between height and mortality in our study was not attenuated even after adjustment for socioeconomic status in adulthood.

Unfavorable behavioral and biologic risk factors have also been found to be associated with exposure to an adverse environment in childhood, and it has been suggested that such factors mediate the association between shorter stature and poor health outcomes in adulthood (24–27). However, we did not find a consistent relation between biologic and behavioral risk factors and height; taller women had better health habits and were less obese, even though they had higher blood pressures and higher glucose levels than shorter women. Furthermore, consideration of those health risk factors did not alter the finding of an inverse association between height and mortality. Therefore, it is unlikely that the association between height and mortality was significantly confounded by the behavioral and biologic risk factors.

Investigators who have examined the association between height and mortality from specific causes have usually reported that the nature of the association with height varies between specific causes (7, 8, 13, 14, 16, 17). For some causes, conflicting results have been reported.

Respiratory disease mortality has been consistently shown to have a strong inverse association with height and socioeconomic position in childhood (7, 8, 14, 28). Although cigarette smoking was more prevalent among shorter persons than among taller persons in our study, adjustment for cigarette smoking did not fully extinguish the inverse

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**FIGURE 1.** Age-adjusted rate of mortality (per 100,000 person-years) from all causes and specific causes, by height, South Korea, 1994–2004.
association, as in other studies (7, 16, 28). Lung function, which is also related to childhood environment, has been suggested to account for the association between height and respiratory mortality in some studies (8, 29). However, we did not address that issue in this study.

Although an opposing report exists regarding suicide (30), shortness is usually associated with increased risk of death from external causes (7, 16, 31). In our study, we reconfirmed the inverse association, which was independent of adult socioeconomic status and behavioral risk factors. Unmeasured psychological and cognitive factors in adulthood that originated in childhood and are associated with shortness might contribute to the increased risk of death from external causes, as well as suicide and violent death (32, 33). Social mobility—that is, occupation and marriage—may be associated with the risk of death from external causes (34), could be selective with respect to height (23, 35), and may explain, in part, the association of height with mortality from external causes.

In a United Kingdom study (15), childhood height was associated with adult cardiovascular disease mortality independently of later socioeconomic circumstances and health risk factors, supporting the role of the early socioeconomic environment. Height was inversely associated with the risk of stroke mortality in many studies (4, 8). We also found that the risk of stroke mortality increased in shorter women, independently of known cardiovascular disease risk factors and socioeconomic factors in adulthood. It is noteworthy that suboptimal profiles of blood pressure and glucose levels were more prevalent among taller women; therefore, those factors did not seem to fully account for the increased risk of stroke death among shorter women.

In most previous studies of Western populations, investigators have reported an independently increased risk of ischemic heart disease in shorter people (8, 14, 17, 36); there have been only a few exceptions (21, 37). However, there was no association between height and ischemic heart disease death in this study or in the previous study involving South Korean males (16). Different relations between height and cardiovascular disease risk factors in the studied populations might partially explain the various findings regarding the association between height and ischemic heart disease mortality. In our study, taller women were more likely to have higher blood pressures and higher fasting blood glucose levels, and no specific relation was found between cholesterol level and height. The role of additional factors, such as an atherogenic diet, was raised as another possible explanation for the increased risk of ischemic heart disease in shorter persons (37), but this needs further study.

Inconsistent findings have been reported on the relation between socioeconomic position and the risk of diabetes mellitus (38, 39), and the association between height and mortality from diabetes mellitus has seldom been studied. In this study, no specific association was found when results were adjusted for only the socioeconomic and behavioral factors. However, taller women were less likely to die of diabetes mellitus when biologic covariates, including glucose level, were considered. Given that long-standing diabetes mellitus with complications is more likely to produce fatal outcomes, our finding of an inverse association between height and mortality from diabetes mellitus independent of known cardiovascular risk factors seems to provide new evidence of a continuum in the risk of diabetes being associated with childhood exposures.

With only a few exceptions (7, 18), a positive association with height has been shown consistently for total cancer and cancers at many sites, such as the prostate, colorectum, breast (in women), ovary, and uterine corpus (40–45). However, the association between height and stomach cancer (8, 46) is controversial, and no association with lung cancer has been reported (16, 40, 46). The various associations between height and cancers at specific sites could be due to the different mechanisms underlying cancer development at those specific sites. Genetic or hormonal factors, such as insulin-like growth factors that are associated with height and also influence susceptibility to cancer, have been suggested to explain the positive association between height and cancer (47). To explain the inverse association between height and stomach cancer, it has been suggested that childhood exposure to infectious organisms, such as Helicobacter pylori, is associated with shorter height (8).

Our study reconfirmed the positive association between height and risk of mortality from all cancers combined but showed somewhat different relations between height and cancers at individual sites. Although a positive association of height with ovarian cancer and the lack of association with cancers of the stomach and respiratory tract found in our study were compatible with the findings from many previous studies, the commonly reported positive associations between height and colorectal and breast cancers were not found. Instead, we found a positive association of height with hepatobiliary cancer mortality and an inverse association with cervical cancer mortality. However, the associations between height and cancers of the hepatobiliary tract and cervix need further evaluation in future studies, because they were seldom evaluated in previous studies, and our study could not provide any evidence to explain the basis for the association.

This study had some limitations. Measurement of height was not specifically guided. We could not directly assess childhood environment and could not determine the influence of genetic factors on height. Since the causes of deaths were identified from the death report data of the Korea National Statistical Office, some misclassification regarding the cause-specific deaths was possible. However, such misclassification would have hardly influenced the association between height and mortality, because it probably occurred in a random fashion. It should be taken into consideration that the relation between height and the risk of disease occurrence may differ from the relation between height and mortality. Although the participation rate of female public servants was very high, bias may have been produced by the fact that only 52 percent of community-dwelling independent women participated. Considering that the decreased mobility of a diseased person is more likely to act as an obstacle to participation in routine health examination, the lower participation rate is more likely to have caused underestimation of an association rather than overestimation. However, we could not examine this problem because of the lack of data from nonparticipants.
<table>
<thead>
<tr>
<th>Cause of death (ICD-10 code)</th>
<th>Association for 5-cm increment in height</th>
<th>HR (95% CI)</th>
<th>No. of cases</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All causes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR (95% CI)</td>
<td></td>
<td>10,097</td>
<td>1</td>
<td>&lt; 149</td>
</tr>
<tr>
<td>HR (95% CI)</td>
<td></td>
<td>9,132</td>
<td>1</td>
<td>149–151</td>
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<td>HR (95% CI)</td>
<td></td>
<td>9,119</td>
<td>1</td>
<td>152–154</td>
</tr>
<tr>
<td>All cancers (C00–C97)</td>
<td></td>
<td>4,153</td>
<td>1</td>
<td>155–157</td>
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<tr>
<td>Stomach cancer (C16)</td>
<td></td>
<td>686</td>
<td>1</td>
<td>158–160</td>
</tr>
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<td>HR (95% CI)</td>
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<td>618</td>
<td>1</td>
<td>≥ 161</td>
</tr>
<tr>
<td>Colorectal cancer (C18–C21)</td>
<td></td>
<td>397</td>
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<td></td>
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<tr>
<td>Hepatobiliary tract cancer (C22–C24)</td>
<td></td>
<td>852</td>
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<td></td>
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<tr>
<td>Pancreatic cancer (C25)</td>
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<td></td>
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<td>Respiratory tract cancer (C30–C34)</td>
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<td>579</td>
<td>1</td>
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<tr>
<td>Breast cancer</td>
<td></td>
<td>287</td>
<td>1</td>
<td></td>
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<tr>
<td>Cervical cancer (C53)</td>
<td></td>
<td>127</td>
<td>1</td>
<td></td>
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<tr>
<td>Ovarian cancer (C56)</td>
<td></td>
<td>157</td>
<td>1</td>
<td></td>
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<tr>
<td>Brain cancer (C71 and C72)</td>
<td></td>
<td>98</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2.** Associations between height and mortality from all causes and specific causes for women aged 40–64 years, South Korea, 1994–2004

**Note:** HR (hazard ratio) and 95% CI (confidence interval).
<table>
<thead>
<tr>
<th>Event Type</th>
<th>HR (95% CI)§</th>
<th>HR (95% CI)$</th>
<th>HR (95% CI)$</th>
<th>HR (95% CI)$</th>
<th>HR (95% CI)$</th>
<th>HR (95% CI)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematopoietic cancer (C81–C96)</td>
<td>0.90 (0.60, 1.34)</td>
<td>0.92 (0.63, 1.35)</td>
<td>0.87 (0.59, 1.30)</td>
<td>1.23 (0.82, 1.84)</td>
<td>1.24 (0.78, 1.97)</td>
<td>1.06 (0.95, 1.20)</td>
</tr>
<tr>
<td>Circulatory diseases (I00–I99)</td>
<td>0.60 (0.60, 1.34)</td>
<td>0.87 (0.58, 1.32)</td>
<td>0.83 (0.54, 1.28)</td>
<td>1.26 (0.82, 1.93)</td>
<td>1.27 (0.77, 2.07)</td>
<td>1.08 (0.96, 1.23)</td>
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<tr>
<td>Stroke (I60–I69)</td>
<td>0.94 (0.62, 1.43)</td>
<td>0.87 (0.58, 1.33)</td>
<td>0.84 (0.55, 1.29)</td>
<td>1.27 (0.83, 1.96)</td>
<td>1.28 (0.78, 2.10)</td>
<td>1.09 (0.96, 1.23)</td>
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<tr>
<td>Ischemic stroke (I63 and I67.8)</td>
<td>0.82 (0.74, 0.92)</td>
<td>0.77 (0.69, 0.86)</td>
<td>0.75 (0.67, 0.85)</td>
<td>0.65 (0.56, 0.75)</td>
<td>0.65 (0.54, 0.78)</td>
<td>0.86 (0.83, 0.89)</td>
</tr>
<tr>
<td>Hemorrhagic stroke (I61)</td>
<td>0.76 (0.74, 0.89)</td>
<td>0.84 (0.78, 0.90)</td>
<td>0.75 (0.69, 0.82)</td>
<td>0.67 (0.55, 0.81)</td>
<td>0.65 (0.50, 0.84)</td>
<td>0.85 (0.81, 0.90)</td>
</tr>
<tr>
<td>Ischemic heart diseases (I20–I25)</td>
<td>0.84 (0.84, 1.09)</td>
<td>0.86 (0.84, 1.07)</td>
<td>0.86 (0.84, 1.06)</td>
<td>0.78 (0.68, 0.90)</td>
<td>0.75 (0.65, 0.89)</td>
<td>0.87 (0.84, 0.90)</td>
</tr>
<tr>
<td>Diabetes mellitus (E10–E14)</td>
<td>0.84 (0.84, 1.11)</td>
<td>0.86 (0.84, 1.11)</td>
<td>0.86 (0.84, 1.11)</td>
<td>0.78 (0.68, 0.90)</td>
<td>0.75 (0.65, 0.89)</td>
<td>0.87 (0.84, 0.90)</td>
</tr>
<tr>
<td>Respiratory diseases (J00–J99)</td>
<td>0.81 (0.80, 1.09)</td>
<td>0.81 (0.80, 1.09)</td>
<td>0.81 (0.80, 1.09)</td>
<td>0.76 (0.63, 0.92)</td>
<td>0.75 (0.62, 0.91)</td>
<td>0.80 (0.76, 0.85)</td>
</tr>
<tr>
<td>External causes (V01–Y98)</td>
<td>0.81 (0.56, 1.17)</td>
<td>0.70 (0.50, 1.07)</td>
<td>0.70 (0.50, 1.07)</td>
<td>0.69 (0.50, 1.07)</td>
<td>0.68 (0.49, 0.99)</td>
<td>0.80 (0.74, 0.98)</td>
</tr>
<tr>
<td>Other causes§</td>
<td>0.80 (0.77, 1.06)</td>
<td>0.82 (0.70, 0.95)</td>
<td>0.76 (0.65, 0.90)</td>
<td>0.84 (0.69, 1.01)</td>
<td>0.84 (0.65, 0.96)</td>
<td>0.91 (0.86, 0.95)</td>
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<tr>
<td>Respiratory diseases (J00–J99)</td>
<td>0.94 (0.79, 1.11)</td>
<td>0.86 (0.73, 1.02)</td>
<td>0.84 (0.71, 1.01)</td>
<td>0.97 (0.79, 1.18)</td>
<td>0.84 (0.65, 1.08)</td>
<td>0.96 (0.91, 1.01)</td>
</tr>
</tbody>
</table>

† HR, hazard ratio; CI, confidence interval.
‡ Adjusted for age, systolic blood pressure, serum total cholesterol level, fasting blood glucose level, body mass index (weight (kg)/height (m))^2^; <18.5, 18.5–24.9, 25.0–29.9, or ≥30), cigarette smoking (ever or never), alcohol consumption (yes or no), and regular exercise (yes or no).
§ Adjusted for age, cigarette smoking, alcohol consumption, regular exercise, quartile of monthly salary, occupation (high occupational group, low occupational group, or housewife (see table 1)), and area of residence (Seoul, other large city, or other area).
¶ Adjusted for age, systolic blood pressure, serum total cholesterol level, fasting blood glucose level, body mass index, cigarette smoking, alcohol consumption, regular exercise, quartile of monthly salary, occupation, and area of residence.
# Causes of death other than cancer, circulatory diseases, diabetes mellitus, respiratory diseases, and external causes.
In conclusion, in this cohort study involving South Korean women, shorter stature was associated with higher risks of death from all causes, respiratory diseases, diabetes, cardiovascular diseases, and external causes and with a lower risk of death from cancer, even after behavioral and biologic risk factors and socioeconomic position in adulthood were taken into consideration. Given that adult height reflects early-life conditions, these findings support the view that there is an influence of childhood environment on health status in adulthood.

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