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New indicators for the evaluation of community policies based on period and cohort effects in cerebrovascular disease mortality rates

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Abstract

Introduction

Countermeasures against cerebrovascular diseases (CVD) are one of the important health policies in Japan. This study proposes new indicators that are based on period and cohort effects in CVD mortality rates. The main aim of the study is to contribute to community diagnosis with the existing policies.

Methods

CVD mortality rates for all prefectures in Japan were analyzed according to age, time period, and cohort effects, using the Bayesian Poisson age-period-cohort model. Several indicators were extracted based on the principal component analysis of the estimates of the effects.

Results

Two indicators named *the change-in-magnitude* and *the time-of-decrease were* extracted from estimates of the period effects, and three indicators named *the change-in-magnitude*, *the pattern-in-recent cohorts* and *the first-cohort-of-improvement* were extracted from estimates of the cohort effects. These were considered to be related to the countermeasures against CVD.

Conclusion

Under the assumption that the new indicators reflect the result of past policies, the new indicators allow us to evaluate the validity of past policies, and to suggest the necessity for improvement in the conventional policies.

Keywords

- Cerebrovascular diseases
- Community diagnosis
- Countermeasures
- Prevention strategies
- Bayesian Poisson age-period-cohort model

Introduction

Cerebrovascular disease (CVD) was the most common disease in Japan during the second half of the 20th century. Decreasing trends in CVD mortality rate were observed since the 1970s due to epidemiological research and increased measures to combat CVD near the end of the 1950s. However, CVD remains to be one of the major three causes of death in Japanese, and the crude CVD mortality rate in Japan is twice as high as that of Europe and the US.[1] CVD has a large impact on individual patients as well as on society, since in many cases, it leaves patients with lasting after-effects. CVD has wide-ranging effects that include death during the prime of life, alterations in healthy life-span, and the quality of life. Therefore, in the year 2000, CVD was designated (by the Ministry of Health, Labour and Welfare) as one of the most important diseases needing effective prevention strategies in the *Health Japan 21* Japanese health policy.[2]

Consideration of existing policies is an important feature in the policy-making cycle, and many cycles begin with evaluation.[3] This is also the case for CVD, where the indicators used in evaluating past CVD prevention strategies are necessary during the current policy-making procedures. Evaluation of past strategies is important for making and implementing community policies that are based on evidence-based decision-making practice. Generally, for regional health policy-making, decision-makers in charge of health preservation for each prefecture use the age-adjusted mortality rates as an indicator for community diagnosis for analysing local problems and characteristics. In many cases, major health problems are detected by comparing the age-adjusted mortality rates for each region with those for the entire country. However, information from the age-adjusted mortality rates provides trends in the mortality rate in a particular region, or recent mortality rate ranking in the entire country. This information is not specific enough for evaluating past strategies or in making effective future strategies.

In this study, new evaluation indicators are proposed to contribute towards evaluating the past CVD prevention strategies and future policy-making for local communities. It was found in our previous studies[4] that the major factors for determining changes in the overall CVD mortality rate in Japan were: age-related factors, period-related factors (from different national policies and environments over each period), and cohort-related factors (arising from different growth environments for each cohort). Among these three factors, only period and cohort factors are partially based on countermeasures against CVD. Therefore, new indicators were extracted from variations in the period and cohort effects reflecting the impact of these factors.

Methods

• Data

The data used for the study was derived from the Vital statistics special report.5 We used the number of deaths from CVD and population data from each prefecture (except Okinawa) in Japan over 5 year intervals from 1960 to 2000. Age groups were divided into 5 year increments beginning with 20 years old. This resulted in a total of 92 datasets in males and females for all prefectures being analysed.

• Estimation of the Effects

Age, period, and cohort effects were estimated using Nakamura's Bayesian Poisson age-period-cohort model (BAPC model) [6-8] as follows:

$$y_{ij} \sim \text{Poisson}(\lambda_{ij}),\ \log\lambda_{ij} = \log P_{ij} + \beta^G + \beta_i^A + \beta_j^P + \beta_k^C$$

where y_{ij} is the number of observed deaths in the ith age group of jth period and assumed to have a Poisson distribution with mean λ_{ij} and offset P_{ij}, the size of the population at risk. The parameters β^G, β_i^A, β_j^P and β_k^C are the grand mean, age, period, and cohort effect, respectively.

One problem with APC analysis is that the linear components of the age, period, and cohort effects cannot be uniquely separated.[9] Therefore, the BAPC model was used to overcome this problem and to separate the three effects including the linear components. In this model, the effects were assumed to be changing gradually. The smoothness parameters were evaluated using the Akaike Bayesian Information Criterion (ABIC). Hence, the result interpretation was possible as they included linear and non-linear components of the effects. A program developed by one of the authors on MATLAB version 7.6 was used for the BAPC analysis.

The age effects change according to the physiological functions and a particular stage in the life cycle. The period effects change according to the social environment that affects the entire population in the same manner. The cohort effects show the differences in generation characteristics due to differences in historical backgrounds that are specific to each cohort during their aging. In this study, we used the period effects and the cohort effects which were affected partially by some countermeasures.

• Construction of the New Indicators

We conducted the principal component analysis of the original and standardized estimates of period and cohort effects. Major components that were considered to be related to the evaluation of the CVD prevention strategies were extracted. The 46 prefectures were classified by gender, based on the component scores corresponding to the extracted components. R version 2.2.0 was used for the principal component analysis and graphical displays.[10]

Results

We analysed a total of 92 datasets of CVD mortality rates in males and females for all prefectures using the BAPC model to estimate age, period, and cohort effects. The results showed similar trends in our previous studies4, with the effects separated from the CVD mortality rate throughout Japan. Specifically, the age effects increased with aging; the period effects decreased after 1965-1970, and increased temporarily in 1995 due to the change in the cause of death classifications based on ICD10 and in the coding of death certificates; and the cohort effects were high for those born in the second half of the 1800s, and low for those born from the 1920s to the 1970s. However, the period effects and the cohort effects showed some different variations, among prefectures.

The principal component analysis was used to extract the major components of the variations in period and cohort effects. Two and three components with major contribution were respectively chosen from the period and the cohort effects, and were considered to relate to countermeasures against CVD.

• Two indicators based on period effects

Based on the principal component analysis of the estimates of period effects obtained using the BAPC model, the two indicators PCIM and PTOD were proposed, The PCIM is considered as *the change-in-magnitude* or *the amplitude indicator*. It corresponds to the first principal component (86% of total variance) of the estimates, indicating whether the change over the entire period is large or small. The PTOD is considered as *the time-of-decrease* or *the phase indicator*. It corresponds to the second principal component (22% of total variance) of the standardized estimates, indicating whether the decrease in the period effect occurred early or late.

Figure 1a and 1b show the characteristics of PCIM and PTOD, respectively. In order to emphasize the characteristics, these were described with trends of period effects from 15 prefectures with the upper component score (dashed lines) and those from 15 prefectures with the lower component score (solid lines).

Figure 2 plots the correlation between PCIM and PTOD with a correlation coefficient of 0.342, using the respective principal component. As seen in this figure, PCIM tended to be *large* in males (plotted by bullet) and *small* in females (plotted by circle) in many prefectures. There were not many prefectures with both *large* PCIM and *late* PTOD (see the 4th quadrant of Figure 2).

• Three indicators based on cohort effects

The three indicators, CCIM, CPIR and CFOI were proposed, based on the principal component analysis of the estimates of cohort effects. The CCIM is considered as *the change-in-magnitude* or *the amplitude indicator*. It corresponds to the first principal component (90% of total variance) of the estimates, and it indicates whether the change over the entire birth-cohorts is large or small. The CPIR is considered as *the pattern-in-recent-cohorts indicator*. It corresponds to the first principal component (39% of total variance) of the standardized estimates, and it indicates whether there was a decrease or increase over the recent birth-cohorts. The CFOI is considered as *the first cohort-of-improvement* or *the phase indicator*. It corresponds to the second principal component (27% of total variance) of the standardized estimates, and it indicates whether the first birth-cohort improvement occurred early or late.

Figures 3a, 3b, and 3c show the characteristics of the CCIM, CPIR and CFOI, respectively. In order to emphasize the characteristics, these were described with trends of cohort effects from 15 prefectures with the upper component score (dashed lines) and those from 15 prefectures with the lower component score (solid lines).

Figures 4a and 4b plot the correlation of the CCIM vs. CPIR, and CCIM vs. CFOI with respective correlation coefficients of 0.383 and 0.732, using the principal component score. This figure shows that the CCIM was *small* in males and *large* in females in many prefectures. It also shows an *increase* in the CPIR in males. As for the CFOI, it was *late* in males and *early* in females in many prefectures. There were few prefectures with the CCIM *large* and CFOI *late* (see the 4th quadrant of Figure 4b).

Discussion

This study proposes new indicators for evaluating regional strategies based on the principal component analysis of trends in estimated period and cohort effects in CVD mortality rates. Available information for CVD prevention strategies evaluation through these indicators was examined.

• Information from the period-effect-based indicator

The period factors affecting CVD in Japan include advances in medical technologies and the treatment environment such as the implementation of the 1st, 2nd and 3rd round of prevention strategies from the 1960s, targeting high blood pressure.[11] Other factors include changes in the living environment that have resulted from high economic growth since the 1960s, such as the use of refrigerators rather than salt for the preservation of food, the popularization of heating devices, and Westernization of the diet. The two indicators, PCIM and PTOD, are explained herein.

PCIM (*change-in-magnitude in period effects*) shows the extent to which CVD prevention strategies and social environment changes over the past 40 years in each prefecture have succeeded in preventing resident deaths from CVD. Although similar strategies were used, different promotion methods were adopted in each area, and the differences can be evaluated using this indicator. Specifically in males, the indicator was *large* in many prefectures, which might be due to the fact that the countermeasures and the living environment changes worked better for the males than for the females.

PTOD (*time-of-decrease in period effects*) indicates the time at which CVD prevention strategies and living environment changes in each prefecture, i.e. their effects were first manifested. In the prefectures where this indicator is assigned *early*, perhaps their countermeasures were implemented early or promoted strong impact.

• Information from the cohort-effects-based indicator

The cohort factor is concerned with the difference in generation characteristics, which arise from the period factors (mentioned previously) at their different ages. For example, the lifestyle of generations born before and after the implementation of CVD prevention strategies should be different. In addition to being affected by the period factor, generation lifestyle is also influenced by habits and traditions that were passed on from previous generations. The three indicators, CCIM, CFOI, and CPIR, are explained herein.

CCIM (*change-in-magnitude in cohort effects*) indicates the level of characteristics regarding deaths from CVD, i.e. the extent to which a particular CVD-prevention lifestyle has been adopted. This indicator is larger for females than for males, which suggests that many prefectures have implemented strategies that made it easy for females to continue a CVD prevention lifestyle.

CFOI (*first-cohort-of-improvement*) indicates first generation lifestyle improvements. Effective promotion of prevention strategies may have resulted in some strategies having an *early* indicator. This indicator was early for females in most prefectures, which suggests that many prefectures have implemented strategies that made it easy for females to adopt a CVD prevention lifestyle.

CPIR (*pattern-in-recent-cohorts*) indicates particular tendencies in CVD characteristics in recent generations, i.e. prefectures with an increase in CPIR may have some newer generations gradually digressing from preventive CVD lifestyle. Therefore, for those with the increase in this indicator, it is necessary to strengthen CVD prevention strategies that target specific generations.

• Distinction in the new indicators

One of the advantages of the new indicators is that the evaluation can be done according to the rate of change in the mortality rate, because they are based on the period and cohort effects over the logarithm of the mortality rate. Second, they compare each area from the viewpoint of validity of the past strategies. For this reason, they also aid in the decision making regarding the necessity for improving the conventional strategy in the future.

Interestingly enough, it is possible to use the period-effect-based indicators in evaluating the population approach,[12] since they evaluate the results of the prevention strategies over the entire population. On the other hand, since the cohort-effect-based indicators evaluate the risks of CVD for each generation, it is possible to use them in evaluating the high-risk approach12 for specific generations. In order to be able to shape future strategies, it will be necessary to concretely examine the meaning of indicators evaluation in past strategies.

Conclusion

This study proposes two period-effect-based indicators and three cohort-effect-based indicators for the evaluation of regional CVD prevention strategies. Assuming that new indicators reflect the result of past policies, it is possible to use them for the evaluation of policies, as well as to suggest the need for change in the policies.

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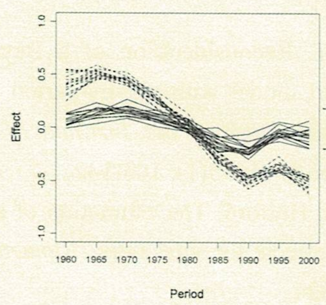
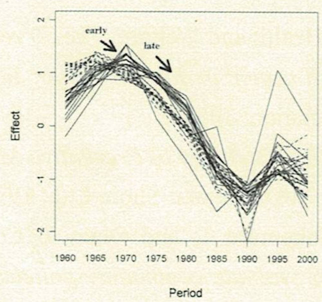
Figures

■ Figure 1: The characteristics of two period-effect-based indicators



(a) PCIM

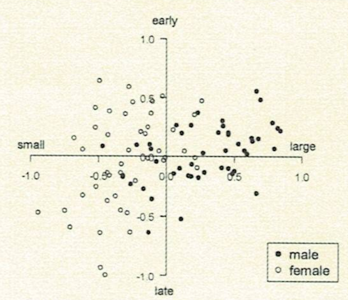


(b) PTOD

These show the characteristics of PCIM and PTOD using:

- The trends of period effects from 15 prefectures with upper component score (dashed lines)
- The trends of period effects from 15 prefectures with lower component score (solid lines)

■ Figure 2: Correlation between the period-effect-based indicators

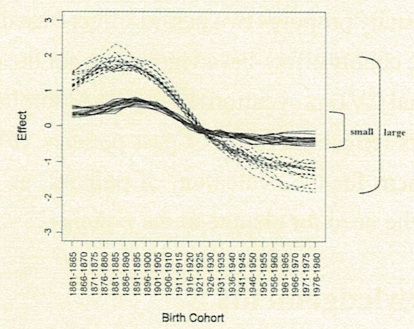


PCIM vs. PTOD

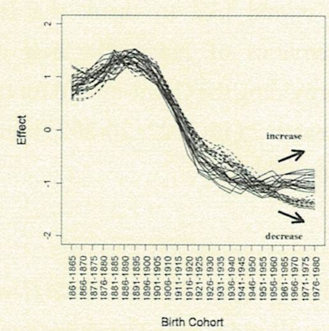
92 principal component scores by gender and prefecture on the two indicators with:

- x-axis is PCIM (*the change-in-magnitude or amplitude indicator*)
- y-axis is PTOD (*the time-of-decrease or phase indicator*).

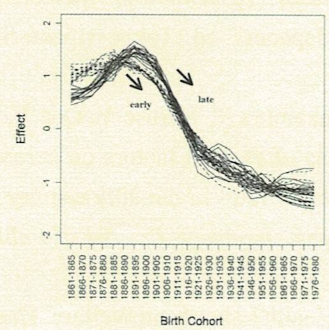
■ Figure 3: The characteristics of three cohort-effect-based indicators



(a) CCIM



(b) CPIR



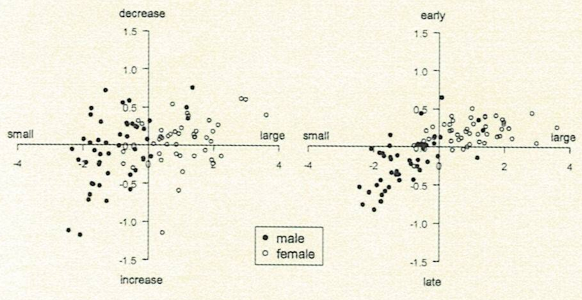
(c) CFOI

These show the characteristics of CCIM, CPIR and CFOI using:

- The trends of cohort effects from 15 prefectures with upper component score (dashed lines)

• The trends of cohort effects from 15 prefectures with lower component score (solid lines)

■ Figure 4: Correlations among the cohort-effect-based indicators



(a) CCIM vs. CPIR (b) CCIM vs. CFOI

92 principal component scores by gender and prefecture on the two indicators with:

• x-axis is CCIM (*the change-in-magnitude or amplitude indicator*) in Fig 4a and Fig 4b.
• y-axis is CPIR (*the pattern-in-recent-cohorts indicator*) in Fig 4a and CFOI (*the first-cohort-of-improvement or phase indicator*) in Fig 4b.