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Time Trend and Age-Period-Cohort Effects on Acute Myocardial Infarction Mortality in Korean Adults from 1988 to 2007

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We examined time trend and age-period-cohort effects on acute myocardial infarction (AMI) mortality in Korean adults from 1988 to 2007. Annual AMI mortality data and population statistics from 1988 to 2007 were obtained from the STATISTICS KOREA website. Age adjusted mortality for four 5-yr calendar periods (1988-1992 to 2003-2007) was calculated by direct standardization using the Year 2000 WHO world standard population. A log-linear Poisson regression model was used to estimate age, period, and cohort effects on AMI mortality. In both genders, age-adjusted AMI mortality increased from period one (1988-1992) to period three (1998-2002) but decreased in period four (2003-2007). An exponential age effect was noted in both genders. The rate ratio of the cohort effect increased up to the 1943 birth cohort and decreased gradually thereafter, and the rate ratio of the period effect increased up to period three (1998-2002) and decreased thereafter. Our results suggest that AMI mortality in Korean adults has decreased since the period 1998-2002 and age, period, and cohort effects have influenced on AMI mortality.

Key Words: Myocardial infarction; Mortality; Trends

INTRODUCTION

Ischemic heart disease, including acute myocardial infarction (AMI), is one of the most common causes of morbidity and mortality in developed countries (1). Korea has experienced marked economic growth over the past 40 yr, with an 80-fold increase in the per capita gross national income from US $250 in 1970 to US $20,000 in 2007 (2). Along with economic growth, Korean lifestyle and dietary patterns have become westernized. Recently, heart disease was the third highest cause of mortality in Korean men and women; the mortality rates were 43.1 and 43.6, respectively, per 100,000 in 2008 (3).

An analysis of time trends is necessary to understand the natural history of a disease and establish public health policies. A nationwide multicenter registry of AMI in Korea, the Korea Acute Myocardial Infarction Registry, was established in November 2005, and studies that have evaluated clinical characteristics and treatment outcomes of AMI patients in Korea have been reported (4, 5). Hong et al. (6) analyzed data from the Korean National Health Insurance Database and reported time trends in the incidence of AMI in Korea from 1997 to 2007. Although these studies showed the recent epidemiology of AMI in Korea, they dealt only with relatively recent data and could not reveal long-term trends in AMI in Korea. Furthermore, no reported study has evaluated the nationwide time trend of AMI mortality in Korea.

Age, period, and birth cohort are important time-related variables in epidemiology, and age-period-cohort (A-P-C) analysis has been used to analyze time trends of disease in populations (7, 8). Age effects are associated with different age groups, period effects affect all ages simultaneously over time, and cohort effects involve changes among groups born in the same year. Age effects reflect biological changes and are important in the development of chronic diseases. Period and cohort effects reflect environmental changes. In particular, cohort effects represent early exposure to environmental factors that have different health risks in different cohorts (9). Thus, in this study, we examined time trend and age-period-cohort effects on AMI mortality in Korean adults from 1988 to 2007.

MATERIALS AND METHODS

The Statistics Korea provides annual data on cause-specific mortality and mid-year population estimates on the Korean Statistical Information Service website at http://www.kosis.kr. These data are presented in five-year age groups (20-24, 25-29, ..., 80 and higher). We used these data to calculate age-specific mortality by gender for 12 five-year age groups (20-24 to 75-79 yr) and four 5-yr calendar periods (1988-1992 to 2003-2007). We excluded the group of people aged 80 yr and older because a wide range of birth years was represented in that group and it was difficult to determine birth cohorts. Using the age and cal-

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endar period classification, 15 overlapping 10-yr birth cohorts were identified and defined according to the central year of a birth cohort (1913, 1918, ..., 1978, 1983).

To evaluate nationwide time trends in AMI mortality in Korean adults, the age-adjusted mortality for each period was calculated by direct standardization using the Year 2000 World Health Organization (WHO) world standard population (10).

Poisson regression analysis was used to estimate age, period, and cohort effects on AMI mortality in Korean adults. This log-linear model uses a logarithmic link function between the outcome (y) variable, which was counts of AMI mortality cases with offset by the count of the denominator population, and the predictor (x) variables: age, period, and cohort. The model was constructed as $y = \mu + \alpha_i \text{Age} + \beta_j \text{Period} + \gamma_k \text{Cohort} + \varepsilon_{ijk}$, where y represents the natural logarithm of counts of AMI mortality cases, μ is the intercept term, α_i is the effect of age i, β_j is the effect of period j, γ_k is the effect of cohort k, and ε_{ijk} is an error term.. A-P-C analysis has an intrinsic problem in that a linear dependency exists among the age, calendar period, and birth cohort variables (C = P-A). However, a modeling approach to overcome this problem using constraints of parameters has been proposed (11, 12). Thus, the present study set age group seven (50-54 yr old), period three (1998-2002) and birth cohorts eight and nine (1948 and 1953) as the constraints of the A-P-C model. The PROC GENMOD procedure in the SAS statistical package (ver. 9.1.3; SAS Institute, Inc., Cary, NC, USA) was used to conduct A-P-C analysis. The results of the A-P-C analysis are expressed as rate ratios of age, period, and cohort effects in graphical form (13).

RESULTS

AMI mortality rates in Korean men were different among age groups during the study period. Those of Korean men aged 20-34 yr decreased steadily during the study period. Those of Korean men aged 35-39 yr increased from period one (1988-1992) to period two (1993-1997), but decreased thereafter. Those of Korean men aged 40-74 yr increased from period one to period three (1998-2002), but decreased in period four (2003-2007). Those of Korean men aged 75-79 yr increased steadily during the study period. Consequently, age-adjusted AMI mortality in Korean men increased from 17.62 per 100,000 in period one to 30.86 in period three, but decreased to 28.50 in period four. AMI mortality rates in Korean women during the study period also differed among age groups. Those of Korean women aged 20-39 yr decreased steadily during the study period. Those of Korean women aged 40-44 yr increased from period one to period two, but decreased thereafter. Those of Korean women aged 45-74 yr increased from period one to period three, but decreased in period four. Those of Korean women aged 75-79 yr increased steadily during the study period. Consequently, age-adjusted AMI mortality in Korean women increased from 7.73 per 100,000 in period one to 13.61 in period three, then decreased to 12.66 in period four (Table 1).

Fig. 1 shows age-specific mortality rates for AMI in Korean men and women with a natural logarithmic scale against birth year during the study period. In both men and women, age-specific mortality rates in younger cohorts decreased during the period; however, those in older cohorts increased consecutively, but mostly decreased in the last time period.

Fig. 2 shows estimates of age, period, and cohort effects on AMI mortality in Korean men and women with 95% confidence intervals (CI) derived from the A-P-C Poisson regression model. An exponential age effect was noted in both genders. The rate ratio of the age effect in men increased exponentially from 0.08 (95% CI, 0.06-0.11) in the 20-24 yr-old group to 11.05 (95% CI, 9.01-13.55) in the 75-79 yr-old group compared with the 50-54 yr-old group (Fig. 2A). The rate ratio of the age effect in women increased exponentially from 0.16 (95% CI, 0.09-0.28) in the 20-24 yr-old group to 33.59 (95% CI, 21.65-52.11) in the 75-79 yr-old group compared with the 50-54 yr-old group (Fig. 2C). The rate ratio of the cohort effect increased up to the 1943 birth cohort

Table 1. Acute myocardial infarction mortality per 100,000 in Korean adults from 1988 to 2007 by gender and age group

Gender	Age (yr)	Calendar period			
		1988-1992	1993-1997	1998-2002	2003-2007
Male	20-24	1.15	0.95	0.53	0.45
	25-29	2.25	1.95	1.57	1.17
	30-34	3.99	3.76	3.18	2.46
	35-39	6.27	7.02	6.48	5.08
	40-44	9.58	11.93	12.29	10.32
	45-49	14.52	18.60	21.01	17.37
	50-54	19.46	28.03	30.80	27.98
	55-59	26.18	37.75	51.16	41.97
	60-64	39.36	54.50	71.60	64.48
	65-69	50.29	81.92	101.81	100.46
	70-74	76.81	114.02	155.15	146.24
	75-79	120.82	157.50	241.42	248.45
	Age-adjusted mortality*	17.62	24.30	30.86	28.50
Female	20-24	0.46	0.35	0.22	0.08
	25-29	0.70	0.69	0.44	0.19
	30-34	0.85	0.77	0.68	0.42
	35-39	1.37	1.13	1.22	0.94
	40-44	1.90	2.49	2.34	1.72
	45-49	3.36	4.06	4.42	3.44
	50-54	4.99	6.82	7.21	5.62
	55-59	8.60	10.38	14.29	9.58
	60-64	15.45	20.34	27.00	21.91
	65-69	26.00	38.64	49.81	44.84
	70-74	48.22	66.39	94.54	89.97
	75-79	84.53	102.09	162.89	182.61
	Age-adjusted mortality*	7.73	10.00	13.61	12.66

*Age-adjusted mortality was calculated by direct standardization using the Year 2000 WHO world standard population.

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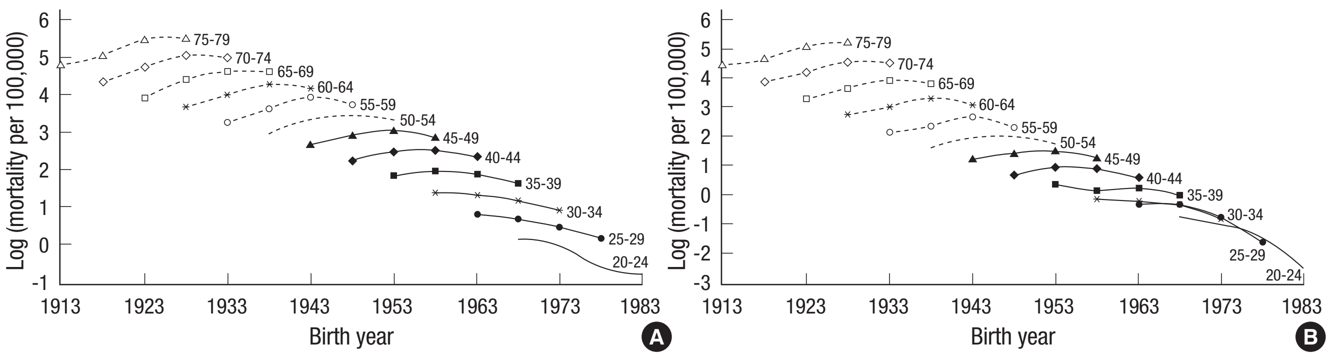

Fig. 1. Age-specific mortality rates for acute myocardial infarction in Korean men (**A**) and women (**B**) on a natural logarithmic scale against birth year from 1988 to 2007.

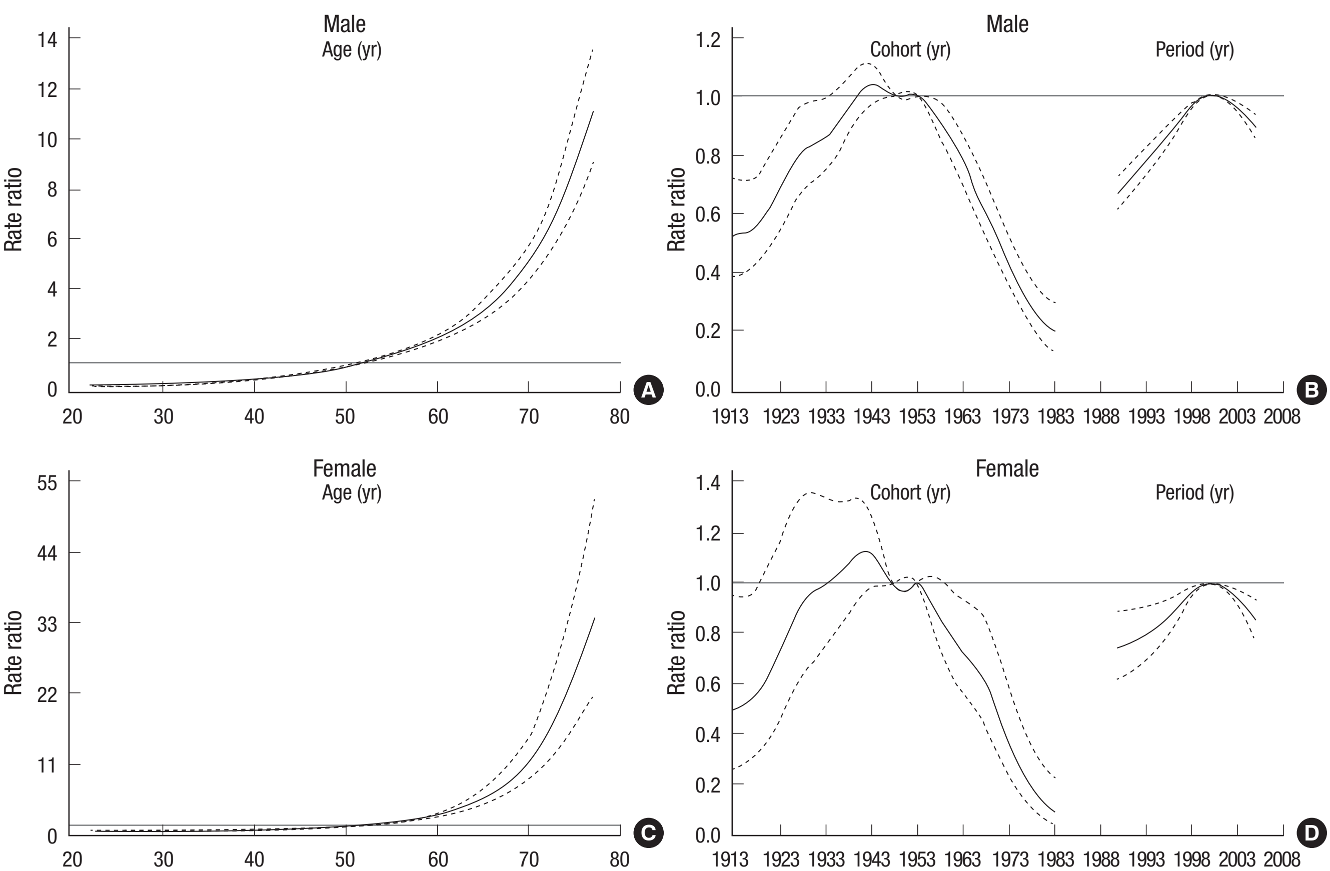

Fig. 2. Estimates (solid line) of age, birth cohort, and period effects on acute myocardial infarction mortality in Korean men (**A**, **B**) and women (**C**, **D**) with 95% confidence intervals (dashed line). Age effects are expressed as rate ratios relative to age 50-54 yr, cohort effects are expressed as rate ratios relative to the 1948 and 1953 birth cohorts, and period effects are expressed as rate ratios relative to the period 1998-2002.

and decreased gradually thereafter in both men and women. The rate ratio of the period effect increased up to the period 1998-2002 and decreased thereafter in both men and women (Fig. 2B, D).

DISCUSSION

We analyzed annual data on AMI mortality in Korean men and women from 1988 to 2007, obtained from the Statistics Korea website. Our results suggest that AMI mortality in Korean adults has decreased since the period 1998-2002 and age, period, and cohort effects have influenced on AMI mortality.

The AMI mortality trend increased in the late 1980s and 1990s in men and women. However, a decreasing trend was observed in the 2000s. Our finding of a decreasing trend in AMI mortality among Korean adults must be confirmed by other studies before it can be concluded that the downward trend will continue. A rapid increase in mortality rates of ischemic heart disease was observed at the beginning of the twentieth century; however, a marked decrease in AMI mortality has been reported in most

Western countries over recent decades (14, 15). A decline in mortality from ischemic heart disease since 1970 has been reported in Japan (16). A decreasing trend of AMI mortality beginning in the early 1990s was reported in Hong Kong (17). Considering previous experiences of mortality from AMI or ischemic heart disease in most Western countries, Japan, and Hong Kong, a further decrease in AMI mortality is likely to be expected in Korean adults.

A study on the incidence of AMI in Korea from 1997 to 2007 based on data from the Korean National Health Insurance Database reported that the incidence of AMI increased from 43.5 per 100,000 in 1997 to 91.8 per 100,000 in 2007; however, the fatality rate of incident AMI cases decreased from 14.1% in 1997 to 10.8% in 2007. Although the incidence of AMI increased from 1997 to 2007, a change in growth pattern during the period was reported. A sharp increase of AMI incidence was noted from 1997 to 2002, but a relatively slow growth of AMI incidence was noted after 2002 (6). We think these results are consistent with ours. Decreased AMI mortality in period four (2003-2007) compared with that in period three (1998-2002) may be explained by slow growth of AMI incidence and decreased case fatality of AMI in period four. Increased awareness of AMI among doctors and the general public and improved care in coronary care units in recent decades likely contributed to the reduction in the case fatality rate of AMI in Korean adults between 2003 and 2007. The changes in incidence pattern and fatality of AMI between periods may explain the period effect on AMI mortality in Korean adults.

It is well-known that incidence and mortality of AMI increase with age. Furthermore, age influences management of patients with AMI. In the clinical setting, elderly patients with AMI are likely to be treated less vigorously than younger patients. However, studies have revealed that the prognosis of AMI is substantially affected by the development of left-ventricular failure and clinical indices rather than age. Thus, vigorous treatment is recommended for elderly patients as well as younger patients (18, 19).

Koreans born after 1950 benefited from economic growth over the past 40 yr compared with those born before 1950. Furthermore, they benefited from the expanded medical coverage that accompanied that economic growth. We believe these factors could explain the downward trend in AMI mortality in men and women born after 1950.

Although a trend towards a reduction in AMI mortality has been observed recently in Korean adults, the age-adjusted AMI mortality in period four was higher than that in period one. Thus, further efforts to reduce AMI mortality in Korean adults are needed. In particular, people in the older age groups and those born between 1940 and 1950 require interventions to reduce their likelihood of death from AMI.

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AUTHOR SUMMARY

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We examined time trend and age-period-birth cohort effects on acute myocardial infarction (AMI) mortality in Korean adults from 1988 to 2007. We analyzed the data from the STATISTICS KOREA website. In both genders, AMI mortality increased from 1988 to 2002, but a decreasing trend was noted after 2003. An exponential age effect was noted in both genders. In relation to birth year, AMI mortality risk was highest in those who were born around 1943 and decreased gradually thereafter. With regard to period, AMI mortality risk was highest during 1998-2002 and decreased thereafter.