# Relationships Between Percentage of Forest Coverage and Standardized Mortality Ratios (SMR) of Cancers in all Prefectures in Japan

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**Abstract:** *Objectives:* To explore whether forest coverage affects the rate of deaths due to cancers in Japan, we investigated the relationships between the percentage of forest coverage and standardized mortality ratios due to cancers in all prefectures in Japan.

*Methods:* Data on the percentage of forest coverage in all prefectures in Japan were collected from the database of the Forestry Agency of Japan. Data on standardized mortality ratios (SMR) due to lung, stomach, kidney, and colon cancers in males and females, breast and uterine cancers in females, and prostate cancer in males, and data of smoking status of males and females in all prefectures in Japan were collected from the database of the Ministry of Health, Labour, and Welfare of Japan. Human development index (HDI) was used as a parameter of the socioeconomic status of each prefecture. The correlation and partial correlation coefficients between the percentage of forest coverage and SMR of cancers, after controlling for the effects of smoking and the socioeconomic status, were calculated.

*Results:* People living in areas with lower forest coverage had significantly higher SMR of cancers compared with the people living in areas with higher forest coverage. There were significant inverse correlations between the percentage of forest coverage and the SMR of lung, breast, and uterine cancers in females, and the SMR of prostate, kidney, and colon cancers in males in all prefectures in Japan, even after the effects of smoking and socioeconomic status were factored in.

*Conclusions:* These findings indicate that increased forest coverage may partially contribute to a decrease in mortality due to cancers in Japan.

**Keywords:** Breast cancer, colon cancer, HDI, kidney cancer, percentage of forest coverage, prostate cancer, SMR, uterine cancer.

## INTRODUCTION

A forest bathing trip, called “Shinrinyoku” in Japanese, involves a visit to a forest area for the purpose of relaxation and recreation by breathing in volatile substances, called phytoncides, released from the trees (Li *et al*., 2007; 2008a; 2008b). These trips were first proposed in the 1980s and have become a recognized relaxation activity in Japan (Ohtsuka *et al*., 1998; Yamaguchi *et al*., 2006; Li *et al*., 2007; 2008a; 2008b; Morita *et al*., 2007; Park *et al*., 2007). Since forests occupy 67% of the land in Japan (Forestry Agency of Japan, 2002), forest bathing is easily accessible. According to a public opinion poll conducted in Japan in 2003, 25.6% of respondents had participated in a forest bathing trip, indicating its popularity in Japan (Morita *et al*., 2007). Moreover, forest bathing is possible in similar environments throughout the world. We reported previously that phytoncides such as alpha-pinene, 1,8-cineole, and d-limonene extracted from trees significantly enhanced human natural killer (NK) activity and intracellular levels of perforin, granulysin (GRN), and granzyme A (GrA) in human NK cells *in vitro* (Li *et al*., 2006). (Komori *et al*., 1995) also reported that citrus fragrance found in forests affects the human endocrine and immune systems as analyzed by the measurement of urinary cortisol and dopamine levels, NK activity, and CD4/8 ratios. These findings suggest that forest bathing may have beneficial effects on human immune function. Thus, we previously investigated the effect of forest bathing trips on human NK activity, and found increased human NK activity, NK cell numbers, and intracellular levels of perforin, GRN, and GrA/B in peripheral blood lymphocytes (Li *et al*., 2007). Moreover, we also found that the increased NK activity, number of NK cells, and intracellular anti-cancer proteins induced by a forest bathing trip lasted more than 7 days, even 30 days, after the trip both in males (Li *et al*., 2008a) and females (Li *et al*., 2008b). Cytolytic molecules such as perforin, GRN, and GrA/B contribute to anti-tumor activity (Krensky and Clayberger, 2005; Huang *et al*., 2007). These findings suggest that forests may have anti-cancer effects by enhancing human NK activity and partially contribute to decreased rates of death due to cancers. These findings also encouraged us to propose a hypothesis that people living in areas with higher forest coverage may show lower mortality due to cancers; thus, we investigated the relationship between the percentage of forest coverage and standardized mortality ratios (SMR) due to cancers in all prefectures in Japan to verify this hypothesis in the present study. SMR measures the level of excess or deficit in mortality in a study population compared with the expected level based on the mortality of a standard population. SMR is computed as the ratio of the observed deaths to the expected deaths in the study population. The expected deaths are obtained by multiplying the age-specific mortality rate of a chosen standard population by the age-specific population

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**Table 1a. Rate of Forest Coverage, SMR of Cancers, and Smoking Rate in Females in Each Prefecture of Japan**

| Prefecture | Forest coverage (%) | Lung Cancer | Breast Cancer | Uterine Cancer | Stomach Cancer | Colon Cancer | Kidney Cancer | Smoking rate (%) | HDI* |
|---|---|---|---|---|---|---|---|---|---|
| Hokkaido | 71 | 109.3 | 105.8 | 97.3 | 89.9 | 106.8 | 116.5 | 12.1 | 0.93 |
| Aomori | 66 | 93.6 | 100.8 | 89.8 | 101.1 | 112.1 | 139.4 | 5.4 | 0.913 |
| Iwate | 77 | 83.7 | 88.8 | 88.3 | 83.9 | 108.7 | 81 | 3.7 | 0.925 |
| Miyagi | 57 | 95.3 | 98.4 | 86.4 | 92.1 | 107.7 | 104.7 | 5.1 | 0.931 |
| Akita | 72 | 87.9 | 80.7 | 77.3 | 118.3 | 113.2 | 114.2 | 3.3 | 0.92 |
| Yamagata | 72 | 89.3 | 79.2 | 82.2 | 122.5 | 108.8 | 98.5 | 4.5 | 0.927 |
| Fukushima | 71 | 91 | 79.8 | 86.2 | 100.7 | 99.9 | 101.8 | 5.5 | 0.928 |
| Ibaraki | 31 | 82.9 | 95 | 105.7 | 108.9 | 96.3 | 124.7 | 5.3 | 0.931 |
| Tochigi | 55 | 89.6 | 96.5 | 99.7 | 115.4 | 92.9 | 85.9 | 6.4 | 0.935 |
| Gunma | 67 | 80.3 | 92.5 | 84.5 | 102 | 89.2 | 88.9 | 7.1 | 0.935 |
| Saitama | 32 | 96.7 | 104.2 | 101 | 108.4 | 101.8 | 98.6 | 7.7 | 0.919 |
| Chiba | 32 | 95.8 | 107.1 | 100.7 | 102.9 | 101.7 | 88.9 | 6.7 | 0.926 |
| Tokyo | 36 | 110 | 132 | 114 | 102 | 111.7 | 111.8 | 9.6 | 0.972 |
| Kanagawa | 39 | 105.4 | 117.4 | 97.5 | 101.4 | 106 | 87.8 | 8.8 | 0.935 |
| Niigata | 69 | 86.2 | 86.9 | 65.4 | 112.9 | 105.8 | 68.1 | 4 | 0.935 |
| Toyama | 67 | 87.3 | 90.9 | 71.3 | 125.5 | 102.2 | 114.2 | 3.6 | 0.943 |
| Ishikawa | 69 | 97 | 96 | 97.7 | 106 | 94.4 | 67.6 | 6.9 | 0.94 |
| Fukui | 75 | 83.6 | 91 | 82.2 | 100.9 | 84.8 | 110.3 | 3 | 0.944 |
| Yamanashi | 78 | 77.3 | 100.2 | 88.3 | 88.9 | 85.7 | 116.5 | 5.9 | 0.937 |
| Nagano | 78 | 72.9 | 88.7 | 81.3 | 94.3 | 98.8 | 61.6 | 3.1 | 0.941 |
| Gifu | 82 | 87.2 | 93.7 | 109.7 | 110.9 | 108.8 | 147.2 | 4.7 | 0.931 |
| Shizuoka | 64 | 83.2 | 91.9 | 93.2 | 89 | 91 | 108.3 | 5.2 | 0.944 |
| Aichi | 43 | 105.8 | 101.4 | 102.5 | 109.3 | 108.8 | 95.6 | 7.3 | 0.949 |
| Mie | 65 | 90 | 95.1 | 94.1 | 99.6 | 88.3 | 88.1 | 3.5 | 0.935 |
| Shiga | 51 | 97.6 | 88.7 | 85.4 | 110.1 | 95.2 | 102.9 | 4.5 | 0.946 |
| Kyoto | 75 | 108.9 | 99.4 | 91 | 105.4 | 102.5 | 79.3 | 7.3 | 0.939 |
| Osaka | 31 | 127.1 | 110 | 115 | 108 | 105.5 | 113.1 | 11 | 0.944 |
| Hyogo | 67 | 110.5 | 101.3 | 112.4 | 103.6 | 99.8 | 110.2 | 4.2 | 0.933 |
| Nara | 77 | 107 | 92.1 | 109.3 | 117 | 93 | 84.2 | 5.3 | 0.92 |
| Wakayama | 77 | 97.7 | 81.3 | 102.4 | 109.3 | 90.8 | 89.6 | 5.7 | 0.921 |
| Tottori | 74 | 94.3 | 88.4 | 105.8 | 110 | 92.3 | 111.2 | 2.4 | 0.931 |
| Shimane | 79 | 84.6 | 77.6 | 84.9 | 99.7 | 95.4 | 61.8 | 2.5 | 0.928 |
| Okayama | 68 | 90.9 | 74.2 | 84.6 | 89 | 90.2 | 118.6 | 3.3 | 0.936 |
| Hiroshima | 72 | 97.1 | 94 | 107.7 | 92.6 | 94.1 | 122.2 | 2.9 | 0.94 |
| Yamaguchi | 71 | 105.9 | 93 | 94.4 | 92.8 | 89.6 | 112.3 | 3.5 | 0.931 |
| Tokushima | 75 | 97.7 | 86.5 | 113.5 | 93.5 | 84.7 | 83.1 | 5.1 | 0.928 |
| Kagawa | 47 | 90.2 | 78.4 | 101.9 | 103.1 | 84.4 | 125.2 | 4 | 0.936 |
| Ehime | 71 | 92 | 88.3 | 101.5 | 98.4 | 79.9 | 68.6 | 2.7 | 0.927 |
| Kochi | 84 | 88 | 79.5 | 106.6 | 91.1 | 84.5 | 52.2 | 3.7 | 0.921 |
| Fukuoka | 45 | 120 | 104 | 109.4 | 98.5 | 104 | 104.9 | 5.9 | 0.928 |
| Saga | 45 | 100.9 | 87 | 111.8 | 98.1 | 101.5 | 109.6 | 3.1 | 0.924 |
| Nagasaki | 60 | 107.3 | 90.1 | 100.1 | 90.6 | 101.5 | 101 | 4.1 | 0.918 |
| Kumamoto | 63 | 98.3 | 85.9 | 96.1 | 71.7 | 83.1 | 138.7 | 4.5 | 0.928 |
| Oita | 72 | 94.3 | 82.2 | 106.4 | 88.9 | 86.7 | 58.2 | 4.3 | 0.935 |
| Miyazaki | 76 | 87.3 | 82.2 | 108.4 | 78.3 | 82.2 | 105.4 | 3.8 | 0.92 |
| Kagoshima | 64 | 96.9 | 75.5 | 107.3 | 68.3 | 87 | 49.7 | 2.1 | 0.919 |
| Okinawa | 46 | 125.1 | 80.9 | 122.6 | 47.4 | 83.6 | 34.6 | 4.6 | 0.914 |

*: HDI: Human Development Index.

**Table 1b. Rate of Forest Coverage, SMR of Cancers, and Smoking Rate in Males in Each Prefecture of Japan**

| Prefectures | Forest coverage (%) | Lung cancer | Stomach cancer | Colon cancer | Prostate cancer | Kidney cancer | Smoking rate (%) | HDI* |
|---|---|---|---|---|---|---|---|---|
| Hokkaido | 71 | 109.2 | 93.6 | 107.8 | 91.5 | 101.8 | 36.2 | 0.93 |
| Aomori | 66 | 110.7 | 111.1 | 116.6 | 119.1 | 149.4 | 47.7 | 0.913 |
| Iwate | 77 | 96.7 | 86.4 | 104 | 118.7 | 109.4 | 31.8 | 0.925 |
| Miyagi | 57 | 103 | 97.2 | 100.7 | 107.8 | 87.5 | 37.7 | 0.931 |
| Akita | 72 | 97.2 | 128.8 | 108.3 | 95.5 | 94.2 | 38.7 | 0.92 |
| Yamagata | 72 | 99.4 | 114.3 | 103.3 | 102 | 112.8 | 35.3 | 0.927 |
| Fukusihma | 71 | 95.8 | 107.9 | 99.7 | 109.9 | 94.8 | 33.6 | 0.928 |
| Ibaraki | 31 | 93.3 | 111 | 98.4 | 108.3 | 111.3 | 36.4 | 0.931 |
| Tochigi | 55 | 94.1 | 117.7 | 98.4 | 101.7 | 96.8 | 39.3 | 0.935 |
| Gunma | 67 | 89.2 | 99.5 | 89.8 | 99.1 | 113.1 | 35.6 | 0.935 |
| Saitama | 32 | 96.5 | 106.7 | 102.5 | 104 | 109.3 | 31 | 0.919 |
| Chiba | 32 | 90.2 | 107.9 | 103.3 | 109.3 | 98.6 | 31.9 | 0.926 |
| Tokyo | 36 | 96.4 | 101.7 | 112.9 | 109.5 | 121.8 | 31.1 | 0.972 |
| Kanagawa | 39 | 92.5 | 101.6 | 108.5 | 112.3 | 105.1 | 33.4 | 0.935 |
| Niigata | 69 | 102.2 | 115.8 | 103.4 | 86.7 | 106.4 | 33.2 | 0.935 |
| Toyama | 67 | 96.2 | 111.8 | 96.1 | 84.5 | 114.7 | 29 | 0.943 |
| Ishikawa | 69 | 103.6 | 106.4 | 97.9 | 87.9 | 92.7 | 47.5 | 0.94 |
| Fukui | 75 | 100.6 | 89.6 | 86 | 92.5 | 114.1 | 32.8 | 0.944 |
| Yamanashi | 78 | 86.3 | 91.3 | 81.4 | 102.1 | 39 | 44.7 | 0.937 |
| Nagano | 78 | 72.4 | 92.7 | 90.2 | 109.1 | 84 | 29.4 | 0.941 |
| Gifu | 82 | 91.8 | 100.1 | 93.7 | 101.5 | 71.4 | 34.8 | 0.931 |
| Shizuoka | 64 | 86.1 | 89.7 | 92.7 | 113.1 | 92.1 | 29.3 | 0.944 |
| Aichi | 43 | 104.5 | 100.9 | 99.7 | 96.5 | 89.7 | 29.1 | 0.949 |
| Mie | 65 | 101.6 | 95.3 | 90.4 | 67.4 | 118.5 | 29.9 | 0.935 |
| Shiga | 51 | 113.8 | 99.3 | 89.7 | 106.6 | 113.5 | 32.6 | 0.946 |
| Kyoto | 75 | 111.9 | 100.7 | 103.2 | 95.1 | 94.9 | 33.3 | 0.939 |
| Osaka | 31 | 117.3 | 109.5 | 103.4 | 90.9 | 106.3 | 42.6 | 0.944 |
| Hyogo | 67 | 111.3 | 104 | 103.8 | 89.6 | 107.9 | 31.4 | 0.933 |
| Nara | 77 | 106.3 | 107.5 | 91.6 | 93.9 | 86 | 31.7 | 0.92 |
| Wakayama | 77 | 115.7 | 104 | 92.6 | 83.2 | 90.2 | 34.6 | 0.921 |
| Tottori | 74 | 99.4 | 101.1 | 106.8 | 83.2 | 61 | 30 | 0.931 |
| Shimane | 79 | 91.2 | 94.3 | 98.8 | 92.3 | 57.2 | 25 | 0.928 |
| Okayama | 68 | 96.7 | 88.5 | 81.2 | 94.6 | 72.7 | 30.3 | 0.936 |
| Hiroshima | 72 | 97.3 | 93.3 | 95.1 | 91.5 | 91.8 | 22.7 | 0.94 |
| Yamaguchi | 71 | 104.5 | 98.2 | 94.5 | 67.2 | 96.6 | 25.7 | 0.931 |
| Tokushima | 75 | 99.2 | 94.5 | 84.7 | 69.8 | 88.5 | 30.1 | 0.924 |
| Kagawa | 47 | 100.4 | 102.3 | 78.5 | 88.7 | 93.3 | 29.7 | 0.936 |
| Ehime | 71 | 100 | 96.7 | 84.2 | 69.6 | 77.1 | 33 | 0.927 |
| Kochi | 84 | 86.2 | 90.3 | 97.5 | 99.8 | 86.1 | 28.6 | 0.921 |
| Fukuoka | 45 | 108 | 100.3 | 101.5 | 98.9 | 106.6 | 31.8 | 0.928 |
| Saga | 45 | 104.8 | 101.1 | 106.6 | 148.5 | 80.6 | 34.1 | 0.924 |
| Nagasaki | 60 | 112.5 | 89.1 | 106.3 | 113.8 | 106.4 | 35.2 | 0.918 |
| Kumamoto | 63 | 90.2 | 70 | 83.8 | 110.1 | 91.5 | 32.4 | 0.928 |
| Oita | 72 | 97.5 | 82 | 87.5 | 101 | 74.4 | 37.2 | 0.935 |
| Miyazaki | 76 | 92.3 | 84.5 | 89.6 | 104.6 | 86.3 | 26.7 | 0.92 |
| Kagoshima | 64 | 99 | 71.3 | 89 | 113.8 | 80.8 | 27 | 0.919 |
| Okinawa | 46 | 123.1 | 56.9 | 96.2 | 104.9 | 80.5 | 25.7 | 0.914 |

*: HDI: Human Development Index.

size of the study population and then adding terms to get the total expected number of deaths (Lai *et al*., 2000).

## MATERIALS AND METHODS

As shown in Tables **1a** and **1b**, data of the percentage of forest coverage in all prefectures in Japan in 2002 were collected from the database of the Forestry Agency of Japan (Forestry Agency of Japan, 2002). Data of standardized mortality ratios (SMR) of lung, stomach, kidney, and colon cancers in males and females, and SMR of breast and uterine cancers in females and prostate cancer in males in all prefectures in Japan in 1998 and 1999 were collected from the database of the Ministry of Health, Labour, and Welfare of Japan (Ministry of Health, Labour and Welfare of Japan, 2001). We used the mean SMR of cancers in 1998 and 1999 for all cancers in the present study. Since smoking status influences the SMR of cancers (Mellemgaard *et al*., 1994; Mizoue *et al*., 2000; Minami and Tateno, 2003; Bjartveit and Tverdal, 2005; Toh *et al*., 2007; Ambrosone *et al*., 2008; Gong *et al*., 2008), especially for lung cancer (Minami and Tateno, 2003; Bjartveit and Tverdal, 2005; Toh *et al*., 2007), data on the smoking status in males and females in 2003 were also collected from the database of the Ministry of Health, Labour, and Welfare of Japan (Ministry of Health, Labour and Welfare of Japan, 2003). Since socioeconomic status is also a risk factor for cancers (Datta *et al*., 2006; Fagundes *et al*., 2006; Goy *et al*., 2008; Menvielle *et al*., 2008) we have to take it into account. The human development index (HDI) is a composite score used by the United Nations Development Programme to rank countries in terms of their human socioeconomic development status (Landry and Raman, 2007), which is a composite index of life expectancy, literacy, and per capita gross domestic product that measures the socioeconomic status of a country (Lee *et al*., 1997). HDI has been used to estimate infant and maternal mortality rates around the world and assessed how well the HDI and its individual components predicted infant and maternal mortality rates for individual countries (Lee *et al*., 1997). In the present study, we used HDI as a parameter of socioeconomic status in each prefecture (Umemura, 2001). We first calculated the correlation coefficients between the percentage of forest coverage and SMR of cancers. Then, if the correlations were significant, the partial correlation coefficients between the percentage of forest coverage and SMR of cancers after factoring in the effects of smoking and socioeconomic status were also calculated.

### Statistical Analysis

The correlation and partial correlation coefficients were calculated and an unpaired t-test was performed using the SPSS 14.0 software package for Windows. The significance level for p values was set at < 0.05.

**Table 2a. Correlation and Partial Correlation Coefficients Between the Rate of Forest Coverage and SMR of Cancers in all Prefectures of Japan Corrected by Smoking Rate and HDI in Females**

| Female | Correlation coefficients | Partial correlation coefficients1# | Partial correlation coefficients2# | Partial correlation coefficients3# |
|---|---|---|---|---|
| Lung Cancer | -0.455** | -0.304* | -0.468** | -0.325* |
| Breast Cancer | -0.530** | -0.312* | -0.501** | -0.308* |
| Uterine Cancer | -0.328* | -0.269 | -0.377* | -0.293* |
| Stomach cancer | -0.050 | 0.027 | 0.008 | 0.048 |
| Colon Cancer | -0.271 | -0.101 | -0.247 | -0.099 |
| Kidney cancer | -0.136 | -0.078 | -0.102 | -0.068 |

*: p<0.05, **: p<0.001.
1#: corrected by smoking rate, 2# corrected by HDI, 3#: corrected by both smoking rate and HDI.

**Table 2b. Correlation and Partial Correlation Coefficients Between the Rate of Forest Coverage and SMR of Cancers in all Prefectures of Japan Corrected by Smoking Rate and HDI in Males**

| Male | Correlation coefficients | Partial correlation coefficients1# | Partial correlation coefficients2# | Partial correlation coefficients3# |
|---|---|---|---|---|
| Lung Cancer | -0.214 | -0.207 | -0.258 | -0.251 |
| Stomach cancer | -0.146 | -0.131 | -0.120 | -0.100 |
| Prostate cancer | -0.315* | -0.309* | -0.351* | -0.345* |
| Kidney cancer | -0.348* | -0.342* | -0.334* | -0.327* |
| Colon Cancer | -0.299* | -0.293* | -0.312* | -0.311* |

*: p<0.05.
1#: corrected by smoking rate, 2# corrected by HDI, 3#: corrected by both smoking rate and HDI.

## RESULTS

### Correlation Between the Percentage of Forest Coverage and SMR of Cancers

As shown in Tables **2a** and **b**, there were significant inverse correlations between the percentage of forest coverage and SMR of lung (r=-0.455, p<0.001), breast (r=-0.530, p<0.0001), and uterine cancers (r=-0.328, p<0.05) in females, and SMR of prostate (r=-0.315, p<0.05), kidney (r=-0.348, p<0.05), and colon cancers (r=-0.299, p<0.05) in males. On the other hand, there was no significant correlation between the percentage of forest coverage and SMR of stomach, kidney, and colon cancers in females and lung and stomach cancers in males.

As shown in Fig. (**1**), we further grouped the SMR of breast cancer in females and the SMR of prostate cancer in males by forest coverage in all prefectures in Japan and found that people living in areas with lower forest coverage had significantly higher SMR of breast and prostate cancers compared with the people living in areas with higher forest coverage.

### Partial Correlation Coefficients Between the Percentage of Forest Coverage and SMR of Cancers after the Effects of Smoking and Socioeconomic Status were Factored in

Since smoking status influences the SMR of cancers (Mellemgaard *et al*., 1994; Mizoue *et al*., 2000; Minami and Tateno, 2003; Bjartveit and Tverdal, 2005; Toh *et al*., 2007; Ambrosone *et al*., 2008; Gong *et al*., 2008), and there was a significant positive correlation between the SMR of lung cancer and smoking rates in each prefecture in females, we further calculated the partial correlation coefficients between the percentage of forest coverage and SMR of cancers after the effect of smoking was factored in. As shown in Tables **2a** and **b**, there were still significant inverse relationships between the percentage of forest coverage and SMR of lung (r=-0.304, p<0.05) and breast (r=-0.312, p<0.05) cancers in females, and SMR of prostate (r=-0.309, p<0.05), kidney (r=-0.342, p<0.05), and colon cancers (r=-0.293, p=0.05) in males after the effect of smoking was factored in. Socioeconomic status also affects the mortality rate due to cancers (Datta *et al*., 2006; Fagundes *et al*., 2006; Goy *et al*., 2008; Menvielle *et al*., 2008), and HDI has been used to evaluate the socioeconomic status of countries (Landry and Raman, 2007). We further calculated the partial correlation coefficients between the percentage of forest coverage and SMR of cancers after the effect of socioeconomic status (HDI) was factored in. As shown in Tables **2a** and **b**, there were still significant inverse relationships between the percentage of forest coverage and SMR of lung (r=-0.468, p<0.001), breast (r=-0.501, p<0.001), and uterine (r=-0.377, p<0.05) cancers in females, and SMR of prostate (r=-0.351, p<0.05), kidney (r=-0.334, p<0.05), and colon cancers (r=-0.312, p<0.05) in males after the effect of socioeconomic status was factored in. Moreover, there were still significant inverse relationships between the percentage of forest coverage and SMR of lung (r=-0.325, p<0.05), breast (r=-0.308, p<0.05), and uterine(r=-0.293, p=0.05) cancers in females, and SMR of prostate (r=-0.345, p<0.05), kidney (r=-0.327, p<0.05), and colon cancers (r=-0.311, p<0.05) in males after the effects of smoking and socioeconomic status were factored in, suggesting that forest coverage indeed affects the SMR of cancers.

## DISCUSSION

We found previously that a forest bathing trip increased human NK activity, number of NK cells, and intracellular levels of perforin, GRN, and GrA/B in PBL (Li *et al*., 2007). Moreover, we also found that the increased NK activity, number of NK cells, and intracellular anti-cancer proteins induced by a forest bathing trip lasted more than 7 days, even 30 days, after the trip (Li *et al*., 2008a; 2008b). On the other hand, a city tourist visit to an area without forests did

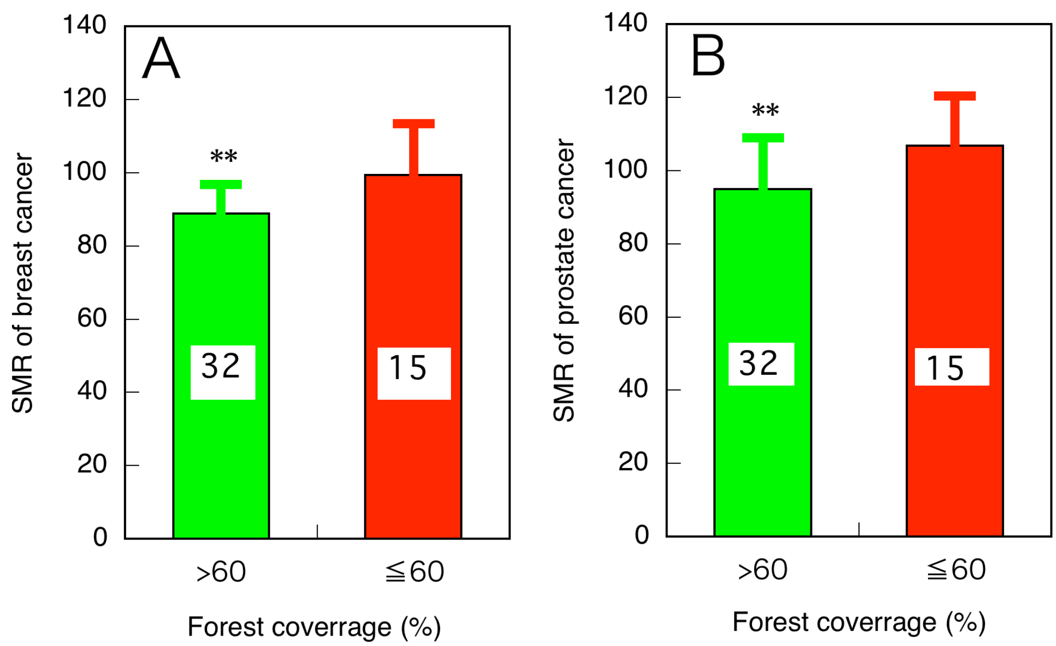


**Fig. (1)**. The SMR of breast cancer in females (**A**) and the SMR of prostate cancer in males (**B**) grouped by percentage of forest coverage of each prefecture in Japan. Data are presented as the mean+SD, the numbers in columns indicate the number of prefectures. **: $p$<0.001, significantly different from the percentage of forest coverage of ≦60%, respectively, by unpaired t-test.

not affect human NK activity (Li *et al*., 2008a). Increased NK activity and intracellular anti-cancer proteins contribute to anti-tumor activity (Krensky and Clayberger, 2005; Huang *et al*., 2007). This suggests that forests may have a preventive effect on cancer development and contribute to a decreased rate of death due to cancers. These findings also encouraged us to propose a hypothesis that people living in areas with higher forest coverage may show lower mortality due to cancers. The present study indicated that there is a significant inverse correlation between forest coverage and SMR of cancers, and that people living in areas with higher forest coverage show a significantly lower SMR of cancers compared with people living in areas with lower forest coverage. This may be important in health promotion and preventive medicine.

Cigarette smoking is an important risk factor for lung (Minami and Tateno, 2003; Bjartveit and Tverdal, 2005; Toh *et al*., 2007) and stomach cancers (Mizoue *et al.*, 2000; Minami and Tateno, 2003) and smoking increases the risk of breast cancer among women (Ambrosone *et al*., 2008). Gong *et al*. (2008) also reported that smoking at the time of diagnosis, independent of key clinical prognostic factors, is associated with an increased risk of prostate cancer death. Both cigarette smoking and socioeconomic status are risk factors for kidney cancer (Mellemgaard *et al*., 1994). Socioeconomic status is a risk factor for uterine cancer by affecting the utilization of efficacious screening tools in the early detection of the disease (Datta *et al*., 2006). Therefore, the effects of smoking and socioeconomic status have also to be factored in. Thus, we further analyzed the partial correlation between forest coverage and SMR of cancers and found significant inverse correlations between forest coverage and SMR of cancers even after the effects of smoking and the socioeconomic status was factored in, suggesting that forests indeed decrease the mortality due to cancers in Japan.

The percentage of forest coverage correlated significantly with the SMR of lung cancer in females, but not in males, whereas, the forest coverage correlated significantly with the SMR of kidney and colon cancers in males, but not in females. Although we can not exactly explain the difference between genders, the higher average smoking rate in males (33.1%) than in females (6.4%) (Ministry of Health, Labour and Welfare of Japan, 2003) may have a larger influence on the SMR of lung cancer than the effect of forest coverage, and the effect of forest coverage on lung cancer was less significant than the effect of smoking. It is well known that smoking increases the risk of lung cancer (Minami and Tateno, 2003; Bjartveit and Tverdal, 2005; Toh *et al*., 2007). However, there was no association between cigarette smoking and the risk of colon cancer (Minami and Tateno, 2003). It is still difficult to explain the difference in the effect of forest coverage on kidney and colon cancers between genders. The percentage of forest coverage correlated significantly with the SMR of breast and uterine cancers in females, and the SMR of prostate cancer in males. Although we can not exactly explain the mechanism, sex hormones may partially contribute to this difference.

The percentage of forest coverage had no effect on the SMR of stomach cancer in either males or females. It is well known that certain bacteria increase the risk of stomach cancer (IARC, 1994). In areas where gastric cancer is highly prevalent, such as Japan, Korea, and China, the great majority of gastric cancers are *Helicobacter pylori*-related. In Japan, the cumulative gastric cancer incidence rate of 0–84-year-olds was estimated to be 21.2% for infected males and 8.0% for infected females, under the conditions that half of the population is infected and infected people have a five-times higher risk of gastric cancer than uninfected people (Hamajima *et al*., 2004). These findings suggest that *H. pylori* infection (IARC, 1994) and dietary habits (Tsugane, 2004) have more effect on stomach cancer than the effect of forest coverage, and the effect of forest coverage on stomach cancer was less significant than the effect of other factors such as *H. pylori* infection and dietary habits.

There are several limitations in the present study. One is the use of information on smoking in 2003, whereas the data of SMR of cancers refer to 1998-99. Unfortunately, we could not obtain the data of SMR of cancers and the smoking rates for the same year; therefore, the use of 2003-related information on smoking as an adjusting factor for the correlations currently assessed should be an approximate indication of the smoking rate. However, the smoking rate should not change much during 1998-2003 in Japan. Many factors could influence SMR of cancers, and we only calculated the confounding effects of smoking and socioeconomic status in the present study. Other confounding factors should also be considered; therefore, further studies are necessary to assess more specific information.

In summary, the present findings suggest that forests may partially contribute to decreased SMR of some cancers in Japan.

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