DOI: 10.1590/1413-81232018235.16092016

Mortality due to acute myocardial infarction in Brazil and its geographical regions: analyzing the effect of age-period-cohort

Juliano dos Santos [1]
Karina Cardoso Meira [2]
Amanda Rodrigues Camacho [3]
Pétala Tuani Candido de Oliveira Salvador [2]
Raphael Mendonça Guimarães [4]
Ângela Maria Geraldo Pierin [1]
Taynãna Cesar Simões [5]
Flávio Henrique Miranda de Araújo Freire [6]

Abstract *The objective of this study was to analyze the effect of age-period and cohort (APC) of birth on mortality for acute myocardial infarction in Brazil and its geographic regions, according to sex in the period from 1980 to 2009. The data was extracted from the Mortality Information System and was corrected and adjusted by means of proportional redistribution of records with sex and age ignored, ill-defined causes, and corrections were made based on the death sub-register. The APC was calculated using the Poisson regression model with estimable functions. The APC analysis on both sexes and in all regions of the country showed gradual reductions in the risk of death in birth cohorts from the decade of the 1940s, except in the Northeast. In this region, there have been progressive increases in the risk of death from the late 1940s for both sexes. This was up until the 1950s for men and the 1960s for women. It was concluded that the observed differences in the risk of death in Brazilian regions is the result of socio-economic inequalities and poor access to health services within the Brazilian territory, favoring early mortality for this cause especially in poorer areas.*
Key words *Myocardial infarction, Mortality, Age effect, Period effect, Cohort effect*

[1] Escola de Enfermagem, Universidade de São Paulo. Av. Dr. Enéas de Carvalho Aguiar 419, Cerqueira César. 05403-000 São Paulo SP Brasil. jlnsantos@yahoo.com.br
[2] Escola de Saúde, Universidade Federal do Rio Grande do Norte (UFRN). Natal RN Brasil.
[3] Hospital Universitário Onofre Lopes. Natal RN Brasil.
[4] Escola Politécnica Joaquim Venâncio, Fundação Oswaldo Cruz (Fiocruz). Rio de Janeiro RJ Brasil.
[5] Instituto de Pesquisa René Rachou, Fiocruz. Belo Horizonte MG Brasil.
[6] Departamento de Demografia e Ciências Atuariais, UFRN. Natal RN Brasil.

Introduction

Cardiovascular diseases, including acute myocardial infarction (IAM), represents an important problem for public health in Brazil and in the world which has resulted in high rates of incidences of mortality[1]. The rates of Brazilian mortality for this group of causes[2] (183,3/100.000) are amongst the highest in the world and is similar to that of countries such as China and areas such as the east of Europe[3].

This reality can be explained by both the changes in the age structure of the population and the increase in the prevalence of exposure to risk factors that have been recognized as being associated with diseases of the circulatory system such as: sedentarism, increase in the consumption of meat and food that contain a high fat content, a reduction in the consumption of fruits and vegetables, the consumption of alcoholic drinks, smoking, the increase in obesity, as well as socioeconomic inequalities and poor access to health services[3-8].

In the last decade the National Policy for the Promotion of Health and the Program for the Prevention and Control of Hypertension and Diabetes (HIPERDIA)[1,3,7,8], were implemented with the view of reducing mortality rates which were high due to diseases of the circulatory system. However, the mortality rates for cardiovascular diseases in Brazil concerning IAM is still high in comparison to the rates in developed countries.

Age, period and birth cohort are factors which influence the development of the incidence rates and the illness rates that lead to mortalities. The effects of age relates to the changes in the development of the mortality rates of certain illnesses based on the age range in which the person is in. The effects of the period refers to the alterations in the mortality tendencies and incidences that are in themselves related to the changes that occur at certain periods and which influence, simultaneously all of the age ranges (the following must be taken into account: innovations in diagnosis and treatment, access to health care, changes in the certification of deaths and improvements in the mortality information system)[9,10].

The effects of the birth cohort have occurred due to factors that have affected a generation, promoting changes at different magnitudes in successive ages and period groups. This permits the analysis of the effects of long term exposure to risk factors. The birth cohort effect, reflects the interaction between the effect of age and period as a result of the accumulation of exposure throughout a person's life[9,10].

Therefore analyzing just the effects of age and period through standard rates of age per period whilst ignoring the effect of birth cohort is not recommended to be done on a routine basis, as there is no evaluation of the interaction between the effect of age and period on the progression of the mortality rates[10].

Continuing on this vein, the APC model (*age-period-cohort*) can be used in any situation in which the objective is the evaluation of the temporal effect of the occurrence of the event. The main reason for using these is to estimate the effect of each of these factors (APC) separately in the increase or otherwise of the rates[9,10].

Following this line of thought, the objective of this study was to analyze the effect of the age-period and the birth cohort (APC) on the mortality rates for acute myocardial infarction in Brazil and the geographical regions based on sex, during the period from 1980 to 2009.

Methods

This was an ecological study with temporal tendencies in which the death registers for IAM were analyzed covering both sexes for those who were 20 years old or over between the period from 1980 to 2009. During this period two revisions of the International Classification Statistics for Diseases and Problems Related to Health (CID) were made. This included the classification in three digits of the ninth revision for the IAM 412 and the code for the tenth revision I-21.

The registers of deaths were extracted from the Information System on Mortality (SIM/DATASUS)[11] as well as population data based on the census for 1980, 1991, 2000 and 2010. The inter-census projections for the 1st July in the years that the census was carried out, were estimated by the Brazilian Institute of Geography and Statistics (IBGE)[12].

We made some corrections due to the poor quality of the information obtained from the Information System on Mortality (SIM) and then we progressed in three steps: (1) proportional redistribution of the classified registers with age and/or sex that we ignored, (2) redistribution of the classified deaths as causes that were poorly defined amongst the known causes[13], with the exception of the external causes, and (3) correction of the sub-register of deaths for each of the geographical regions and sexes in accordance with the description that follows.

The deaths that were observed in relation to all of the causes of deaths were corrected using

Ciência & Saúde Coletiva, 23(5):1621-1634, 2018

the demographic methods of death distribution particularly: a) extinct generations[14], b) general equation of the balance or general growth balance[15] and c) adjusted extinct generation that consist in a combination of the first two[16].

These methods are robust for non-stable populations. However, when populations are open to migration, care needs to be taken in some areas. The correction factors taken from the degree of cover used in this work follows the recommendation to minimize the effect of migration which consists in adopting an average from the estimates generated from previous methods, as well as not considering the ideas that are most affected by migration[16].

The estimates of the degree of coverage of deaths by sex and region used in this study were developed by a group of researchers in the ambit of a research project for the Estimates of Mortality and Construction of Life Tables for Small Areas in Brazil, 1980 to 2010 that were supported by official acts: MCTI/CNPQ/MEC/ CAPES/ Social Science Applied eMCTI/CNPQ/Universal 14/2014.

More methodological details and the degree of coverage for the general deaths of men by region in Brazil, can be found in Lima and Queiroz[17]. For the women, the degree of coverage for regions was kindly given by the research project team using the same methodological strategy. The inverse of the degree of coverage is the factor through which the total deaths (all of the causes of death) are corrected.

After the carrying out of the adjustments and corrections of the deaths per sex and geographical region for the period of study, the rates of mortality per IAM according to sex were calculated. The rates of mortality in relation to age range and geographical region per 100,000 inhabitants were also calculated. The above was done based the standards for world populations proposed by the World Health Organization (WHO)[18].

The age range, periods and the birth cohort were grouped in intervals of five years. The age ranges started from 20 to 24 and went up to 80, with a total of 13 groups. The periods were also grouped in five years (1980 to 1984, 1984, 1985 to 1989, 1990 to 1994, 1995 to 1999, 2000 to 2004 and 2005 to 2009) adding up to six periods.

The choice of the period of analysis (1980-2009), even faced with the availability of data for mortality that is the most recent data (2010-2013), was subject to the restrictions of the APC methodology. This suggests that the age and period groups ought to have the same size so that there is no overlapping of the birth cohorts. Also in this study we opted to work with age ranges and periods of death with intervals from 5 in 5 years[9,10].

In relation to the birth cohorts, they started in 1985 and ended in 1989, adding up to 19 cohorts.

The effects of age-period-birth cohort (APC) were calculated assuming a Poisson distribution for the number of deaths and that the temporal effects (age-period-birth cohort) act in a multiplicative way on the rates[9,10,19]. This being the case, the logarithm for the value of the rate that was hoped for is a linear function of the effect of the age, period and cohort[9,10,19,20].

The estimates of the parameters of the APC effect showed that the main limitation of the problem of the non-estimation of the complete model, is known as *noindentifiability problem*. This limitation occurs owing to the exact linear relation amongst the temporal effects (age-period-birth cohort)[9,10,19]. It is noted that there is no consensus in the field-related journals on the best methodology to be used to correct this problem[9,10,19,20]. This being the case, in the present study we opted for estimating the parameters of the APC effects through the estimable functions[9,10,19].

The estimable functions limit the analysis of the effects of the linear combinations and curvatures. The curvatures are the estimable functions of the parameters and they remain constant in spite of the parameterization that was used. The linear tendency of the effects is divided into two components: the first is the linear effect of age and the other is called *drift,* being the linear effect of the period and the cohort. The longitudinal tendency of the age is equal to the sum of the age and of the inclination of the period and which covers linear tendency of age and period respectively. The term *drift* represents the linear tendency of the logarithm for the specific rates of age. It is equal to the sum of the inclinations of the period and the cohort in which there is linear tendency for the period and the cohort respectively[9,10,19].

The specific rates of age for the cohort/period of reference will be the relative risk (RR) for every cohort referring to the reference cohort and to every period relative to the period of reference. In this article we used as a reference the cohort for 1935-1939 and the period from 1990 to 1994[21].

The adjustment of the models for the data was checked through statistical deviance[9,10,19]. The results were considered to be statistically significant with ≤ 0,05. The analysis for the estimation of the APC model was carried out through the library Epi 1.1.18a. program R, version 3.2.1 .

Results

In the period of study, the rate of the common average mortality rates for Brazil for males (108,14 death/100,000 man) was 1.75 times greater than that of females (61,49 deaths/100,000 women). We noted that the highest common rate existed for males covering all of the period that was analyzed. This was a reality that was also observed in all of the geographical regions of the country.

In relation to development of the rates in six five year periods that were analyzed, we noted that for females the highest rates between the period from 1995-1999 was observed in the southern region of the country. This is a period from which occurred a reduction for females, being rates of the subsequent periods similar to those that were checked in the south east region.

The profile of the mortality in the south east region suggests a lowering of the rates from the period from 1985 to 1989. Brazil showed signs of a reduction in the rates between 1995-1999 for the above group reaching an incident peek in the period from 2000 to 2004, and then showing a reduction in the following period.

It is still important to highlight that the regions of the north and the central western regions showed lower rates in all periods when compared to other geographical regions and in Brazil increases in rates of mortality in the northern region were seen from 1995 to 1999.

In this context the north east region can be highlighted because the same region showed a steady increase in the rates of mortality from 1990 to 1994 reaching its highest value in the last period of the historical series that was analyzed (Figure 1).

For males the profile of the rates of mortality for IAM suggested a descendent tendency for Brazil in the south and south east regions. There was an increase in the most accentuated rates of mortality in the northern regions and the north east from 1995 to 1999 and a minor increase in the central western regions from 1990 to 1994 (Figure 1).

In relation to the rates of mortality for birth cohort and the age range, we checked the progressive reduction of mortality in the women born after the 1940s decade in Brazil and the south and south east regions.

However, in the central western and northern regions we saw a reduction in the birth cohort from the decade of the 1960. The reduction in the rates of mortality is more pronounced in the age ranges for the young people from the age of 30.

An opposite profile was seen in the northeast region as there is an increase in the rates of mortality in women born after the 1940 decade in the age range from 45 to 49 years old. On the other hand we also saw a reduction in the rates amongst young people from the age of 30.

A similar profile was seen in the progression of the rates for men except in the north and north east region. In the northern region there was an increase in the rates for those in the age range of 30-34 and 35 to 39 and in the north east, because there is a reduction of the mortality rates in men born in the 1960s.

In relation to the analysis of the effects of age (A), period (P) and birth cohort (C), we saw that in both sexes, the model was better when adjusted to the data of the complete APC model ($p < 0,0001$) in Brazil and all of the geographical regions that. This was the case when compared to the model just with the age, birth-cohort, age-period and age-drift (Table 1 and 2).

With respect to the effect of age in both sexes for Brazil and in all of the regions, we noted an increase in the progression of the mortality rates whereas the age ranges increased (Figure 2 and 3).

Continuing on this vein, what stood out was the mortality rates in the northeastern region for men in the age group being 80 or over, as this was higher for the mortality rates in Brazil and the other geographical regions (Figure 3).

In relation to the effect of period we saw a profile difference in the risk of death in relation to the period of reference (1990-1994) amongst the sexes and the geographical Brazilian regions.

For women in Brazil and particularly in the south and the south east we noted an increase in the risk of death by IAM in the periods from 1994 to 1995 and 2000 and 2004 (RR ≥ 1), with a subsequent reduction of the risk in the period showing the effect of protection in relation to the period from 1990 to 1994 (RR ≤ 1). This highlighted the same for men in the southern region. In the north and north east regions we saw a reduction of the risk of death in all of the periods from 1985 to 1989 (RR ≤ 1) in relation to 1990-1994 (Figure 2).

The central western region showed an interesting situation for both the men and women as there was a reduction of the risk of death in the period from 1995 to 1999 and then there was a

Ciência & Saúde Coletiva, 23(5):1621-1634, 2018

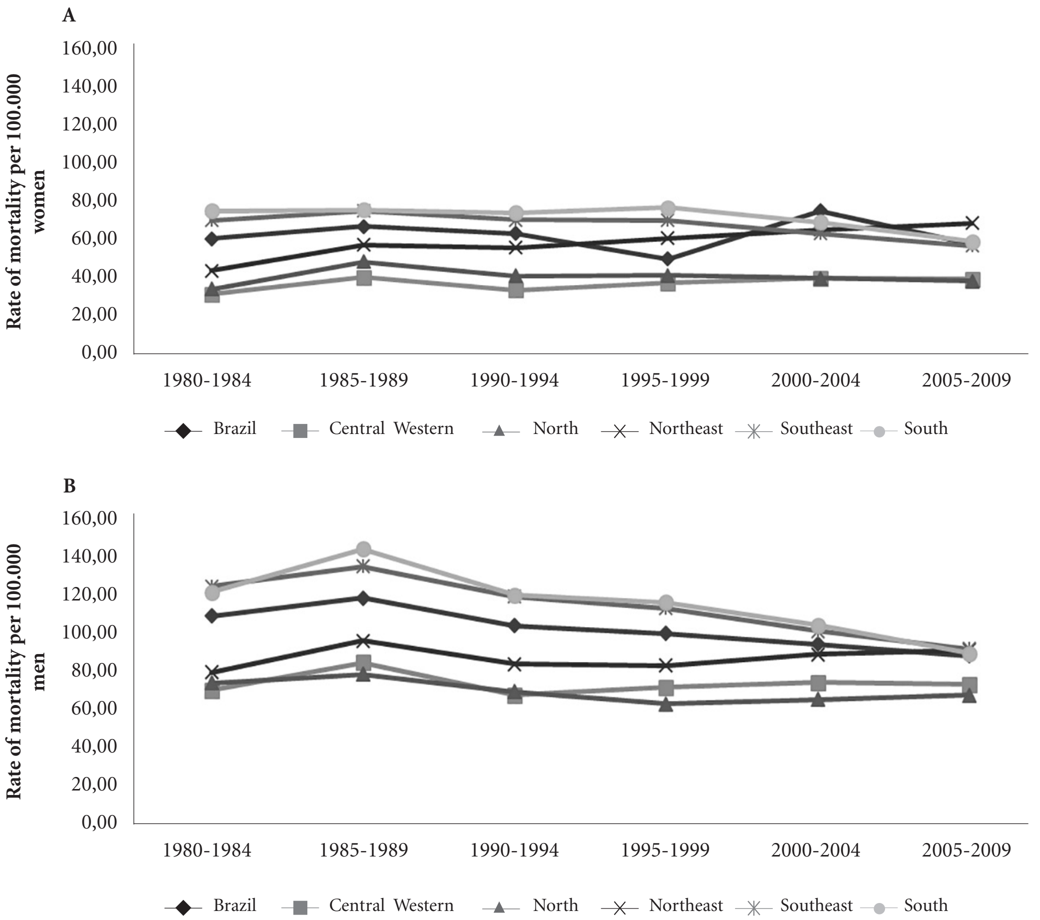

Figure 1. (A) Rate of mortality due to acute myocardial infarction for women, Brazil and the geographical regions, five year periods from 1980 to 1984 to 2005 to 2009. (A) Rate of mortality due to acute myocardial infarction for men, Brazil and the geographical regions, five year periods from 1980 to 1984 to 2005 to 2009.

subsequent increase which once again showed a protective effect for the period from 2005 to 2009 (Figure 2 and 3).

On the other hand for men in Brazil we noted an increase of the risk of death for this disease in all of the periods after 1995 to 1999 in the period of reference.

In the north and the north east region we observed an increase of the RR in the last period that was analyzed (2005 to 2009) in relation to 1990 to 1994 and for the period from 2000 to 2004 the increase was also seen in the north east. We highlighted the south east region because it was the only region to show the effect of protection for the periods after 1995 to 1999 in relation to the period of reference being 1990 to 1994.

In relation to the birth cohort in both sexes in the southern regions and the regions of the south east, north and central western regions, we noted progressive reductions in the risk of dying due to IAM compared with the cohort of reference from 1935-1939. The initial cohort showed the effect of protection for the individuals born from the 1940s.

However in the north east region for women we saw an inverse pattern as the risk of death increased progressively from the birth cohort with reference to the cohort from 1960-1964 based on the risk becoming stable. However it maintained itself as a risk factor (RR ≥ 1) in relation to the cohort of reference (1935 to 1939). In the same way we checked the increase of the risk for men considering the cohort from 1950-1954 from which there was a reduction in the relative risk and thus went to being lower than 1 (Figure 2 and 3).

Table 1. Adjustments for the model of the effect age-period-cohort, for the mortality for acute myocardial infarction in women, according to regions in Brazil, for the period from 1980 to 2009.

Models	gl	Dev. Res	Value of p
Brazil			
Age	73	17774.50	
Age-drift*	72	4605.20	< 0.00001
Age-Cohort	68	3712.10	< 0.00001
Age-Period-Cohort	63	2018.80	< 0.00001
Age-Period	64	2571.70	< 0.00001
Age-Drift**	72	4605.20	< 0.00001
The Central Western Region			
Age	73	548.15	
Age-drift*	72	375.47	< 0.00001
Age-Cohort	68	337.33	< 0.00001
Age-Period-Cohort	63	242.08	< 0.00001
Age-Period	64	273.63	< 0.00001
Age-Drift**	72	375.47	< 0.00001
North			
Age	73	686.12	
Age-drift	72	523.76	< 0.00001
Age-Cohort	68	502.91	< 0.00001
Age-Period-Cohort	63	308.83	< 0.00001
Age-Period	64	338.92	< 0.00001
Age-drift	72	523.76	< 0.00001
Northeast			
Age	73	2548.42	
Age-drfit*	72	1614.07	< 0.00001
Age-Cohort	68	1231.41	< 0.00001
Age-Period-Cohort	63	885.82	< 0.00001
Age-Period	64	1317.06	< 0.00001
Age-Drift**	72	1614.07	< 0.00001
South			
Age	73	8110.50	
Age-drift	72	1575.50	< 0.00001
Age-Cohort	68	1256.70	< 0.00001
Age-Period-Cohort	63	407.20	< 0.00001
Age-Period	64	556.50	< 0.00001
Age-Drift**	72	1575.50	< 0.00001
Southeast			
Age	73	19816.30	
Age-drift*	72	3285.70	< 0.00001
Age-Cohort	68	2445.90	< 0.00001
Age-Period-Cohort	63	979.00	< 0.00001
Age-Period	64	1417.60	< 0.00001
Age-Drift**	72	3285.70	< 0.00001

*Linear tendency of the logarithm of the specific rates for age through the time is equal to the sum of the inclinations of the period and the cohort ($\beta L + \gamma L$) where βL and γL are the linear tendency for the period and the cohort respectively; ** The longitudinal tendency of the age is equal to the sum of the age and of the inclination of the period, in which and are linear tendency of age and period respectively.

Table 2. Adjustments for the model of the effect for age-period-cohort, for mortality due to acute myocardial infarction in men, according to regions in Brazil, for the period from 1980 to 2009.

Models	gl	Dev. Res	Value of p
Brazil			
Age	73	33683.00	
Age-drift*	72	4618.00	< 0.00001
Age-Cohort	68	3015.00	< 0.00001
Age-Period-Cohort	63	1055.00	< 0.00001
Age-Period	64	2378.00	< 0.00001
Age-drift	72	4618.00	< 0.00001
The Central Western Region			
Age	73	1182.55	
Age-drift*	72	631.73	< 0.00001
Age-Cohort	68	409.39	< 0.00001
Age-Period-Cohort	63	271.54	< 0.00001
Age-Period	64	491.85	< 0.00001
Age-drift*	72	631.73	< 0.00001
North			
Age	73	837.86	
Age-drift	72	366.29	< 0.00001
Age-Cohort	68	313.96	< 0.00001
Age-Period-Cohort	63	166.24	< 0.00001
Age-Period	64	226.32	< 0.00001
Age-drift	72	366.29	< 0.00001
Northeast			
Age	73	1990.39	
Age-drift*	72	1979.23	< 0.00001
Age-Cohort	68	1600.62	< 0.00001
Age-Period-Cohort	63	546.82	< 0.00001
Age-Period	64	950.54	< 0.00001
Age-drift	72	1979.23	< 0.00001
South			
Age	73	13111.8	
Age-drift	72	1178.5	< 0.00001
Age-Cohort	68	852.1	< 0.00001
Age-Period-Cohort	63	214.9	< 0.00001
Age-Period	64	433.3	< 0.00001
Age-drift	72	1178.5	< 0.00001
Southeast			
Age	73	30579.1	
Age-drift*	72	3419	< 0.00001
Age-Cohort	68	2608.4	< 0.00001
Age-Period-Cohort	63	725	< 0.00001
Age-Period	64	1235.6	< 0.00001
Age-drift	72	3419	< 0.00001

*Linear tendency of the logarithm of the specific rates for age through the time is equal to the sum of the inclinations of the period and the cohort ($\beta L + \gamma L$) where βL and γL are the linear tendency for the period and the cohort respectively; ** The longitudinal tendency of the age is equal to the sum of the age and of the inclination of the period, where and are linear tendency of age and period respectively.

Ciência & Saúde Coletiva, 23(5):1621-1634, 2018

Discussion

The present study showed a progressive increase in mortality by IAM with the increase in mortality rates for men when compared to women in all of the regions of the country and in both sexes.

We highlighted the effect of the birth cohort that consists in the interaction between the effect of age and period, as we observed progressive reductions of the risk of death in the birth cohort after the 1940s. This showed the effect of protection in relation to the cohort from 1935-1939 in both sexes in Brazil and in all of the regions except for the north east. In this region we saw an increase of the risk of death from 1935-1939. In relation to the progression of the rates throughout the evaluated five year periods, it is worth noting the increase of the mortality rates from the period between 1995 to 1999 in the north and north east.

The alterations in the progression of the rates of mortality reflect the changes in the exposure to risk factors (the environment and style of life) as well as improvements in diagnosis, treatment, checking and the certification of deaths. Such modifications can occur in an unequal way which can go towards explaining the differences in the development of the mortality rates in different Brazilian geographical regions which we noted in this study.

In relation to the effect of age, our results also came from other Brazilian studies[22,23] and from other countries such as: Australia[24], Japan[25], China[26], Hong Kong[27], South Korea[28], England and Wales[29].We noted progressive increases in mortality rates as people got older in both sexes and particular for the over 50s.

Such a reality was expected as this is a Chronic-degenerative disease which is directly related to the accumulation of exposure to the risk factors throughout a person's life which in turn increases incidences for the elderly. Therapeutic measures also contribute to this profile, in so far as the elderly tend to receive treatment that is less intensive for IAM than young people[23]. This explains, in part, the high mortality rate in the age groups from 80 and over with the north east region featuring high and the fact that the majority that suffer there are men.

Backing up what was found in the other studies[1,7,8,18,20-23,30], the magnitude of the mortality rates in our study was greater in men than women, being 1.78 times greater.

This reality may owe itself to the unequal exposure to risk factors for both sexes in relation to known risk factors for an illness. Also we understood that women showed more care in relation to their health than men due to sociocultural reasons and the construction of masculinity[3,4].

In the last three decades the mortality rates in Brazil for both sexes was higher than those observed in developed countries such as: Western Europe[31], the United States[32], Australia[19], Japan[20], South Korea[23] and Hong Kong[22]. We noted in these regions that there was a epidemic of cardiovascular diseases up until the middle of the 1960s and then there was a decrease. However the rates of mortality in Brazil are similar to those observed in Russia, Eastern Europe and Central Asia[26].

The risks of death in accordance with the birth cohorts are similar for both sexes as it signals the effect of protection (RR < 1) for the younger cohorts who were born in the 1940s when compared to the cohort of reference being 1935-1939 in the northeastern region. These results go to further understand the studies done in Australia, Japan, Hong Kong[22] and South Korea[23].

The explanation for the reduction in the mortality rates in the developed countries is not clear cut and has different explanations. Some authors argue that this tendency in the rates decreasing can be explained by: early diagnosis, the quality of pre-hospital care, protocols for treating people, the availability of intensive care beds and teams of health specialist to treat IAM. The above can also be coupled with the identification of risk factors related to cardiovascular diseases which permits the implementation of measures for prevention and control which occurs in an incipient way in developing countries. This is one explanation[4,31-34].

However there are studies that affirm that the reduction in mortality due to cardiovascular diseases in developed countries that started from the 1960s, occurred before the reduction of the prevalence of the risk factors and the appearance of advances in therapy for these diseases that started in the 1970s[35-38]. These authors attribute the reduction to: improvements in basic sanitation, the wider use of vaccines and the increase in babies' weights at birth as there is evidence of the primordial role of the inflammatory process on the etiology of the atherosclerosis. Continuing on this vein, the improvements can be seen in people's conditions of life where people are less exposed to infectious disease and due to this, the risk of developing cardiovascular diseases in adult life is reduced[35].

This theory can explain in part the differences in the patterns of mortality by IAM that was

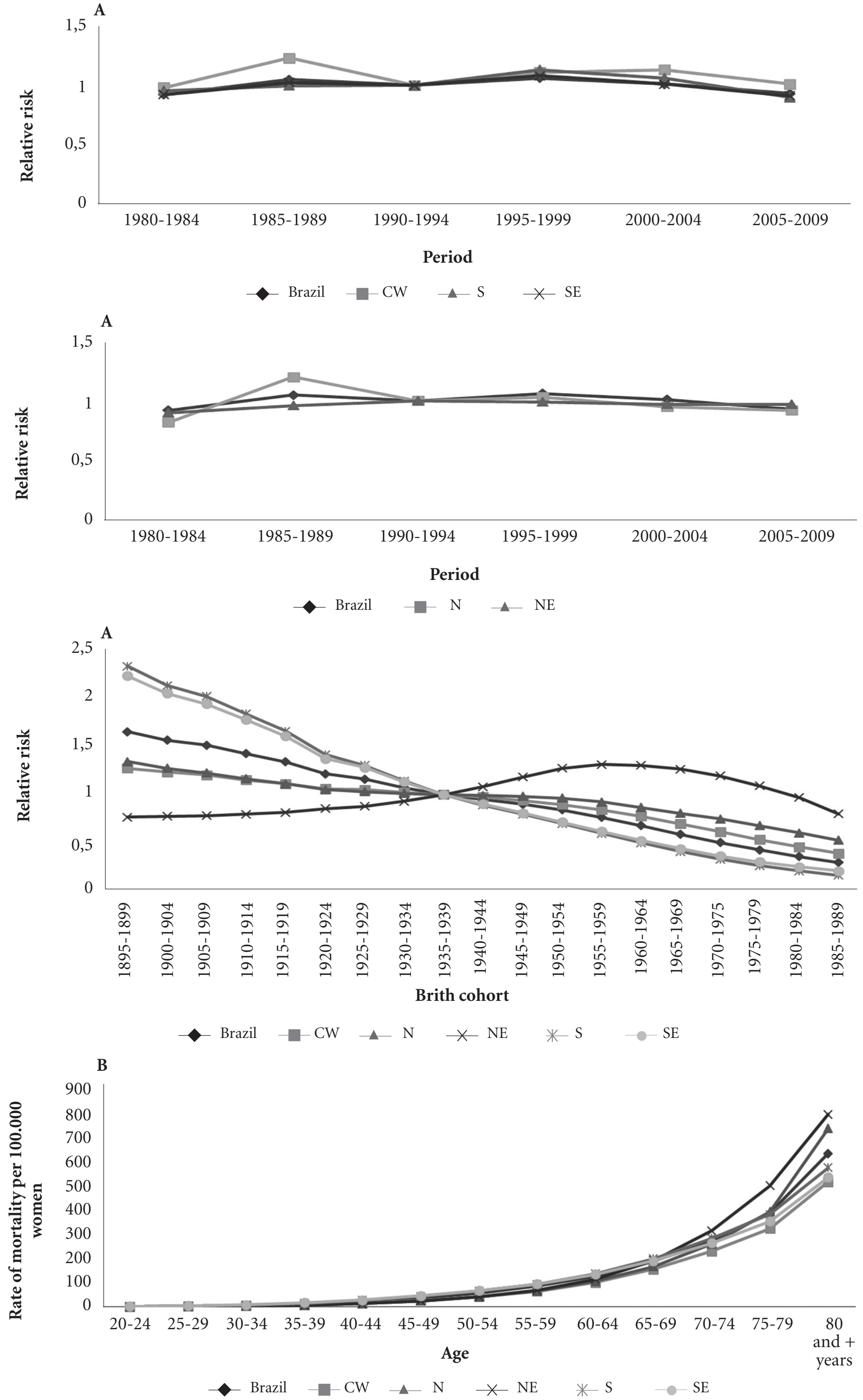

Figure 2. (A) Results of the effect of the period and the birth cohort on mortality for acute myocardial infarction in women, according to regions in Brazil, for the period from 1980 to 2009. (B) Results of the effect of the age cohort on mortality for acute myocardial infarction in women, according to regions in Brazil, for the period from 1980 a 2009.

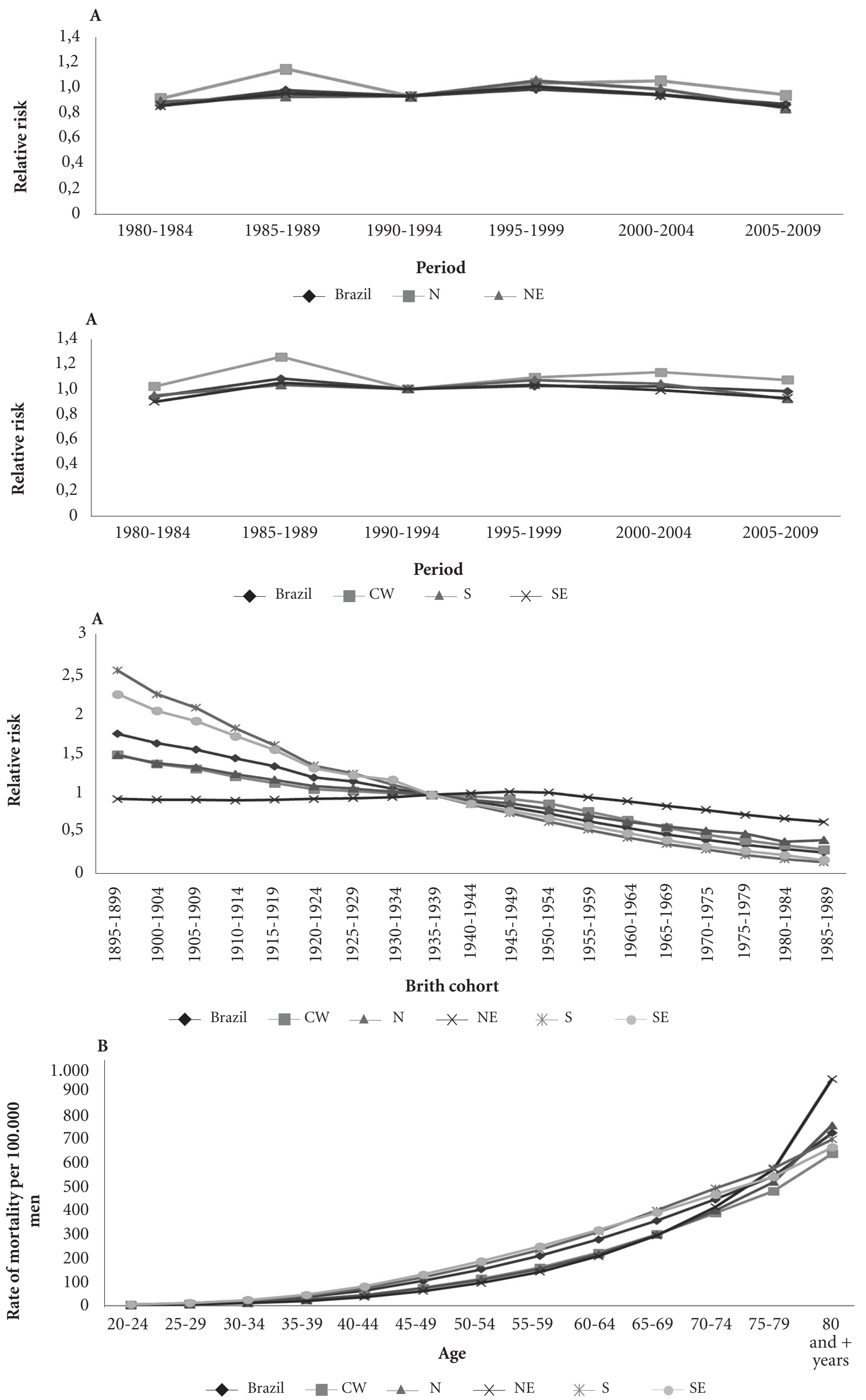

Figure 3. (A) Results of the effect of the period and the birth cohort on mortality for acute myocardial infarction in men, according to regions in Brazil, for the period from 1980 to 2009. (B) Results of the effect of the age on mortality for acute myocardial infarction in men, according to regions in Brazil, for the period from 1980 a 2009.

observed in this study. There is an interaction between the effect of the period and the age (birth cohort) as the north east region was the only part of the country that showed a progressive increase in the risk of dying due to this risk pathology after the 1940s. There was a more pronounced increase for women being RR>1, including young people and men until the cohort of the 1960s. Aside from this, only the north and the northeastern regions showed increases in the mortality rates in the 2000s.

These regions are the poorest in the country with high levels of social inequalities due to the high concentration of income. These areas have the highest levels of infant mortality and they have poor basic sanitation as well as difficulties in accessing primary health care and complex treatment[39,40]. The implementation of the National Health Service in Brazil increased access to health care in Brazil owning to its universal nature. However the quality of the care varies from region to region.

That is the reason why we did not see the same epidemiological transition that has occurred in industrialized countries, largely due to the socioeconomic inequalities.

These iniquities greatly influenced the mortality rates principally in relation to the premature deaths associated with cardiovascular diseases having the greatest impact on the poorest in the population. This, in part, explains the growing mortality rates in the decade from the year 2000 in the north and northeastern regions[40].

It is believed that the reduction in the mortality rates observed in the south, south east and the central western regions in the decade from the year 2000 as well as the reduction in the risk of death by IAM in the cohorts for younger people in by sexes in these regions, can be explained by the interaction between the effect of the period promoted by the improvements in life conditions, access to health services with SUS and advances in therapy for this disease. All of the aforementioned permitted the reduction in the risk of death for the younger cohorts even though they were being more exposed to the risk factors (nutritional transition, reduction in the practice of physical activity etc)[1-4,35].

A completely different reality was seen in the north east region principally for women in which social inequality and access to health services associated with the effects of the epidemiological and nutritional transition increased the risk of death including in the birth cohort for young people.

SUS, in spite of its limitations, has managed to increase access for the Brazilian population to health services and medication. This has aided in controlling hypertension and diabetes which are diseases that basic primary health care plays a very important role in tackling, through the program HIPERDIA. This program was launched in 2000 with the view of treating and accompanying health care users at an ambulatorial level[41].

Nevertheless, in spite of the reduction in mortality due to IAM for both men and women in the south, south east and central western regions principally in the decade starting from the year 2000, these rates continue to rise in relation to the developed countries. This fact highlights the differences between developed countries and developing countries, which includes differences in: life conditions, the prevention and control of cardiovascular diseases (principally arterial hypertension) and the assistance given to individuals after they have a heart attack.

According to Pinho e Pierin[42] the control of systemic arterial hypertension in Brazil is considered low, however detailed national data is not available. A study of the medical literature in this area identified a prevalence of control that varies from 10.0 to 57.6%. It was noted that there was low prevalence of control even amongst the assisted users through the Family Health Strategy (ESF)[29]. Such results are worrying as arterial hypertension that is not controlled is one of the principal factors associated with acute myocardial infarction.

A study carried out in Ribeirão Preto with a view to identifying the causes of deaths for those who were suffering from hypertension and were users of a public health unit, showed that the most common causes were related to diseases of the circulatory system, highlighting: IAM (12.9%), encephalic vascular accident (5.8%), respiratory insufficiency (3.2%) and ventricular flutter-fibrilation[43].

Aside from this, research carried out in a cohort of adults above 20 years old in the city of Rio de Janeiro showed that the risk of cardiovascular diseases was 6.1 times greater in individuals with uncontrolled hypertension when compared with those that did not have hypertension. It has also 2.7 times greater for patients with uncontrolled hypertension when compared with patients with controlled hypertension[44].

Additionally in relation to the limitations observed in the primary prevention of cardiovascular diseases, it is important to highlight the need for organizations to have a line of care for IAM,

Ciência & Saúde Coletiva, 23(5):1621-1634, 2018

which consists in a structured assistance network which covers pre-hospital care to hospital admittance for intensive therapy[45,46].

Therefore the results of this study show the need for urgent actions to deal with the problems in the prevention and control of IAM starting from health care promotional actions to pre-hospital treatment. This is needed at both secondary and tertiary levels. Also these measures need to take into account the specific needs of each of the country's geographical regions.

In this study an analysis of the effect of age-period and the birth cohort on mortality by IAM was one of the contributions of this study because the majority of manuscripts only evaluate the effect of age and the period of death without evaluating the effect of the birth cohort. This is an important factor for understanding the progression of the rates of incidences and mortality from diseases.

Another important contribution was the carrying out of the correction of the classified register as badly defining causes, including the sub-register. This produced more reliable rates for acute myocardial infarction in Brazil and its geographical regions. However, it is important to note that a greater number of deaths for badly defined causes could correspond to deaths by IAM, which in turn may increase the growing tendency of mortality in the north and north east regions.

Nevertheless it is important to highlight the limitations related to the APC model because the models are still being developed and there is no consensus in the literature on the best methodology to rectify the problem of not identifying and estimating the complete model. Thus the findings vary in accordance with the assumptions that are used in the construction of the models[9,10,19,20].

Conclusion

The present study showed the reduction of the risk of death by IAM for both sexes and for all of the Brazilian regions except in the north east region for individuals born after the decade that started in 1940. Aside from this, we saw an increase in the mortality rates for both sexes in the north and north east regions. This is due to the socioeconomics disparities and the access to health services that exists in Brazil.

Therefore it is vital and urgent that intensive actions be taken to improve life conditions and to emphasize the need for prevention and control of risk factors for this disease. Also improvements are needed in accessing health services from basic primary health care to tertiary care.

Collaborations

J Santos, KC Meira, AR Camacho participated in the coming up with the idea for this study as well as defining its scope and remit. J Santos, KC Meira, TC Simões, FHMA Freire participated in the analysis and the interpretation of the data. J Santos, KC Meira, AR Camacho, RM Guimarães, PTCO Salvador, AMG Pierin, TC Simões, FHMA Freire contributed to drafting this paper and critically reviewed it. J Santos, KC Meira, AR Camacho, RM Guimarães, PTCO Salvador, AMG Pierin, TC Simões, FHMA Freire participated in approving the final version of this paper for it to be published.

Acknowledgements

The authors would like to thank Matheus de Sousa Mata for the support given in scoping this study and providing the concept for the paper.

References

1. Baena CP, Olandoski M, Luhm KR, Ortiz Costantini C, Guarita-Souza LC, Faria-Neto JR. Tendência de mortalidade por infarto agudo do miocárdio em Curitiba (PR) no período de 1998 a 2009. *Arq Bras Cardiol* 2012; 98(3):211-217.
2. Malta DC, Moura L, Prado RR, Schimidt MI, Duncan BB. Mortalidade por doenças crônicas não transmissíveis no Brasil e suas regiões, 2000 a 2011. *Epidemiol Serv Saúde* 2014; 23(4):599-608.
3. Moran AE, Forouzanfar MH, Roth GA, Mensah GA, Ezzati M, Murray CJ, Naghavi M. Temporal trends in ischemic heart disease mortality in 21 world regions, 1980 to 2010: the Global Burden of Disease 2010 study. *Circulation* 2014; 129(14):1483-1492.
4. Kulasmaa K, Tunstall-Pedoe H, Dobson A, Fortmann S, Sans S, Tolonen H, Evans A, Ferrario M, Tuomilehto J. Estimation of contribution of changes in classic risk factors to trends in coronary-event rates across the WHO MONICA Project populations. *Lancet* 2000; 355(9205):675-687.
5. Instituto Brasileiro de Geografia e Estatística (IBGE). *Pesquisa Nacional de Saúde* [Internet] 2013. [acessado 2015 out 15] Rio de Janeiro: IBGE; 2013. Disponível em: http://www.ibge.gov.br/home/estatistica/populacao / pns/2013/
6. Instituto Brasileiro de Geografia e Estatística (IBGE). *Pesquisa de orçamentos familiares 2008-2009: análise do consumo alimentar pessoal no Brasil* [Internet] 2011 [acessado 2016 jan 02] Rio de Janeiro: IBGE; 2011. Disponível em: http://www.ibge.gov.br/home/ estatistica/ populacao/condicaodevida/pof/2008_2009_analise_ consumo/pofanalise_2008_2009.pdf
7. Mansur AP, Favarato D. Mortalidade por doenças cardiovasculares no Brasil e na região metropolitana de São Paulo: atualização 2011. *Arq Bras Cardiol* 2012; 99(2):755-761.
8. Mansur AP, Lopes AIA, Favarato D, Avakian SD, César LAM, Ramires JAF. Epidemiologic transition in mortality rate from circulatory diseases in Brazil. *Arq Bras Cardiol* 2009; 93(5):506-510.
9. Holford TR. The estimation of age, period and cohort effects for vital rates. *Biometrics* 1983; 39(2):311-324.
10. Holford TR. Undestranding the effects of age, period, and cohort on incidence and mortality rates. *Annu Rev Public Health* 1991; 12(1):425-457.
11. DATASUS. *Sistema de Informação sobre Mortalidade*. [Internet] 2014 [acessado 2016 Jan 02]. Disponível em: http:// www2.datasus.gov.br/DATASUS/index.php?area=0205
12. Instituto Brasileiro de Geografia e Estatística. *SIDRA* [Internet] 2015 [acessado 2016 Jan 02]. Disponível em: ftp://ftp.ibge.gov.br
13. Soares DA, Gonçalves MJ. Mortalidade cardiovascular e impacto de técnicas corretivas de subnotificações e óbitos mal definidos. *Rev Panam Salud Publica* 2012; 32(3):199-206.
14. Bennett NG, Horiuchi S. Estimating the Completeness of Death Registration in a Closed Population. *Population Index* 1981; 47(2):207-221.

15. Hill K. Estimating census and death registration completeness. *Asian and Pacific Census Forum* 1987; 1(3):8-13.
16. Hill K, You D, Choi Y. Death Distribution Methods for Estimating Adult Mortality: sensitivity analysis with simulated data errors. *Demographic Research* 2009; 21(9):235-254.
17. Lima EEC, Queiroz BL. Evolution of the deaths registry system in Brazil: associations with changes in the mortality profile, under-registration of death counts, an dill-defined causes of death. *Cad Saúde Pública* 2014; 30(8):1721-1730.
18. Ahmad OB, Boschi-Pinto C, Lopez AD, Murray CJL, Lozano R, Inoue M. Age standartization of rates: a new who standard. *World Health Organization – GP discussion papers series* 2000; 31:1-14.
19. Robertson B, Boyle P. Age period-cohort analysis of chronic disease rates I: Modelling approach. *J Start Med* 1998; 17(12):1305-1323.
20. Holford TR. Approaches to fitting age-period-cohort models for the Lexis diagram. *Stat Med* 2006; 26(1):3018-3045.
21. Carstensen B, Plummer M, Hills M, Laara E. *A package for statistical analysis in epidemiology* [Internet] 2001 [acessado 2016 Jan 02] Vienna: Institute for Statistics and Mathematics; 2001. Disponível em: http://cran.r-project.org/web/packages/Epi/index.html
22. Vilella LCM, Gomes FE, Melendez JGV. Tendência da Mortalidade por Doenças Cardiovasculares, Isquêmicas do Coração e Cerebrovasculares. *Rev Enf Recife* 2014; 8(9):3134-3141.
23. André C, Curioni CC, Braga da Cunha C, Veras R. Progressive decline in stroke mortality in Brazil from 1980 to 1982, 1990 to 1992, and 2000 to 2002. *Stroke* 2006; 37(11):2784-2789.
24. Taylor R, Page A, Danquah J.The Australian epidemic of cardiovascular mortality 1935-2005: effects of period and birth cohort. *J Epidemiol Community Health* 2012; 66(7):e18.
25. Ma E, Hiroyasu I, Takahashi H, Yamagishi K, Tanigawa T. Age-Period-Cohort Analysis of Mortality due to Ischemic Heart Disease in Japan, 1955 to 2000. *Circ J* 2008; 72(6):966-972.
26. Wong IOL, Cowling BJ, Leung GM, Schooling M. Age-period-cohort projections of ischaemic heart disease mortality by socio-economic position in a rapidly transitioning Chinese population. *PLoS One* 2013; 8(4):e614-695.
27. Yu IT, Li W, Wong TW. Effects of age, period and cohort on acute myocardial infarction mortality in Hong Kong. *Int J Cardiol* 2004; 97(1):63-68.
28. Jhun HJ, Kim H, Cho SI. Time trend and age-period-cohort effects on acute myocardial infarction mortality in Korean adults from 1988 to 2007. *J Korean Med Sci* 2011; 26(5):637-641.
29. Allender S, Scarborough P, O'Flaherty M, Capewell S. Patterns of coronary heart disease mortality over the 20th century in England and Wales: Possible plateaus in the rate of decline. *BMC Public Health* 2008; 8(148):1-12.
30. Passos LC, Lopes AA, Lessa I, Sanches A, Santos-Jesus R. Tendência da mortalidade por infarto agudo do miocárdio (1981 a 1996) na cidade de Salvador, Brasil. *Arq Bras Cardiol* 2000; 74(4):329-331.
31. Mirzaei M, Truswell AS, Taylor R, Leeder SR. Coronary heart disease epidemics: not all the same. *Heart* 2009; 95(9):740-746.
32. Ford ES, Ajani UA, Croft JB, Critchley JA, Labarthe DR, Kottke TE, Giles WH, Capewell S. Explaining the decrease in U.S. deaths from coronary disease, 1980-2000. *N Engl J Med* 2007; 356(23):2388-2398.
33. Gaziano T. Cardiovascular Disease in developing world and its cost-effective management. *Circulation* 2005; 112(23):3547-3553.
34. Wijeysundera HC, Machado M, Farahati F, Wang X, Witteman W, van der Velde G, Tu JV, Lee DS, Goodman SG, Petrella R, O'Flaherty M, Krahn M, Capewell S. Association of temporal trends in risk factors and treatment uptake with coronary heart disease mortality, 1994-2005. *JAMA* 2010; 303(18):1841-1847.
35. Oliveira Gláucia MM, Klein Carlos H, Souza e Silva NA. Mortalidade por doenças cardiovasculares em três estados do Brasil de 1980 a 2002. *Rev Panam Salud Publica* 2006; 19(2):85-93.
36. Vaessen N, Janssen JA, Heutink P, Hofman A, Lamberts SW, Oostra BA, Pols HA, van Duijn CM. Association between genetic variation in the gene forinsulin-like growth factor-I and low birth weight. *Lancet* 2002; 359(9311):1036-1037.
37. Barker DJ, Winter PD, Osmond C, Margetts B, Simmonds SJ. Weight in infancy and death from ischaemic heart disease. *Lancet* 1989; 2(8663):577-580.
38. Finch CE, Crimmins EM. Inflammatory exposure and historical changes in human lifespans. *Science* 2004; 305(5691):1736-1739.
39. Martine G. A evolução espacial da população brasileira. In: Affonso RBA, Silva PLB, organizadores. *Desigualdades regionais e desenvolvimento*. São Paulo: FUNDAP, Editora UNESP; 1995. p. 61-91.
40. Guimarães RM, Andrade SSCA, Machado EL, Bahia CA, Oliveira MM, Jacques FVL. Diferenças regionais na transição da mortalidade por doenças cardiovasculares no Brasil, 1980 a 2012. *Rev Panam Salud Publica* 2015; 37(2):83-89.
41. Jorgetto GV, Jorgetto JL, Freitas PS. Análise epidemiológica da relação hipertensão arterial, infarto agudo do miocárdio e acidente vascular encefálico. *Revista Nursing* 2010; 12(144):225-229.
42. Pinho NA, Pierin AMG. O Controle da Hipertensão Arterial em Publicações Brasileiras. *Arq Bras Cardiol* 2013; 101(3):65-73.
43. Vieira CP, Neves DV, Nogueira MS, Hayashida M, Souza L, Cesarino EJ. Análise da mortalidade de pacientes hipertensos de unidade pública e especializada na cidade de Ribeirão Preto (SP). *Rev Bras Cardiol* 2012; 25(4):276-281.
44. Silva TLN, Klein CH, Nogueira AR, Salis LHA, Silva NAS, Bloch KV. Cardiovascular mortality among a cohort of hypertensive and normotensives in Rio de Janeiro - Brazil - 1991–2009. *BMC Public Health* 2015; 15(623):1-11.

45. Caluza AC, Barbosa AH, Gonçalves I, Oliveira CA, Matos LN, Zeefried C, Moreno ACC, Tarkieltaub E, Alves CMR, Carvalho AC. Rede de infarto com supradesnivelamento de ST: sistematização em 205 casos diminui eventos clínicos na rede pública. *Arq Bras Cardiol* 2012; 99(5):1040-1048.
46. Marcolino MS, Brant LC, Araujo JG, Nascimento BR, Castro LR, Martins P, Lodi-Junqueira L, Ribeiro AL. Implantação da linha de cuidado do infarto agudo do miocárdio no município de Belo Horizonte. *Arq Bras Cardiol* 2013; 100(4):307-314.

Article submitted 28/02/2016
Approved 29/07/2016
Final version submitted 31/07/2016