Chapter 1

Introduction

1.1 Introduction

The study of frequency, distribution and determinants of health-related events (including diseases) and its application in the control of diseases and other health problems is called epidemiology (Porta, 2008). It offers feedback to policy decisions and evidence-based practice by identifying risk factors for disease and targets for preventive healthcare. It is the cornerstone of public health because for policy making and health planning, it is necessary to have reliable information about health situation of population at micro level.

Understanding health in a society and providing appropriate health care requires evidence about death and disease (Evans and Standsfield, 2003). The crude death rate, maternal mortality rate, child mortality rate and life expectancy are basic indicators of the general welfare of a population and provide an indication of the quality of life (United Nations, 1984). The health situation in a country can generally be judged by looking at the cause of death patterns because mortality transition and subsequent fertility decline brings changes in population composition. Subsequently, there will be changes in the diseases pattern – transition from the age of famines and epidemics to the age of degenerative and life style related diseases (Reddy, 1989).

India does not have good quality data on health situation of its population particularly the rural population where three-fourth of its total population live. Information on causes of death is of key importance in understanding the determinants of health and mortality (Palloni, 1991). Reddy (1993) pointed out that cause of death information from hospital based data suffer from several types of selection biases and do not provide a true picture of the population. In India, reliable standardized cause-specific mortality rates are not computed because of unsatisfactory death certification even for the urban population (Bhat 1991, 1995).

Mortality influences the rate of growth of population and provides the dimensions of demographic perspective. Identifying consistent regional or temporal
discrepancies in the cause structure of mortality is a strong component in understanding the health situation of a country. The pattern of death by causes reflects the health status of a community and in turn provides a rational basis for health planning. Preston (1976) pointed out that ignoring causes of death in the study of mortality is somewhat akin to ignoring fecundity, exposure, contraceptive use effectiveness and foetal wastage in the study of fertility. Consideration of differential effects of causes of death on measures of survivorship can provide additional information in the planning of and assigning priorities to health services (Carr and Lee, 1978). It is also important to consider the effect of population age composition and its inter-relationship with mortality for intervention and/or the health plan implementation (Carr and Lee, 1978). In case of overall mortality, United Nations (1998) pointed out that the extent of the excess male mortality varies by age and cause of death. Especially in the developed countries male rates exceed female rates for majority of the causes. Pandey et al., (1998, 2004) found that in India child mortality is 40% high in girls than boys.

In the current century, the level of mortality has declined considerably in most of the countries worldwide and thus generally improved the health standard of population. However, this mortality decline further triggered morbidity rates upward as the new survivors had their condition worsened as they developed new illness during their extra age years (Verbrugge, 1996). It demands for evaluation of the reasons behind the mortality decline. The causes of death analysis will throw some light on this. It is important in mortality analysis because morality levels in various cause categories often respond to different determinants and also since illness vary in the duration and severity of the impairments they entail prior to fatality (Kingkade and Tore, 1992). It is also noted that expectation of life measure gives more importance to causes of death which act earlier in the life span, as these causes of death result in the loss of a larger expected future life time (Tickle, 1997). The cause of death structure on age patterns of mortality is a serious endeavour and will provide explanation to the variation in age pattern of mortality.

Apparently, it is critical for determining public health policy, planning health programmes, and evaluating health care activities and intervention results (Quigly et al., 1999). Measuring cause-specific mortality and burden of chronic morbidity in
developing countries is however problematic due to the fact that vital registration systems are often non-existent and many deaths occur at home (Gray et al., 1990).

Data on mortality by age, sex and cause are primary inputs for assessing population health status, and a cornerstone of the evidence base for health policy, in combination with other epidemiological and socio-economic information. While medically certified cause of death data from complete civil registration systems is the ‘gold standard’ for such statistics, these are generally not available in over two-thirds of all countries (Mathers et al., 2005). Even if the levels and trends were reliably estimated, further improvements in population health would require accurate information on cause-specific mortality to guide policy and programme priorities (Ruzicka and Lopez, 1990). There are also well understood connections between temporal changes in mortality patterns and epidemiological transition making it possible to extrapolate from mortality findings to estimate fatal disease burden in a community (Gribble and Preston, 1991).

Mortality transition reflects improvement in the quality of life through improvements in the health and nutritional status of people and therefore, it is a necessary requirement for improvement in the standard of living (United Nations, 1973). The analysis of mortality transition also contributes to the evolution of health policy. Ideally, there should be congruence between transition in mortality and the evolution of health policy, as health policy directly reflects levels and trends in mortality. The evolution of health policy should essentially be a response to the health status of the population, as reflected in changes in mortality. With an improvement in the health status of a population, the disease profile changes and there is a shift in patterns of causes of death with a transition in the age pattern of mortality. The evolution of the health policy, therefore, should also be a response to mortality transition resulting from the improved health status of the population.

In the absence of cause of death statistics, Spiegelman (1955) and Kitagawa (1964) suggested a number of mortality indexes and discussed their merits and demerits. Kitagawa (1966) found that the use of different indexes of mortality may provide different pictures of mortality transition. Aggregative indexes present problems of choosing the appropriate standard population, and various factors
involved in the selection of the standard are of appreciable significance (Spiegelman and Marts, 1966). However, there is no widely accepted average of relative index that is intuitively simple, easy to calculate, expressive of underlying mortality function and independent of the choice of the ‘standard’ population. It would, therefore, be desirable to focus on differences in the patterns of death rate over the whole age spectrum (Schoen, 1970).

Analysis of mortality transition which takes into consideration the whole age spectrum can be done in different ways. The common approach is to decompose the change in the expectation of life at birth into the change in the expectation of life at different ages (Pollard, 1982; United Nations, 1982). Such analyses have been carried out for India in the past by Gupta (1972), Chandrasekharan (1986), Navaneetham (1993) and Chaursaia (1993). This approach has also been used to analyze mortality transition in urban India (Chauraia, 2006). Ponnapalli (2005) has reviewed different methods of decomposition and concluded that all methods give exactly the same result.

In order to have a uniform procedure for tabulating statistics and enhancing their usefulness as instruments of research, the Sixth Decennial International Revision Conference, meeting in Paris in 1948, recommended that the cause of death should be the underlying cause and defined as "(a) the disease or injury which initiated the train of morbid events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury". To ensure uniformity in application of this principle, the Revision Conference designed the International Form of Medical Certificate of Cause of Death.

Since 1949, cause-of-death statistics have been based on the underlying cause of death. The official international statistical classification defines cause of death as "the disease or injury that initiated the train of events leading directly to death, or the circumstances of accident or violence which produced the fatal injury" (Dublin, et al., 1949; WHO, 1977; Bogue, et al., 1993).
1.2 Classification of Cause of Death

The International Classification of Disease (ICD), published by the World Health Organisation (WHO), is designed to promote international comparability in the collection, processing, classification, and presentation of morbidity and mortality data. It is the international standard diagnostic classification for all general epidemiological purposes, many health management purposes and clinical use. It is used worldwide to classify diseases and other health problems recorded on many types of health and vital records, including death certificates. In addition to enabling the storage and retrieval of diagnostic information, these records provide the basis for the compilation of national mortality and morbidity statistics by WHO member states.

The ICD is revised periodically. The latest version available is ICD-10 which was endorsed by the Forty-third World Health Assembly in May 1990 and came into use in WHO member states from 1994 (WHO, 1993). In ICD-10 diseases have been classified under 21 categories as follows:

i. Certain infectious and parasitic diseases (A00-B99)
ii. Neoplasms (C00-D48)
iii. Diseases of the blood and blood forming organs and certain disorders involving the immune mechanism (D50-D89)
iv. Endocrine, nutritional and metabolic diseases (E00-E89)
v. Mental and behavioural disorders (F01-F99)
vi. Diseases of the nervous system (G00-G98)
vii. Diseases of the eye and adnexa (H00-H59)
viii. Diseases of the ear and mastoid process (H60-H95)
ix. Diseases of the circulatory system (I00-I99)
x. Diseases of the respiratory system (J00-J98)
xi. Diseases of the digestive system (K00-K92)
xii. Diseases of the skin and subcutaneous tissue (L00-L98)
xiii. Diseases of the musculoskeletal system and connective tissue (M00-M99)
xiv. Diseases of the genitourinary system (N00-N99)
xv. Pregnancy, childbirth and the puerperium (O00-O99)
xvi. Certain conditions originating in the perinatal period (P00-P96)
xvii. Congenital malformations, deformations and chromosomal abnormalities
(Q00-Q99)

xviii. Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (R00-R99)

xix. Injury, poisoning and certain other consequences of external causes (S00-T98)

xx. External causes of morbidity and mortality (V01-Y89)

xxi. Factors influencing health status and contact with health services (Z00-Z99)

Each of the above categories has been divided into subsections and each section has a listing of further division and each division is further divided into a decimal digit code. When analyzing past trends it is important to allow for changes introduced when the ICD coding changes. For example, significant changes between ICD-9 and ICD-10 include a change in the format of the code, an expansion of the number of codes used, a movement of some diseases and conditions between broad groups and changes to the rules governing the selection of the underlying cause of death, which has had a large effect.

The main innovation differed from the previous revision is in the use of an alphanumeric. The cause of death code begins with an alphabet, A to Z, except U (25 categories). An exceptional alphabet is being prepared for adding and changing the cause of death in the future. So, the tenth Revision code was expanded to more than double the ninth Revision. The result of ICD revisions effected terms and definition of cause of death diagnosis which influenced the number of deaths as well.

One thousand groups of diseases have been identified and these are re-grouped in an intermediate list of 150 causes numbered A1, A2, A3, etc. These, in turn, are regrouped into an abbreviated list of 50 causes numbered as B1, B2, B3, etc. This list of 50 groups of causes is used for computing deaths and death rates on the basis of the causes of death.

Again, from this list of 50 groups of causes, various diseases have been re-grouped in five categories according to their response to various health programmes and medical care. These are:
Group I Infectious, parasitic, and respiratory diseases.

Group II Cancer

Group III Diseases of the circulatory system

Group IV Deaths from violence

Group V All other causes, including gastrointestinal diseases, diabetes mellitus, birth injuries and diseases peculiar to the first week of life.

At the global level, the 10 leading causes of the death are due to specific diseases such as ischaemic (coronary) heart disease, cerebrovascular diseases, acute lower respiratory infection, tuberculosis, chronic obstructive pulmonary disease, diarrhoea and dysentery, HIV/AIDS, malaria, pre-maturity and cancer (bronchus and lungs).

Cause of death statistics plays an important role in health administration. These constitute a link between vital and health statistics. Statistical information for the cause of death is collected as a part of vital statistics system. In India, the registration system classify mortality statistics in eight causes or groups of causes, viz. (1) Cholera, (2) Small pox, (3) Plague, (4) Dysentery and Diarrhoea, (5) Respiratory Diseases, (6) Fevers, (7) Accidents and injuries, (8) and other causes.

Life expectancy is one of the most widely used population health indicators. These estimates are used by public health workers, demographers, actuaries, policy makers, and many others in studies of longevity, fertility, migration, and population growth. Estimates of life expectancy are derived from a demographic model that describes and summarizes the mortality and survivorship of a population in the form of a life table. Practically, life expectancy depends on health status, age, sex, marital status, lifestyle, income, place of residence, etc. Statistically, life expectancy is influenced by the method used to calculate life tables and by the population estimates chosen.

Life expectancy \( (e_x) \) especially life expectancy at birth \( (e_0^0) \) is a good indicator of current health conditions and the most commonly cited life expectancy measure. Certainly, it can be calculated by the average number of years a person could expect
to live with the life table method. The most fundamental step in life table construction is to convert age-specific death rates \((a_{mx})\) to the probability of dying \((a_{qx})\). The life expectancies \((e_x)\) are derived in the last step. Life expectancy is a hypothetical measure; it is a calculable and comparable indicator. As a matter of fact, life expectancy at birth is an indicator of current health outcomes (Shryock, et al., 1971; Population Reference Bureau, 2000; Prasartkul and Vapattanawong, 2001).

The measurement of cause-specific mortality is needed for several purposes viz., (i) to establish the relative public health importance of different causes of death; (ii) to evaluate the probable impact of intervention programmes; (iii) to investigate the circumstances surrounding the death of children from specific causes and to devise effective actions to decrease mortality; (iv) to investigate the reason for differing rates of infant and child mortality between geographical areas; and (v) to evaluate the effectiveness of specific health intervention in controlled settings (WHO/UNICEF, 1994).

Understanding the trends and patterns of mortality is essential for the future planning of any country. This is necessary because the trends are used in the projection of future population and considered as base for allocations made for each section of the population. In the various stages of the demographic transitions, all countries have experienced differential levels of mortality by sex. A clear idea about sex differentials in mortality can be observed by a careful examination of the level of mortality in various countries which are at different levels of demographic transition. The cause of death pattern gives a clear idea about the mortality situation in the study population. The causes of death pattern are different for males and females. As per Preston et al., (1972), study of cause of death in the study of mortality is as important as the inclusion of abortion and still births in the analysis of fertility. It is very important to look into the role of each cause in influencing the life expectancy at various ages.

Changes in the pattern of causes of death is a reflection of epidemiological transition which is characterized by the shift from the predominance of infectious and parasitic disease to that of chronic and degenerative diseases of adulthood as the main cause of death (United Nations, 1998). Demographic transition, health transition,
nutritional transition and epidemiological transition overlap and it is difficult to affirm which one precedes the others. All these transitions are the product of socio-economic development and modernization. Demographic and epidemiologic changes are characterized by growth of middle-aged and elderly persons and diseases that occur in these age groups. The transition is the result of an increase in life expectancy, improved maternal and child health, reduction in fertility and maternal and infant mortality.

1.3 Epidemiological Transition

Demographic transition is a fundamental component of development (Dyson, 2010) that occurs often but not always in tandem with economic growth (Caldwell, 2006). The demographic transition began during 19th century in developed countries of the world and developing countries initiated their transitions during 20th century. Fertility decline is a key feature of the demographic transition toward the replacement level of 2.1 children per women or even lower. Mortality decline is a second key feature with mortality rates fall first among children and gradually among adults as well (United Nations, 2012).

For the world’s population as a whole, life expectancy at birth increased from 48 years in 1950-1955 to 68 years in 2005-2010. Asia was the region with the largest increase in life expectancy, from 43 years in 1950-1955 to 69 years in 2005-2010. Latin America and the Caribbean saw an increase in life expectancy from 51 years in 1950-1955 to 73 years in 2005-2010. In 1950-1955 developing Oceania (including the populations of Melanesia, Micronesia and Polynesia) and Africa were the regions of the world with the lowest life expectancies at birth at 39 years and 38 years respectively. Developing Oceania witnessed a 25-year increase in life expectancy by 2005-2010, while in Africa, life expectancy at birth advanced by 17 years. In the “more developed regions, excluding Eastern Europe,” average life expectancy at birth exceeded 66 years in 1950-1955 and life expectancy increasing to 80 years in 2005-2010. Life expectancy at birth increased in Eastern Europe over the period 1950-1955 to 1965-1970 from 64 years to 70 years, but then stagnated and even declined somewhat at various periods till 2005-2010 (United Nations, 2012).
In Africa, 59% of the 17-year gain in life expectancy between 1950-1955 and 2005-2010 was due to mortality decline among children under five. Another 12% of that gain was due to improvements in survival between ages 5 and 14, while the other four age groups each contributed less than 10% of overall improvement in life expectancy. In “more developed regions, excluding Eastern Europe,” 35% of the 13-year increase in life expectancy was attributable to survival gains above age 60. Age group 30-59 had loss of life expectancy of just over 1 year because mortality rates actually increased in this age group over that period. Improvements in survival of children under five accounted for nearly all of the gain in life expectancy at birth. But although deviations from the typical course of mortality decline can occur (Caselli et al., 2002) as is the case in Eastern Europe.

Together, falling fertility and mortality rates produce a third key feature of the demographic transition: population ageing. Declining mortality rates among young people, together with population ageing, yields an increasing concentration of deaths at older ages as populations progress through the demographic transition.

Over the period 2005-2010 in Africa, 37% of deaths took place among children under five, while 22% occurred among adults aged 60 or over. In Asia, children under-five contributed to 14% of deaths and 57% were to older adults, while in the “more developed regions, excluding Eastern Europe,” less than 1% of deaths were to children under five and 85% were concentrated among adults over 60. Eastern Europe departs from the typical pattern of the demographic transition, with a smaller proportion of deaths occurring among children under five (1%) compared to Latin America and the Caribbean (9%). Notably, the proportion of deaths occurring between the ages of 45 and 59 is higher in Eastern Europe at 18% than in all the other regions (United Nations, 2012).

The increasing concentration of deaths at older ages that occurs as population age is a key phenomenon contributing to the changing patterns of deaths by cause.

Underlying patterns of mortality decline that occur with the demographic transition is a change in the distribution of deaths by cause from communicable diseases to non-communicable diseases. This process, known as the epidemiological
transition, was first elaborated by Abdel Omran in 1971. He described how infectious diseases including tuberculosis and diarrhoeal diseases among others, accounted for more than half of all deaths in England and Wales around the mid-19th century. The contributions of these causes to overall mortality declined dramatically by mid-20th century and accounted for around one in ten deaths. A similar transition was observed in Japan. Infectious diseases accounted for approximately 40% of all deaths in Japan around 1945, but by 1964 their contribution had fallen to less than 10% of overall mortality (Omran, 1971).

Those countries that initiated their epidemiologic transitions in mid-19th century had a shift in burden of diseases from infectious to non-communicable diseases gradually over a century. In contrast, countries that began their transitions in mid-20th century or later had progressed much more rapidly. In Sri Lanka, where the epidemiologic transition began around 1940, the proportion of deaths due to infectious diseases declined from around 40% to 20% in 25 years (Omran, 1971).

Estimates of distribution of deaths by cause shed light on various populations’ stages within the epidemiologic transition. The World Health Organization (WHO) produces estimates of the number of deaths by cause for 193 of its Member States. For the 2008 estimates (WHO, 2011), 76 countries representing 24% of all deaths globally had reasonably complete cause-of-death information from vital registration corresponding to ICD-9 or ICD-10 and with less than 15% of deaths with inappropriate or non-specific cause of death codes. For an additional 36 countries representing 46% of global deaths, death registration was incomplete or cause-of-death information was available from other nationally representative sources. For the remaining 79 countries, representing 30% of all deaths, country information on causes of death was not available for most causes.

In summarizing deaths by cause, the WHO considers three broad categories of causes of death (WHO, 2011): Group I encompass communicable diseases as well as maternal, perinatal and nutritional conditions; Group II includes non-communicable diseases; and Group III comprises causes of death resulting from external sources, namely injuries, including both intentional and unintentional injuries. Of the estimated 56.9 million deaths worldwide during 2008, 36.1 million (63.5%) were caused by
Group II NCDs, especially cardiovascular diseases, cancers, diabetes and chronic respiratory diseases. Group I health conditions caused 15.6 million deaths (27.5%), with lower respiratory infections (pneumonia), perinatal conditions and diarrhoeal diseases as the leading causes. The injuries classified in Group III caused the remaining 5.1 million deaths (9.0%), with road traffic accidents, suicides and homicides accounting for the largest share of deaths (United Nations, 2012).

In Africa, the majority of deaths (61.0%) were due to Group I health conditions, while the NCDs in Group II and the injuries in Group III accounted for 32.0% and 7.0% of deaths respectively. It indicates that the region is still in the early stage of the epidemiologic transition. In contrast, in the “more developed regions, excluding Eastern Europe”, 6.6% of deaths were attributed to Group I causes, while Group II NCDs caused 87.5% of deaths; Group III injuries were responsible for 5.8% of deaths. It confirms the region to be in the later stage of the epidemiologic transition (United Nations, 2012).

In developing Oceania, where 78% of deaths were located in Papua New Guinea, 41.9% of mortality was due to Group I conditions, but close to half of deaths (49.7%) were caused by Group II NCDs. In both Asia and Latin America and the Caribbean, the NCDs in Group II caused the majority of deaths (65.5% and 72.0%, respectively), while Group I conditions were responsible for 16.4% and 14.0% of deaths. The proportion of deaths due to Group II NCDs was large (85.5%), while the proportion due to Group I causes was comparatively small (4.7%) (United Nations, 2012).

According to Omran’s epidemiologic transition model, during the early stages of demographic and epidemiologic transitions mortality is high among both children and adults as the result of frequent epidemics and periods of famine that produce a large burden of Group I health conditions. With improvements in nutrition, hygiene, sanitation, public health and medical technologies, such as vaccines, the incidence of Group I condition declines – especially among children – and the population progresses to the mid-stage of the epidemiologic transition, which Omran labelled as the “age of receding pandemics”. During this stage, Group I health conditions account for a shrinking proportion of all deaths, giving way to an increasing
predominance of non-communicable diseases. In the late-stage of the epidemiologic transition, Group II NCDs, which Omran referred to as the “degenerative and man-made diseases”, are the main drivers of mortality patterns.

In 1986, Olshansky and Ault proposed a fourth stage of the epidemiologic transition to be appended to Omran’s model. The “age of delayed degenerative diseases” is characterized by continued improvements in life expectancy that result in part from improvements in medical technologies and the introduction of social and public health programmes that target chronic disease, producing a shift in Group II NCD mortality to progressively older ages (Olshansky and Ault, 1986).

Grouping countries by level of life expectancy at birth yields some insight into the associations between the improvements in longevity that occur with the demographic transition and progress through the epidemiologic transition. For populations with the lowest life expectancies, below 50 years in 2005-2010, nearly 70% of all deaths were attributable to Group I causes. At progressively higher levels of life expectancy at birth, the percentage of all deaths that were due to communicable, maternal, nutritional and perinatal conditions declined. Accordingly, Group I causes accounted for 21% of deaths in countries with life expectancies at birth between 65 and 69 years and only 7% of deaths in countries with life expectancies between 75 and 79 years. While less than one quarter of deaths in countries with life expectancies at birth below 50 years in 2005-2010 were due to NCDs, in countries with life expectancies greater than 75 years, 86% of all deaths were attributable to NCDs (United Nations, 2012).

Countries that experienced high mortality, as evidenced by life expectancies at birth below 50 years in 2005-2010, around 7% of all deaths were due to Group III causes. Countries in the middle-stages of their demographic and epidemiologic transitions, with life expectancy at birth between 60 and 64 years had greatest percentage of deaths due to external injuries at close to 11%. For countries advanced in their transitions, with life expectancy at birth greater than 80 years in 2005-2010, around 6% of deaths were due to Group III causes (United Nations, 2012).
Vital registration records indicate that in the middle part of the 20\textsuperscript{th} century, when life expectancy at birth in Chile was around 55 years, more than 40\% of deaths were attributable to communicable diseases and perinatal, maternal and nutritional conditions. Over the last 50 years, however, mortality from Group I causes has declined substantially in Chile such that by 2005 these conditions were responsible for less than 10\% of all deaths and life expectancy at birth soared to nearly 79 years (United Nations, 2012).

In 1986, more than 60\% of all deaths in the Matlab surveillance area were due to communicable diseases and maternal and neonatal conditions, while less than 10\% were attributable to non-communicable diseases and 5\% were due to injuries. By 2006, the pattern of deaths by cause had shifted dramatically such that communicable diseases and maternal and neonatal conditions as a group accounted for less than 20\% of all deaths, while non-communicable diseases were responsible for the majority of mortality (68\%). A 10-year improvement in life expectancy at birth was observed in Matlab over this period, from 58 years in 1986 to close to 68 years in 2006 (United Nations, 2012).

1.4 Age and Sex Patterns in Epidemiological Transition

The impacts of different health conditions vary by age and sex as a result of both biological and behavioural factors that determine susceptibility to certain illnesses or injuries. Also, the relative weight of different age groups in the population interacts with the age-specific risks of death from various causes to determine the percentage distribution of deaths by cause over the course of demographic and epidemiologic transitions. Therefore, examining causes of mortality by age and sex is critically important for understanding the transition processes.

Among children under five, Group I causes accounted for the overwhelming majority of deaths (89.2\%), while Group II and Group III causes accounted for 7.4\% and 3.4\%, respectively, of deaths in 2008. NCDs were responsible for 17.6\% of deaths of children age 5 to 14 years, while injuries accounted for another 27.1\% of deaths. Group I causes accounted for 35.7\% of deaths to those age 15 to 29. NCDs were responsible for 24.0\% of deaths, while injuries caused the largest proportion of deaths (40.3\%). Within the age groups 30 to 44 years and higher, NCDs (Group II)
caused the greatest proportion of deaths, ranging from 39.2% among those age 30 to 44 to 85.5% among those age 60 or above. While Group I conditions caused 37.6% of deaths among adults age 30 to 44, reflecting a concentration of AIDS-related mortality in this age group, the proportion of deaths due to Group I causes fell to 16.8% for those age 45 to 59 and to 10.5% among those age 60 and above. Group III conditions accounted for 23.2% of mortality among those age 30 to 44, but only 4.0% of mortality among those age 60 and above (United Nations, 2012).

Among children under five, death rates from the three major groups of causes were similar by sex. Cause-specific death rates also differed little by sex among children and adolescents age 5 to 14 years. Among those age 15 to 29 years, the mortality rate due to Group III causes among males (1.0 death per 1,000 persons) was more than twice the rate among females (0.4 deaths per 1,000 persons). In the age group 30-44 years, death rate due to Group II conditions among males (1.5 deaths per 1,000 males) was about 50% higher than among females (1.0 death per 1,000 females). The death rates due to Group I conditions were identical for males and females (1.2 deaths per 1,000 persons), thus the higher male mortality was due entirely to excess deaths from NCDs and injuries. At age 45-59 years, males were 59% more likely than females to die from a Group I cause, 58% more likely to die from a Group II NCD and 189% more likely to die as a result of a Group III injury. Males age 60 and above were 18% more likely than females in that age group to die of a Group I cause, 19% more likely to die of a Group II NCD, and 53% more likely to die from a Group III injury (United Nations, 2012).

Young children are particularly susceptible to death from communicable diseases because their immune systems are relatively immature and they are more frequently exposed to disease-causing organisms (Simoes et al., 2006). In 2008, the rate of death from Group I causes was highest amongst children, with 11.7 deaths per 1,000 children under age five. After age five, death from Group I causes remained rare until old age; among those age 60 and over, the mortality rate from Group I causes was 4.6 per 1,000. The sharp increase in the death rate from Group I causes above age 60 was due to large increase in deaths from pneumonia at older ages. Pneumonia was responsible for 55% of Group I deaths above age 80. Death rates from Group I causes were substantially lower among those age 5 to 14 years and 15 to
29 years compared to children under five. Deaths from Group II and Group III causes were similarly rare among these age groups, with each group of causes resulting in less than 1 death per 1,000 person age 5 to 14 years and 15 to 29 years in 2004. While Group II causes produced only 0.4 deaths per 1,000 person age 15 to 29 in 2008; the death rate from NCDs increased sharply with age to 1.3 deaths per 1,000 person age 30 to 44; 5.7 deaths per 1,000 person age 45 to 59; and 37.7 deaths per 1,000 person over age 60 (United Nations, 2012).

Global death rates from Group III causes ranged from 0.3 per 1,000 among those age 5 to 14 years to 1.8 deaths per 1,000 among people age 60 and above. Despite a common perception that adolescents and young adults face higher risk of death from injury (WHO, 2003b), the mortality rate from injuries was lower among those age 15 to 29 compared to older adults (0.7 injury-related deaths per 1,000 people age 15 to 29 versus 1.8 injury-related deaths per 1,000 people age 60 and over). However, because the death rate from all causes was low among those age 15 to 29 years, Group III causes comprised a larger proportion of all deaths in this age group (40.3%) relative to the other age groups (United Nations, 2012).

1.5 Epidemiological Transition in India

India is currently in the third phase of demographic transition during which the increase in population is mainly in the 15-60 age group. Optimal use of this demographic opportunity can result in rapid improvement in economic growth, nutrition and health status of the population. This demographic phenomenon is one of the major challenges of health sector reforms because of diverse socio-cultural groups and variation in health needs of the people of different regions.

The population of India, at the turn of the 20th century was around 238.4 million. This has increased by more than four times in a period of one hundred and ten years to reach 1210 million in 2011. Interestingly, the population grew by one and half times in the first half of the 20th century, while in the later half it recorded a phenomenal three-fold increase. The growth rate was more than 2% per annum between 1961-1991 census periods. During 2001-2011, it has declined to 1.64% per annum from 1.97% during 1991-2001. The sex ratio (female to male) in the age group 0-6 years has decreased from 945 in 1991 to 927 in 2001 and 914 in 2011 (RGI, 1991,
It is expected that the population will stabilize around 2060 with estimated population size of 1.72 billion (United Nations, 2011). However, other estimates provided by Population Foundation of India and the Population Reference Bureau (PFI-PRB 2007) suggest stabilization by 2080, with a population size of 1.86 billion.

The country is also experiencing epidemiological transition (Gowariker, 1994; James 2011). Combined effect of decreased fertility and mortality and better survivorship are affecting the level and patterns of mortality and morbidity. While chronic diseases, such as heart disease and diabetes are on the rise, still communicable disease remains the major challenge. It has the highest burden of communicable diseases in the world, with malaria and tuberculosis among the leading causes of death. Children bear the greatest burden of communicable diseases. Pneumonia and diarrhoea cause most of the childhood mortality. Reversing communicable disease epidemic is one of the Millennium Development Goals.

In the 21st century, there has been a paradigm shift in the health problems from communicable disease to non-communicable diseases (NCDs) which is a major public health challenge of growing magnitude. The major non-communicable disease prevalent in India includes diabetes, hypertension, cardiovascular disease, mental illness, chronic obstructive pulmonary disease, and cancer etc. Cardiovascular disease, cancer and Type 2 diabetes mellitus account for 53% and 44% of all deaths and disability adjusted life years (DALYs) respectively (WHO, 2005). Prevention of NCDs becomes a major task which demands a unified approach at the national level.

Prevalence of diabetes and its adverse health effects have risen more rapidly in South Asia, including India. By 2030, while most people with diabetes in developed countries will age 65 years or more, in the developing countries the majority will be in the 45-64 years age category and afflicted in their most productive years (Ramachandran et al., 2001; WHO, 2005). India leads the world presently with 35 million diabetic subjects and this figure is projected to increase to about 80 million by the year 2030. Approximately 20% of world’s diabetic population resides in India.

It has been estimated that in India more than 2.4 million deaths are due to
cardiovascular disease, which is approximately 25% of all deaths, which is far greater than the deaths due to infectious diseases like diarrhoea, respiratory infection and tuberculosis. In about 15 years, India is expected to lead the world in cardiovascular mortality. CVD deaths are more seen in working people age 35-64 years, in whom 35% of CVD deaths occur (Leeder et al., 2004).

Estimates suggest that nearly 55 million Indians are currently affected by hypertension. Various epidemiological studies in Indian subcontinent have indicated a rising trend of 20-36% in the prevalence of hypertension.

Cancer alone contributed to 14% mortality in the South East Asia region in 2002 (WHO, 2002, 2003b) and 7% deaths were attributed to cancers in India alone in the year 2005 (Reddy et al., 2005). Annually around 70 new cancer cases are detected for every 100,000 population in India and in any given year, there are almost 15 lakhs cancer patients.

In India, deaths from non-communicable diseases are projected to almost double from about 4.5 million in 1998 to 8 million by the year 2020. In the year 2005, 53% of all deaths were due to NCDs and this is projected to increase by 18% over the next 10 years.

1.6 Review of Literature

Cause of death statistics by age, sex and other socio-economic characteristics are essential inputs to understand the magnitude and distribution of the health problem in any society. The pattern of cause of death has been well documented in developed countries. Among them, Abdel Omran’s (1971) theory of epidemiological transition is an attempt to account for the extraordinary advances in health care made in industrialized countries since the 18th century (Caselli et al., 2006). According to epidemiologic transition theory there is a regular transformation of the causes of death pattern in a population. The mean ages at death increases progressively with the progress in medicine and health care services and major infectious and parasitic diseases give way to a variety of manmade and degenerative diseases (Omran, 1971).
1.7 Previous Global Studies on Cause of Death

Preston and Nelson (1974) developed a model of mortality cause-structure grouped into eleven causes of death viz., respiratory tuberculosis; other infectious and parasitic diseases; malignant and benign neoplasm; cardiovascular diseases; influenza, pneumonia, bronchitis; diarrhoea, gastritis, enteritis; certain chronic diseases; maternal mortality; certain diseases of infancy; violence and all other and unknown causes at various levels; mortality from all causes, by using data for 165 populations, undifferentiated by period or region. The findings showed that as time progressed the infectious and parasitic diseases have contributed very little to a particular level of overall mortality. On the other hand, substantial sex differentials were observed in case of cardiovascular diseases and neoplasm. Each of these causes contributed significantly for males; while for females, neoplasm did not show such a tendency and the trend of cardiovascular diseases is very low.

Preston also presented the first comprehensive model relating total mortality and cause-specific mortality by analyzing the historical registration data of industrialized countries and a few developing countries (Preston, 1976). This analysis showed that except for neoplasm in both sex and cardiovascular disease in males, the mortality rates from each specific cause were expected to decline as total mortality declined.

The United States National Center for Health Statistics examined the causes of death on the assumption that when a specific cause of death or a group of causes of death are eliminated, it is not possible to die from the eliminated causes. It prepared a abridged life table for the total population of the United States in 1959-1961 on the assumption that malignant neoplasm is eliminated. A series of causes combined provided measures of the relative importance of different causes of death. The result showed that 2.27 years of life would be added to life expectancy at birth for the total United State population in 1959-1961 if cancer was eliminated (United States, 1968).

Manton et al., (1976) examined the multiple cause mortality for the state of North Carolina in 1969 and focused on chronic disease. They considered only the death of those over 30 to 95 years and over with the sample size of 39,631, and fixed the terminal age of life expectancy at 2.5. The first age group (30-34 years) had a life
expectancy of 36.75 years. They found that the life expectancy would be increased by 5.80 years for cardiovascular diseases, 2.21 years for neoplasm, 0.06 for respiratory condition and 0.20 for hypertension, if eliminated.

In the United States of America, Tsai et al., (1978) found that elimination of cardiovascular disease would result in addition of 12.36 years in expectation of life at birth for combined population, 11.10 years for white males and 10.74 years for non-white males. The gain in life expectancy was 12.81 years for white females and 15.66 years for non-white females.

Manton (1980) prepared the cause elimination life tables for United States white and black population classified by sex. The result showed that in white, in the single causes of death, cancer and stroke, females (cancer 2.6, stroke 1.4 years) have more gain in life expectancy at birth than males (cancer 2.3, stroke 0.9 years). Among blacks, the result showed when all the causes were eliminated; females (cancer 2.5, stroke 2.4 years) have more gain in life expectancy at birth than males (cancer 2.3, stroke 1.5 years).

Hakulinen et al., (1986) identified seven major causes of death as infectious and parasitic diseases; neoplasm; circulatory system and certain degenerative diseases; complications of pregnancy; certain perinatal conditions; injury and poisoning; and other causes. These categories correspond to specific codes in the International Statistical Classification of Diseases, eighth and ninth revisions (ICD 8-9). The countries which routinely reported their cause of death information to the World Health Organization (WHO) were supplemented with regression estimates for many non-reporting countries. The regression approach, initially by Preston (1976) was continued and developed by Hakulinen et al., (1986). This study was used only in the prediction of mortality rates by cause for age-sex groups as linear functions of mortality rates for all causes, and was estimated for each of the 24 world regions. These regression equations indicated that mortality rates for most causes, except neoplasm, increased with overall mortality. The increases were greatest for infectious and parasitic diseases. Half of the mortality increases was due to infectious and parasitic diseases, 25% from perinatal conditions and 22% from other causes. The results also vary by age and sex; there was a 7% change in age group 1-4 years, 4% in
65 years and over, and a difference by sex of males 13% and females 4%.

Porapakkam and Prasartkul (1986) conducted a study and examined the major causes of death for the time period 1968 through 1983. The result indicated that the major causes were predominantly communicable diseases such as diarrhoea, diseases of the respiratory system especially pulmonary tuberculosis and pneumonia. Non-communicable diseases such as heart disease, cancer and malnutrition were not the major causes. The study also indicated that the causes of death since 1980 have changed markedly.

The Global Burden of Disease study (Murray and Lopez, 1996, 1997) provided the first comprehensive assessment of global and regional mortality patterns based on the measurement of fatal disease and injury. Overall, the causes of death were divided into three broad disease categories (Group I: Communicable diseases, maternal causes, conditions arising in the perinatal period and nutritional deficiencies, Group II: Non-communicable diseases, and Group III: Injuries). Each group was divided into sub-categories of disease and injury which was further disaggregated into specific causes of death. The deaths assigned to ‘ill-defined categories’ were reassigned to specific causes of death within the above mentioned classification scheme by redistributing ill-defined deaths occurring in childhood to Group I (Communicable diseases) and ill-defined adult deaths to Group II (Non-communicable diseases) (Lopez and Murray, 1998).

White (1999) examined the cardiovascular and tuberculosis diseases by using multiple decrement and cause elimination life tables of the United States from 1900 to 2000. His study showed that cardiovascular diseases have added slightly more gain than tuberculosis mortality. Without tuberculosis mortality improvement, life expectancy at birth would be 70.8 years. If tuberculosis mortality trend were constant, life expectancy at birth in 2000 would be 76.1 years and if cardiovascular death rate were still constant, life expectancy at birth would be 69.9 years. The change in cardiovascular mortality has a greater effect on life expectancy than change in tuberculosis mortality.

Susanna et al., (1999) evaluated the contribution of potential effects of major
cardiovascular diseases (CVD), malignant neoplasms (MN), accidents and AIDS mortality to life expectancy in Italy in 1994 and found that potential gains in life expectancy at birth from complete elimination of CVD, MN, accidents and AIDS were respectively, 5.01, 3.84, 0.87 and 0.33 years among men and 5.23, 2.77, 0.40 and 0.11 years among women.

Salomon and Murray (2002) did a study by using data from 58 countries for the years 1950 to 1998. This study confirms the general principles of the epidemiologic transition with a few deviations for certain age-sex groups. It also suggests that most of the changes in cause structure of mortality occur among children and young adults. For older adults, the cause composition of mortality remains stable but deaths shift to the older ages.

In a study undertaken by Seval et al., (2007) in Turkey found that leading causes of death include major vascular diseases (ischaemic heart disease, stroke) causing 35–38% of deaths, chronic obstructive lung disease and lung cancer in men, but also perinatal causes, lower respiratory infections and diarrhoeal diseases in the year 2000. Injuries caused about 6–8% of deaths.

Hoque (2008) conducted a study to evaluate the effect of elimination of diarrhoeal and infectious diseases separately and combinedly on the life expectancies of the rural (Matlab) population of Bangladesh for the years 2000 and 2003. The study found that elimination of diarrhoeal and infectious diseases separately added 0.84 years and 0.85 years at birth respectively and combined elimination added 1.73 years in 2000. In the year 2003, it added 0.67 and 0.70 years respectively when eliminated separately and combined elimination added 1.43 years at birth.

Bawah and Binka (2007) analyzed the longitudinal demographic surveillance data from northern Ghana for the year 1995 and found that life expectancy at birth would increase by more than six years if malaria were eliminated as a cause of death.

Weerasinghe et al., (2009) evaluated the potential effects of reduction in major disease mortality on life expectancy in New South Wales in 2000-2002 and found that people (male and female both) who eventually die from ischaemic heart disease are
likely to have lived longer than people who die from other diseases.

A large scale field study was undertaken to verify registered causes of death in a nationally representative sample of 11,984 deaths that occurred in 2005 in Thailand. The study found that stroke was the leading cause of death (10.7%) followed by ischemic heart disease (7.8%) and HIV/AIDS (7.4%). Other leading causes were road traffic accidents (males) and diabetes mellitus (females) (Porapakkham et al., 2010).

As per Global Burden Study 2010, at the most aggregate level, communicable, maternal, neonatal, and nutritional causes account for 13·2 million (24·9%) of 52·8 million global deaths at all ages in 2010. Non-communicable causes account for 34·5 million or 65·5%. The third category, injuries, accounts for 5·1 million or 9·6%. The continued decrease in deaths from communicable, maternal, neonatal, and nutritional disorders is striking, if not surprising. The number of deaths from these disorders decreased by 2·7 million from 15·9 million in 1990 to 13·2 million in 2010, representing a 17% decrease. The annual number of deaths from non-communicable diseases, by contrast, rose by just under 8 million, to 34·5 million, or two of every three deaths in 2010. The global fraction of deaths due to injuries increased slightly (from 8·8% to 9·6%), but this masks some important trends in mortality from these causes (Murray et al., 2012).

1.8 Previous Indian Studies on Cause of Death

Namboodari and Suchindran found that the gain in life expectancy at 65 years of age was 12.61 years after elimination of cardiovascular disease (CVD) (Namboodari and Suchindran, 1987).

Jayachandran (1999) constructed cause of death elimination tables by age and sex at the national level by using NFHS-1 data. All causes of death were grouped into eleven major causes viz., accidents and injuries; fevers; digestive disorders; coughs; disorders of central nervous system; disease of circulatory system; other clear symptoms and cause unknown or missing. The study found that the gains in life expectancy at different ages were varied by sex and cause. The maximum gain in life expectancy at birth for males from respiratory disorders (cough) eliminated cause was 3.49 years but for females the cause was fever (3.21 years).
A study estimated the years of life lost (YLL) due to top 9 causes of death viz., tuberculosis of the lungs; pneumonia; anaemia; bronchitis and asthma; heart attack; cancer; paralysis; vehicular accidents; and suicides, in rural areas of major states of India by analyzing the Survey of Causes of Death (Rural), 1995 data and found that the all-cause YLL in rural India in 1995 were 207 per 1000 population. The minimum was 74 in Kerala and maximum 276 in Madhya Pradesh. Pneumonia was the top cause responsible for 15 YLL. The inter-state variation was high as Tamil Nadu had only 1.6 and Uttar Pradesh 30.5 YLL from this cause. Cancers were a uniform burden across the states. Heart attack, and bronchitis and asthma cut across more and less developed states. Suicides were a heavy burden in Andhra Pradesh and vehicular accidents in Haryana and Rajasthan. Bihar, Gujarat, Madhya Pradesh, Orissa, Rajasthan and Uttar Pradesh had communicable and nutritional conditions as predominant causes, while Kerala and Punjab had non-communicable diseases as the predominant cause of YLL due to premature mortality (Indrayan et al., 2002).

Ghosh and Kulkarni (2004) found that social deprivation among the weaker section of the society as manifested by ‘caste’ and ignorance due to illiteracy and directly observable low standard of the household is the most important determinants of the pattern of cause of death across the age and sex groups in Indian population. Chronic and degenerative diseases of adulthood have a growing prevalence among the better-off, educated and urban population, while communicable diseases remain relatively more prevalent among the rural based illiterate and semi-literate, poor and socially weak sections of the society.

Kulkarni et al., (2004) conducted a study in Goa to estimate the potential gain in life expectancy when mortality due to cardiovascular diseases was eliminated and found that net gain in life expectancy at birth was 11.5 years in males and 15.2 years in females.

Analysis of Survey of Cause of Death (Rural) data from 1966 to 1994 shows that asthma and bronchitis was a leading cause during 1971-91 in rural India accounting more than 8% of all deaths in India followed by tuberculosis of the lungs accounting 6.1% deaths (Ramanakumar and Chattopadya, 2005).
The global burden of disease study reveals that in India communicable, maternal, perinatal and nutritional deaths are the leading causes of deaths for the young age group (0-15 years), whereas for adults of age 15-60 years, communicable and non-communicable diseases share as almost equal percentage of causes of death (Murray and Lopez, 1997). The study also projected that the number of deaths due to chronic diseases would rise from 3.8 million in 1990 (40% of all deaths) to 7.6 million in 2020 (67% of all deaths).

A study on 45 villages of rural Andhra Pradesh by using the verbal autopsy tool concluded that diseases of the circulatory system were the leading cause of mortality (32%) with comparable proportions of ischemic heart disease (14%) and cerebrovascular disease (13%) followed by injury and other external causes of mortality (13%). The other main causes were infectious diseases (12%), neoplasm (7%) and diseases of the respiratory system (5%). These five leading causes of death accounted for two-thirds of all deaths (Joshi et al., 2006).

The verbal autopsy of 38,836 deaths in rural Tamil Nadu revealed that injuries accounted for 19% of total deaths and half of these were suicides. Among all suicide deaths, three-fourths were in the socially and economically productive age group of 15-44 years (Gajalakshmi and Peto, 2007). The Global Burden of Disease study also discussed about high suicide rates in south India particularly among females (Murray and Lopez, 1997).

The world’s largest prospective study of cause and correlates of mortality in India is being undertaken by the Registrar General India in close collaboration with the Centre for Global Health Research, Canada. The study will monitor nearly 14 million people in 2.4 million nationally representative Indian households (6.3 million people in 1.1 million households in the 1998–2003 sample frame and 7.6 million people in 1.3 million households in the 2004–2014 sample frame) for vital status and, if dead, the causes of death through a well-validated verbal autopsy (VA) instrument. The first objective to reliably document cause-specific mortality from 2001 to 2003 within the SRS to establish regional, sex and age-specific variation and pattern of mortality has been achieved and report published. The study is progressing to
document causes of death with routine use of verbal autopsy in the new SRS sampling frame from 2004 to 2014 (Jha et al., 2006).

A recent report of the Special Survey of Deaths (SSD) conducted during 2004-2005 covering deaths for the period 2001-2003 in Sample Registration System (SRS) revealed that non-communicable diseases are the leading causes of death in the country, constituting 42% of all deaths. Communicable, maternal, perinatal and nutritional conditions constitute another 38% of deaths. Injuries and ill-defined causes constitute 10% of deaths each. Overall, the leading cause of death is cardiovascular disease (19%), followed by respiratory diseases (9%) (namely, chronic obstructive pulmonary disease or COPD, asthma, other respiratory diseases), diarrhoeal diseases (8%), perinatal conditions (6.3%), respiratory infections such as acute pneumonia (6.2%), tuberculosis (6%), malignant and other neoplasms (5.7%), senility (5.1%) which is concentrated at ages 70 and higher, unintentional injuries: other (4.9%), and symptoms, signs and ill-defined conditions (4.8%). Notable differences by sex are seen in the case of diarrhoeal diseases with 10% of female deaths against 7% of male deaths, tuberculosis with 5% of female deaths versus 7% male deaths, and cardiovascular diseases with 17% female deaths versus 20% male deaths. There is a marked regional variation in the contribution of various causes to the leading deaths (RGI, 2009a).

In Population Registry of Lifestyle Diseases (PROLIFE) study in Kerala analysis of the cause of 3411 deaths that occurred from 1996 to 2001 shows that 49% of deaths were due to cardiovascular diseases (CVDs). This was followed by external causes of mortality (12%) and cancer (9%). Infections contributed to <6% of deaths. Nearly 10% of deaths could not be assigned specific causes (Soman et al., 2009).

Indian Council of Medical Research (ICMR) conducted a study on causes of death by verbal autopsy in five selected states of India namely, Assam, Bihar, Maharashtra, Rajasthan and Tamil Nadu during 2003-2005. The study found that infectious and parasitic diseases were the most common causes of death in Assam, Bihar, and Rajasthan. However, diseases of the circulatory system were the most common causes of death in Maharashtra and Tamil Nadu (ICMR, 2009).
1.9 **Objectives of the Study**

Keeping in view the above discussion, this study aims to concentrate broadly on the cause of death pattern and specific objectives framed are as under:-

1. To study the quality of data collected in the Medical Certification of Causes of Death (MCCD) Scheme for the period from 1989 to 2008 and to make required adjustments;

2. To study the cause of death pattern by age and sex for the period from 1989 to 2008 in India and selected States by using MCCD data

3. To construct the abridged life tables of India and selected States by age and sex by using MCCD data

4. To construct and study the cause of death elimination tables by age and sex.

5. To study the influence of cause of death by computing potential gain in life expectancy after partial and complete elimination of causes of death by age and sex.

1.10 **Need of the Study**

This study provides a comprehensive idea about levels and trends of causes of death in India and selected states for the period 1989 to 2008. It also highlights the influence of each cause of death on the mortality scenario and ascertains the effect of causes of death on life expectancy in selected states in India. The pattern of death by cause reflects the health status of the study population and in turn provides a rational basis for health planning. Furthermore, the study is also expected to broaden our understanding of the epidemiology of deaths in India.

1.11 **Organization of the Thesis**

The thesis is organized in seven chapters.

Chapter 1 contains introduction; theoretical background; epidemiological transition; literature review; objectives and need of the study.
Chapter 2 describes history and types of global and Indian mortality reporting system.

Chapter 3 describes the epidemiological transition in India and selected states.

Chapter 4 describes the data sources and methodologies used in the analysis. This chapter contains a consolidated description of the methodologies and sources of data used in the study.

Chapter 5 describes the causes of death statistics in India and selected States. It describes the levels and trends of causes of death in India and selected States for the period from 1989 to 2008. It also gives comparative overview of results of MCCD and ICMR.

Chapter 6 describes the potential gain in life expectancy after partial and complete elimination of causes of death in India and selected States for the year 2003.

Chapter 7 describes summary and conclusion.