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Research Article
Age-period-cohort Analysis of Non-communicable Diseases in India

Dinesh Chaurasiya

International Institute for Population Sciences, Mumbai, India

Abstract

Background and Objective: There are stacks sweeping the knowledge on changing pattern of diseases around the world with distinctive approaches. One such technique is age-period-cohort (APC) analysis on cross-sectional sample survey data. The current study assessed effect of three time related factor age, period and cohort on the non-communicable diseases (NCD) in India. **Methodology:** Three rounds of National Sample Survey (NSS) India (52nd, 60th and 71st round) data had been analyzed using a hierarchical age period cohort (HAPC) approach. **Results:** Four thousand among one lakh Indian adults likely to have a NCD in 2014 as compared to just 900 in 1995. There was five fold increase in predicted probability of getting a disease among 1981-1990 cohorts as those of 1901-1910 born. Independent of age and cohort effects, the predicted probability of getting NCDs increased substantially over the period 1995-2014. **Conclusion:** Study affirmed that period and birth cohort membership may significantly influence the chance of getting NCDs in India. This peculiar accession may challenge existing source of knowledge in the field.

Key words: National sample survey, non-communicable disease, APC approach, period effect, cohort effect

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Corresponding Author: Dinesh Chaurasiya, International Institute for Population Sciences, Mumbai, India Tel: +918898276123

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Non-communicable diseases (NCDs) are one of the major health and development challenges of the 21st century. These diseases cause human suffering and the harm on the socioeconomic fabric of countries, particularly low and middle-income countries. NCDs also known as chronic diseases, do not pass from person to person and are of long duration and slow progression. The four main types of NCDs are cardiovascular diseases, cancers, chronic respiratory diseases and diabetes. All age groups and all regions are affected by NCDs. NCDs are often associated with older age groups, but evidence shows that 16 million of all deaths attributed to NCDs occur before the age of 70. Of these "premature" deaths, 82% occurred in low and middle-income countries. Children, adults and elderly all are vulnerable to the risk that contribute to NCDs, whether from unhealthy diets, physical inactivity, exposure to tobacco smoke or use of alcohol[1].

The present study aimed to estimate the effect of age, period and cohort on the prevalence of NCDs in Indian population. Effect of age represents the variation associated with different age groups brought about by physiological changes, the build-up of social experience and role or status changes. Effects of period represent variation overtime periods that affect all age groups simultaneously-often resulting from shifts in social, cultural or physical environments. Cohort effects reflect variation in risk among individuals who are defined by some shared historical experience, such as year or decade of birth or marriage[2].

MATERIALS AND METHODS

This study used secondary data brought from three different rounds of National Sample Survey (NSS), round 52, round 60 and round 71 conducted in India[3-5]. The 52 round of NSS collected information on Health and Education in 1995-1996. The 60 round of NSS was conducted for a survey on household consumer expenditure, employment and unemployment and morbidity and healthcare in 2004-2005. The 71 round of NSS was devoted to the subject of social consumption and earmarked for surveys on health and education in 2014. The sample design was a two-stage stratified design. Census villages and urban blocks were taken as the first stage units for rural and urban areas, respectively and household, as the second stage units were drawn independently in the form of two sub-sample. Data on ailment in last 15 days from the day of survey extracted from these three rounds. Sample sizes are 629888, 383323 and 333104 individuals for NSS 52, NSS 60 and NSS 71 round, respectively.

Extracted data from all three rounds were pooled. Sample weights for different rounds were adjusted for pooling of three rounds. For analyses, the individual was dichotomized into two categories whether suffered from NCD or not in the last 15 days from the day of the survey. The International Classification of Diseases tenth revision (ICD 10) was used to classify the diseases into non-communicable and other disease[6]. Due to repeated cross-sectional survey data, it was not possible to track the same individual overtime, as in a prospective cohort study[7].

However, it was possible to construct synthetic birth cohorts from such data. Age was subtracted from the period (i.e., year of study) to identify birth cohorts, which ranged from 1883-2014. Cohorts were arranged into 10-years groups, like 1901-1910, 1911-1920, etc., except the initial cohort (1883-1900) and ending cohort (1991-2014) which covered a broader range of years to ensure a sufficient number of subjects. In caste group-1, schedule caste (SC) and schedule tribe (ST) are included. In caste group-2, other backward caste (OBC) and other caste included. For bivariate analysis, number of per 1000 person suffers from NCD had shown by place of residence and caste group for different age-group, birth cohort and period.

For multivariate, this study adopted a hierarchical age period cohort (HAPC) approach and specified cross-classified random effects models (CCREMs). It consisted of a two-component model: The level 1 component was a regression of an individual level outcome variable on a set of individual-level explanatory variables with intercept term, fixed regression slope coefficients and an individual level random error term. Level 2 models used level 1 regression coefficients as outcomes and contain intercepts and specification of random effect coefficients for the effects of each cohort and period distinguished in the model. The level 2 model also contained cohort or period explanatory variables with fixed effect coefficients that were hypothesized to explain, at least in part. For analysis, Individuals below 18 years were removed from the analysis. Along with age, this study focused some individual variable such as sex,

education and marital status that may affect the probability of being suffered from the NCD. To get a proper interpretation for random effects, the coefficients of random effects were converted into predicted probability. To model the likelihood of an outcome, the following HAPC mixed model was specified:

Level 1 model:

$$\text{Logit Pr}(\text{Outcome}_{ijk}=1) = \begin{matrix}\beta_{0jk} + \beta_1\text{AGE}_{ijk} + \beta_2\text{SEX}_{ijk} \\ + \beta_3\text{MARITAL STATUS}_{ijk} \\ + \beta_4\text{EDUCATION}_{ijk}\end{matrix}$$

Level 2 model:

$$\beta_{0jk} = \gamma_0 + u_{0j} + \upsilon_{0k},\ u_{0j} \sim N(0, \tau_u)\ \upsilon_{0k} \sim N(0, \tau_v)$$

Combined model:

$$\text{Logit Pr}(\text{Outcome}_{ijk}=1) = \begin{matrix}\gamma_0 + \beta_1\text{AGE}_{ijk} + \beta_2\text{SEX}_{ijk} \\ + \beta_3\text{MARITAL STATUS}_{ijk} \\ + \beta_4\text{EDUCATION}_{ijk} + u_{0j} + \nu_{0k}\end{matrix}$$

For:

i = 1, 2, ..., n_{jk} individuals within cohort j and period k
j = 1, 2, ... 9 birth cohorts
k = 1, 2, 3 survey years

In this study, bivariate analysis was done using STATA 13 and Excel. For multi-variate analysis SAS 9.4 was used.

RESULTS

Prevalence of non-communicable diseases: Descriptive statistics are shown in Table 1, 2 and 3 for all age-group, periods of observation and birth cohort in the Indian population, NSS 1995-2014. The prevalence of NCDs increased with age peaking at 70+ age group. The prevalence of NCDs also increased gradually by period of observation. In 1995, the prevalence of NCDs was about 10.29 per thousand among Indian. By 2014, it had climbed to 67 per thousand. According to descriptive data, prevalence of NCDs is decreasing over the cohort peaking for cohort (1911-1920) with 153.86 per thousand. As the people

Table 1: Prevalence of NCDs in different age-groups: Total, place of residence and caste group

		Place of residence		Caste groups	
Age (years)	Total	Rural	Urban	1	2
0-10	16.02	14.36	21.85	13.82	17.00
11-20	12.96	12.34	14.64	11.62	13.46
21-30	17.65	17.32	18.42	16.39	18.15
31-40	34.71	30.53	44.64	27.12	37.61
41-50	67.47	38.56	88.12	58.89	70.63
51-60	101.82	82.53	151.91	71.26	112.71
61-70	194.63	169.65	266.28	147.79	210.06
70+	256.27	227.80	322.38	200.33	269.44

Table 2: Prevalence of NCDs in different Period: Total, place of residence and caste group

		Place of residence		Caste groups	
Periods	Total	Rural	Urban	1	2
1995	10.29	9.80	11.84	7.39	11.48
2004	38.47	34.75	48.95	27.32	42.80
2014	67.01	57.96	88.14	52.36	72.73

Table 3: Prevalence of NCDs in different birth cohort: Total, place of residence and caste group

		Place of residence		Caste groups	
Birth cohorts	Total	Rural	Urban	1	2
1901-1910	108.03	84.74	173.64	78.58	115.41
1911-1920	153.86	133.07	215.89	113.51	163.36
1921-1930	144.63	125.84	202.16	102.05	156.45
1931-1940	145.20	129.19	194.82	103.59	159.35
1941-1950	115.88	99.14	162.09	77.69	129.35
1951-1960	77.70	63.50	112.77	58.27	84.86
1961-1970	48.43	41.21	66.39	38.06	52.39
1971-1980	31.05	27.50	39.58	26.01	32.98
1981-1990	15.63	14.24	19.18	14.22	16.16

Table 4: Results from hierarchical age-period-cohort models of NCDs for Indian adults and group defined by place of residence and caste, NSS 1995-2014

		Place of residence		Caste groups	
	Indian adults	Rural	Urban	1	2
Fixed effects					
Intercept	-3.8410**	-3.8682**	-3.6133**	-3.8149**	-3.7431**
Age	0.07044***	0.0694***	0.0677***	0.0604***	0.0695***
Sex					
Female®					
Male	-0.3655***	-0.3364***	-0.3391***	-0.2903***	-0.3598***
Marital status					
Never married®					
Currently married	-0.04125	-0.0587	-0.0019	-0.02636	-0.05375*
Widowed	-0.03395	-0.0520	-0.0274	0.05085	-0.05170
Separated	0.2849**	0.1918*	0.3606***	0.2117	0.3371***
Education					
Illiterate®					
Below primary	0.4044***	0.3572***	0.2936***	0.1228***	0.4249***
Secondary and above	0.3635***	0.2845***	0.1653***	0.07133*	0.3357***
Random effects					
Period effects (τ_{v0})	0.6150	0.5537	0.7525	0.7991	0.6179
1995	-0.8683*	-0.8236*	-0.9641*	-0.9760*	-0.8703*
2004	0.2126	0.2016	0.2488	0.1995	0.2130
2014	0.6557	0.6220	0.7153	0.7764	0.6572
Cohort effects (τ_{u0})	0.3526**	0.3304**	0.2978**	0.1401	0.3405**
1901-1910	-1.3495***	-1.2666***	-1.2646***	-0.7837***	-1.3324***
1911-1920	-0.5070**	-0.5183**	-0.4164**	-0.3818**	-0.4879**
1921-1930	-0.1021	-0.0923	-0.0820	0.02664	-0.1091
1931-1940	0.1869	0.1505	0.2410	0.1409	0.2099
1941-1950	0.2009	0.1187	0.2843	0.03230	0.2374
1951-1960	0.3372*	0.2789	0.3608*	0.1850	0.3486*
1961-1970	0.4295**	0.4223**	0.3584*	0.2845**	0.4129**
1971-1980	0.4505**	0.4883**	0.3222	0.2732*	0.4254**
1981-1990	0.3572*	0.4186**	0.1965	0.2229	0.2952

***p-value<0.01, **p-value<0.05, *p-value<0.1

Table 5: Predictive probability of NCDs for Indian adults by period: Total, place of residence and caste group, NSS 1995-2014

		Place of residence		Caste groups	
Periods	Total	Rural	Urban	1	2
1995	0.009	0.009	0.010	0.008	0.010
2004	0.026	0.025	0.033	0.026	0.028
2014	0.040	0.037	0.052	0.046	0.044

from earlier cohort are older than people from recent cohort, that may be reason for high prevalence of NCDs in earlier cohort people. The recent birth cohort has only prevalence of 15.63 per thousand.

Period effects: Results from Table 4 show that period of observation had not a significant influence on the odds of having NCDs between 1995 and 2014. After controlling birth cohort effect, the predicted probability of having NCDs for adult was 0.009 in 1995 (Table 5). By 2014, the predicted probability of having NCDs for adult was rise to 0.040, representing an increase of around 340%. Also, the pattern of predicted probabilities of having NCDs suggests that over the period risk of having NCDs will increase.

Cohort effects: Table 4 shows that odds of having NCDs significant by birth cohort membership in the India, after controlling other variables (τ_{u0} = 0.3526, p<0.05). From nine random cohorts, six cohort effects were statistically significant in Table 4. The coefficient pattern of cohort effects suggests that recent birth cohorts are at more risk of suffering from NCDs. The transformed predicted probabilities of having NCDs in different birth cohort from coefficient are shown in the Table 6. As the predicted probability of having NCDs for adult in the Indian population inclined steadily from 0.006 for the 1901-1910 birth cohort to 0.030 in the 1981-1990 birth cohort. This indicates that the probability of having NCDs increased to 5 times for cohorts born between 1901-1910 and 1981-1990. The overall pattern of random effects shows an upward trend from 1901-1910 birth cohorts to 1971-1980 birth cohorts.

Table 6: Predictive probability of NCDs for Indian adults by birth cohort: Total, place of residence and caste group, NSS 1995-2014

		Place of residence		Caste groups	
Birth cohorts	Total	Rural	Urban	1	2
1901-1910	0.006	0.006	0.008	0.010	0.006
1911-1920	0.013	0.012	0.017	0.015	0.014
1921-1930	0.019	0.019	0.024	0.022	0.021
1931-1940	0.025	0.024	0.033	0.025	0.028
1941-1950	0.026	0.023	0.035	0.022	0.029
1951-1960	0.029	0.027	0.037	0.026	0.032
1961-1970	0.032	0.031	0.037	0.028	0.035
1971-1980	0.033	0.033	0.036	0.028	0.035
1981-1990	0.030	0.031	0.032	0.027	0.031

Period and cohort effects on NCDs by place of residence: In Table 4, age effect is significantly associated with having NCDs in both rural and urban area. As age is increased, the chance of getting NCDs of individual increased. The period effect is insignificant with NCDs in both rural and urban area. The predicted probability of having NCDs is increasing over the period in rural as well as urban (Table 5). The predicted probability of NCDs was 0.009 in 1995 rose to 0.037 in 2014 for a rural area. While for the urban area the predicted probability was 0.010 in 1995 increased to 0.052 in 2014 for an urban area. The urban people are at high risk of developing NCDs compare to rural peoples as the period is increasing. The birth cohort effect is significant with NCDs in both places of residence. There is the same trend in cohort effects for rural and urban areas. The initial birth cohorts have less risk of developing NCDs compare to the younger birth cohort. From birth cohort 1901-1910, the predicted probabilities of having NCDs rise slowly for subsequent cohorts of the rural and urban area (Table 6). From a low value of 0.006 and 0.008 for adult from the 1901-1910 birth cohort of rural areas and urban areas respectively, the predicted probability of having NCDs increased to 0.031 for rural area and 0.032 for urban areas for 1981-1990 cohort.

Period and cohort effects on NCDs by caste group: From Table 4, age is significantly associated with NCDs in both caste groups. As the age is increasing the risk of getting suffered from NCDs is also increasing. Females are more likely to suffer from NCDs in both caste groups. Educated peoples are more risk of getting NCDs than illiterate people. The period effect is not significant with the suffering of NCD. The predicted probability of suffering from NCDs for adult is 0.008 in 1995 for caste group 1 (Table 5). However, for caste group 2, this probability is 0.010. In 2014, the predicted probability of suffering from NCDs became 0.046 for caste group 1.While the predicted probability of suffering from NCDs became 0.044 for caste group 2. In short, the predicted probability of suffering from NCDs is increasing over the period for both groups. The cohort effect is significantly associated with suffering from NCDs in both caste groups. The predicted probability of suffering from NCDs in different birth cohort is shown in Table 6. The initial cohort has less probability of getting NCDs in both caste groups. While across the cohort probability of getting NCDs is increasing in both caste groups.

DISCUSSION

Age effects represent the variation associated with different age groups brought about by physiological changes, accumulation of social experience and role or status changes. Age effects reflect biological and social processes of aging internal to individuals and represent developmental changes across the life course. Age is the main risk factor for major debilitating and life-threatening conditions, including cancer, cardiovascular disease and neurodegenration[8,9]. From this study, it is clear that old age people are at high risk of NCDs. Study by Yadav and Arokiaswamy[10] supports these current findings. They also have found age a predominant risk factor for NCDs in India[10]. Another study conducted to find leading cause of deaths in rural India, found that NCDs and chronic diseases were leading cause of death in old age population[11].

Period effects represent variation over time periods that affect all age groups simultaneously-often resulting from shifts in social, cultural or physical environments. Shifts in social, cultural, economic or physical environments may in turn induce similar changes in the lives of all people at a given point time. Research evident proved that over the time non-communicable diseases are increasing in India. A systematic review by Gupta *et al.*[12] reported that coronary heart disease (CHD) led to 17% of total deaths and 26% of adult deaths in 2001-2003, which increased to 23% of total and 32% of adults deaths in 2010-2013 in India. Also CHD prevalence over the last 60 years have been increased from 1-10% in urban populations and <1-5% in rural populations.

This study also finds the same kind of results as literature have shown about period effects. Independent of age and cohort effects, the predicted probability of NCDs increased substantially over the period 1995-2014.

Cohort effects are associated with changes across groups of individuals who experience an initial event such as birth or marriage in the same year or years, these may reflect the effects of having different formative experiences for successive age groups in successive time periods[13]. Ryder[14] articulated the conceptual relevance of birth cohort to the study of social-historical change. First, a birth cohort moves through life together and encounters the same historical and social events at the same ages. Cohort effects then reflect formative experiences resulting from the intersection of individual biographies and macro-social influences. Second, the succession of birth cohorts with different life experiences termed demographic metabolism by Ryder[14], constantly changes the composition of the population and transforms the society. Therefore, cohorts can be conceived as the essence of social change. Third, cohort membership could be considered as a social structural category that has an analytic utility similar to that of social class. They both have explanatory power because they are surrogate indices of common characteristics of individuals in each category. Comparisons of historical cohorts can thus be useful in addressing an extraordinary range of substantive issues in social research. Hobcraft *et al.*[15] suggested the use of cohort analysis to capture the process by which the imprint of past events in differentiated by age and becomes embodied in cohorts differentially[15]. The objective of the study is to assess effect of three time related factor age, period and cohort on the non-communicable diseases in India. In addition to confirming the existence of birth cohort effects, this current study also affirms that birth cohort membership has significantly influenced the chance of being suffering from NCDs in India. Relative to earlier cohorts the recent cohort has a higher chance of suffering from NCDs. This indicates that newer birth cohort membership has independently contributed to increase the chance of suffering from NCDs.

This study also detected important differences in age, period and cohort effects by place of residence and caste group in India. The effect of age on the chance of suffering NCDs has nearly same effect in both rural and urban peoples. For instance, rural people did not exhibit substantially different period trends than urban groups. The predicted probabilities of NCDs were substantially increasing higher in urban than rural group across different period. The people from caste group 1 and caste group 2 have an almost same period effect on NCDs in India. The people from caste group 2 have different cohort effects on NCDs than people from caste group 1. For initial cohort predicted probability of NCDs is more in caste group 1 than caste group 2. However, for young cohort probability of NCDs is more in caste group 2.

Strengths of this study include a large nationally representative sample, micro-level data and refined measures of age, period and cohort. This methodological approach enabled us to demonstrate to find the effect of age, period and cohort controlling other covariates on NCDs. The adoption of CCREMs also provides a framework for future analyses to incorporate covariates that may account for incline or decline rate of NCDs in India. Presuming that the inclusion of such variables leads to substantial attenuation of the period and cohort effects, it will contribute much to our understanding of the etiological factors responsible for the health problems. The unavailability of hospital-based information about ailment cases is one limitation of the study. Also, this study uses only three cross-sectional data, NSS 1995, NSS 2004 and NSS 2014. The effect of the period may not be seen due to a small range of the period. Future research should conduct using covering an extended range of period. That will help to learn the true effect of period on the health problem in India.

CONCLUSION

This study concluded that age, period and cohort have effect on the non-communicable disease in India. Along with age, period and cohort are also responsible for increasing prevalence of NCDs in India. Also this effect has differential according to place of residence and caste wise.

SIGNIFICANCE STATEMENT

The present study has used different approach to find the determinant of non-communicable disease in India. This study used the age, period, cohort approach to investigate the risk of non-communicable diseases in India. This method provides the risk of the outcome in different survey year (Period) controlling the cohort effects. Similarly, provides the risk of the outcome in different cohorts controlling the period effects. And also, this type of study was not conducted in India on the risk of NCDs. Very first study in India which has used three time variant factors to see changing pattern of NCDs. This study will help policy makers to frame policies considering generational changes of getting NCDs in Indian population.

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