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# Trends in mortality from major causes and lifestyle factors by per capita prefectural income: Ecological panel data analysis from 1995 to 2016 in Japan

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ABSTRACT

In Japan, trends in mortality and lifestyle have not been fully investigated according to subnational socioeconomic factors. Forty-seven prefectures (subnational units) were divided into quartiles by annual per capita prefectural income. Age-standardized mortality from all causes, cancer, heart disease, and stroke was averaged by quartile in 1995, 2000, 2005, 2010, and 2015. Data from the National Health and Nutrition Survey were obtained for periods 1 (1995–1997), 2 (1999–2001), 3 (2003–2005), 4 (2007–2009), 5 (2012), and 6 (2016). Body mass index (BMI), the intake of vegetables and salt, the number of steps, and the prevalence of current smoking and drinking for the 40–69-year age range were standardized by 10-year age groups in the 2010 Japanese population and were averaged by quartile. Differences in mortality and lifestyle by year and period, and quartile were tested using a two-way analysis of variance. Mortality decreased in both sexes and mortality in men from all causes, cancer, and stroke differed by quartile, with mortality highest in the first (lowest) quartile. BMI in men and smoking prevalence in women increased, whereas remaining lifestyle factors except for the prevalence of drinking decreased in women. BMI and the number of steps in both sexes and current smoking prevalence in women differed by quartile, with lower quartiles showing a higher BMI and fewer step counts. In conclusion, favorable trends and significant differences in mortality from all causes, cancer, and stroke in men and BMI in women were observed by per capita prefectural income level.

## 1. Introduction

The Japanese archipelago, with its four main islands from the northeast to the southwest, is divided into 47 prefectures (subnational units). Because prefectures exhibit diversity in nature, climate, and culture, regional differences in health-related factors have been investigated by prefecture. The association of stroke mortality—which has historically been higher in northeastern Japan—with salt intake and alcohol consumption was studied in the 1980 s (Kono et al., 1983; Ueshima et al., 1986). Hayashi et al. (Hayashi et al., 2009) examined the relationship from 2001 to 2005 of dietary intake and health behavior with total and disease-specific mortality in an ecological analysis by prefecture using datasets from Japan's National Health and Nutrition Survey. The authors found positive correlations between body mass index (BMI) and mortality from myocardial infarction and cerebral hemorrhage, and between salt intake and mortality from cerebral

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hemorrhage in both sexes. Li and Hashimoto (Li and Hashimoto, 2019) performed a panel data analysis with a repeated cross-sectional panel design from 2012 to 2015 to regress prefecture-level disease-specific mortality on dietary consumption. The authors revealed that ischemic heart disease mortality was related to the average household expenditure on processed foods.

Extended life expectancy and the decline in the number of newborns have ushered in a super-aged society in Japan, and the urban population is increasingly concentrated in prefectures such as Tokyo and Osaka on the central main island. Thus, distinct geographical variation such as that from the northeast to the southwest is less likely to be observed at present. Disparities by prefecture in life expectancy have been studied, with socioeconomic factors such as household employment type and the proportion of health-insured persons identified as relevant factors (Gao and Kakehashi, 2006; Tanabe and Suzuki, 2015). Investigating factors related to disability-free life expectancy at 65 years of age across prefectures in 2010, Minagawa and Saito (Minagawa and Saito, 2018) observed that income per capita, the proportion of older workers, and welfare expenditures were positively related to life expectancy whereas unemployment and long-term care insurance expenditures per capita were inversely related. These studies were cross-sectional analyses of existing panel data. Recently, Ikeda et al. (Ikeda et al., 2022) assessed socioeconomic inequalities in BMI across prefectures using a concentration index based on population density from 1975 to 2018. The authors observed that for most of the study period, mean BMI was highest in the southernmost prefecture followed by the northeastern prefectures. However, few studies have longitudinally investigated the associations of socioeconomic factors with mortality and lifestyle using Japanese panel data. Such investigations could provide reliable longitudinal evidence to guide public health policy.

This study aimed to examine the trends in mortality and lifestyle in Japanese prefectures according to per capita prefectural income (PCPI).

## 2. Materials and Methods

### 2.1. Mortality

Data on age-standardized mortality from all causes, malignant neoplasms (cancer), heart disease, and cerebrovascular disease (i.e., stroke) by prefecture and sex were obtained for 1995, 2000, 2005, 2010, and 2015 from the Specified Report of Vital Statistics (Ministry of Health, 2022). A model population of Japan in 1985 was used as the standard population for age standardization. International Classification of Diseases (10th revision) codes were C00-C97 for cancer, I01-02.0, I05-I09, I20-I25, I27, and I30-I51 for heart disease, and I60-I69 for stroke. Deaths caused by the 1995 Great Hanshin–Awaji Earthquake in Hyogo Prefecture were excluded.

### 2.2. Lifestyle

Lifestyle data were obtained from the National Health and Nutrition Survey (formerly the National Nutrition Survey). Details of the survey method have been described elsewhere (Ikeda et al., 2015). In this study, data for 1995—when individual dietary intake data were first calculated and reported (Katanoda and Matsumura, 2002)—and annual data for subsequent years were categorized as follows: Period 1 (1995–1997), period 2 (1999–2001), period 3 (2003–2005), period 4 (2007–2009), period 5 (2012), and period 6 (2016). A 3-year average was used for periods 1 to 4. Data for the single years 2012 and 2016— when expanded surveys were conducted—were used for periods 5 and 6, respectively. Data for Kumamoto Prefecture were missing for 2016, the year the survey was canceled because of the earthquake. The numbers of participants in the survey were 17,445 for period 1; 16,077 for period 2; 12,352 for period 3; 11,715 for period 4, 13,909 for period 5; and 11,611 for period 6.

Lifestyle, BMI, the intake of vegetables and salt, the number of steps, and the prevalence of current smoking and current drinking were selected. BMI was calculated as weight (in kg) divided by the square of height (in m). For comparability of food group classification, data from periods 2 to 6 were used for the intake of vegetables and salt. For comparability of questions on drinking habits, data from periods 3 to 6 were used for the prevalence of current drinking.

### 2.3. Per capita prefectural income

PCPI is the sum of per person employee compensation, property income, and business income in a prefecture and was obtained from the website of the Economic and Social Research Institute of Cabinet Office, Government of Japan (Economic and Social Research Institute of Cabinet Office, 2022). Forty-seven prefectures were divided into quartiles for each year as follows: 12 prefectures each in the first, second, and third quartiles and 11 prefectures in the fourth quartile. Because PCPI is periodically re-calculated using a later standard, the latest values for selected years are shown in Supplementary Table S1.

### 2.4. Statistical analysis

Mortality and lifestyle data were averaged by quartile. To avoid including prefectures without participants classified by age group, lifestyle data for only the 40–69-year age range were used by standardizing 2010 Japanese population data by 10-year age groups. Differences in mortality by year and lifestyle by period and differences within quartiles were tested using a two-way analysis of variance. All analyses were conducted using IBM SPSS Statistics version 25 (IBM, Tokyo, Japan). P values $< 0.05$ were considered statistically significant. To describe the magnitude of the inequality in PCPI, the relative inequality index (RII) (Mackenbach and Kunst, 1997) was calculated using Public Health England's Inequalities Calculation Tool (https://www.gov.uk/guidance/phe-data-and-analysis-tools#health-inequalities).

### 2.5. Ethical considerations

This study used vital statistics and PCPI data, which are publicly available and anonymized data from the National Health and Nutrition Survey, and they were obtained with the legal approval of the Ministry of Health, Labour and Welfare. Thus, the study was exempted from review by the institutional review board.

## 3. Results

Mortality from all causes, cancer, heart disease, and stroke was statistically different by year for both men and women ($P < 0.001$) and decreased between 1995 and 2015 (Fig. 1, Supplementary Tables S2–1 and 2–2). Mortality from all causes ($P < 0.001$), cancer ($P = 0.005$), and stroke ($P < 0.001$) in men was statistically different by quartile; except for stroke mortality in 1995, mortality was highest in the first (lowest) quartile. In women, mortality from all causes, cancer, heart disease, and stroke was not statistically different by quartile.

In men, BMI, vegetable and salt intake, the number of steps, and the prevalence of current smoking and drinking were statistically different by period ($P < 0.001$); BMI increased and the intake of vegetables and salt, the number of steps, and the prevalence of current smoking and drinking decreased through the periods (Fig. 2 and Supplementary Table S3–1). BMI and the number of steps were statistically different by quartile in men ($P < 0.001$); BMI was higher and the number of steps was lower in the lower quartiles than in the higher quartiles.

In women, BMI ($P < 0.001$), vegetable ($P < 0.001$) and salt ($P < 0.001$) intake, the number of steps ($P < 0.001$), and the prevalence of current smoking ($P = 0.03$) were statistically different by period; BMI, the intake of vegetables and salt, and the number of steps decreased whereas the prevalence of current smoking and current drinking increased through the periods (Fig. 2 and Supplementary Table S3–2).

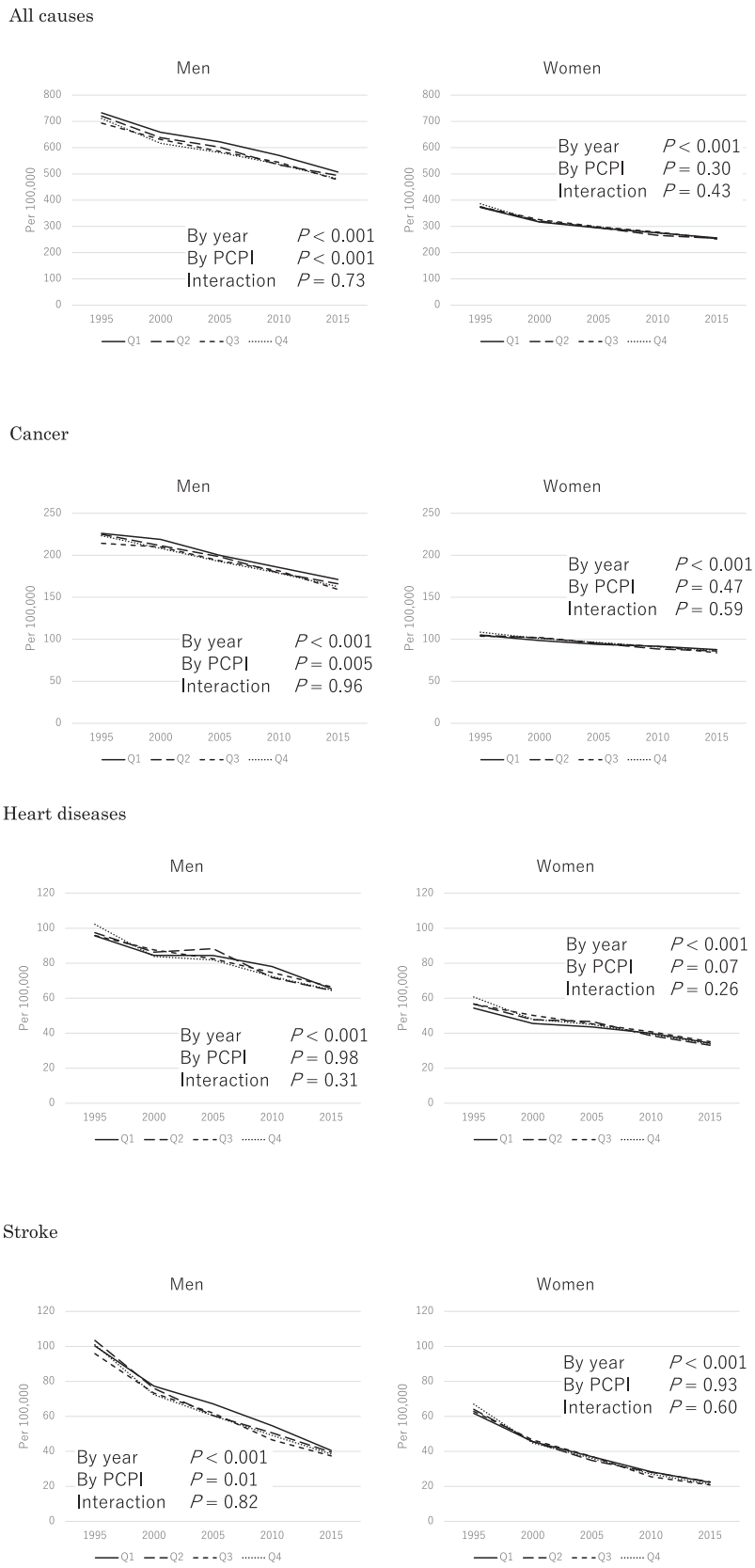


**Fig. 1.** Mortality from all causes, cancer, heart disease, and stroke by quartile of per capita prefectural income (PCPI) in 1995, 2000, 2005, 2010, and 2015 in Japan.

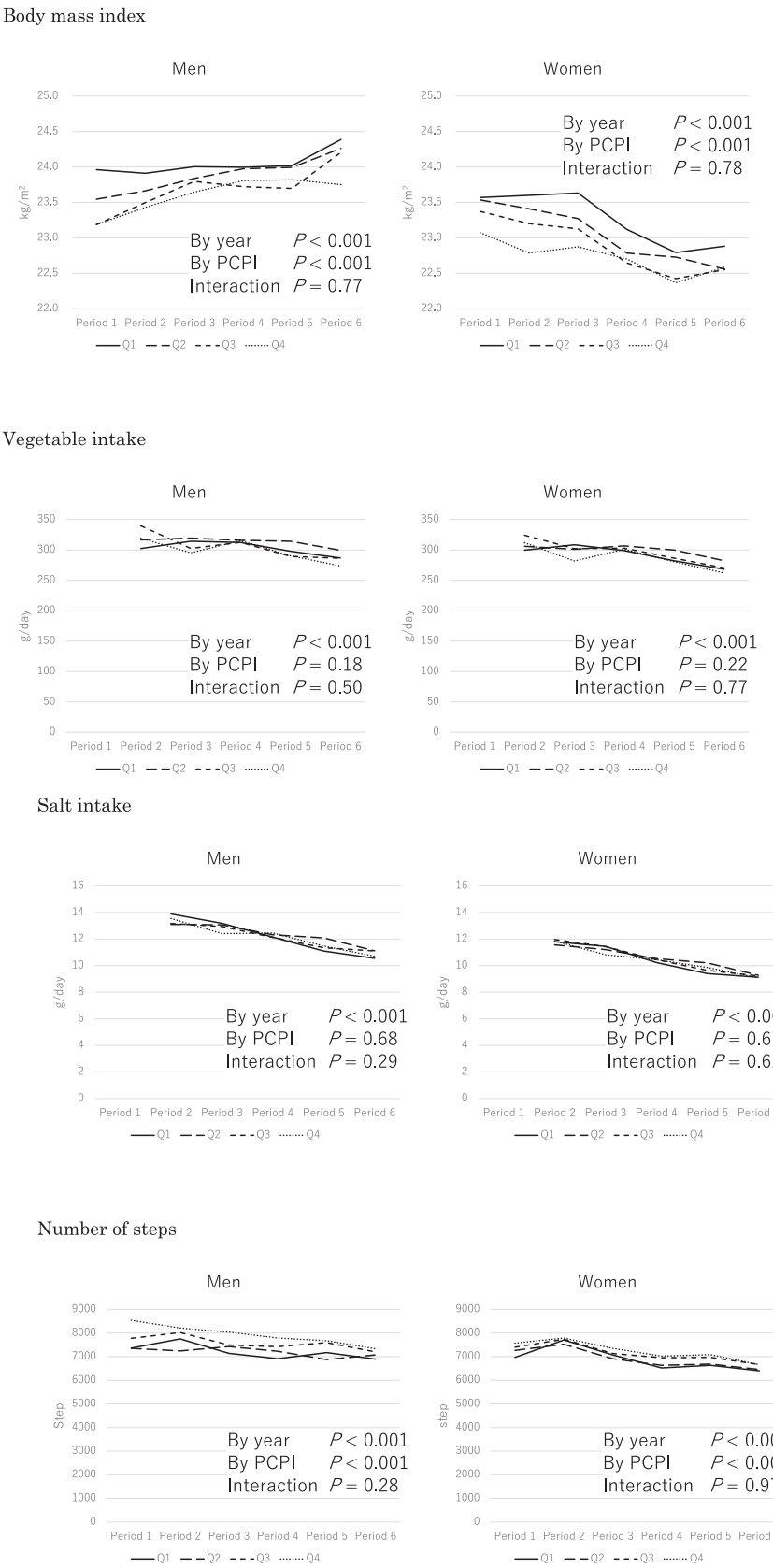


**Fig. 2.** Lifestyle factors by quartile of per capita prefectural income (PCPI) from periods 1 to 6 in Japan.

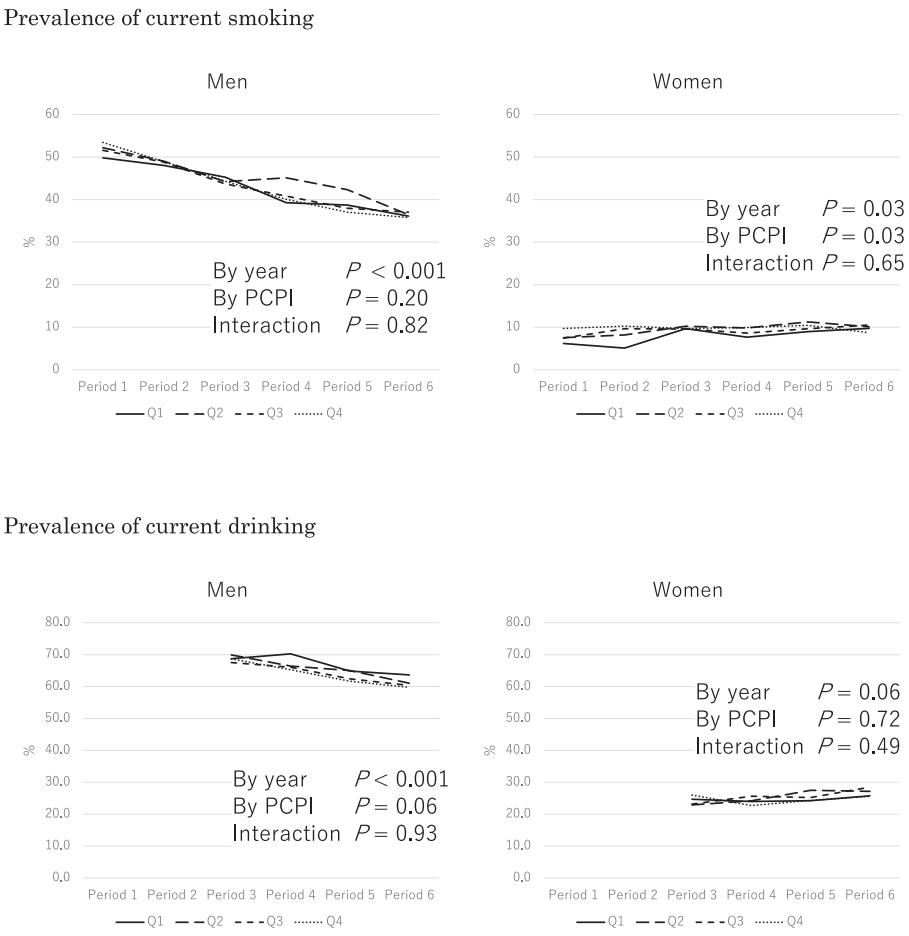


**Fig. 2.** (*continued*).

BMI (P < 0.001), the number of steps (P < 0.001) and the prevalence of current smoking (P = 0.03) were statistically different by quartile in women; BMI was higher and the number of steps and the prevalence of current smoking were lower in the lower quartiles than in the higher quartiles.

## 4. Discussion

This study used over 20 years of panel data of vital statistics and data from the National Health and Nutrition Survey. Trends in mortality from all causes, cancer, and stroke in men and the trend in BMI in women were favorable and were significantly different by PCPI. This study was made possible through the continual yearly collection of vital statistics and National Health and Nutrition data in all Japanese prefectures. To the best of our knowledge, this is the first study to examine mortality and lifestyle trends in Japanese prefectures by a socioeconomic factor, namely PCPI.

Mortality from all causes, cancer, heart disease, and stroke significantly decreased from 1995 to 2015 in men and women, but statistically significant differences by PCPI were observed for only all causes, cancer, and stroke in men. In men, point estimates of the RII were over 1.00 for mortality from all causes, cancer, and stroke in 1995 and 2015. However, estimates were below 1.00 in 1995 and nearly or over 1.00 in 2015 for mortality from heart disease in men and all causes, cancer, heart disease, and stroke in women. Given that the RII increased from 1995 to 2015 in both men and women, the difference observed between men and women may have been attributable to a delay in the transition of the RII from below 1.00 to over 1.00 in women. Examining the relationships between life expectancy and various factors in an ecological study by prefecture in 2000, Gao and Kakehashi (Gao and Kakehashi, 2006) reported that sex-specific life expectancy was significantly associated with sex-specific average income in men only. If the gender gap in labor force participation and the average wage narrows in the future (OECD, 2012), statistically significant differences in mortality by PCPI could be detected in women.

Such a distinct gender difference in mortality by PCPI was not observed with lifestyle; BMI was higher and the number of steps was lower in the lower quartiles than in the higher quartiles in both men and women although the trend in BMI was opposite between men and women. Such a difference in a trend of BMI has been reported by Fallah-Fini et al. (Fallah-Fini et al., 2021); the present study adds findings by PCPI. The prevalence of current smoking was lower in the lower quartiles than in the higher quartiles in women; however, the prevalence in the highest quartile was lowest in period 6. The order in the prevalence of current smoking by PCPI may be reversed in the future so that prevalence is higher in the lower quartiles than in the higher quartiles.

The discrepancy in the results by gender between mortality and lifestyles may be attributable to the selection of socioeconomic indicators. As described in the Materials and Methods, PCPI is the sum of per person employee compensation, property income, and business income in a prefecture. Between 1995 and 2010, the labor force participation rate declined to 70%–80% in men and remained nearly stable at approximately 50% in women (Kawata and Naganuma, 2023). Such differences may be related to mortality results for which age-specific mortality rates for all ages were standardized. However, given that lifestyle data were derived from the economically active ages of 40 to 69 years, gender differences may have been attenuated for lifestyles.

Because mortality in men from all causes, cancer, and stroke decreased and was significantly different by PCPI, we assumed that lifestyle factors had changed favorably and were significantly different

by PCPI. A decreasing trend and a statistically marginal difference by PCPI were observed for only the prevalence of current drinking in men. In contrast, a favorable trend and a significant difference by PCPI were observed for BMI in women. Reasons for such discrepancies may exist. First, because this is an ecological study using panel data, results may not necessarily reflect epidemiological causality at the individual level. Second, mortality trends may be influenced by many types of non-lifestyle factors such as the utilization of medical and welfare services. Third, other socioeconomic factors that are superior to PCPI may show consistent associations with mortality and lifestyle. However, a modification of the analytical model may not be sufficient to generate evidence for improvements in mortality and lifestyle. One of the options for producing evidence to guide public health policy may be to empirically construct a causal loop diagram of system dynamics at the population level to elucidate complex systems characterized by relationships, interactions, and feedback among major factors (Homer and Hirsch, 2006; Atkinson et al., 2015).

Japan and South Korea are reported to share two contradictory characteristics: a high life expectancy and a low proportion of people with good self-rated health (Kim and Khang, 2019). Using individual-level data, Khang et al. (Khang et al., 2004) reported that the relative level of socioeconomic mortality inequality remained unchanged, whereas inequalities in self-rated health increased from 1990 to 2000 in both sexes. In 2016, the subnational sociodemographic indices for 250 regions in South Korea were correlated with years of life lost, years lived with disability, and disability-adjusted life years (Go et al., 2020). To reduce regional differences by socioeconomic status, collaborative studies between South Korea and Japan to explore policy measures for public health are encouraged.

## 5. Limitations

This study had several limitations. First, because PCPI data by prefecture was for both men and women, sex-specific characteristics may not have been fully elucidated. However, PCPI appears to be one of the best socioeconomic indicators for examining differences in mortality and lifestyle by quartile. Second, to avoid including prefectures that lacked data by age group, lifestyle data for only the 40–69-year age range were used. Therefore, because of the small number of participants, estimates appear unreliable for some lifestyle factors such as the current prevalence of smoking in women. Third, the number of lifestyle factors appears small. We aimed to include only major lifestyle factors such as diet, physical activity, and smoking and drinking status to avoid examining too many lifestyle factors that could lead to reporting statistically significant results by chance.

## 6. Conclusion

In an examination of mortality and lifestyle by PCPI using panel data, favorable trends and significant differences by PCPI were observed in mortality from all causes, cancer, and stroke in men and in BMI in women. Continuing to observe mortality and lifestyle trends by PCPI or other socioeconomic factors is important for detecting implications to public health policy. Moreover, empirically constructing a causal loop diagram of system dynamics can elucidate complex systems at the population level.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The authors do not have permission to share data.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2023.102348.

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