EXPLORING ETHNIC INEQUALITIES IN CARDIOVASCULAR DISEASE USING HOSPITAL EPISODE STATISTICS

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Exploring Ethnic Inequalities In Cardiovascular Disease Using Hospital Episode Statistics

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for the Degree of Doctor of Philosophy.

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June 11, 2009

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Abstract

This thesis is based on a population study conducted to explore ethnic inequalities in cardiovascular disease using Hospital Episode Statistics (HES). The Hospital Episode Statistics have significant potential for health studies for ethnic groups, due to the large number of events from minority ethnic groups, comprehensive clinical information, full England coverage and fine geographical scale. However, the percentage of Finished Consultant Episodes (FCEs) with invalid ethnicity codes is at a high level. This thesis starts by developing a record linkage method and a coding rate method to improve the data quality of ethnicity codes in the HES.

This thesis then further examines ethnic inequalities in cardiovascular disease incidence in England at both national and local geographical scales. The patterns of ethnic inequalities in cardiovascular disease appear to have changed little in the last ten years. However, large variations of geographical relative risk of cardiovascular disease were observed for ethnicity-sex groups. The relationships between areal socioeconomic status measured at different geographical scales and ethnic inequalities in different types of cardiovascular disease were also explored.

As there are very limited data on the mortality of minority ethnic groups in the UK, few studies have compared the incidence and outcome of cardiovascular disease from the same population. This thesis came up with some novel findings, for example, that people from minority ethnic groups, who generally have increased risk of cardiovascular disease incidence, have better cardiovascular disease survival than white people. The contribution of areal socioeconomic status, distance to treatment sites and cardiovascular disease severity and treatment to the ethnic inequalities in cardiovascular survival was examined. The relationships between socioeconomic status measured at different geographical scales and ethnic inequalities in cardiovascular disease severity and treatment were investigated in this thesis as well.

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Chapter One: Introduction

1.1 Introduction

Ethnicity is a way to describe personal identity or social stratification based on a combination of categories, including a shared history, common ancestry, shared culture, geographical origin, language, religion, nationality and physical appearances and so on (Office for National Statistics, 2003). Forming one important dimension of understanding health inequalities, ethnicity is a key element in the relationship between health and individuals. Understanding ethnic inequalities in health is essential to design specific health policy in needs assessment, resource allocation, health care planning and provision to tackle inequalities in health (Acheson, 1998).

Notable ethnic inequalities in health have been observed all around the world. In the UK, the health of people from minority ethnic groups is generally poorer than that of the majority White British population, particularly in cardiovascular disease. Ethnic inequalities in cardiovascular disease have been highlighted in national surveys, such as the Fourth National Survey of Ethnic Minorities 1993-1994 (Nazroo, 1997), Health Survey for England 1999 (Primatesta and Brooks, 2001) and Health Survey for England 2004 (Mindell and Zaninotto, 2005), and existing literature (Wild and McKeigue, 1997, Cappuccio, 1997, Gill et al., 2002, Chaturvedi, 2003).

However, further study on ethnic inequalities in cardiovascular disease is limited by the availability of health data with ethnicity information, because firstly, most routinely collected health data in the UK fail to collect information on ethnicity (Sultana and Sheikh, 2008), and secondly, the completeness of ethnicity codes in those routinely collected health data is poor (London Health Observatory, 2008).

Hospital Episode Statistics (HES), which is a data warehouse containing details of all the admissions to NHS hospitals in England, have significant potential for exploring ethnic disparities in health, due to the large number of events, comprehensive clinical information, full England coverage and fine geographical scale. However, the percentage of Finished Consultant Episodes (FCEs) with invalid ethnicity codes is at a high level. The first objective of this thesis is to examine the potential of the Hospital Episode Statistics (HES) for research on ethnic inequalities in cardiovascular disease, and more broadly in health research in general, by developing a methodology to improve the quality of ethnicity code data. And then this thesis moves forward to explore ethnic inequalities in incidence of different types of cardiovascular disease in England at both national and local geographical scales.

Furthermore, this study contributes to research on ethnic inequalities in cardiovascular disease by examining ethnic disparities in cardiovascular disease survival, severity and treatment, which are seldom covered in the existing literature. Although the mortality rates of cardiovascular disease for certain minority ethnic groups in the UK are usually higher than that of white people, it does not necessarily imply people from minority ethnic groups have poorer cardiovascular disease survival than the white people. The higher mortality rates for minority ethnic groups might be a result of their higher incidence rates. There is no explicit clinical information in the HES that measures cardiovascular disease severity. However, the available information in the HES, such as cardiovascular operation and cardiovascular emergency admission might serve as severity indicators. These severity indicators could also reflect the level of treatments for cardiovascular disease, since cardiovascular emergency admissions and operations mean intensive treatment and care to some extent, which will enhance survival. Ethnic inequalities in cardiovascular emergency admissions and operations are examined in this study as well.

Given that in the UK people from most minority ethnic groups are associated with lower socioeconomic status and that there are established well-known relationships between socioeconomic status and health, it seems that socioeconomic inequalities may be the main cause of ethnic inequalities in health. Indeed, the contribution of socioeconomic inequalities to ethnic inequalities in health has been much debated over the last three decades. There were inconsistent conclusions about whether socioeconomic inequalities were the fundamental causes of ethnic inequalities in health in the 1990s (Marmot et al., 1984a, Harding and Maxwell, 1997, Nazroo, 1998). In recent years, a number of studies suggested that socioeconomic status could largely explain ethnic inequalities in self-reported health (Chandola, 2001, Nazroo and Karlsen, 2001, Nazroo, 2003b).

However, most studies on the contribution of socioeconomic status to ethnic inequalities in health only included one measure of health, self-reported health, obtained from two main datasets, the Fourth National Survey of Ethnic Minorities (1993-1994) and the Health Survey for England, which may not adequately capture different dimensions of health, such as cardiovascular disease and mental health. Fewer studies examined whether socioeconomic inequalities are the main determinant of ethnic inequalities in cardiovascular disease. Furthermore, ethnic groups other than Caribbean and South Asian, such as Black Africa, Mixed, Other Asian and Chinese, seldom have been studied in analysis of socioeconomic effect on ethnic inequalities in health. To what extent socioeconomic inequalities contribute to the disparities in health for these groups is unknown.

Therefore another main objective of this thesis is to investigate to what extent socioeconomic status inequalities contribute to ethnic inequalities in cardiovascular disease, more specifically, to investigate to what extent socioeconomic status contributes to ethnic inequalities in incidence of different types of cardiovascular disease, cardiovascular disease survival and severity. Area socioeconomic status measures are used in this study due to unavailability of individual socioeconomic status measures in the HES, which would offer another opportunity to investigate the potential of using areal socioeconomic measures for studying ethnic inequalities in cardiovascular disease when individual socioeconomic measures are seldom available in health data.

However, using areal measures is subject to the Modifiable Areal Unit Problem (MAUP), i.e. the results being affected by the geographical scale at which the analysis is conducted and how the geographical boundaries are drawn at that scale (Flowerdew et al., 2001). In order to address this problem, this study examines whether the effect of areal socioeconomic status measured at different geographical scales is consistent on ethnic inequalities in cardiovascular disease incidence, survival and severity. In addition, it is acknowledged that using areal measures will introduce bias, known as the ecological fallacy (Selvin, 1958, Firebaugh, 1978). However, as long as health data offer few other options, areal socioeconomic measures will continue to be used to proxy unavailable individual socioeconomic variables, with careful interpretation of study results (Geronimus, 2006).

1.2 Rationale

1.2.1 What is Ethnicity?

Ethnicity is regarded as one of the most difficult concepts to define in the social sciences. The definition of ethnicity is subject to much discussion because of disagreement on the meaning of the term from researchers and different expressions of ethnicity between social groups, and the credibility of the concept is challenged by some theorists (Banks, 1996).

In English, the word ‘ethnic’ was originally applied to non-Judeo-Christian peoples. As a replacement for the word ‘race’, the noun of ethnic, ethnicity, first entered the English language in the early 1940s to be associated with the genocidal policies of the Nazi party. (Hiebert, 2000) In contemporary usage, ethnicity is viewed as a way to describe personal identity or social stratification. *“Ethnicity is seen as both a way in which individuals define their personal identity and a type of social stratification that* *emerges when people form groups based on their real of perceived origins. Members of ethnic groups believed that their specific ancestry and culture mark them as different from others. As such, ethnic group formation always entails both inclusionary and exclusionary behaviour, and ethnicity is a classic example of the distinction people make between 'us' and 'them'. "* Hiebert (2000)

Much attention is given to theories of ethnicity. However, there are two particularly common misconceptions surrounding the concept of ethnicity (Hiebert, 2000). Firstly, ethnicity is often only applied to minority groups, assuming that everyone else other than the majority group is 'ethnic', which was only acceptable in the nineteenth century, but no longer correct in the contemporary era (Hiebert, 2000). In fact, everyone has an ethnicity. Ethnic groups cover people from all communities not just those of minority ethnic groups. For example, in the UK, White British people, who comprise 87% of the population, are an ethnic group and also the majority ethnic group at the national level (Department of Health, 2005b).

The second confusion is that the terminologies 'race' and 'ethnicity' are usually used interchangeably (Hiebert, 2000), particularly in the US (Crespo et al., 2000, Comstock et al., 2004, Thomas et al., 2005), because race and ethnicity are complex, multidimensional concepts and there are no explicit definitions for them. This doesn't permit comparisons between studies, particularly internationally (Bhopal and Rankin, 1999). Some researchers have built a clear boundary between race and ethnicity. Race is commonly defined to be a biological term, which differentiates people based on physical or visible criteria that are assumed to be genetic, such as skin colour, nose shape and type of hair (Jackson, 2000), and ethnicity refers to a social construction of identity (Hiebert, 2000). However, the boundary between race and ethnicity is not that visible. It is extremely difficult to describe races using such a broad biological classification, because human genes are not that pure (Pearce et al., 2004). Race has come to be widely regarded as a political and social construction rather than a biological term (Bhopal and Rankin, 1999). However, Chaturvedi (2001) argued that ‘ethnicity’ is scientifically preferable to race. Afshari and Bhopal (2002) conducted a research on changing patterns of use of ‘ethnicity’ and ‘race’ in scientific literature and concluded that ‘ethnicity’ has been gradually replacing the scientifically and conceptually limited term of ‘race’ in the scientific literature.

In British studies, ‘race’ is seldom used and ‘ethnicity’ is a favoured term for describing ethnic inequalities in health (Nazroo, 2003a). Definitions from British government research have avoided the confusion in using race and ethnicity interchangeably, but employed the term ‘ethnic group’ as a replacement to describe personal identity or social stratification, which was based on a combination of categories including ‘race’, skin colour, national and regional origins, language and so on (Office for National Statistics, 2003). The definitions from British government research are as follows:

Bulmer’s (1996) definition of an ethnic group is as follows:
“An ethnic group is a collectivity within a larger population having real or putative common ancestry, memories of a shared past, and a cultural focus upon one or more symbolic elements which define the group’s identity, such as kinship, religion, language, shared territory, nationality or physical appearance. Members of an ethnic group are conscious of belonging to an ethnic group.”

Berthoud, Modood and Smith (1997) define ethnic group as follows:
“In principle, an ethnic group would be defined as a community whose heritage offers important characteristics in common between its members and which makes them distinct from other communities. There is a boundary, which separates ‘us’ from ‘them’, and the distinction would probably be recognised on both sides of that boundary. Ethnicity is a multi-faceted phenomenon based on physical appearance, subjective identification, cultural and religious affiliation, stereotyping, and social exclusion. But it is not possible in advance to prescribe what the key distinguishing characteristics might be; the components of ethnicity will be different in Britain

compared with, say Northern Ireland, Belgium, Bosnia, the United States, Rwanda, India or Singapore. So it is necessary to adopt a flexible and practical approach to choosing the specific criteria to identify the important ethnic boundaries in any particular society."

Currently, in the UK, given that ethnic groups are unevenly distributed in different countries, the ethnicity classifications are not identical in England and/or Wales, Scotland and Northern Ireland, where England and/or Wales, and Scotland have a two level ethnicity classification, and Northern Ireland has one level classification, which are introduced in detail in Chapter Two. Historical and socioeconomic background of ethnic groups in the UK is introduced in Chapter Two as well.

1.2.2 Monitoring Ethnicity in Health

Ethnicity, which is one of the key factors that determine differences in the incidence, prevalence and mortality from disease in a population, is gaining more and more interest in social science and public health literature. Internationally, many empirical studies have examined the association between ethnicity and health, where people from minority ethnic groups are at a higher risk of poor health than the general population, for example, in overall mortality (Muntaner et al., 2004, Barrow et al., 2005, Thomas et al., 2005) and in morbidity, cardiovascular disease (Shah et al., 2006, Thomas et al., 2005, Feigenbaum et al., 2006, Natori et al., 2006), cancer (Sanderson et al., 2006, Smigal et al., 2006, Penedo et al., 2006, Naeim et al., 2006), mental health (Takeuchi and Williams, 2003, Marie et al., 2004, Primm et al., 2005, Klineberg et al., 2006) and health behaviour studies (Voils et al., 2006, White et al., 2006, Bennett et al., 2006, Seo and Torabi, 2006).

In the UK, ethnicity forms an important dimension of health inequalities. Generally, the health of people of minority ethnic groups is poorer than that of the majority White British population. Bangladeshi and Pakistani people are found to have the poorest health, followed by Caribbean people and then Indian people, however, Chinese and White people having the best health (Nazroo, 2003b). Significant ethnic inequalities have been identified in the UK in mortality (Chaturvedi and Fuller, 1996, Prasad et al., 2004, Lane et al., 2007, Gunarathne et al., 2008a), cardiovascular disease (Chaturvedi and Fuller, 1996, Abbotts et al., 2004, Lip et al., 2007, Gunarathne et al., 2008b), cancer(Lodge, 2001, Stiller et al., 2000, Jack et al., 2007, Lane et al., 2007), mental health (Ananthanarayanan, 1994, Silveira and Ebrahim, 1998, Andres, 2004), diabetes (Chaturvedi and Fuller, 1996, Soljak et al., 2007, Davis, 2008, Lloyd et al., 2008), child health (McKinney et al., 2003, Bansal et al., 2008, Balakrishnan et al., 2008), use of health services (Szczepura, 2005, Sedgwick et al., 2003, Robb et al., 2008) and unhealthy behaviour (Jayakody et al., 2006, Sriskantharajah and Kai, 2007).

In a report submitted to the Home Office, Johnson et al. (2004) critically reviewed the evidence of ethnic inequalities in a number of diseases in the UK and came up with a summary of patterns, as shown in the table below:

Condition	**Summary of patterns**
Diabetes	Lower rates of Insulin Dependent Diabetes (Type I) in South Asian and Caribbean populations but poor life expectancy were found. Much higher rates of Non-Insulin Dependent (Type II; later onset) in Black and South Asian groups. Higher rates of diabetes also linked with other conditions such as renal failure and coronary heart disease, and consequent service needs.
Tuberculosis	High mortality amongst people born in Ireland. High incidence amongst new entrants to the UK from South Asia
CHD	Mortality rates high in South Asian and white populations, and lower in Caribbean and Chinese people
Stroke	Higher mortality rates amongst people from African and Caribbean Commonwealth.
Thalassaemia	More common amongst people from Southern Europe, Middle East and South Asia.
Sickle Cell	Only occurs in populations of African and Caribbean ancestry.

Cancer	Mortality rates high amongst people born in Ireland. Lower rates for major cancers in those born in Indian sub-continent and (except cervical) Caribbean and African Commonwealth. Oral cancers high in South Asian, African groups.

Table 1-1: Summary of patterns of ethnic inequalities in health in the UK (Johnson et al., 2004)

Considering the observed ethnic inequalities in mortality and morbidity in the UK, Sir Donald Acheson's *Independent Inquiry into Inequalities in Health* (1998), which initially set a framework for health inequalities policy, recommended that inequalities in health by ethnicity were best tackled through further development of services which were sensitive to the needs of minority ethnic people and promote greater awareness of their health risks and specific consideration of minority ethnic groups in needs assessment, resource allocation, health care planning and provision (Acheson, 1998).

On April 2nd, 2001 the Race Relations Amendment Act 2000 (RRAA) came into force. The RRAA places a new positive duty, the General Duty, on key public bodies (including all government departments) to *"eliminate unlawful racial discrimination, promote equality of opportunity; and promote good relations between persons of different racial groups"* (Department of Health, 2005a).

The Department of Health has commissioned a number of initiatives to generate or collate good practice in race equality aiming to reduce ethnic inequalities in health through providing equal access to high quality services and targeting resources and programs to ethnic groups most in need. For example, the Department of Health has funded a NHS based programme *"Race for Health"* carried out by PCTs and Trusts to continually drive forward improvements in health, particularly in diabetes, mental health, peri-natal mortality, coronary heart disease and stroke, for people from minority ethnic groups (Department of Health, 2007). The *"Department of Health Race Equality Scheme 2005-2008"* addressed the need to focus on race equality in designing and delivering health and social care services, with a review of the

“*Department of Health's Race Equality Scheme 2002-5*” (Department of Health, 2005a). The most recent “*No patient left behind: how can we ensure world class primary care for black and ethnic minority people?*” emphasized the NHS should provide a model of flexible personalised care to meet the needs of patients from black and minority ethnic groups (Lakhani, 2008). There are also some initiatives specifically designed for some health problems, such as “*Heart disease and South Asians: Delivering the National Service Framework for Coronary Heart Disease*”,” *Black and Minority Ethnic (BME) Mental Health programme*” and “*Primary Health Care Services for children from Ethnic Minority Groups*”.

Ethnic inequalities in incidence, prevalence and mortality of many diseases are well known. And increasing attention has been paid to provide equitable health care and service to patients from all ethnic backgrounds from both legal and policy perspectives. In order to address them, first of all, there must be relevant health data with ethnicity information which would help to highlight possible inequalities and investigate the underlying causes. However, in the UK, there are limited data currently collected in health across ethnic groups, which hampers investigation of ethnic inequalities in health. Firstly, there are only a limited number of routine health data sets with ethnicity information that are available for analysis. Most routinely collected health data in the UK fail to collect information on ethnicity (Sultana and Sheikh, 2008). Secondly, the completeness of ethnicity codes in those routinely collected health data is poor, which precludes the usage of these data for identifying disparities in health and healthcare. Historically, the quality of ethnicity coding in data collection in the NHS is poor, including hospital episode statistics, general practitioner data, cancer registrations, and disease registers (London Health Observatory, 2008). For example, in London, the proportion of hospital admissions where records for circulatory disease in 2002/03 had a missing or invalid ethnicity coding was 24% on average, with individual acute Trusts ranged from 5% in Hillingdon to 50% in Queen Mary's Sidcup (London Health Observatory, 2008).

1.2.3 Trends in Ethnic Inequalities in CVD

Notable ethnic inequalities in cardiovascular disease morbidity and mortality have been observed all around the world. In the UK, it is generally known that South Asians (including Indian, Pakistani and Bangladeshi population) usually have a higher risk of cardiovascular disease than the white population. In the US, African Americans were found to have the highest age-adjusted death rate from cardiovascular disease, followed by Whites, Hispanics, and Asians (Albert, 2007). And the death rate of African Americans of cardiovascular disease was 2-3 times higher than that of Asians in the US (Cooper, 2001). The mortality for ischemic heart disease and stroke was generally highest for African Americans, intermediate for non-Hispanic whites, and lowest for Hispanics (Karter et al., 1998). In the Netherlands, compared with the native Dutch population, cardiovascular disease mortality was found low among Moroccan males and high among Surinamese males and females (Bos et al., 2004). In Canada, South Asians had one of the highest rates of coronary artery disease, and had a greater carotid artery intimal thickness compared to Europeans and Chinese (Gupta et al., 2002, Gerstein et al., 2003, Bolli, 2005). Death rates from ischemic heart disease were highest among Canadians of South Asian origin and European origin and were markedly lower among Canadians of Chinese origin (Sheth et al., 1999). In Australia, compared with the Australia-born population, the mortality rate of cardiovascular disease was generally lower for migrants born in Europe, east Asia and south Asia (Gray et al., 2007). In addition, strong ethnic difference in cardiovascular disease was found in Singapore where Malays and East Indians have greater coronary heart disease rates than Chinese (Mak et al., 2003).

In the UK, there have been several national surveys that have highlighted ethnic inequalities in cardiovascular disease, including the Fourth National Survey of Ethnic Minorities, Health Survey for England (1999) and Health Survey for England (2004). The Fourth National Survey of Ethnic Minorities conducted from 1993 to 1994 was one of the most comprehensive health-check for Britain's ethnic minorities in 1990s, which used a national representative community sample, consisting of 2867 white respondents, 5196 respondents of Caribbean and Asian origin (1,205 Caribbean respondents, 1,947 Indian/African Asian respondents, 1,232 Pakistani respondents, 598 Bangladeshi respondents and 214 Chinese respondents). It was found in this survey that Pakistani and Bangladeshi people had a greater risk of heart disease than white people, while there were only small and statistically non-significant differences between the white group and Caribbean and Chinese people. And Caribbean people had the highest rate of hypertension (Nazroo, 1997).

The Health Survey for England is a series of annual surveys about the health of people in England beginning in 1991. It is designed to provide regular information on various aspects of the nation’s health and to underpin and improve targeting of nationwide health policies. Each year, the Health Survey for England focuses on a different demographic group, for example, ethnic minorities, children and young people, and older people, and looks at such health indicators as cardiovascular disease, accidents and health behaviours. There are two Health Surveys for England (1999, 2004) looking at the health of ethnic minorities, both of which have a larger sample than the Fourth National Survey of Ethnic Minorities and identified ethnic inequalities in cardiovascular disease.

In the Health Survey for England (1999), for almost all the cardiovascular disease conditions with the exception of diabetes, the risk of Chinese men and women was lower than the general population; however, generally all South Asian groups had higher rates than the general population in most conditions. The rates of both Pakistanis and Bangladeshis were higher than Indian people. Significant lower prevalence of angina and heart attack was found among Black Caribbean men. And Irish people had a similar prevalence of cardiovascular disease conditions to the general population (Primatesta and Brooks, 2001).

The Health Survey for England (2004) with an emphasis on cardiovascular disease might provide the most recent evidence about the health of ethnic minorities at national level. The main findings were that the prevalence of angina and heart attack was highest in Pakistani men and Indian men and women, and lowest in the Black African and Chinese groups. Black Caribbean people were found to have the highest prevalence of stroke. However, people from ethnic minorities reported lower rates of heart murmur, abnormal heart rhythm (except for Irish women) and 'other' heart trouble (except for Black Caribbean women) (Mindell and Zaninotto, 2005).

Along with the national surveys, some studies and research also have examined ethnic inequalities in cardiovascular disease, particularly in mortality. Wild and McKeigue (1997) reported that in the period 1989-92, amongst men the coronary heart disease mortality rates were highest for people born in South Asia (combining Indians, Pakistanis and Bangladeshis). However, the rates were very low for both Caribbean and West African groups. Similar difference has been found amongst women. Cappuccio (1997) came up with the evidence that in the UK mortality from coronary heart disease, stroke and end-stage renal failure were high in South Asian migrants. Black migrants have higher mortality from stroke and end-stage renal failure, but lower from coronary heart disease. Based on routine mortality data from 1985-86 and 1981 Census, African-Caribbean people were found to be 3.5-4 times higher than those in the England and Wales population in stroke mortality rate (Chaturvedi and Fuller, 1996). And high stroke mortality for Bangladeshis was persistently found in the censuses in 1981, 1991, and 2001 (Balarajan and Raleigh, 1997, Bhopal et al., 2005b, Bhopal et al., 2005a, Gill et al., 2002). In recent years, the ethnic difference between South Asians and the general population in cardiovascular disease became wider, and the greatest difference had been found in the youngest age groups, although there was a decline in death caused by heart disease for the general population (Chaturvedi, 2003).

Compared to coronary heart disease and stroke, other heart disease has not been well studied in terms of ethnic inequalities. But Gill et al. (2002) showed that Black

Africans had higher mortality rates from chronic rheumatic heart disease than Afro-Caribbeans. And based on limited data provided by Birmingham hospitals, compared to Europeans, the ratio of relative risk of heart failure to white people, in those aged 60–79 years was 3.1 in African Caribbeans, and 5.2 in South Asians (Chaturvedi, 2003). Patients in the South Asian group, as well as African Caribbeans or African Americans usually bear a greater burden of heart failure, since they usually develop their heart failure at a younger age (Sosin et al., 2003).

1.3 Measuring Ethnic Inequalities in CVD Incidence, Survival and Severity

There have been substantial studies on ethnic inequalities in cardiovascular disease, which indicates sharply increased interest in this field from researchers and governments. However, probably due to the limitation of data, some aspects of research on ethnic inequalities in cardiovascular disease could add more value in future study. Four potential aspects, including more specific cardiovascular disease, more detailed classification of ethnicity, larger geographical coverage and finer geographical scale, and ethnic inequalities in cardiovascular disease survival and severity, have been identified. One of the main objectives of this thesis is to further measure ethnic inequalities in cardiovascular disease incidence, survival and severity in England by addressing these four aspects as follows.

Firstly, previous studies usually concentrate on general cardiovascular disease, coronary heart disease and stroke (Nazroo, 2001, Chaturvedi, 2003, Bardsley et al., 2000b, Bhopal and Sengupta-Wiebe, 2000, Khan and Beevers, 2005, Hsu et al., 1999, Markus et al., 2007), the latter two of which are the leading cardiovascular disease (World Health Organization, 2003c). However, other subtypes of cardiovascular disease, such as hypertensive heart disease, rheumatic heart disease and heart failure, have been less studied. Although in the UK, South Asians generally have a higher risk of cardiovascular disease, however, it might not be true for all the subtypes of cardiovascular disease. The same ethnic groups probably would have different degree of risk in different subtypes of cardiovascular disease. Some ethnic groups which have lower risk of a certain type of cardiovascular disease might be very sensitive to other subtypes of cardiovascular disease. Therefore it would be worthy to investigate ethnic inequalities in different types of cardiovascular disease rather than to apply the knowledge about ethnic difference in general cardiovascular disease to subtypes.

Secondly, more detailed and comprehensive classification of ethnicity needs to be incorporated into the analysis of ethnic inequalities in cardiovascular disease. Indian, Pakistani and Bangladeshi were often combined together as South Asians in the analysis (Wild and McKeigue, 1997), which would neglect the heterogeneity of these three ethnic groups. The UK 2001 Census introduced a new classification of ethnic groups, which classified population into 11 main categories, including White, South Asian (Indian, Pakistani and Bangladeshi), Black (Black Africa, Black Caribbean and other black), Mixed, Other Asian, Chinese and Other. Most previous research focussed on South Asians (Bhopal and Sengupta-Wiebe, 2000, Nazroo, 2001b, Markus et al., 2007) and the black population (Markus et al., 2007). However, few studies have taken other ethnic groups into analysis, particularly Mixed and Other Asian groups, about whose cardiovascular health little is known. Therefore it would be worthwhile to look at cardiovascular health among these ethnic groups as well. In addition, the results would be more comparable if different ethnic groups can be analyzed in the same study. It would be useful to break ethnic groups into males and females, since there exists much difference in cardiovascular disease between men and women.

Thirdly, few studies examined ethnic inequalities in different types of cardiovascular disease at English national level, and there is no research that has explored the geographical relative risk of cardiovascular disease for ethnic groups in the UK. Most previous research usually focussed on large cities, such as London (Aspinall and Jacobson, 2004, Khan et al., 2006, Markus et al., 2007) and Birmingham (Lip et al., 2004, Conway and Lip, 2003, Lane et al., 2005), where a large proportion of ethnic minorities in the UK are living. There were some national surveys on cardiovascular disease, including the Fourth National Survey of Ethnic Minorities 1993-1994 and Health Survey for England (1999, 2004). However, the samples in these surveys were relatively small, and could not be broken into different types of cardiovascular disease. Furthermore, there was no geographical information available in these national surveys. Gaining more insight into how ethnic inequalities in cardiovascular disease vary across geographical areas, especially at relatively small geographical scales, such as the local authority, would be more helpful for local government to target ethnic groups at risk, customize local health policy and conduct local health promotions.

Last but more important, few studies highlighted ethnic inequalities in cardiovascular disease survival and severity. Ethnic inequalities in cardiovascular disease incidence have been well documented in previous research worldwide, particularly in the United Kingdom and the United States. Given that mortality rates of cardiovascular disease for ethnic minorities, such as South Asians in the UK and black American in the US, are usually higher than that of white people, it would seem that the overall survival would be poorer in minority ethnic groups. However, higher mortality rates of cardiovascular disease for minority ethnic groups may be a result of their higher incidence rates. In addition, although people from minority ethnic groups have a higher risk of getting cardiovascular disease, it doesn’t imply they develop more serious cardiovascular disease than the white people. However, ethnic inequalities in cardiovascular disease survival and severity are less studied, but need investigation.

Hospital Episode Statistics (HES) is a data warehouse containing details of all the admissions to NHS hospital trusts in England. Each HES record contains a wide range of information about an individual patient admitted to an NHS hospital, including, clinical information (such as diagnoses, operations and discharge method), patient information (such as patient identifier (HESID), age, gender and ethnic category), administrative information (such as time waited and date of admission and outpatient) and geographical information (such as where the patient was treated and the output area in which they lived). HES has significant potential for further examining ethnic inequalities in cardiovascular disease by addressing the four aspects discussed above, due to the large number of events, comprehensive clinical information, full England coverage and fine geographical scale.

However, the percentage of Finished Consultant Episodes (FCEs) with invalid ethnicity codes is at a high level. Before further measuring ethnic inequalities in cardiovascular disease incidence, survival and severity, this thesis starts with developing a methodology to improve the data quality of ethnicity coding in the HES and to reduce uncertainties caused by missing data, exploring the potential of the HES for research on ethnic inequalities in cardiovascular disease, and more broadly in health research in general, as introduced in Chapter Four.

1.4 Measuring Socioeconomic Effects on Ethnic Inequalities in CVD

There have been consistent findings about ethnic inequalities in cardiovascular disease. However, what causes the increased occurrence of cardiovascular disease for some ethnic groups is still not well understood. Effort has been made to investigate the underlying reasons of ethnic inequalities in cardiovascular disease from different perspectives, including classical risk factors, novel risk factors, gene-environment interactions, racial discrimination and socioeconomic status, although little is known to what extent these factors contribute to ethnic inequalities in cardiovascular disease.

The prevalence of classical causal factors, such as high blood pressure, diabetes mellitus, insulin resistance, obesity and physical inactivity, is comparatively high in minority ethnic groups, which might account for part of the observed ethnic disparities (Cappuccio et al., 1997, Primatesta et al., 2000, Ehtisham et al., 2005, Teers, 2001). Ethnic difference also has been found in some novel cardiovascular risk factors, specifically lipoprotein(a) or Lp(a) (Bhatnagar et al., 1995, Anand et al., 1998), C-reactive protein (CRP) (Danesh et al., 2004, Forouhi et al., 2001), fibrinogen (Kain et al., 2001) and homocysteine (Chambers and Kooner, 2001). Migration was identified to be an important factor in determining the increased risk of coronary heart disease of immigrants due to changes in dietary patterns and lifestyles, known as adverse gene-environment interactions (Bhatnagar et al., 1995, Khunti and Samani, 2004, Patel et al., 2006). However, the migration explanation might not be applicable to the second or third generation of immigrant population. In addition, racial discrimination is argued to be a central component of ethnic inequalities in health, which refers to personally perceived bias that occurs between individuals, or discriminatory policies or practices of organizations that result in differential access to resources and societal opportunities (Williams et al., 2003, Karlsen and Nazroo, 2002, Krieger, 2000). However, because racial discrimination is hard to measure and no data about it are available, little quantitative research has examined the contribution of racial discrimination to ethnic inequalities in cardiovascular disease.

Given that in the UK, people from most minority ethnic groups are associated with lower socioeconomic status (which is introduced in Chapter Two) and that there are established well-known relationships between socioeconomic status and health, ethnic inequalities in health might be explained by socioeconomic inequalities among ethnic groups. Indeed, the contribution of socioeconomic inequalities to ethnic inequalities in health has been much debated over the last three decades with inconsistent conclusions about whether socioeconomic inequalities are the fundamental causes of ethnic inequalities in health.

The Black Report, which was published in 1980 by the Department of Health and Social Security (now the Department of Health) in the UK, has suggested four possible explanations for the existence of health inequalities between social classes in Britain, including artefact, natural or social selection, cultural/behavioural factors and materialist/structural explanations. The latter one placed emphasis on the role of economic and associated socio-structural factors, including poverty, poor housing conditions, poor conditions of work and lack of resources in health and education, in distribution of health and well-being (Townsend and Davidson, 1982). This would suggest that socioeconomic factors might also be relevant to ethnic inequalities in health.

However, Marmot et al. (1984a) don't consider socioeconomic gradient to be an important factor for ethnic inequalities in health. In an examination of migrant mortality statistics for 1970-1978 in England and Wales, socioeconomic gradient was found unrelated to higher mortality rates for most migrant groups. For people born in the Caribbean, there was even an association between higher socioeconomic status and higher mortality. Marmot et al. concluded that: "*(a) differences in social class distribution are not the explanation of the overall different mortality of migrants; and (b) the relation of social class (as usually defined) to mortality is different among immigrant groups from the England and Wales pattern.*" The analysis of recent migrant mortality statistics for 1991-1993 in England and Wales also suggested that socioeconomic differences, as measured by social class, didn't explain the different rates of mortality between groups born in different countries (Harding and Maxwell, 1997).

Nazroo (1998, 2003a, 2003b) suggested that social and economic inequalities were fundamental causes of ethnic inequalities in health by analyzing the Fourth National Survey of Ethnic Minorities (1993-1994), which is a nationally representative survey of ethnic minority and white people living in England and Wales. Topics in The Fourth National Survey of Ethnic Minorities include economic position, education, housing, health, ethnic identity, and experiences of racial harassment and discrimination. The contribution of socioeconomic effects to ethnic inequalities in health had been investigated for three broad ethnic minority groups (Indian or Africa Asian, Bangladeshi or Pakistani, Caribbean) and six different health outcomes. After controlling for socioeconomic index, the relative risk of six diseases for minority ethnic groups reduced to some extent. The importance of socioeconomic inequality to ethnic differences in the reporting of fair or bad general health was also reported in the same papers based on the Health Survey for England 1999. A clear reduction in odds ratios for most minority ethnic groups was identified when adjusting for socioeconomic status measures (income, housing tenure, economic activity). However, in both of the two pieces of evidence, socioeconomic inequalities can't fully explain ethnic inequalities in health.

Chandola (2001) did a similar study but with a slightly different conclusion. The author investigated the contribution of socioeconomic status to inequalities in self-rated health among a White group, an Indian group, and a combined Pakistanis and Bangladeshis group based on The Fourth National Survey of Ethnic Minorities (1993-1994) as well, using a new measure of socioeconomic status, the National Statistics Socioeconomic Classification (NS-SEC). The result showed that after controlling for standard of living, the NS-SEC and the percentage of households within a ward without access to a car, there were no significantly higher odds of poorer health for South Asians compared to the white people. However, it was acknowledged that due to small sample size, Pakistanis and Bangladeshis were combined into a single group for analyses, and men and women were combined into a single group as well.

Cooper (2002) also addressed whether socioeconomic inequalities were a potential explanation for ethnic inequalities in self-reported health using the data of the Health Survey for England combined over 4 years from 1993 to 1996. The key finding was that, socioeconomic status, measured as educational level, employment status, occupational social class and material deprivation, was found to account for a large proportion of the inequalities in self-reported health among Black Caribbean, Pakistani and Bangladeshi groups. However, significant ethnic inequalities in health remained after controlling for socioeconomic status.

Although recently it is generally accepted that socioeconomic inequality is the main cause of ethnic inequalities in health, there are some gaps in previous studies. Firstly, most studies examined the contribution of socioeconomic status to ethnic inequalities in only one measure of health, self-reported health, using the two main data the Fourth National Survey of Ethnic Minorities (1993-1994) and the Health Survey for England, which may not adequately capture different dimensions of health, such as cardiovascular disease and mental health. Few studies investigated whether socioeconomic inequalities were the main cause of ethnic inequalities in cardiovascular disease, with one exception of Nazroo's study (2001) which assessed the importance of socioeconomic position in South Asians' higher risk of cardiovascular disease.

Secondly, ethnic groups other than Caribbean and South Asian seldom have been studied in analysis of the socioeconomic effect on ethnic inequalities in health. Furthermore, in previous studies using the Fourth National Survey of Ethnic Minorities (1993-1994), Bangladeshi and Pakistani groups were usually combined into one group, Indian and Africa Asian were combined into one group as well, due to small sample size, which ignored the heterogeneities between these groups. However, as more and more immigrants enter the UK over the last decade and the understanding of ethnic groups evolves, more ethnic groups have been identified and classified. For example, in the UK 2001 Census, there were eleven categories in the ethnicity classification, among which Black Africa, Mixed, Other Asian and Chinese groups have been less studied. For these groups, it is unknown to what extent socioeconomic inequalities contribute to ethnic inequalities in health.

One of the main objectives of this study is to investigate to what extent socioeconomic inequalities contribute to ethnic inequalities in different types of cardiovascular disease, given that subtypes of cardiovascular disease might have different risk factors and the role of socioeconomic status in subtypes of cardiovascular disease may be different. Furthermore, if ethnic inequalities in cardiovascular survival and severity are observed, whether socioeconomic inequalities have a contribution to the inequalities is also a question that needs investigation in this study. However, given that information about individuals' socioeconomic status is not available in the HES, areal socioeconomic status measures have to be used, which offers an opportunity to investigate the potential of using areal socioeconomic measures for studying ethnic inequalities in cardiovascular disease when individual socioeconomic measures are seldom available in health data

Nazroo (2003a) suggested the geographical location of residence of people from minority ethnic group might be an important source of social disadvantage that determines their poor health. Karlsen et al. (2002) explored the contribution of individual level and ward level characteristics to self-reported fair or poor health among four ethnic groups (Caribbean, Indian, Pakistani and Bangladeshi, and white) in the UK based on the Fourth National Survey of Ethnic Minorities (1993-1994). On the whole, none of the ward level indicators, including the quality of the local environment, the provision of local amenities and local problems of crime and nuisance, was statistically and significantly associated with self-reported health among ethnic groups. However, the relationship between socioeconomic environment and ethnic inequalities in cardiovascular disease is less studied.

Using areal socioeconomic status measure is subject to two problems. Firstly, the ecological fallacy, which refers to the bias introduced when using areal measures alone to make inference about individual level relationships (Selvin, 1958, Firebaugh, 1978). However, there is substantial evidence based on the individual level supporting the conclusion that ecological correlations between socioeconomic deprivation and health could reflect associations among the relevant variables in individuals (MacRae, 1994). Geronimus (2006) concluded that as long as health data offer few other options, areal socioeconomic measures will continue to be used to proxy unavailable individual socioeconomic variables, with careful interpretation of study results.

Secondly, the Modifiable Areal Unit Problem (MAUP), which refers to the problem that statistical results defined over a set of essentially arbitrary areal units vary according to the geographical scale at which the analysis is conducted (scale problem of the MAUP) and how the geographical boundaries are drawn at that scale (zonation problem of the MAUP) (Flowerdew et al., 2001). In order to examine how the results vary across geographical scales, the effect of areal socioeconomic status measured at different geographical scales is investigated in this study.

1.5 Research Objectives

Based on the previous review, this study contributes to ethnic inequalities in cardiovascular disease through three key research objectives:

1. To examine and explore the potential of the Hospital Episode Statistics (HES) for research on ethnic inequalities in cardiovascular disease, more broadly in health research in general, by developing a methodology to improve the data quality of ethnicity code in the HES.

- Develop a record linking method to restore invalid ethnicity codes in the HES
- Develop a coding rate method to further reduce uncertainties caused by invalid ethnicity codes

2. To examine ethnic inequalities in cardiovascular disease in England at both national and local geographical scales

- Examine the disparities of incidence of cardiovascular disease subtypes for ethnicity-sex groups at English national level.
- Investigate the geographical relative risk of cardiovascular disease for ethnicity-sex groups at local authority scale.
- Examine ethnic inequalities in cardiovascular disease survival in England.
- Examine ethnic inequalities in cardiovascular disease severity/treatment

in England.

3. To explore the relationships between socioeconomic status and ethnic inequalities in cardiovascular disease

- Investigate how ethnic inequalities in cardiovascular disease incidence vary between geodemographics groups with different socioeconomic status profiles.
- Investigate to what extent socioeconomic status contributes to ethnic inequalities in incidence of different types of cardiovascular disease, cardiovascular disease survival, and severity/treatment.
- Meanwhile, to investigate whether the effect of areal socioeconomic status measured at different geographical scales is consistent on ethnic inequalities in cardiovascular disease incidence, survival and severity/treatment.

1.6 Structure of the Thesis

In Chapter Two, this thesis starts with introducing background about how the principal theme of this thesis, ethnic inequalities in health might be explained by socioeconomic inequalities, is formed. Three topics are covered in this chapter, including a more detailed introduction to ethnic groups in the UK with a focus on different aspects of socioeconomic status, a conceptual model of cardiovascular disease risk factors and a literature review about the relationships between socioeconomic status and health, particularly cardiovascular disease.

Chapter Three introduces the data and the methods used throughout this thesis. The data used in the whole study include Hospital Episode Statistics (HES), Population Estimates by Ethnic Group 2004, The UK 2001 Area Classification, the UK 2001 Census and English Indices of Multiple Deprivation 2004. The methods which are used to analyze these data are standardised incidence ratios (SIR), empirical Bayes estimation, multiple logistic regression, generalized linear mixed model for multilevel modelling and survival analysis.

Chapter Four mainly deals with the first thesis objective, developing a methodology to improve the data quality of ethnicity code in the Hospital Episode Statistics (HES). After a review of existing studies using ethnicity data of HES and the problems within the main method they used, a record linking method is firstly developed to restore the missing ethnicity codes in the HES. And then, two different coding rate methods are developed to further reduce uncertainties caused by missing ethnicity data. The final section discusses which one of the two coding rate methods is selected and why it is selected.

Chapter Five examines ethnic inequalities in incidence of different types of cardiovascular disease at both English national level and local authority level. Firstly, standardised incidence ratios of different types of cardiovascular disease have been calculated for ethnicity-sex groups at English national level, and are presented by cardiovascular disease types and ethnicity separately. Examining geographical relative risk of cardiovascular disease for ethnicity-sex groups is greatly affected by the small number problem. Thus two empirical Bayes estimation methods are used to shrink unstable SIRs, particularly for minority ethnic groups, followed by a comparison between crude SIRs and empirical Bayes estimations. Finally, the geographical relative risk of cardiovascular disease for ethnicity-sex groups is presented in maps.

Chapter Six explores the relationships between socioeconomic status and ethnic inequalities in cardiovascular disease, starting by investigating how ethnic inequalities in cardiovascular disease vary between geodemographics groups with different socioeconomic status profiles. Areal socioeconomic status measured in different ways, socioeconomic status measured for the general population from the English Indices of Multiple Deprivation 2004 and socioeconomic status measured specifically for ethnic groups from the UK 2001 Census, have been separately fitted into the models to examine how areal socioeconomic status measures contribute to ethnic inequalities in different types of cardiovascular disease. The effect of areal socioeconomic status measured at different geographical scales also has been investigated.

Chapter Seven is about ethnic inequalities in cardiovascular disease survival and severity/treatment. Firstly, ethnic inequalities in cardiovascular disease survival are examined, followed by investigating whether areal socioeconomic measures, distance to treatment sites and cardiovascular severity indicators (length of stay in hospital, cardiovascular operations, cardiovascular emergency admissions and diabetes) contribute to ethnic inequalities in cardiovascular disease survival. Secondly, ethnic inequalities in cardiovascular disease severity/treatment, i.e. cardiovascular operations, and cardiovascular emergency admissions are examined. How areal socioeconomic status measured at different geographical scales contributes ethnic inequalities in cardiovascular operations and cardiovascular emergency admissions are examined as well.

Chapter Eight concludes this thesis by summarizing the main results in relation to the three objectives of this thesis. The limitations of this study are acknowledged and the opportunities for further research are discussed in this chapter as well, followed by the policy implications of the thesis.

Chapter Two: Ethnicity, Socioeconomic Status and CVD

2.1 Introduction

Building on the introduction to this thesis in Chapter One, this chapter provides detailed background knowledge of this study, covering three themes, including an introduction to ethnic groups in the UK, cardiovascular disease risk factors and the established relationships between socioeconomic status and cardiovascular disease.

The UK historically has a mixture of diverse ethnic groups. Over 4.6 million people from a variety of ethnic groups make the UK today more culturally diverse than ever before. Ethnicity is a dimension of social structure. Each ethnic group possesses their own distinct culture, tradition and sometimes their own language or religion (Office for National Statistics, 2003). They arrived in the UK at different times, have different population size and age structure, distribute unevenly across the UK and tend to live in large urban areas. There also have been great differences between ethnic groups in socioeconomic characteristics, such as economic activity, social class and housing, which are the focus of this chapter.

Cardiovascular disease is the number one cause of deaths in the UK, which places a big burden on individuals, families, communities and society. Notable ethnic inequalities in cardiovascular disease morbidity and mortality have been observed in the UK. Therefore cardiovascular disease is of particular interest in this study. Generally, outcomes of cardiovascular disease are cumulative results of early life risk factors, biological risk factors and socioeconomic risk factors. Over 300 cardiovascular disease risk factors have been identified. This chapter briefly introduces the background of cardiovascular disease, including different types of cardiovascular disease studied in this thesis, the burden of cardiovascular disease and a conceptual model of cardiovascular disease risk factors.

The hypothesis of this study is that socioeconomic inequalities might be an important potential explanation of ethnic inequalities in cardiovascular disease, given that people from minority ethnic groups are usually of low socioeconomic status and that low socioeconomic status is a major risk factor of cardiovascular disease. This chapter reviews the established associations between socioeconomic status and cardiovascular disease in the final section. The effect of socioeconomic status measured at both individual and neighbourhood level on cardiovascular disease has been well studied in the literature, based on which further studies on the contribution of socioeconomic status to ethnic inequalities in cardiovascular disease are conducted in the following chapters.

2.2 Ethnic Groups in the UK

2.2.1 Historical Background of Ethnic Groups in the UK

Britain has a long history of immigration (Stillwell and Duke-Williams, 2005). The current formation of ethnicity structure in the UK could be traced to the post-World War II period, when substantial numbers of immigrants from other parts of the world, particularly Ireland and the former colonies of the British Empire, such as India, Bangladesh, Pakistan, Caribbean and South Africa, came to the UK to seek either economic prosperity or protection as refugees (Haskey, 1997, Monahan, 2004). Most of the current overseas-born old residents of the UK arrived during or shortly after that period, two thirds arrived before 1960 and four out of five (87 per cent) arrived before 1971 (Rendall and Ball, 2004).

In the 1950s, under the labour shortages in the post-war period, large numbers of migrants came into the UK. Immigrants from Ireland and the West Indies increased. Caribbean workers were also encouraged to help rebuild post war Britain, and

Caribbean migrants reached its maximum in the early 1960s. Workers mainly from India and Pakistan arrived in the 1950s and 1960s, and peaked in the late 60s and early 70s, followed by the inflows from Bangladesh and the African Commonwealth countries including Kenya and Tanzania, which expanded in the early 1980s. (Haskey, 1997) In the 1970s, East African Asians escaping from persecution and Vietnamese escaping from war arrived in the UK. Eastern European refugees arrived from war and political unrest in Romania and the former Yugoslavia coming to the UK in the 1980s. (Monahan, 2004) At the end of the 1990s, asylum seekers and refugees from Iraq and Afghanistan came into the UK because of wars fought during the 1980s and 1990s in their countries. On May 1st 2004, Eastern Europe countries (including the Czech Republic, Slovakia, Estonia, Hungary, Latvia, Lithuania and Poland) were admitted to the European Union. Since then, large numbers of Eastern Europe workers have come to the UK, which represented the largest wave of immigration since the 1950s and 1960s. According to the Home Office figures in 2006, the population size of immigrants from Eastern Europe countries was around 375,000. And 60 per cent of these new migrants were Polish. A table about the brief history of the UK immigrants in recent 200 years is shown as follows.

19th Century • Jewish arrivals fleeing persecution in Russia and Poland • Irish settlers escaping poverty • Trade brings Indian and Chinese people to main ports
1930s • Refugees from Nazi oppression arrive in the UK
1948 • The boat Windrush brings 492 Jamaicans to the UK –thousands more follow • Immigration from Caribbean encouraged to help rebuild post-war Britain
1950s and 60s • Settlers from other new Commonwealth nations arrive –India, Pakistan and Bangladesh
1970s • East African Asians and Vietnamese arrive
1980s • African community expands

	• Refugees arrive from Eastern Europe – Romania and former Yugoslavia
2000s	
	• Asylum seekers and refugees from Iraq, Afghanistan and Zimbabwe
	• Eastern European workers head UK's 'biggest wave of immigration' since 2004

Table 2-1 Timeline: immigration to the UK in the last 200 years, modified from Monahan (2004)

2.2.2 Ethnicity Classification in the UK

Studying ethnic groups requires a clear ethnicity classification, which is a method of classifying people into different ethnic groups according to their common features to ensure consistent description and comparison of statistics over time. However, due to the complexity and changing nature of ethnicity, there is no single and permanent ethnicity classification and ethnicity classification changes over time as the understanding of ethnic groups evolves. There are a number of possible ways available which have been used over time to differentiate ethnic groups, which include country of birth, nationality, language spoken at home, parents' country of birth in conjunction with country of birth, skin colour, national/geographical origin, racial group and religion. In the British government research, ethnicity is measured based on a combination of categories, such as 'race', skin colour, national and regional origins, and language (Office for National Statistics, 2003), as introduced in Chapter One.

In the UK, ethnicity classification or ethnic group presentation in the national census is usually regarded as the standard classification, because census is the most comprehensive population survey and is used for many years, often together with other surveys and administrative data sources. In the censuses, the ethnicity classifications have been limited to a number of groups only to obtain a balance between the complexity in ethnic data collection and representing the majority of the population accurately. As the understanding of ethnicity improves, the ethnic classification has been modified over time in the censuses. Furthermore, as ethnic groups were unevenly distributed in England and/or Wales, Scotland and Northern

Ireland, the questions in the census were different between countries. And the ethnicity classifications were not identical in different countries. (Office for National Statistics, 2003)

There are two levels in the ethnic classification in the England and/or Wales 2001 Census. As presented in the table below, there are 5 main ethnic groups in Level 1, including White, Mixed, Asian or Asian British, Black or Black British, and Chinese or Other Ethnic Group, which is a coarse classification. The 5 groups in Level 1 are further classified into sub-categories in Level 2, which is a finer classification. (Office for National Statistics, 2003)

Level 1	**Level 2**
White	White British White Irish Any Other White
Mixed	White and Black Caribbean White and Black African White and Asian Any Other Mixed
Asian or Asian British	Indian Pakistani Bangladeshi Other Asian
Black or Black British	Black Caribbean Black African Other Black
Chinese or Other Ethnic Group:	Chinese Other

Table 2-2 Presentation of ethnic groups in England and Wales (Office for National Statistics, 2003)

There are also two levels in the ethnic classification in the Scotland 2001 Census, as presented in the table below. However, there are obvious differences in the main groups and sub-categories from those of the English ethnicity classification, which was determined by the distribution of ethnic groups in Scotland (Office for National Statistics, 2003).

Level 1	Level 2
White	White Scottish
	Other White British
	White Irish
	Any Other White
Indian	Indian
Pakistani and other South Asian	Pakistani
	Bangladeshi
	Other (South) Asian
Chinese	Chinese
Other ethnic group	Caribbean
	African
	Black Scottish and other Black
	Any Mixed Background
	Other ethnic group

Table 2-3 Presentation of ethnic groups in Scotland (Office for National Statistics, 2003)

The ethnicity classification in the Northern Ireland 2001 Census is significantly different from those in England and/or Wales and Scotland. As presented in the table below, there is only one level in the classification and no sub-categories are available. And there are fewer groups in the Northern Ireland than other countries. (Office for National Statistics, 2003)

White
Irish Traveller
Mixed
Indian
Pakistani
Bangladeshi
Other Asian
Other Black
Chinese
Any other ethnic group

Table 2-4 Presentation of ethnic groups in Northern Ireland (Office for National Statistics, 2003)

To be compatible with the ethnicity classification in the census, the same ethnicity classification has been used in other national surveys. However, because the population size of some ethnic groups is very small, it is often the case that in most surveys there are only small numbers of people from minority ethnic background. The ethnicity data can't be analysed by separate ethnic group due to statistical unreliability or disclosure control. Therefore the ethnic data are often aggregated either by combining more than one year's data or by combining different ethnic groups according to their similar patterns of the outcome variable of interest, acknowledging that the distinction between these ethnic groups is lost. For example, Indian, Pakistani and Bangladeshi groups are often aggregated as South Asians in some research on cardiovascular disease. Although how to combine some particular ethnic groups depends on the specific purpose of the surveys or user needs, there are three suggested ways of combining ethnic groups, including two-category ethnicity classification, six-category ethnicity classification and eleven-category ethnicity classification, as presented in the tables below. (Office for National Statistics, 2003, Office for National Statistics, 2006a) The eleven-category ethnicity classification is employed in this thesis.

Presentation group	**Combined categories**
White	White British White Irish Any Other White
Non-White	White and Black Caribbean White and Black African White and Asian Any Other Mixed Indian Pakistani Bangladeshi Black Caribbean Black African Other Black Chinese Other Asian Other ethnic group

Table 2-5 Two-category ethnicity classification (Office for National Statistics, 2003)

Presentation group	Combined categories
White	White British White Irish Any Other White
Mixed	White and Black Caribbean White and Black African White and Asian Any Other Mixed
Indian	Indian
Pakistani and Bangladeshi	Pakistani Bangladeshi
Black or Black British	Black Caribbean Black African Other Black
Other Ethnic Group (inc. Chinese and Other Asian)	Chinese Other Asian Other ethnic group

Table 2-6 Six-category ethnicity classification (Office for National Statistics, 2003)

Presentation group	Combined categories
White	White British White Irish Any Other White
Mixed	White and Black Caribbean White and Black African White and Asian Any Other Mixed
Indian	Indian
Pakistani	Pakistani
Bangladeshi	Bangladeshi
Other Asian	Other Asian
Black Caribbean	Black Caribbean
Black African	Black African
Other Black	Other Black
Chinese	Chinese
Other ethnic group	Other ethnic group

Table 2-7 Eleven-category ethnicity classification (Office for National Statistics, 2003)

2.2.3 Population Size

Although people from minority ethnic groups only account for a small proportion of the total population, the population size of minority ethnic groups keeps on growing since the post-war period, particularly in recent three decades. The total population of non-white people in the UK was 2.1 million in the 1981 Census, and 3.0 million in the 1991 Census (ethnic group data were not collected on the Northern Ireland Census). However, this number reached 4.6 million in the 2001 Census, rising by 53 per cent (Office for National Statistics, 2005, Rees and Butt, 2004).

Although there is no single and permanent ethnicity classification, what is fixed is that white people are the majority of the UK populations, which accounted for 92.1 per cent of the UK population in the 2001 Census (April 2001). The remaining 7.9 per cent of the UK populations belonged to minority ethnic groups. The population size of different ethnic groups and the proportions they accounted for in the total population are shown in the table as well as in the pie graph below, which is reproduced from the relevant tables in *Focus on Ethnicity and Identity* (Office for National Statistics, 2005).

The major groups of ethnic minorities were Indian, Pakistani, Mixed and Black Caribbean groups. The Indian group was the largest minority ethnic group and accounted for 1.8 per cent of the UK population. People from Bangladeshi, Other Asian, Other Black, Chinese groups and Other ethnic group were the small minority ethnic groups, which separately accounted for around 0.4-0.5 per cent of the UK population and around 5-6 per cent of British ethnic minority population.

Around half of the ethnic minority population (50.3 per cent) were from the main group All Asian or Asian British, which included Indian, Pakistani, Bangladeshi and Other Asian groups. All Black or Black British, which included Black Caribbean, Black Africa and Other Black groups, was another major ethnic group, which accounted for a quarter of the ethnic minority population and was followed by Mixed group (14.6 per cent).

	(Numbers)	Total population (Percentages)	Non-White population (Percentages)
White	54,153,898	92.1	.
Mixed	677,117	1.2	14.6
Indian	1,053,411	1.8	22.7
Pakistani	747,285	1.3	16.1
Bangladeshi	283,063	0.5	6.1
Other Asian	247,664	0.4	5.3
All Asian or Asian British	2,331,423	4.0	**50.3**
Black Caribbean	565,876	1.0	12.2
Black African	485,277	0.8	10.5
Other Black	97,585	0.2	2.1
All Black or Black British	1,148,738	2.0	**24.8**
Chinese	247,403	0.4	5.3
Other ethnic groups	230,615	0.4	5.0
All minority ethnic population	**4,635,296**	7.9	100.0
All population	58,789,194	100	

Table 2-8 Population size by ethnic groups in the UK, 2001 (Office for National Statistics, 2005)

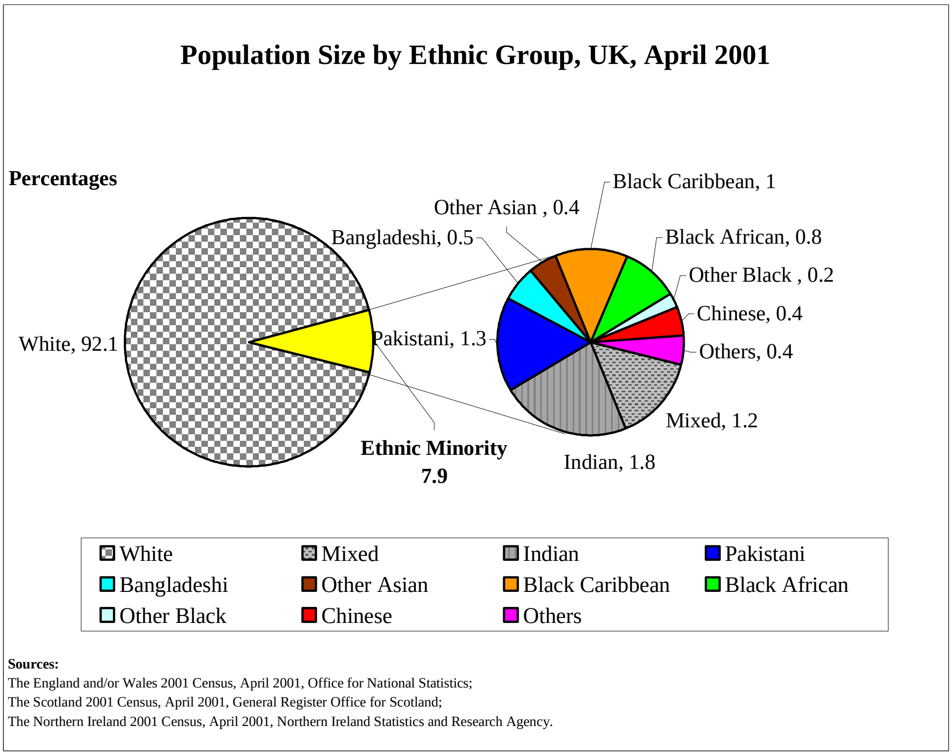


Figure 2-1 Population size by ethnic groups in pie graph, UK, April 2001

The graph below shows the four-year population growth rates by ethnic groups from mid-2001 to mid-2005 in England, according to the data Population Estimates by Ethnic Group for England from Office for National Statistics. Compared with other ethnic groups, the population of white group was very steady, increasing by only 0.16 per cent. However, the populations of minority ethnic groups increased significantly. The ethnic groups whose population grew fastest during the five-year period were Chinese group and Other ethnic group, where the growth rates were over 40 per cent, followed by Black African, Other Asians and Mixed population. The four-year population growth rates for Indian, Pakistani and Bangladeshi people were similar, which were around 15 per cent.

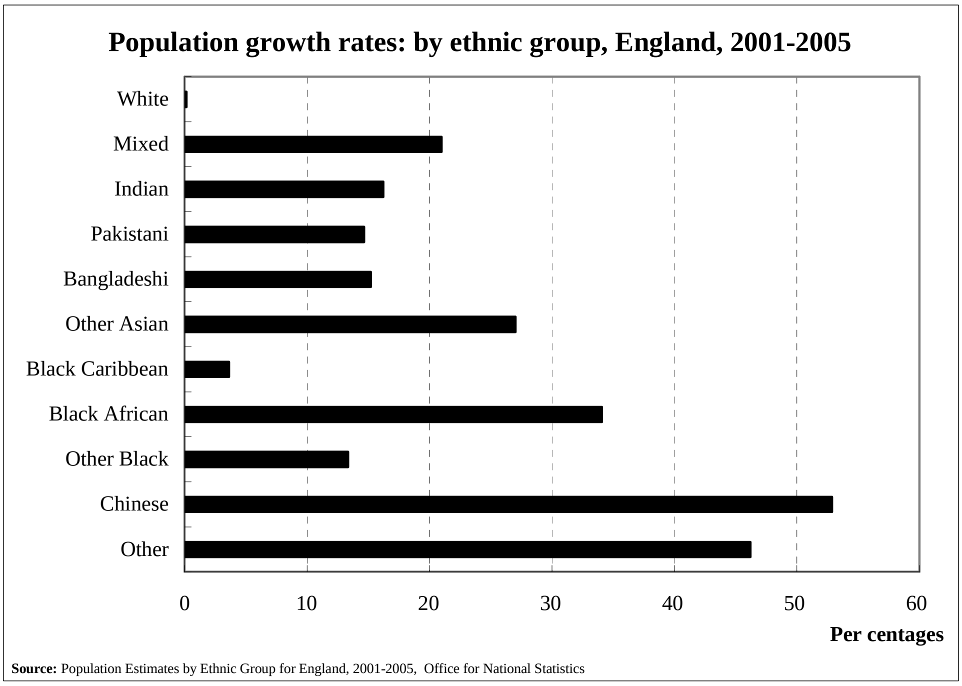


Figure 2-2 Population growth rates by ethnic groups, England, 2001-2005

2.2.4 Age Distribution

In the UK, not only had the populations of minority ethnic groups grown faster than the white group, but also the ethnic minority population had a younger age structure than the white people, as shown in the graph below reproduced from *Focus on Ethnicity and Identity* (Office for National Statistics, 2005). Compared with other ethnic groups, the white group had the largest proportion of people aged 65 and over, which was about 17 per cent, followed by Black Caribbean (around 11 per cent). The Mixed group had the youngest age structure, where half were under the age of 16. The age structures of Bangladeshi, Other Black and Pakistani people were also younger, particularly for Bangladeshi people, where around 38 per cent of Bangladeshi were under the age of 16 and 58 per cent were aged between 16 and 64.

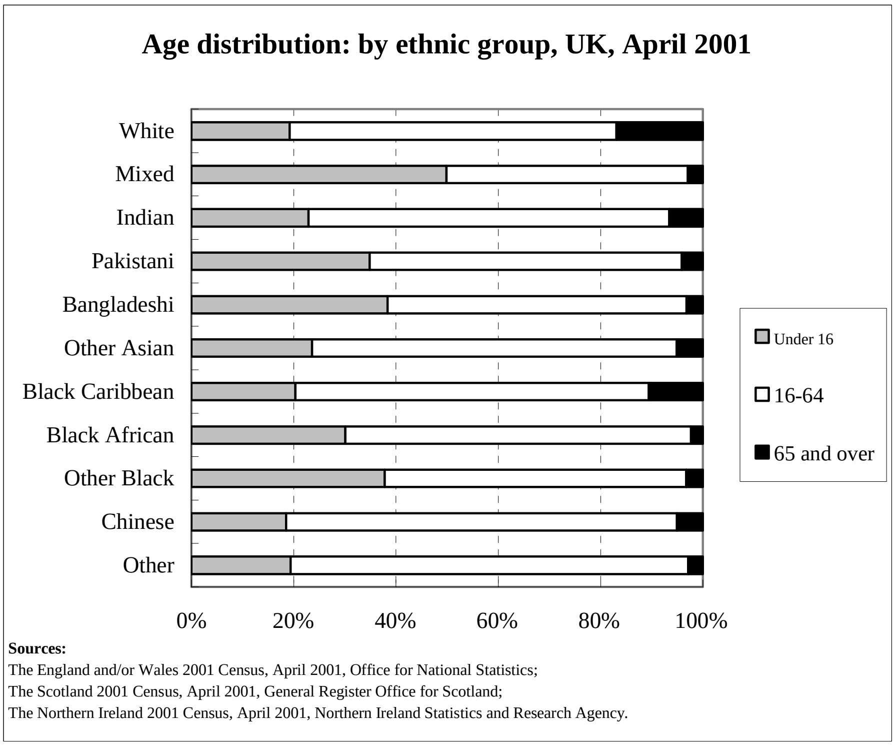


Figure 2-3 Age distribution by ethnic group, UK, April 2001

2.2.5 Geographic Distribution

The graph reproduced from *Focus on Ethnicity and Identity* (Office for National Statistics, 2005) below shows geographic distribution of minority ethnic groups. The majority of people of ethnic minorities (around 96 per cent) in the UK were living in England, which comprised 9 per cent of the total population in England. However, in Scotland, only 2 per cent of the total populations were from non-white ethnic groups. In Northern Ireland, this number was less than 1 per cent. (Office for National Statistics, 2005)

London had the largest concentration of ethnic minorities, which was about 45 per cent of total ethnic minorities in the UK and made up 29 per cent of its total population. Around 13 per cent of the ethnic minority population were living in West Midlands, which was the second largest proportion, followed by South East (8 per cent), North West (8 per cent), and Yorkshire and the Humber (7 per cent). However, the proportions of ethnic minorities were less than 3 per cent in North East and South

West. (Office for National Statistics, 2005) The map below from Office for National Statistics shows the geographical distribution of ethnic minorities in the UK in detail.

London also had the largest concentration of some ethnic groups, particularly for Black African, Black Caribbean and Bangladeshi people, where the proportions of their total population were 78 per cent, 61 per cent and 54 per cent respectively. However, other minority ethnic groups were more dispersed. (Office for National Statistics, 2005)

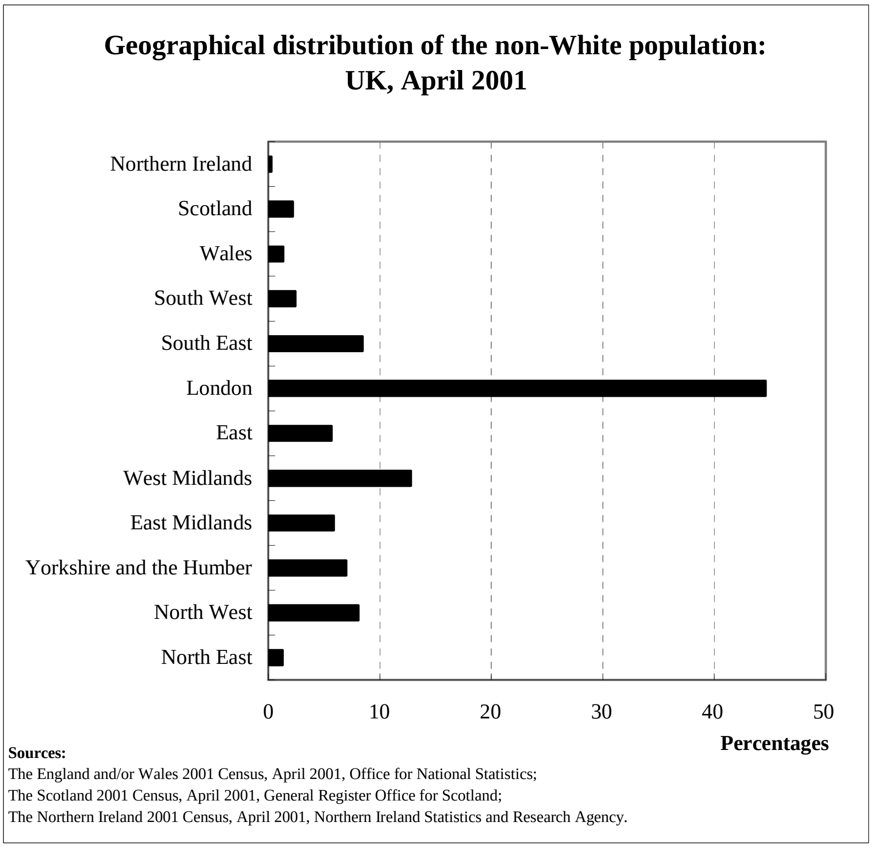


Figure 2-4 Geographical distribution of the non-White population, UK, April 2001

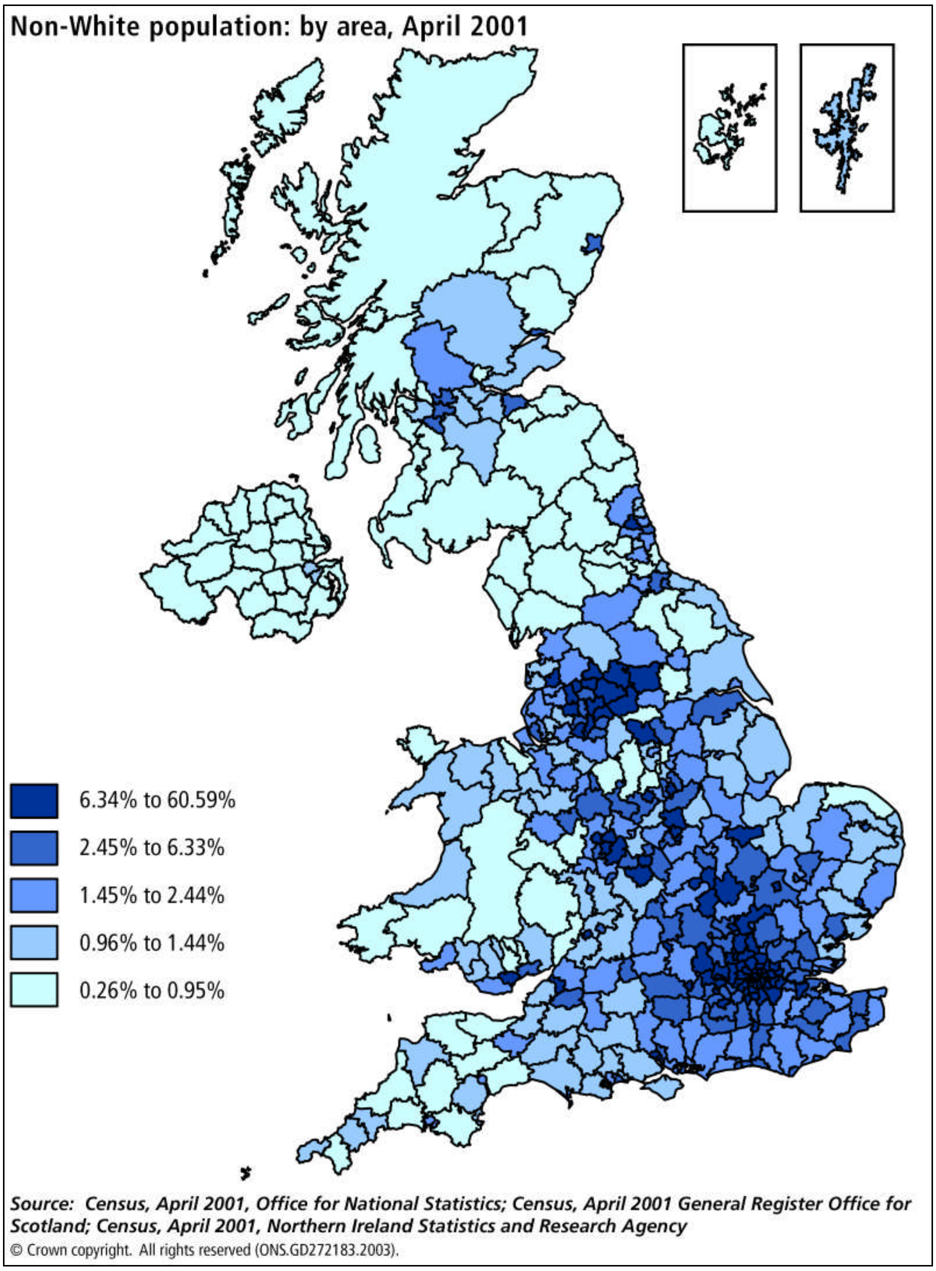


Figure 2-5 Map of non-White people distribution, UK, April 2001

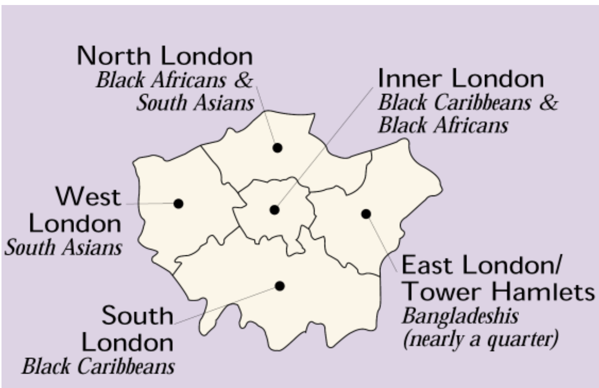


Figure 2-6 Distribution of major ethnic groups in London (Monahan, 2004)

2.2.6 Lower Qualifications

The graph below shows the rates of lower qualifications by ethnic groups in England in 2001, where lower qualifications were aggregated from no qualification and qualifications equivalent to levels 1 to 3 of the National Key Learning Targets (i.e. GCSE's O levels, A levels, NVQ levels 1-3). Bangladeshi (82 per cent) and Pakistani people had the highest rates of lower qualification. More than three quarters of people from these two groups had lower qualification. And 48 per cent of Bangladeshi women, 40 per cent of Bangladeshi men, 40 per cent of Pakistani women and 28 per cent of Pakistani men even had no qualifications (Office for National Statistics, 2005). The rates for White, Black Caribbean and Other Black were also significantly high (over 70 per cent). However, Black African, Chinese and Other ethnic groups were less likely to have lower qualification than other ethnic groups.

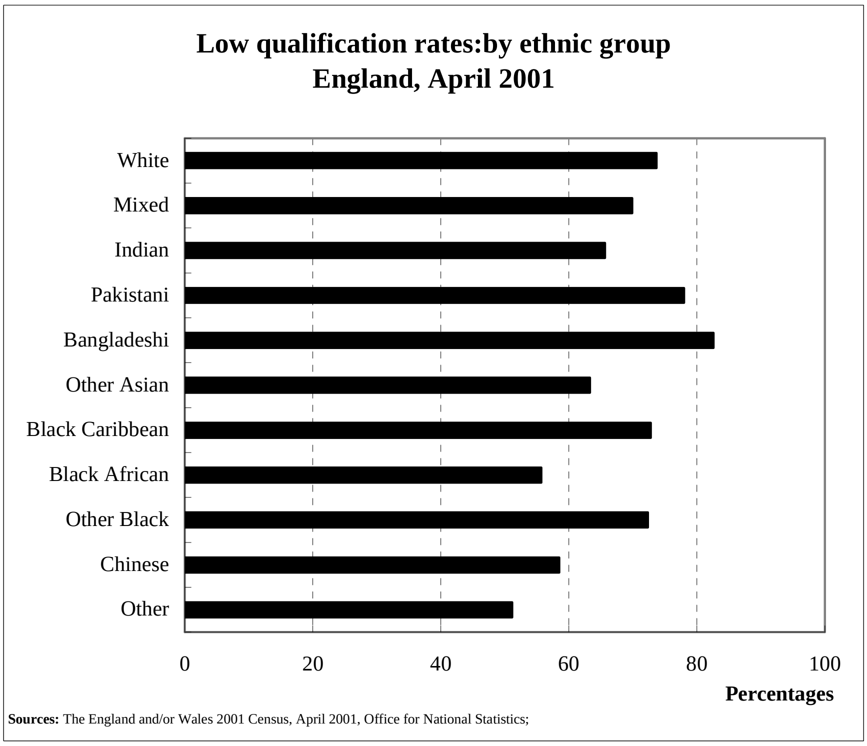


Figure 2-7 Lower qualification rates by ethnic group, England, April 2001

2.2.7 Labour Market

This section discusses the ethnic difference in the UK labour market, in terms of the rates of unemployment and economic inactivity. The ethnic data used to produce the graphs below were summarized from the Annual Population Survey (January 2004 to December 2004) by the Office for National Statistics.

The graph below shows unemployment rates by ethnic groups in Great Britain in 2004. Generally, unemployment rates for people from minority ethnic groups were higher than those from white groups in both males and females. Among men, the unemployment rates of Indian people were second lowest among all the ethnic groups, followed by Chinese men. However, their rates were still higher than the national average. The unemployment rates for Asian British, including Pakistani, Bangladeshi and Other Asian groups, were significantly higher than those of white people. Black men had the highest unemployment rates in the UK, although the rate of Other Black was not statistically reliable. The rate of Black Caribbean (14.5 per cent) was even 3 times higher than that of White British (4.5 per cent). Among women, Indian, Other Asian and Chinese women had lower unemployment rates among women from minority ethnic groups. The unemployment rate of Pakistani women (19.7 per cent) was particularly high, which was more than 5 times higher than that of White British, followed by Black African, Mixed and Other ethnic groups. However, the rates of Bangladeshi and Other Black females were not statistically reliable, according to the Office for National Statistics.

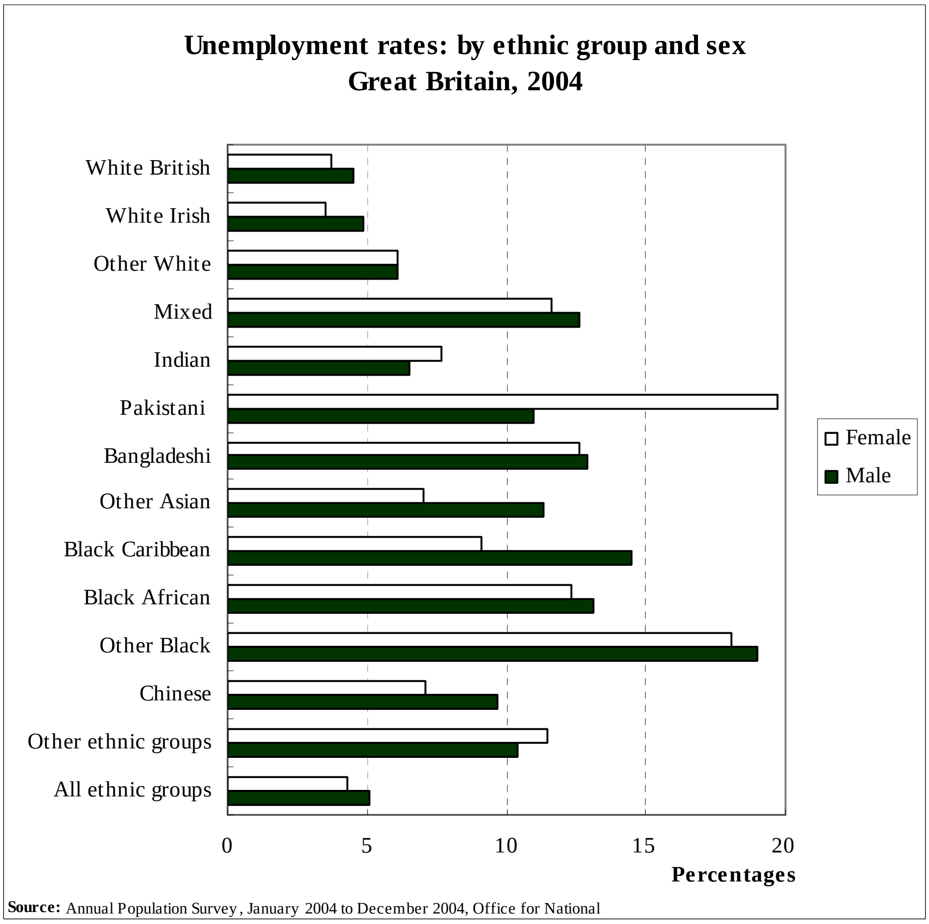


Figure 2-8 Unemployment rates: by ethnic group and sex, Great Britain, 2004

Also based on the Annual Population Survey (January 2004 to December 2004), the graph below shows ethnic disparities in economic inactivity rates in the UK calculated by the Office for National Statistics. The economic inactivity rate was the proportion of people who were not available for work and/or not actively seeking work among all people of working age (Males aged 16-64, Females aged 16-59). The reasons for economic inactivity include being a student, being disabled or looking after the family and home (Office for National Statistics, 2005).

Generally, the rates of economic inactivity for white groups were lower than those for other ethnic groups in both genders. Among men, the Chinese group had the highest rate in economic inactivity (37 per cent), because the vast majority of inactive Chinese men were students (Office for National Statistics, 2005). The rates for

Bangladeshi, Pakistani, Other ethnic group, Black African groups were also particularly high, around 27-29 per cent. However, the rate for Other Black men was not statistically reliable, according to the Office for National Statistics. Compared with men, women were more likely to be economically inactive. The rates for Pakistani and Bangladeshi people were extremely high, nearly three quarters of people from these groups were economically inactive, which were almost three times higher than those of white groups. Women from Chinese, Other ethnic group, Black African and Other Asian groups also had relatively high rates of economic inactivity.

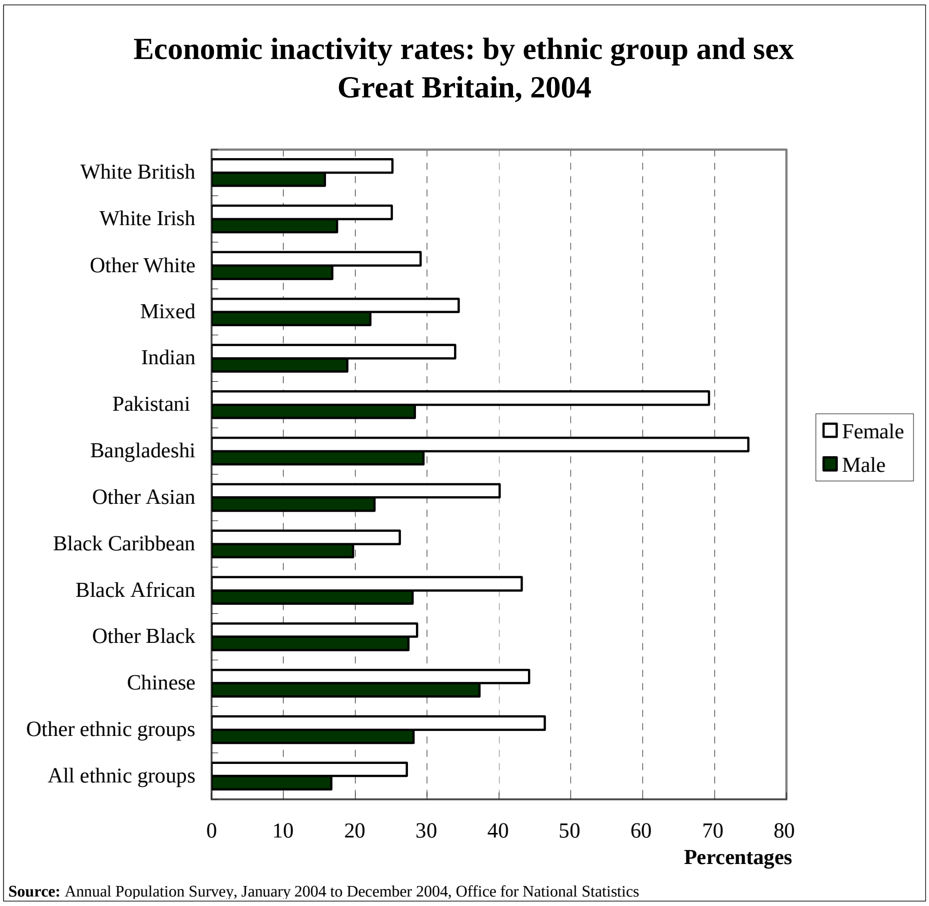


Figure 2-9 Economic inactivity rates: by ethnic group and sex, Great Britain, 2004

2.2.8 Socioeconomic Status

Ethnic differences in the rates of lower socioeconomic class also have been identified through the 2001 Census (England), as shown in the graph below. Here lower social class was aggregated from semi-routine occupations, routine occupations and long term unemployed in the National Statistics Socioeconomic Classification (NS-SEC).

Among men, more than 30 per cent of Bangladeshi men were of the lower socioeconomic class. The rates for Black Caribbean, Other Black and Pakistani were similar and equally high, around 27 per cent. People from the Chinese and Other ethnic groups had the lowest rate of being in the lower socioeconomic class, particularly for Chinese men, whose rate was nearly 20 per cent lower than that of Bangladeshi men. The rate for White men was around 20 per cent. Among women, White, Indian and Other Black group had the highest level of lower socioeconomic status, which were around 21-23 per cents. Black African and Black Caribbean people also had significantly high rates. However, the rates for Bangladeshi, Pakistani and Chinese were much lower, probably because the majority of people from these groups were in economic inactivity.

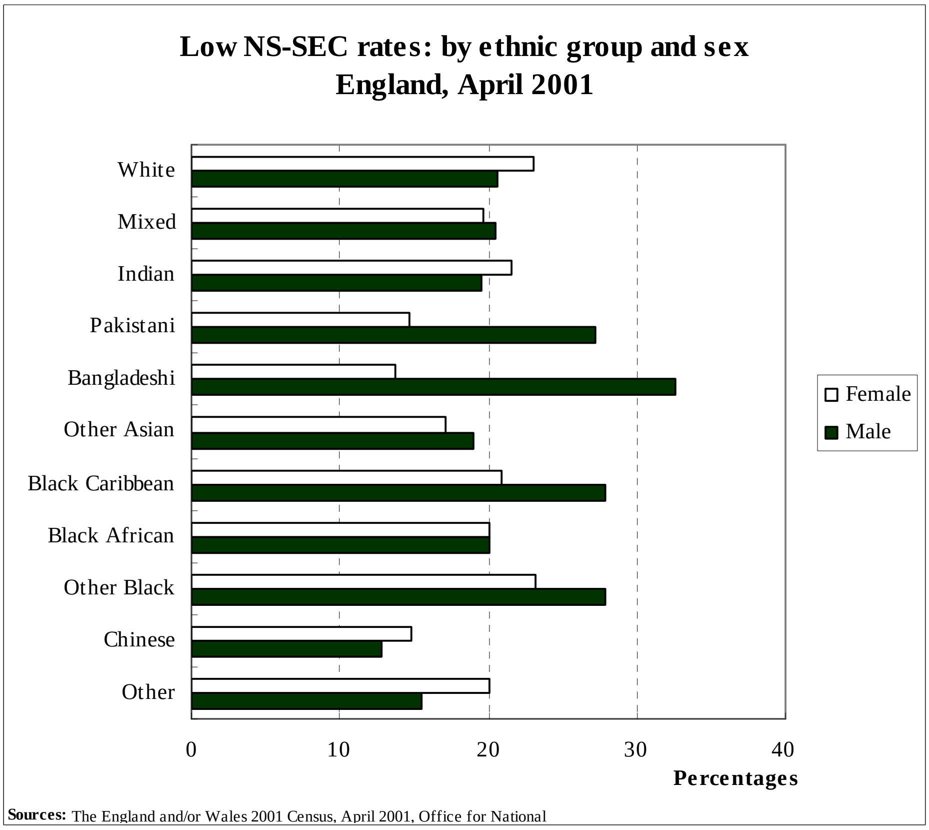


Figure 2-10 Lower socioeconomic class rates: by ethnic group and sex, England, April 2001

2.2.9 Housing

Significant ethnic differences also have been found in housing, such as living in overcrowded accommodation and social rented accommodation. The data used to create the graphs below were summarized from the 2001 Census (England).

The graph below shows the rates of living in overcrowded accommodation by ethnic groups in England in 2001. White people had the lowest rate of living in overcrowded accommodation among all the ethnic groups, which was only around 7 per cent. People from minority ethnic groups were much more likely to experience overcrowding than White people, particularly for Bangladeshi and Black African groups. Around half of people from these two groups lived in overcrowded accommodation, which was 7 times higher than that of the White group. The rate for Other Asian was also significantly high (around 35 per cent), followed by Pakistani, Other Black and Other ethnic groups.

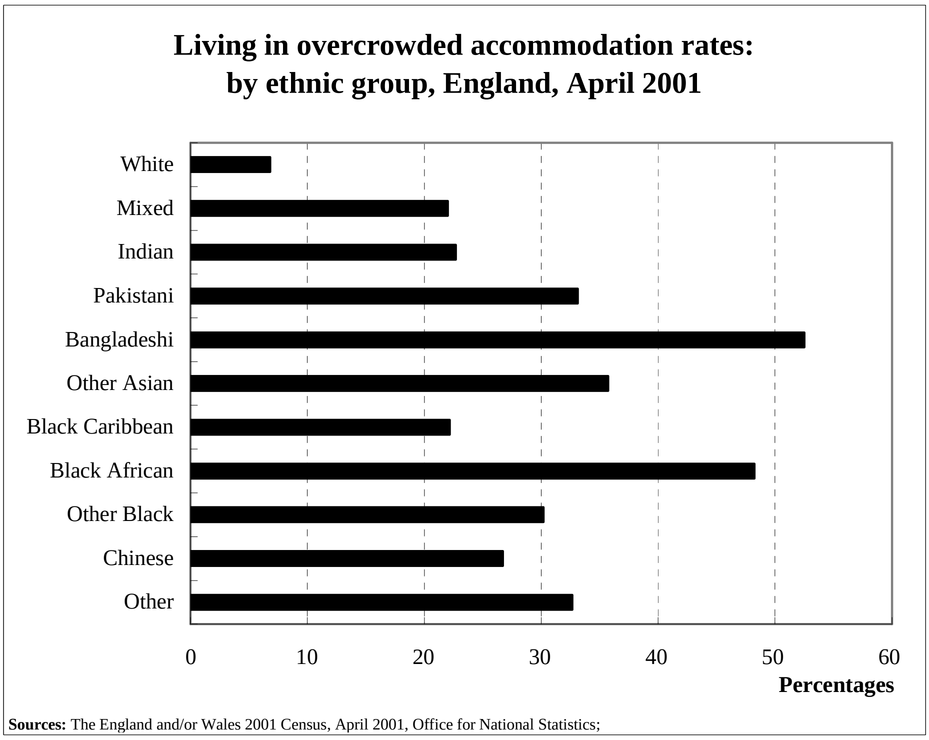


Figure 2-11 Living in overcrowded accommodation rates by ethnic group, England, April 2001

The graph below shows the rates of living in social rented accommodation by ethnic groups in England in 2001. The Indian group had the lowest proportion living in social rented accommodation, which was around 9 per cent, followed by Chinese, Pakistani and Other Asian groups. However, the rates were particularly high for Other Black, Black African, and Bangladeshi groups. Around half of their total populations lived in social rented accommodation, reflecting their lower income. The rate for Black Caribbean, which was more than 40 per cent, was also significantly high.

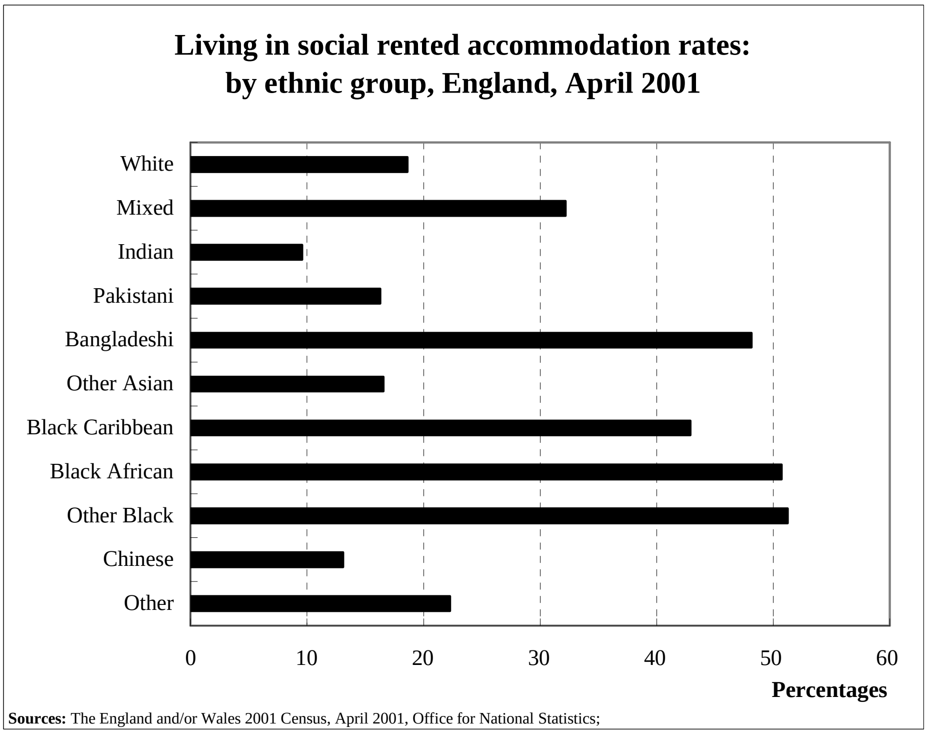


Figure 2-12 Living in social rented accommodation rates by ethnic group, England, April 2001

2.2.10 Health

Not only had ethnic difference in labour market, housing, qualification and socioeconomic status been identified, ethnic inequalities in health also have been identified in the UK. The graphs reproduced from *Focus on Ethnicity and Identity* (Office for National Statistics, 2005) show age standardised rates of reporting 'not good' health and limiting long term illness by ethnic group and sex calculated by Office for National Statistics using the 2001 Census (England), based on a slightly different classification of ethnicity from the one used in the previous graphs.

In the statistics of reporting ‘not good’ health, among men, Pakistani and Bangladeshi men reported the highest rates of ‘not good’ health in 2001, where the rates were around 13 per cent. The rates for White Irish, Mixed, Black Caribbean and Other Black groups were also significantly high, which were around 10 per cent. Chinese and Black African groups reported the lowest rates of ‘not good’ health, followed by White British and Other White. Generally women were more likely to report ‘not good’ health than men except for White Irish group. Pakistani and Bangladeshi women also reported highest rates of ‘not good’ health, followed by Indian, Black Caribbean and Other Black groups. However, Chinese and Other White women were less likely to report ‘not good’ health than other ethnic groups.

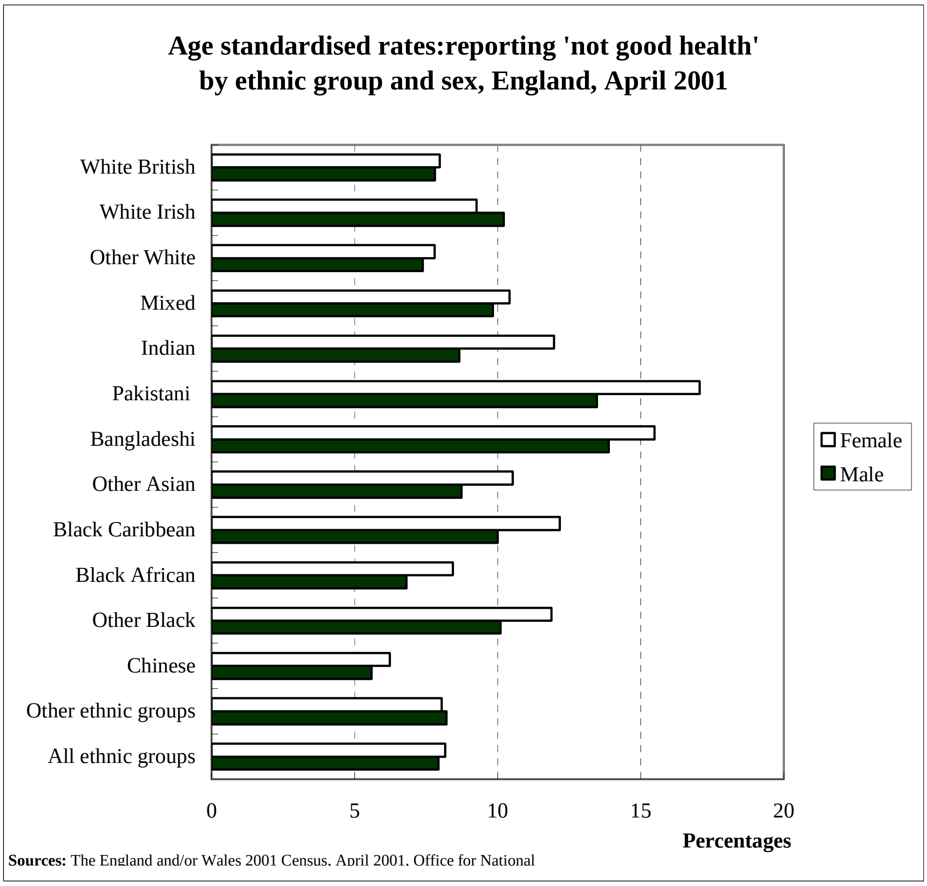


Figure 2-13 Age standardised rates: reporting ‘not good health’ by ethnic groups, April 2001

The graph below shows standardised rate ratios of limiting long term illness by ethnic groups and sex in England in 2001, where White British was the reference group and a standardised rate ratio greater than 1.00 means that the group's age standardised rate was higher than that of the White British group. Among men, the ratios for Pakistani and Bangladeshi men were the highest, followed by Other Black. Black Caribbean, Mixed and White Irish groups, whose ratios were around 1.1. However, the ratios of Chinese, Black African and Other White groups were significantly lower than that of White British, particularly for Chinese men with a ratio of 0.7. Among women, the ratios of groups from Asian or Asian British and Black or Black British were much higher than their male counterparts. Pakistani and Bangladeshi women also had the highest ratios of limiting long term illness, followed by Indian, Other Black, Black Caribbean and Other Asian women. The groups who had lower ratios than White British women were Other White, Other ethnic group and Chinese women, particularly for Chinese women.

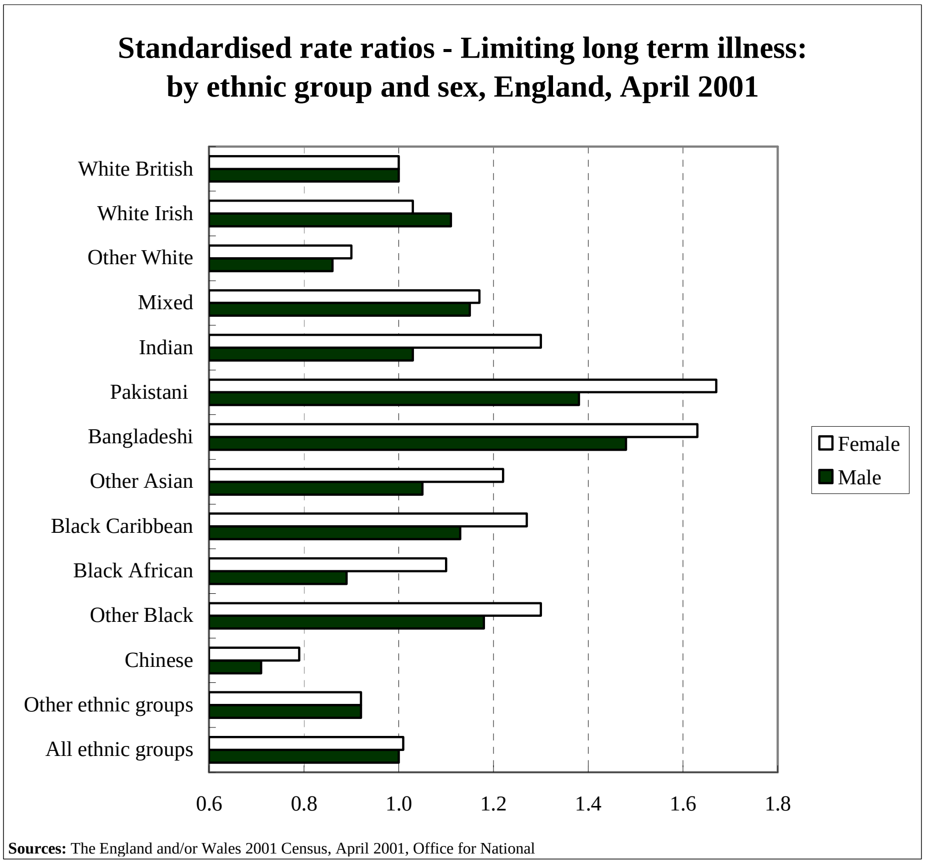


Figure 2-14 Standardised rate ratios of limiting long term illness by ethnic group, April 2001

2.3 Cardiovascular Disease

2.3.1 Types of Cardiovascular Disease

The heart is the strongest muscle and the most important organ in the human body, which delivers oxygen and nutrition to other body organs by pumping out blood. However, this system is vulnerable to breakdown, which results in cardiovascular disease (CVD) (World Health Organization, 2004). The major CVDs include coronary heart disease, cerebrovascular disease, hypertension (high blood pressure), heart failure and rheumatic heart disease (World Health Organization, 2003a). A brief introduction to subgroups of cardiovascular disease is as follows:

- **Coronary heart disease (CHD):** also known as coronary artery disease (CAD), arteriosclerotic heart disease and ischaemic heart disease, is a group of disease of the blood vessels supplying the heart muscle, caused by a combination of fatty material, calcium, and scar tissue (plaque), where plaque often narrows the artery so that the heart does not get enough blood. The slowing of blood flow causes chest pain, or angina. And if plaque completely blocks blood flow, it may cause a heart attack (myocardial infarction) or a fatal rhythm disturbance (sudden cardiac arrest). (Gandelman, 2007, World Health Organization, 2004)
- **Cerebrovascular disease:** disease of the blood vessels within the brain or supplying blood to the brain, usually caused by atherosclerosis where plaque narrows the arteries. Cerebrovascular disease often leads to stroke, which includes ischaemic stroke, caused by a sudden blockage of a blood vessel within the brain, and haemorrhagic stroke, resulted from rupture of a blood vessel. (World Health Organization, 2004)
- **Raised blood pressure (hypertension):** is defined as a systolic blood pressure of 140 mmHg or over, or a diastolic blood pressure of 90 mmHg or over. Hypertension increases the workload of hearts and causes the heart muscle to thicken, which in turn may aggravate atherosclerosis. A late complication of

hypertension is hypertensive heart disease, which is the leading cause of illness and death from hypertension. (Gandelman, 2007)

- **Rheumatic heart disease:** is damage to the heart muscle and heart valves from rheumatic fever, caused by streptococcal bacteria. (World Health Organization, 2004)
- **Heart failure:** also called cardiac failure, CHF, left-sided heart failure or right-sided heart failure. Heart failure is a condition in which the heart can't pump enough blood throughout the body, which may cause blood and fluid to back up into the lungs, edema in feet, ankles and legs, or tiredness and shortness of breath. The leading causes of heart failure are coronary artery disease, high blood pressure and diabetes.
- **Peripheral artery disease:** is disease of blood vessels supplying the arms and legs. (World Health Organization, 2004)
- **Congenital heart disease:** is malformation of heart structures present before or at birth, which may be caused by genetic factors or by adverse exposures during gestation. Examples are holes in the heart, abnormal valves, and abnormal heart chambers. (World Health Organization, 2004)
- **Other heart disease:** Tumours of the heart; vascular tumours of the brain; disorders of heart muscle (cardiomyopathy); heart valve disease; disorders of the lining of the heart.

2.3.2 Burden of Cardiovascular Disease

Cardiovascular disease (CVD) is a major cause of disability and the leading cause of premature death globally. According to *World Health Report 2003* (World Health Organization, 2003c), CVD made up 16.7 million, or 29.2% of total global deaths, of which 7.2 million were due to coronary heart disease, 5.5 million were due to stroke, and an additional 3.9 million were due to hypertensive and other heart conditions. The number of global deaths from cardiovascular disease is on the rise. In 2005, the number of global CVD deaths was estimated as 17.5 million, accounting for 30% of the global deaths, of which 7.6 million were due to coronary heart disease and 5.7 million were due to stroke (World Health Organization, 2005). By 2015, this number is estimated to be 20 million, mainly due to coronary heart disease and stroke (World Health Organization, 2005). In addition to the large number of CVD deaths, at least 20 million people suffer heart attack and stroke every year (World Health Organization, 2003a), which in turn requires continuing costly clinical care and places a burden on family and community.

The total burden of cardiovascular disease is usually measured using disability adjusted life years (DALY), which is a indicator of overall impact of illness, disability and mortality on population health and is calculated as the sum of the years of life lost due to premature mortality (YLL) in the population and the years lost due to disability (YLD) for incident cases of the health condition (Mathers et al., 2003). 10% of DALYs lost in low and middle income countries are due to cardiovascular disease, however, in high income countries, this number is about 18%. The DALY of coronary heart disease is projected to rise from around 47 million globally in 1990 to 82 million in 2020, followed by stroke, of which the burden is projected to rise from around 38 million DALYs globally in 1990 to 61 million DALYs in 2020. (World Health Organization, 2004)

In the UK, cardiovascular disease causes more death than any other disease, where over 208,000 people died from cardiovascular disease each year, accounting for 36% of death in the UK, i.e. more than one in three people die from CVD (Allender et al., 2007, Scarborough et al., 2008). The main forms of CVD are coronary heart disease (CHD) and stroke, where half of all the deaths from CVD are from CHD and about a quarter are from stroke (Petersen et al., 2005, Allender et al., 2007, Scarborough et al., 2008). CHD causes over 101,100 deaths a year in the UK, approximately one in five deaths in men and one in seven deaths in women (Scarborough et al., 2008). Stroke causes over 55,000 deaths a year in the UK, accounting for 8% of deaths in men and 11% of deaths in women in 2006. Cardiovascular disease is also the leading cause of premature death in the UK (death before the age of 75). In 2005, 31% of premature deaths in men and 23% of premature deaths in women were from CVD, and 20% of premature deaths in men and 11% of premature deaths in women were caused by coronary heart disease. (Allender et al., 2007)

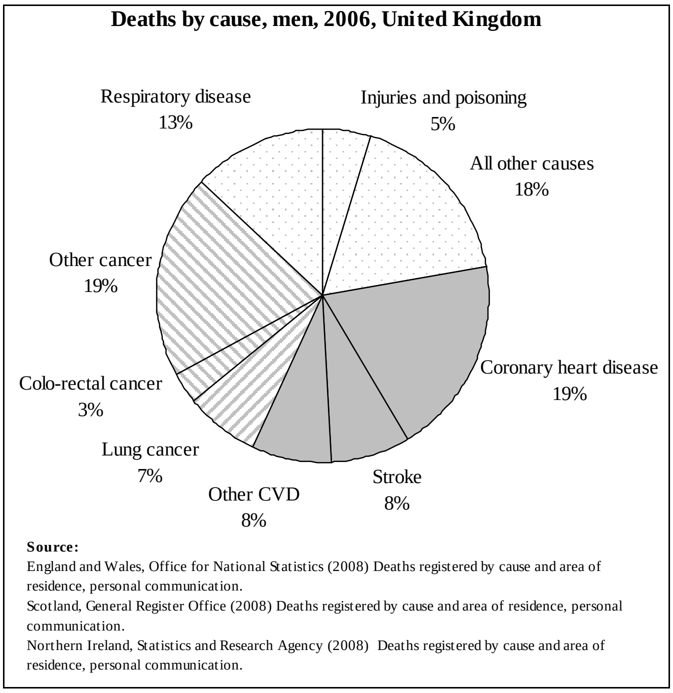


Figure 2-15 Death by cause for men, UK, 2006

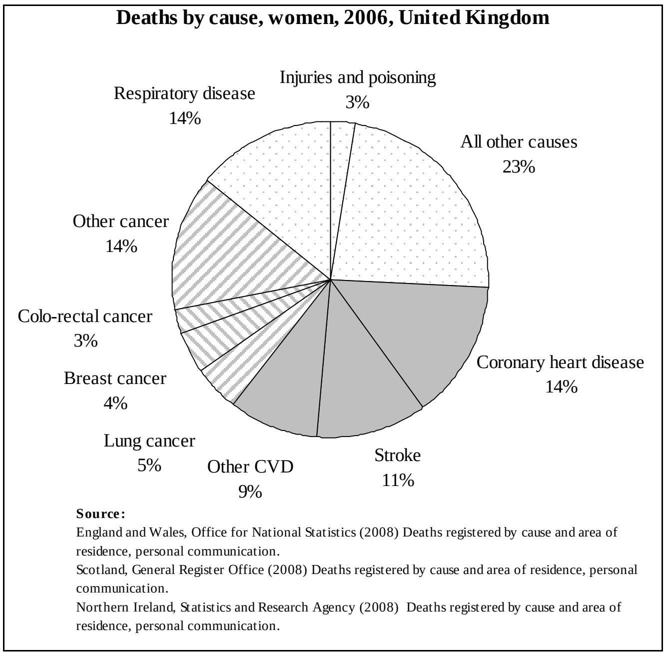


Figure 2-16 Death by cause for women, UK, 2006

There are considerable geographical variations in CVD mortality in the UK. Given that coronary heart disease is the biggest killer among cardiovascular disease, regional variations in CHD death rates are of interest in many national studies (Petersen et al., 2005, Allender et al., 2007, Scarborough et al., 2008). The figure below presents the age-standardised death rates from CHD per 100,000 populations in 2006 by countries and government office regions. Men had much higher death rates of coronary heart disease than women. Death rates were highest in Scotland and the North of England for both men and women aged 35-47, and lowest in the South West and South East, the death rate in Scotland being 60% higher than that in South West and South East for men and 102% higher for women.

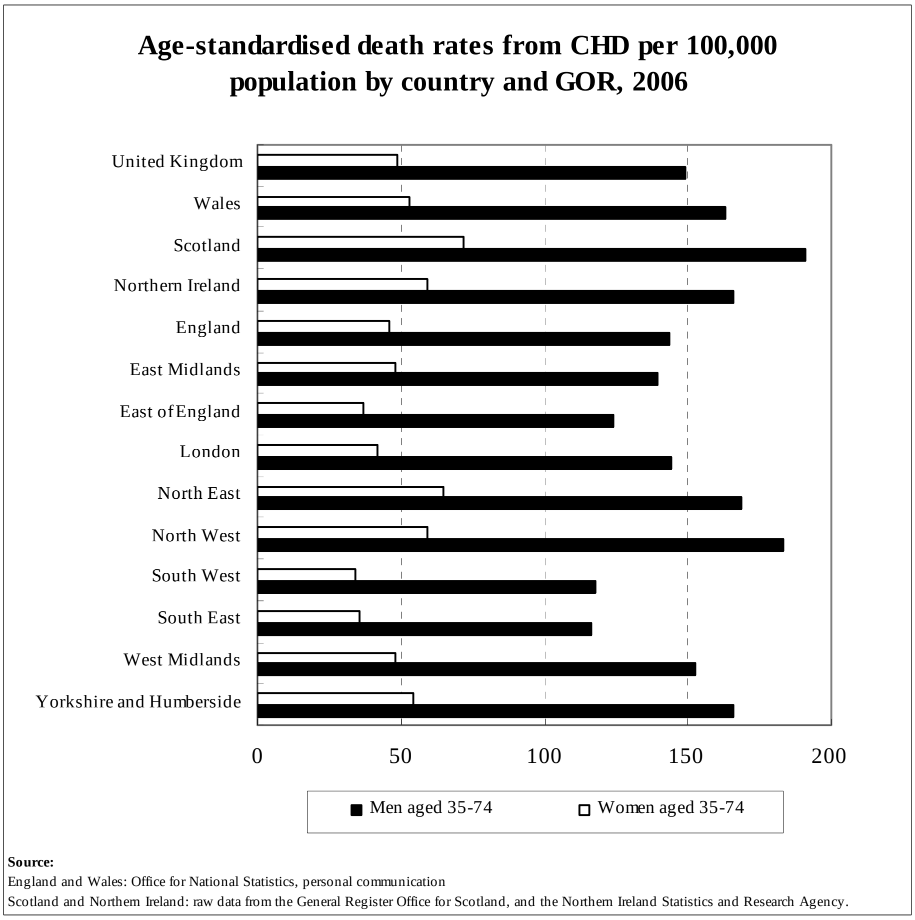


Figure 2-17 Age-standardised death rates from CHD per 100,000 population, UK, 2006

According to the Health Surveys for England and Scotland 2003, which collected data on cardiovascular conditions of the general population, among men, 14% of men in England and 15% of men in Scotland reported a diagnosis of any CVD; among women, 13% of women in England and 15% of women in Scotland reported a diagnosis of any CVD. It was estimated that in England, 2.8 million men and 2.8 million women had a diagnosis of CVD, and in Scotland, 300,000 men and 320,000 women had a diagnosis of any CVD. (The British Heart Foundation, 2003)

There are some geographical variations of cardiovascular disease prevalence across the UK. In the Health Survey for England 2003, among men, the prevalence of CVD was highest in Yorkshire and the Humber (19.6%) and the West Midlands (19.3%), but lowest in South West (15.1%), London (15.5%) and East of England (15.5%). For women, CVD prevalence in the West Midlands (20.1%) was particularly high, followed by the North East (18.7%). However, London and the South West had the lowest prevalence of CVD, which was less than 15%.

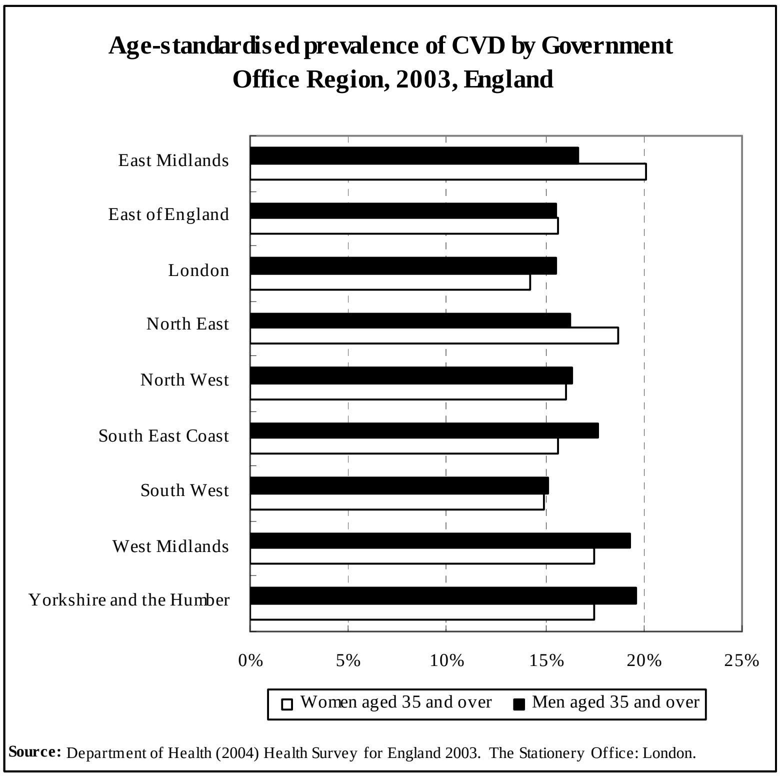


Figure 2-18 Age-standardised prevalence of CVD by Government Office Region, England, 2003

Cardiovascular disease places a big burden on individuals, community and the UK economy. Cardiovascular disease costs over £30bn a year in healthcare expenditure and lost productivity, of which over £14bn is spent on health care, over £8.2bn due to production loss and £8bn on informal care (Allender et al., 2008).

	£ million	**% of total**
Health care costs	14,373	46.9
Production losses due to mortality	4,417	14.4
Production losses due to morbidity	3,839	12.5
Informal care	8,041	26.2
Total	30,669	100.0

Table 2-9 Total costs of cardiovascular disease, 2006, United Kingdom (Allender et al., 2008)

2.3.3 Conceptual Model of CVD Risk Factors

Over 300 risk factors have been identified to be associated with cardiovascular disease (World Health Organization, 2004). Generally, the increased risk of cardiovascular disease is a cumulative result of early life risk factors, biological risk factors and socioeconomic status risk factors. Meanwhile, these risk factors also contribute to cardiovascular disease severity, survival and mortality (Black, 1992, Cox et al., 2006, World Health Organization, 2004). A conceptual model of cardiovascular risk factors is presented as follows.

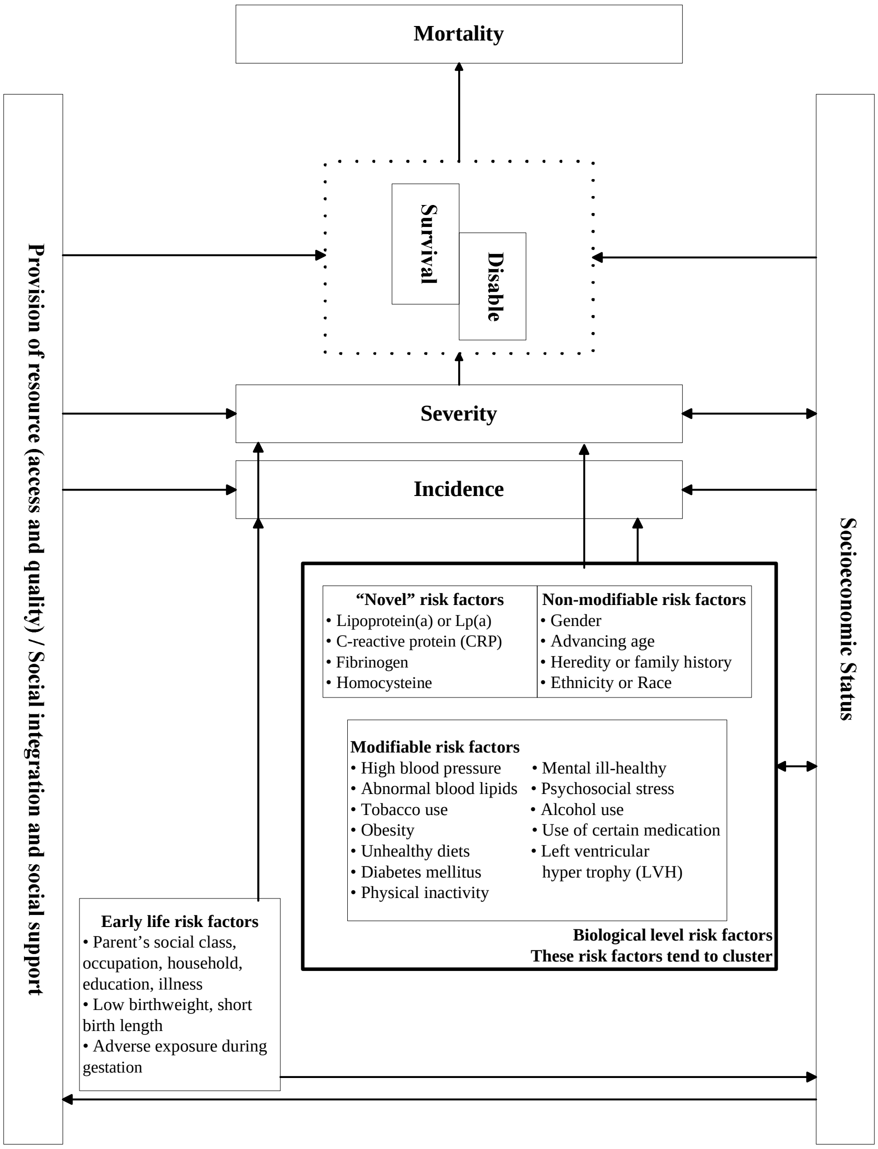


Figure 2-19 Cardiovascular risk factors and possible pathways (modified from Cox et al., 2006, page 184)

A number of studies have identified that increased risk of cardiovascular disease is associated with early life risk factors, particularly for childhood socioeconomic circumstances, where children from family in a lower socioeconomic background are more likely to be of low birth weight, to have poorer diets, and to have fewer educational opportunities (Ben-Shlomo and Kuh, 2002, Galobardes et al., 2004). Parents' social class and occupation are the most common indications of childhood socioeconomic status. For example, people whose parents were working in lower social class or manual occupations during their childhood were found to have a higher risk of overall cardiovascular disease (Heslop et al., 2001, Smith et al., 2001, Pensola and Martikainen, 2003a), coronary heart disease (Smith et al., 1998, Frankel et al., 1999) and stroke (Smith et al., 1998, Frankel et al., 1999, Hart et al., 2000), after controlling for their own adult socioeconomic status. Housing conditions and living in overcrowded accommodation during childhood were also related to adult cardiovascular disease (Dedman et al., 2001, Claussen et al., 2003, Pensola and Martikainen, 2003b). Other childhood socioeconomic status indicators used were home ownership, parental education, number of siblings, farm size, indicators of the mother's marital status, and presence of both natural parents during childhood (Galobardes et al., 2004). In addition, increased risk of adult cardiovascular disease was found to relate to low birth weight and short body length at birth (Frankel et al., 1996, Eriksson et al., 2000, Osler et al., 2003, Pfab et al., 2006).

The biological risk factors are individual's unhealthy conditions that have a clear biological pathway with cardiovascular disease or are directly associated with increased risk of cardiovascular disease (Black, 1992, World Health Organization, 2004). These risk factors tend to cluster (Boreham et al., 1999, Twisk et al., 2001, Lawlor et al., 2005). Some biological risk factors can't be changed, such as age, gender, heredity and ethnicity, which are termed as non-modifiable risk factors. However, some major biological risk factors can be prevented, treated, and controlled, such as high blood pressure, high blood cholesterol, overweight and obesity, diabetes mellitus and psychological well being, which are known as modifiable risk factors (World Health Organization, 2004). Beyond the established risk factors, some 'novel' risk factors have been identified to be associated with increased risk of cardiovascular disease as a result of growing understanding of cardiovascular disease, such as lipoprotein(a) or Lp(a) (Castelli, 1998, Kollerits et al., 2006, Berglund and Anuurad, 2008), C-reactive protein (CRP) (Hirschfield and Pepys, 2003, Kushner and Elyan, 2008), fibrinogen (Kannel et al., 1987, Stec et al., 2000) and homocysteine (Chambers and Kooner, 2001, Wald et al., 2002).

The biological risk factors have a broad definition, which not only include such unhealthy conditions, but also include other unhealthy personal lifestyle and unhealthy behaviours which result in unhealthy conditions. For example, smoking damages the endothelium lining of the blood vessels, increases cholesterol plaques (fatty deposits in the arteries) and clotting, raises low-density lipoprotein (LDL)-cholesterol levels and lowers high-density lipoproteins (HDL) (World Health Organization, 2004). Smokers, especially heavy smokers, and passive smokers are at significant risk of cardiovascular disease (Steenland, 1992, Black, 1992, Law et al., 1997). Physical activity, which could significantly increase the level of protective HDL cholesterol, reduces the risk of obesity, diabetes and high blood pressure, and is an important independent protective factor in cardiovascular disease (Shaper et al., 1991, World Health Organization, 2004, Batty and Lee, 2004). Poor nutrition and unhealthy diet which includes the high consumption of saturated fats, dietary sodium or salt, and refined carbohydrates, as well as inadequate intake of fruits, vegetables and antioxidant-rich foods, could fundamentally and biologically contribute to the development of cardiovascular disease (World Health Organization, 2003b, Hooper et al., 2001, Mann, 2002). Drinking alcohol has a two-side effect on cardiovascular disease. Moderate alcohol consumption has a positive effect on cardiovascular disease (Rimm and Moats, 2007). However, heavy drinking may lead to high level of some fats in the blood, high blood pressure, heart failure and stroke (World Health Organization, 2004, Black, 1992).

A large number of studies have examined the inverse relationships between socioeconomic status and cardiovascular disease morbidity, outcome (survival and severity), and mortality. The most commonly used socioeconomic status indicators are education, income, occupation, employment status, home and goods ownerships, living conditions, and area-base deprivation indices (Kaplan and Keil, 1993, Mieczkowska and Mosiewicz, 2008). In addition, there is substantial evidence suggesting the inverse relationships between socioeconomic status and other biological cardiovascular disease risk factors, most of which has to do with high blood pressure (Brackbill et al., 1995, Colhoun et al., 1998). There are also inverse relationships between socioeconomic status and unhealthy behaviour, such as smoking (Laaksonen et al., 2005, Harwood et al., 2007), obesity (Stunkard and Sorensen, 1993, McLaren, 2007), diabetes (Connolly et al., 2000, Chaturvedi, 2004) and physical inactivity (Ford et al., 1991, Lee et al., 2007). Generally, most socioeconomic epidemiology assumes that socioeconomic status is an independent risk factor. However, the pathways through which socioeconomic status affect health are not well understood. There seem to be complex interaction and mechanisms between these risk factors (McNeill et al., 2006).

2.4 Socioeconomic Determinants of Health

The fact that individuals' socioeconomic conditions, such as poverty, unemployment and poor housing, strongly influence health behaviour and health outcome is widely, historically and formally recognized (Cooper, 2002). In addition, as a response to stressful and hazardous environments, people living in neighbourhoods with social and physical deprivation are at increased risk of engaging in unhealthy behaviours and poor health outcome (Geronimus, 2000, McNeill et al., 2006). Thus individual socioeconomic status and environmental factors simultaneously influence health behaviours and outcome directly or indirectly through mediating mechanisms, and these mechanisms might differ for different outcomes (McNeill et al., 2006).

In this part, firstly, a conceptual model of socioeconomic determinants of health which unifies previous qualitative research is introduced. And the effect of social inequality and neighbourhood environments on health, particularly on cardiovascular disease, will be further reviewed and discussed after the conceptual model.

2.4.1 Conceptual Model of Socioeconomic Determinants of Health

The conceptual model developed by Schulz and Northridge (2004) with minor modification below outlines the multiple dynamic pathways and diverse mechanisms through which underlying social, political, and economic conditions influence individual and population health and well-being.

Generally, the conceptual model involves fundamental factors, interpersonal relationships, social inequalities, neighbourhood and community characteristics, and individual characteristics. The fundamental factors, such as political, economic, and legal processes and unequal distribution of material resources affect population health fundamentally by influencing socioeconomic inequality, and neighbourhood physical and social environment. In the intermediate level, both socioeconomic inequality and neighbourhood characteristics influence population health outcomes and health behaviours directly or indirectly through their associated physical and psychosocial stressors that have more immediate effects on health. Socioeconomic inequality plays the most important role compared to neighbourhood characteristics, because it is socioeconomic inequality that positions certain groups of people in a neighbourhood with poor physical and social environment. Socioeconomic inequality also has an effect on social integration and social support, which influence population health directly (in a physical way or as stressors in a psychosocial way), or directly through unhealthy behaviours.

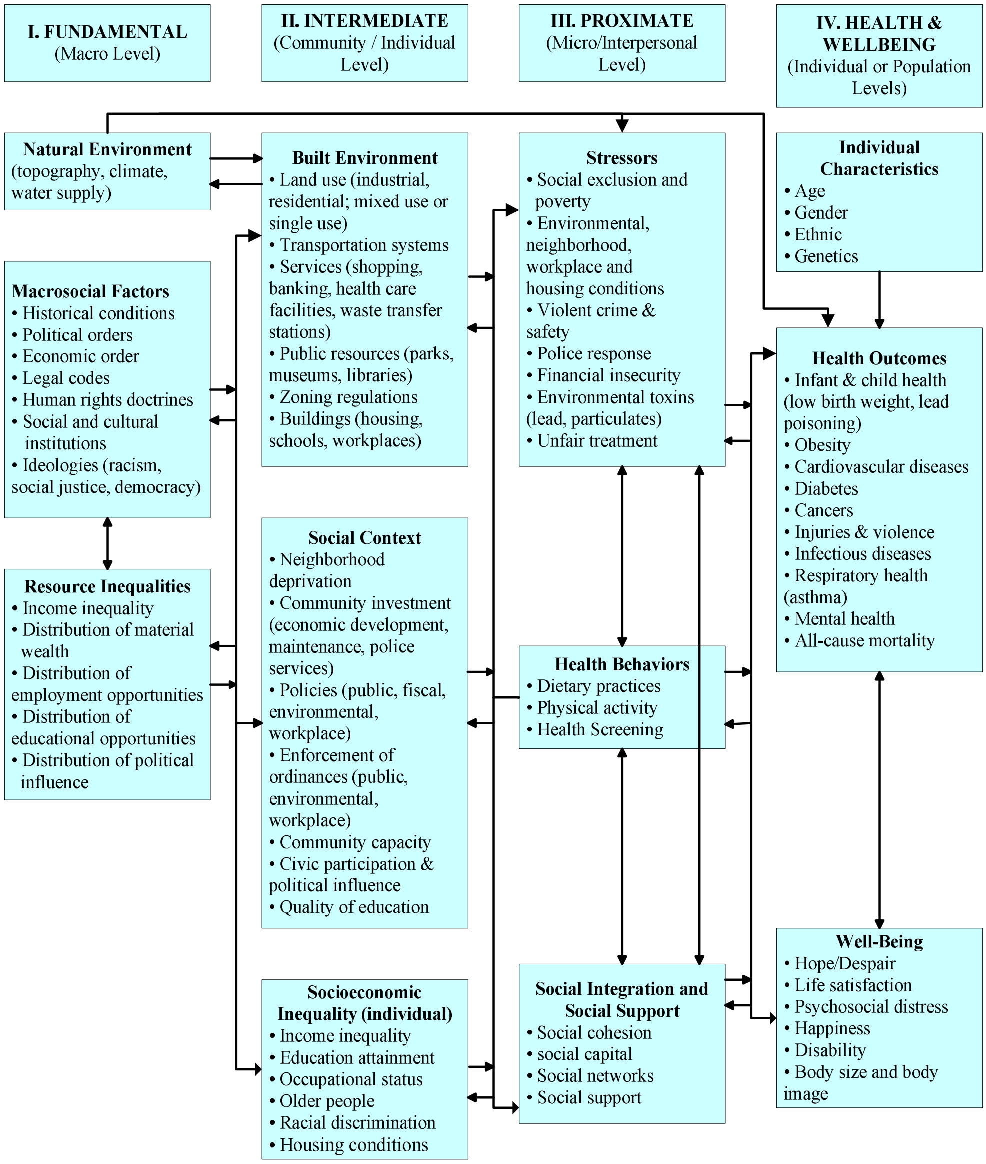


Figure 2-20 Conceptual model of socioeconomic determinants of health (modified from Schulz and Northridge, 2004, page 457)

2.4.2 Individual Socioeconomic Status and Health

From the landmark Whitehall studies which found health gradients based on occupational class (Marmot et al., 1984b) to current health disparities research, social and health scientists and epidemiologists have sought to understand how socioeconomic position, income inequality or poverty influence population health (McNeill et al., 2006).

Socioeconomic status is a measure of an individual's position or status in society's hierarchy and is associated with differential access to social and material resources (Williams and Collins, 2002). Numerous studies have investigated the effect of socioeconomic status or its components, including income, education, occupation, housing conditions, and other socioenvironmental characteristics, on individual's health (Diez-Roux et al., 2001a, Naess et al., 2005, Galobardes et al., 2006a, Galobardes et al., 2006b).

Among the common socioeconomic status indicators, income, which is the fundamental resource that provides access to goods and service, is of the most fundamental interest (Thorbecke and Charumilind, 2002). The pathway that income inequality affects health seems straightforward: it influences individuals' consumption of commodities that promote their health or cause malnutrition. However, it may not be that straightforward and the relationship between income inequality and health *per se* is still under investigation (Wilkinson and Pickett, 2006). A large number of studies have suggested that a high level of income has positive effect on individual's health (Beecham, 1996, Lynch, 2000, Marmot, 2001, Subramanian et al., 2003a). In addition, the effect of income inequality on health exists not only at individual level, but also at the levels of community (Stanistreet et al., 1999, Pattussi et al., 2001, Subramanian et al., 2003a, Massing et al., 2004), metropolitan areas and cities levels (Sanmartin et al., 2003, Larrea and Kawachi, 2005), state or region (Blakely et al., 2001, Pickett et al., 2005, Subramanian et al., 2003a), country and international levels (Drain et al., 2004, De Vogli, 2005), which affect population health in multiple pathways.

However, there are some limitations in using income information, because the measurement of income level is complex. Firstly, lower income might be the result of poorer health. Secondly, income could be measured in different forms, such as individual income, family income and noncash benefits, and varies over time. In addition, income measures are subject to perceived sensitivity, which makes many studies fail to include income measure due to incompleteness of the income variable. (Kaplan and Keil, 1993)

Education is the most widely used measure of socioeconomic status in epidemiologic studies. This is because education is not complex and has a low nonresponse rate in questions. In addition, education is usually fixed after young childhood, which is unlikely to be affected by poor health among adults (Kaplan and Keil, 1993). Education shapes future occupational opportunities and earning potential (Adler and Newman, 2002). Better-educated people are more likely to be employed, to have better paid jobs. However, individuals with lower qualifications tend to be employed in more routine occupations with lower payment. Employment and occupation might be one of the links between education and health. Studies have shown that, in general, people with higher qualifications are healthier, report better health (Mirowsky and Ross, 2003, Knesebeck et al., 2006, Cavelaars et al., 1998) and have lower mortality from chronic disease (Kunst and Mackenbach, 1994, Schrijvers et al., 1999, Martikainen and Valkonen, 2000, Martikainen et al., 2001, Regidor et al., 2003).

2.4.3 Individual Socioeconomic Status and CVD

The inverse relationships between socioeconomic status and cardiovascular disease morbidity, outcome (survival and severity), and mortality have been well examined in previous studies. There also is substantial evidence suggesting the relationships between socioeconomic status and other cardiovascular disease risk factors, such as high blood pressure, smoking, obesity and physical inactivity. The widely used socioeconomic status indicators include income, education, occupation, employment status, socioeconomic class, home and goods ownerships and living conditions.

The relationship between income and cardiovascular disease has been well established. For example, in a population based study which involved 6903 first stroke events in the FINMONICA Stroke Register in Finland during 1983 to 1992, it was found that the age-standardised incidence and mortality of stroke, as well as the adjusted odds ratio of stroke within 1 year after the onset, were significantly higher in the low-income group than in the high-income group in both genders (Jakovljevicacute et al., 2001). Keles et al. (2003) used family income as a measure of socioeconomic status. It was found that although household income was not predictive of overall mortality, lower household income was a significant independent predictor of CHD risk, after adjusting for age, sex, systolic blood pressure, total cholesterol and smoking status.

Education has a considerable influence on cardiovascular disease. In the US Stanford Five-City Project with 2380 participants, Winkleby et al. (1992) have examined the independent contribution of education, income, and occupation to a set of cardiovascular disease risk factors (cigarette smoking, systolic and diastolic blood pressure, and total and high-density lipoprotein cholesterol), and reported that education had the strongest and most consistent relationships with cardiovascular disease risk factors. And when income and occupation were included in the model, education was the only measure that was significantly associated with the risk factors. Higher education was recommended to be the best socioeconomic status predictor of good health in this study. In addition, in the PRIME (Prospective Epidemiological Study of Myocardial Infarction) study, where 10593 men aged 50–59 years were examined between 1991 and 1994 in Northern Ireland and France, Yarnell et al. (2005) found that the men who showed some evidence of coronary heart disease at screening examination were more likely to have less full time education, be unemployed, and live in poorer material circumstances than men without coronary heart disease. Among men who were initially free of coronary heart disease, socioeconomic measures (years of fulltime education, unemployment, and educational level) were strongly associated with the risk factors, including smoking habit, systolic blood pressure, body mass index, and fibrinogen.

Social class and occupation are also important socioeconomic characteristics that are associated with cardiovascular disease. Substantial social difference in risk of coronary heart disease in British men was found in the British Regional Heart Study (BRHS). The BRHS is a prospective study of cardiovascular disease, where 7735 middle aged men in 24 British towns were enrolled in 1978–1980 and have been followed up for all-cause mortality. It was reported that the manual-work socioeconomic status groups had higher ischemic heart disease prevalence and attack rates than non-manual work groups, even after adjustment for the adult coronary risk factors (Pocock et al., 1987, Emberson et al., 2004). In the South London stroke register, occupational social class was found to play a significant independent part in stroke. The incidence rate ratio for the manual occupations group was 1.6 times higher than that of the non-manual occupations group (Wolfe et al., 2002). Pereira et al. (1998) suggested that occupational status was also associated with cardiovascular disease risk factors, such as systolic and diastolic blood pressures, alcohol consumption, and cigarette smoking.

The Whitehall study, which has examined the relationships between employment status and cardiovascular disease, is one of the outstanding studies on the association between socioeconomic position and heart disease (Kaplan and Keil, 1993). It was designed to investigate social determinants of health, specifically the cardiorespiratory disease prevalence and mortality rates among British civil servants between the ages of 20 and 64. The first phase, the Whitehall I Study, which was set up in 1967 and completed in 1988, has followed about 18,000 people for more than two decades (Bell et al., 2004). In the Whitehall I study, compared with the men in the top (administrative) grade, the age adjusted prevalence of angina pectoris was 53 per cent higher for men in the lowest employment grade. The ischemic-type electrocardiogram abnormalities were 77 per cent higher in the lower than in the top grades. In addition, the follow-up 10-year coronary mortality rate was 3.6 times higher for men in the lowest grade than in the top grades. (Rose and Marmot, 1981) In the Whitehall II study, it was found that men and women with little work control face a significantly higher risk of heart disease than those with authority to influence their job conditions. However, other risk factors, such as low social support, hostility, sedentary lifestyle, and smoking could not explain the gradient as well as work control does (Bosma et al., 1997).

Unemployment affects cardiovascular disease risk factors as well. For example, in the MONICA survey in northern Sweden, Janlert et al. (1992) studied the relationship between unemployment or the threat of unemployment and cardiovascular risk factors, and reported that in men, unemployment for more than one year correlated significantly with systolic blood pressure, serum cholesterol level, HDL-quotients, cigarette smoking and physical inactivity. In women, unemployment correlated significantly with body mass index, HDL-quotient, cigarette smoking and physical inactivity.

Housing tenure was found to be the 'most' discriminating measure of socioeconomic status in predicting risk of coronary heart disease in the analysis of the Scottish Heart Health Study. Woodward et al. (1992) have examined four socioeconomic status measures, including level of education, years of education, housing tenure, and occupational status. When the four measures were independently examined, each of the four measures significantly associated with coronary heart disease prevalence. However, the odds ratios for housing tenure are the highest. When the relations among the four socioeconomic status measures were investigated, housing tenure could remove the significant effect of education and occupation in men and education in women, however, none of the other three measures could remove the significant effect of housing tenure.

2.4.4 Neighbourhood Characteristics and Health

Winkelst (1972) pointed out that "*ecological factors may be the most important determinants of the health and disease status of a population*", which has laid a foundation of publications investigating relationships between place and health. Numerous reports on area or neighbourhood characteristics influencing population health have recently been published in social science, public health and epidemiology journals (Diez-Roux, 2001). Characteristics of a place in which one lives is a broad category involving many issues, i.e. neighbourhood socioeconomic deprivation, neighbourhood physical deprivation, which are the core environmental factors that influence population health and health related behaviours (Diez-Roux, 2001, Diez-Roux et al., 2001a, Macintyre and Ellaway, 2003, McNeill et al., 2006).

Studies show that social composition of areas have a significant effect on health, where people living in neighbourhoods with higher socioeconomic deprivation, for example, deprivation measured in terms of neighbourhood income, neighbourhood education, neighbourhood occupational levels, may experience increased exposure to stressors that are detrimental to health and thus have a higher risk of poor health, even after controlling for individual-level factors such as income (Diez-Roux, 2001, Macintyre and Ellaway, 2003, Dragano et al., 2007). Other common neighbourhood stressors include the prevalence of attitudes towards health and health related behaviours, home ownership or housing conditions, and perception of violence and crime (Macintyre and Ellaway, 2003, McNeill et al., 2006)

The effect of neighbourhood physical characteristics on health also has been well investigated in previous research (Diez-Roux, 2001). For example, lack of public service (such as, health care facilities, banking, shopping, waste transfer stations, parks, sport facilities) may result in decreased access to resources that provide health care service and promote healthy behaviours. Affordable travel cost could improve access to health screenings. Stores selling healthy foods at affordable prices may influence dietary practices. Well-maintained public spaces such as parks and waterfronts would facilitate physical activity (McNeill et al., 2006, Schulz and Northridge, 2004, Macintyre and Ellaway, 2003, Diez-Roux, 2001, Diez-Roux et al., 2001a).

In empirical research, the investigations of neighbourhood effects are usually conducted in multilevel analysis, which takes both contextual effect (area or neighbourhood characteristic) and compositional effect (characteristics of individuals living in different areas) in to account simultaneously, because omitting either will result in incomplete model bias (Pickett and Pearl, 2001). By simultaneously including both neighbourhood and individual level predictors in multilevel models, it is possible to separate neighbourhood effect and individual effect on health (Diez-Roux, 2001). There are a number of studies which examined the neighbourhood or community level effect on individual health while accounting for the hierarchical structure of the data, where individuals are nested within neighbourhoods (Sundquist et al., 1999, Diez-Roux, 2001, Merlo, 2003, O'Campo, 2003, Subramanian et al., 2003b, Cubbin and Winkleby, 2005, Taylor et al., 2006).

Studies using these approaches usually linked information on small-area characteristics to individual level covariate and outcome data from surveys, epidemiologic studies, or other vital statistics (Diez-Roux, 2001). Neighbourhood factors are frequently assessed using area level measures available in the census or deprivation index which were aggregated from the area level data in the census, such as the Townsend (Townsend et al., 1988) and Carstairs Index (based on four census indicators: low social class, lack of car ownership, overcrowding and male unemployment) (Schulz and Northridge, 2004, Morris and Carstairs, 1991). The advantages of using a composite index include statistical efficiency and simple result presentations. However, it will make it impossible to differentiate the independent and interactive effects of each component and valuable information can be obscured (Pickett and Pearl, 2001). On the other hand, using many single measures separately may lead to collinearity and cumbersome or cluttered results (Pickett and Pearl, 2001).

2.4.5 Neighbourhood Characteristics and CVD

In parallel with individual socioeconomic status, neighbourhood deprivation, including neighbourhood socioeconomic status and neighbourhood physical characteristics, is documented to contribute to the development and persistence of cardiovascular disease. Some empirical evidence about the influence of neighbourhood deprivation on cardiovascular disease is discussed as follows.

2.4.5.1 Neighbourhood Socioeconomic Characteristics and CVD

The association between neighbourhood socioeconomic environment and cardiovascular disease has been well established, although the definitions of neighbourhood socioeconomic environment are different in different studies.

Residents of social disadvantaged neighbourhoods, measured in terms of neighbourhood income, neighbourhood education and neighbourhood occupational levels, are found to have a higher risk of cardiovascular disease than residents of social advantaged neighbourhood. Diez-Roux et al. (2001b) constructed a summary score of the socioeconomic environment for each neighbourhood that included information about wealth and income, education, and occupation, and found that residents of disadvantaged neighbourhoods had a higher risk of coronary heart disease than residents of advantaged neighbourhoods, even after controlling for personal income, education, and occupation. In the study conducted by Leyland (2005) that investigates socioeconomic gradients in the prevalence of cardiovascular disease in Scotland, Carstairs score, which is a unweighted combination of male unemployment rate, overcrowding rate, car ownership rate and low social class (Social Class IV and V) rate, was found to dominate the relation between socioeconomic status and cardiovascular disease prevalence in Scotland.

In a multilevel study on neighbourhood deprivation and incidence of coronary heart disease of 2.6 million women and men in Sweden, Sundquist et al. (2004) used the Care Need Index as neighbourhood socioeconomic status measures, which is a composite deprivation score of proportions of single parents, residents who have moved, people with low educational status, children under age 5, elderly living alone, foreign born people and unemployed people. High levels of neighbourhood socioeconomic deprivation independently predict coronary heart disease for both women and men.

Based on the theoretical frameworks from the Chicago school (Shaw and McKay, 1942) and the Stirling County group (Leighton et al., 1963), which indicates that neighbourhoods characterized by poverty, residential instability, large employment and dilapidated housing had increased rates of crime, delinquency, and adverse health outcomes such as infant mortality and low birth weight, Sundquist et al. (2006) attempted to examine the impact of the neighbourhood social disorganization and disintegration, measured as violent crime and unemployment rate, on coronary heart disease in an urban setting. Both neighbourhood violent crime and neighbourhood unemployment rate have an effect on coronary heart disease, and the effect remains almost unaltered when individual socioeconomic factors, including age, income, employment status, and marital status, are included in the model. In addition, residents of neighbourhoods with social isolation and low level of social cohesion may be less likely to take positive health behaviour, being influenced by less social support and solidarity (Cubbin and Winkleby, 2005). Thus they might have a higher risk of cardiovascular disease.

2.4.5.2 Neighbourhood Physical Environment and CVD

The effect of neighbourhood physical characteristic on cardiovascular disease incidence has been well investigated in previous research. Generally, there are two possible pathways, indirect and direct. The indirect pathway might be that the availability, quality, accessibility and cost of local services and resources could contribute to the development and persistence of cardiovascular disease through affecting cardiovascular related health behaviour, such as physical activity, taking healthy food, and smoking. And the direct pathway might be that air and noise pollution within a neighbourhood could affect a variety of biological risk factors of cardiovascular disease directly.

Accessibility of recreational facilities, opportunity for activity (e.g., the presence of sidewalks and bike lanes, street connectivity, and the design of public spaces), and neighbourhood aesthetic quality (e.g., the presence of green spaces, interesting features, and pleasant surroundings) may influence participation in sports, leisure-time physical activity and walking as part of daily lives (Humpel et al., 2002, Diez-Roux, 2003). For example, Ball et al. (2001) investigated relationships between environmental aesthetics, convenience, and walking companions and walking for exercise or recreation, and found that the men and women reporting a more convenient environment (including proximity of a park or beach, a cycle path, or shops) or a more aesthetically pleasing environment (a friendly, attractive, or pleasant neighbourhood) were more likely to report walking for exercise or recreation. Booth et al. (2000) also found that safe footpaths for walking and access to local facilities were significantly associated with being active. van Lenthe et al. (2005) concluded that neighbourhood with poorer general physical design could partly explain why some people almost never participate in walking, cycling and other sports activities.

Not only does the neighbourhood with poorer physical design provide a barrier for physical activity, but also features of the local food environment, such as proximity to healthy food stores, convenience store concentration as well as food and tobacco advertising will affect individuals' dietary habits, e.g., eating healthy food, fast food and smoking, and thus increase their risk of being obesity and overweight and enhance individuals' smoking (Diez-Roux, 2003). For example, in a cross section study that includes 10623 participants in the Atherosclerosis Risk in Communities (ARIC) Study in the US, Morland et al. (2002) found that people living in a neighbourhood with at least one supermarket are more likely to report meeting dietary guidelines for fruits and vegetables than people living in neighbourhoods without a supermarket, after controlling for individual education and income. In the same survey, Morland et al. (2006) reported that the presence of supermarkets was associated with a lower prevalence of obesity and overweight, while the presence of convenience stores was associated with a higher prevalence of obesity and overweight.

Mujahid et al. (2006) examined associations between features of neighbourhood and hypertension, and found that after adjusting for age, gender, income, education, and race/ethnicity, residents of neighbourhood with better walking environments and more availability of healthy foods, were less likely to be hypertensive.

Neighbourhood noise level, air pollution and traffic contribute to residents' cardiovascular disease directly as well, bringing biological effect to residents (Diez-Roux, 2003). Stansfeld et al. (2000) investigated the relations between noise and health and concluded that cardiovascular disease was associated with noise, although the relation was weak. They also reported that chronic aircraft noise exposure may be associated with increased blood pressure in children. Maschke (2003) concluded that the noise and the stress response it produces have the potential to be linked to hypertension and cardiovascular disease. Finkelstein et al.(2005) found that long term exposure to ambient particulate and gaseous pollutants and proximity to traffic was found to be associated with cardiovascular disease mortality rate. Some other epidemiological studies also demonstrated a consistent increased risk of cardiovascular events in relation to both short term and long term exposure to concentrations of ambient particulate (Schwartz, 2001, Verrier et al., 2002, Brook et al., 2004).

2.5 Summary

This chapter starts by examining the background of ethnic groups in the UK from multi perspectives. Substantial immigrants came into the UK after World War II under the labour shortage. South Asian and African communities have been expanding since 1960s. According to the UK 2001 Census, the population size of people from minority ethnic groups reached over 4.6 million, representing almost 8 per cent of the total population. And this number continues to grow. People from minority ethnic groups have a younger age structure than the white people and are more likely to live in large urban areas, particularly in London. Based on their own culture, tradition and other common features, they have been officially classified into different ethnic groups.

However, compared with the white people, people from minority ethnic groups are usually of low socioeconomic status, particularly Bangladeshi and Pakistani people. In the labour market, the unemployment rates of minority ethnic groups are much higher that the white people. They have higher rates of economic inactivity as well. South Asian and Africa people are more likely to be in lower socioeconomic class. All the minority ethnic groups have significantly high rate of living in overcrowded accommodation. And more than 40 per cent of populations from Bangladeshi and Black groups are living in social rented accommodation.

Low socioeconomic status is a major risk factor of cardiovascular disease, which has been studied extensively in literature. A conceptual model of socioeconomic determinants of health has been reviewed in this chapter. Both individual socioeconomic status and neighbourhood characteristics influence population health outcomes and health behaviours directly or indirectly through their associated physical and psychosocial stressors, which is also the case for cardiovascular disease. Substantial evidence suggests the inverse relationships between cardiovascular disease and individual socioeconomic status indicators, including income, education, occupation, employment status, socioeconomic class, home and goods ownerships and living conditions. Previous studies also investigate the influence of neighbourhood socioeconomic status and neighbourhood physical characteristics on cardiovascular disease.

In summary, the background knowledge discussed above leads to the hypothesis that low socioeconomic status experienced by people from minority ethnic groups may be the main cause of their relative high risk of cardiovascular disease. This will be examined in the following chapters.

Chapter Three: Data and Methods

3.1 Introduction

Chapter Two reviewed the background knowledge of the research objectives to achieve in the following chapters, with an emphasis on socioeconomic determinants of cardiovascular disease. Before moving forward to the analytical chapters, Chapter Three introduces the data and methods employed to achieve these research objectives. In particular, Hospital Episode Statistics (HES) is the key data used throughout the following chapters. A few methods are employed to analyze the Hospital Episode Statistics from different perspectives in this study.

As introduced in previous chapters, currently in the UK, further research on ethnic inequalities in health is limited by the availability of health data with ethnic information, because few health data routinely collect information about ethnicity. In addition, analyses of these ethnically coded health data are usually subject to small sample size, which results in statistical unreliability. Ethnic minorities could be over sampled, however, because of cost they rarely are. Therefore ethnic groups with similar patterns of disease of interest have to be combined into one group; however, this will lose the heterogeneities between ethnic groups. Furthermore, the available health data with ethnic information usually contain information about limited types of disease, which makes it impossible to study ethnic inequalities in other kinds of disease.

Under this circumstance, Hospital Episode Statistics, which is a data warehouse containing details of all the admissions to NHS hospital trusts in England, becomes valuable in studying health among ethnic groups. HES is one of the few national health datasets that routinely collect ethnic information. Given the substantial advantages of HES, including large number of events, detailed classification of ethnicity, geographically national coverage, fine geographical scale, and comprehensive clinical information, HES is the key data in this study and is analyzed for different purposes. A few methods are employed to analyze the data for different aims.

Chapter	Aims	Data	Method
Four	Improving the data quality of ethnic data in the HES	Hospital Episode Statistics (HES)	1. Record Linking Method 2. Local Area-Age-Sex Coding Rate Method
Five	Examining ethnic inequalities in different types of cardiovascular disease at English national level	Hospital Episode Statistics Population Estimates by Ethnic Group 2004	Standardised Incidence Ratio (SIR)
	Examining geographical relative risk of general cardiovascular disease for different ethnicity-sex groups	Hospital Episode Statistics Population Estimates by Ethnic Group 2005	Empirical Bayes Estimation 1. An estimation method combining maximum likelihood (ML) and moments estimators 2. A moment estimation method
Six	Investigating ethnic inequalities in cardiovascular disease across geodemographics groups with different socioeconomic profile	Hospital Episode Statistics The UK 2001 Area Classification	1.Linking the UK 2001 Area Classification to Hospital Episode Statistics 2.Standardised Incidence Ratio
	Investigating whether areal socioeconomic status measured for the general population contributes to ethnic inequalities in cardiovascular disease	Hospital Episode Statistics English Indices of Multiple Deprivation 2004	Generalized Linear Mixed Model for Multilevel Modelling
	Investigating whether areal socioeconomic status measured specifically for different ethnic groups contributes to ethnic inequalities in cardiovascular disease	Hospital Episode Statistics The UK 2001 Census	Multiple Logistic Regression
Seven	Examining ethnic inequalities in cardiovascular disease survival at English national level	Hospital Episode Statistics	1. Kaplan-Meier Survival Curves 2. Cox Proportional Hazards Model
	Investigating whether areal socioeconomic status contribute to ethnic inequalities in cardiovascular disease survival	Hospital Episode Statistics The UK 2001 Census	Cox Proportional Hazards Model
	Examining ethnic inequalities in cardiovascular disease severity/treatment at English national level	Hospital Episode Statistics The UK 2001 Census	Multiple Logistic Regression

Table 3-1 Introduction to data and methods

3.2 Data

3.2.1 Hospital Episode Statistics (HES)

Hospital Episode Statistics (HES), which is a data warehouse containing details of all the admissions to NHS hospital trusts in England, plays a key role throughout this study. HES was first introduced in 1987, aiming to collect a detailed record for each episode of a patient admitted to NHS hospitals or independent sector that are commissioned by the NHS in England. HES data contain a wealth of information for research purposes, including (Liffen et al., 1988):

- Policy development.
- Illustrating variations in health status and health delivery through time and across geographic area.
- Providing answers to Parliamentary Questions (PQs).
- Production of comparative statistics to assist in performance management.
- Medical research - HES contains a wealth of information of use to clinicians and others who are developing new treatments, investigating causal factors and monitoring trends.
- Helping to determine how much of the taxpayers money should be spent on healthcare, and how it should be distributed.

Each HES record contains a wide range of information about an individual patient admitted to an NHS hospital, for example, clinical information (such as diagnoses, operations and discharge method), patient information (such as patient identifier (HESID), age, gender and ethnic category), administrative information (such as time waited and date of admission and outpatient) and geographical information (such as where the patient was treated and the area in which they lived). From 1989 onwards, more than 12 million new records have been added in HES each year; from 2003 onwards, this number reached 14 million per year.

On April 1st 1995, the Department of Health introduced the mandatory collection of ethnic information on all inpatients in the Admitted Patient Care contract minimum data and Hospital Episode Statistics to help identify and address health inequalities among ethnic groups (Aspinall, 2000). The Hospital Episode Statistics became to be one of the only 10 routinely collected data that are ethnically coded in the English regions (Fitzpatrick et al., 2005).

The substantial advantages of HES make it a valuable data source with significant potential for further analyzing ethnic disparities in cardiovascular disease. Firstly, HES has a large number of events, since it contains all the hospital episodes in England. Whereas, most other ethnically coded health data are subject to small sample size. Secondly, HES is a population dataset with a detailed classification of ethnicity, thus HES covers all the ethnic groups rather than only focusing on some certain ethnic groups of interest in other data. Thirdly, HES has a geographically national coverage and fine geographical scale. The lowest level of patient geographical identifier is output area, which is also the most local geographical level in the UK 2001 Census, each having around 125 households. This geographical information makes it possible to identify where people live and the associated neighbourhood deprivation. However, few other data include geographical identifiers. Furthermore, HES has a wealth of clinical information. If ethnic inequalities in cardiovascular disease can be analyzed using HES, HES can be used to analyze other kinds of disease as well. So HES has significant potential for studying ethnic inequalities in health.

Personal, clinical, administrative and geographical details of patients with cardiovascular disease admitted to hospitals in England have been extracted from HES and are analyzed from different perspectives in the following chapters. The variables extracted from HES used in the following chapters are shown in the table below.

Chapter	HES Variables	Data Year
Chapter Four: Methods for Improving Quality of Ethnicity Coding in the HES	Age Sex Ethnicity Diagnosis Geography (Output Area code)	2004/05
Chapter Five: Ethnic Inequalities in Cardiovascular Disease	Age Sex Ethnicity Diagnosis Geography (Output Area code)	2004/05
Chapter Six: Ethnic Inequalities in CVD and Socioeconomic Status	Age Sex Ethnicity Diagnosis Geography (Output Area code)	2004/05
Chapter Seven: Ethnic Inequalities in CVD Survival and Severity	Age Sex Ethnicity Primary diagnosis Operation code Date of admission Date of outpatient Treatment sites code Discharge method Geography (Output Area code)	2003/04 2004/05 2005/06

Table 3-2 Variable list from HES used in the following chapters

3.2.2 Population Estimates by Ethnic Group 2004

Given the substantial potential of Hospital Episode Statistics for research on ethnic inequalities in cardiovascular disease discussed above, ethnic inequalities are examined in different types of cardiovascular disease in Chapter Five using a standardised incidence ratio (SIR) method, which requires both cardiovascular disease data and population data. The most recent HES data was for 2004 when this study started. It is common that population data from census continues to be used in most research on public health until the next census is available as the general population are more likely to be relatively consistent across years. However, given that populations of most minority ethnic groups grow more quickly over the time (Office for National Statistics, 2006b), as shown in the figure below, information about population by ethnic groups in the UK 2001 Census seems to be a little old. People from minority ethnic groups who have records in HES 2004 might not be observed in the UK 2001 Census. So in Chapter Five, when calculating the standardised incidence ratios, the recent *Population Estimates by Ethnic Group 2004* from Office for National Statistics rather than the UK 2001 Census is used.

Population Estimates by Ethnic Group provide up-to-date estimates of the population size of ethnic groups in England based on an orthodox cohort component methodology (Large and Ghosh, 2006). Population estimates by ethnic group are available for England and constituent administrative areas (Government Office Regions, counties, local authority districts and strategic health authorities), by age and sex. Compared with the population by ethnic groups from The UK 2001 Census, Population Estimates by Ethnic Group 2001-2005 shows that the White British and White Irish groups decrease in size over the period, due to the net international emigration and the fact that there were more deaths than births for the relatively old White Irish population, however, this decrease has been offset by the increase in other ethnic groups, particularly for Other White, Asian Indian and Black African groups. The table below shows the average annual population growth rate for different ethnic groups, according to Population Estimates by Ethnic Group 2001-2005, England.

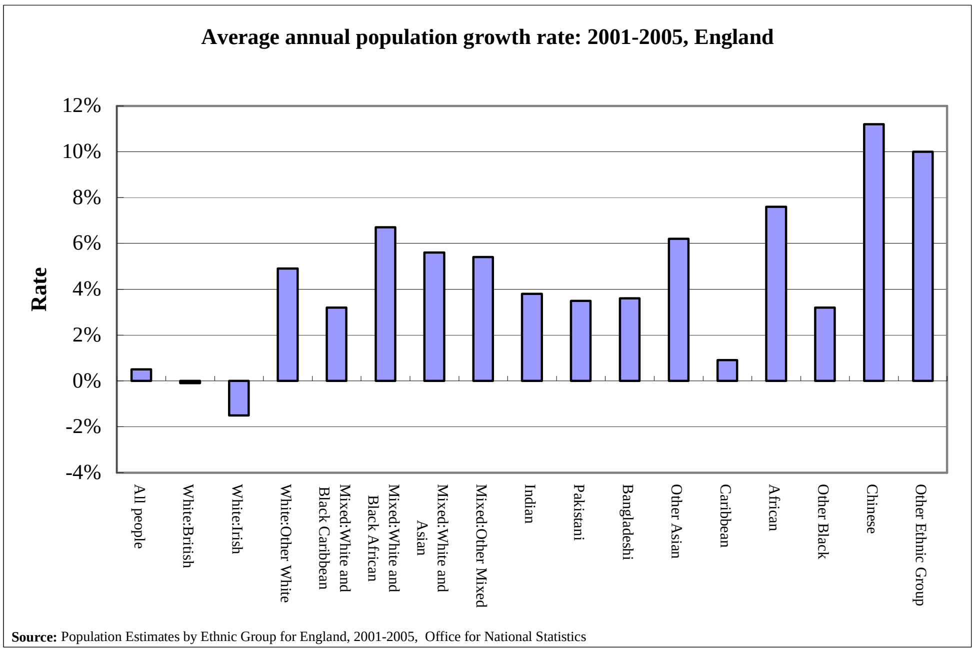


Figure 3-1 Average annual population growth rate: 2001-2005, England

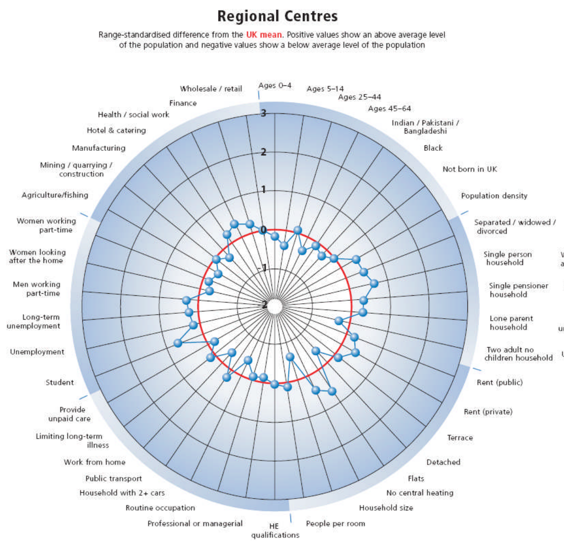
3.2.3 The UK 2001 Area Classification

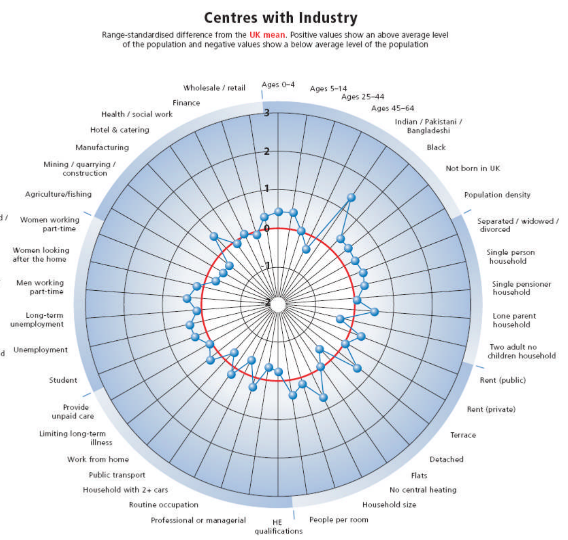
In Chapter Six, ethnic inequalities in cardiovascular disease between geodemographics groups with different socioeconomic status profiles are examined by linking the UK 2001 Areal Classification to the Hospital Episode Statistics. The UK 2001 Area Classification is a geodemographics dataset which grouped together geographic areas with more similar characteristics and is available at local authority, health area and ward level. 42 Variables were selected from the UK 2001 Census Key Statistic tables to create the UK 2001 Area Classification of local authority, containing six main census dimensions: demographic, household composition, housing, socioeconomic, employment and industry sector. Cluster analysis method created a hierarchical classification of local authorities according to their particular combination of characteristics, which included 8 supergroups, 13 groups and 24 subgroups. The largest cluster was supergroup. Each supergroup was further split into ‘groups’ and further to ‘subgroups’. Names which can represent the characteristics of clusters as a whole have been given to each supergroup and group. Given that the aggregated population of some certain ethnicity-sex groups can be very small in some subgroups, ‘group’ level classification of local authorities are used in this study. The memberships of group level are: (Office for National Statistics, 2004)

Supergroup Number	Supergroup Name	Group Number	Group Name
1	Cities and Services	1.1	Regional Centres
		1.2	Centres with Industry
		1.3	Thriving London Periphery
2	London Suburbs	2.4	London Suburbs
3	London Centre	3.5	London Centre
4	London Cosmopolitan	4.6	London Cosmopolitan
5	Prospering UK	5.7	Prospering Smaller Towns
		5.8	New and Growing Towns
		5.9	Prospering Southern England
6	Coastal and Countryside	6.10	Coastal and Countryside
7	Mining and Manufacturing	7.11	Industrial Hinterlands
		7.12	Manufacturing Towns
8	Northern Ireland Countryside	8.13	Northern Ireland Countryside

Table 3-3 The UK 2001 Area Classification of local authorities supergroup and group

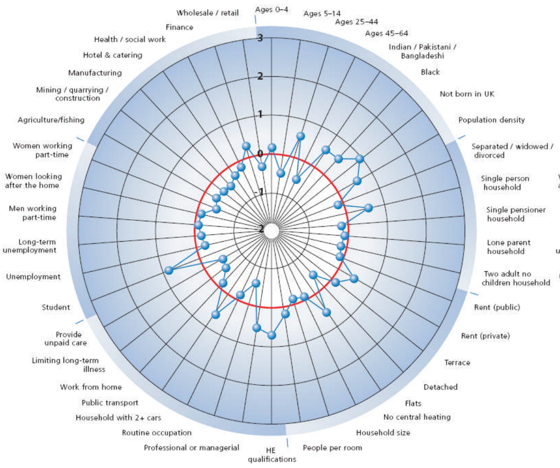
The radar charts below obtained from Office for National Statistics (ONS) highlight the main socioeconomic and demographic characteristics of each group. Each spoke represents a variable for the area classification. Whether the variable has a proportion far below, or close to or far above the national average are indicated by the plotted points, where the red circle is the UK mean.





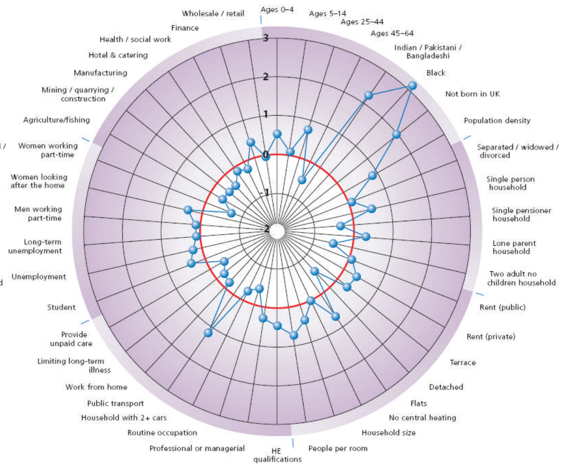
Thriving London Periphery

Range-standardised difference from the UK mean. Positive values show an above average level of the population and negative values show a below average level of the population



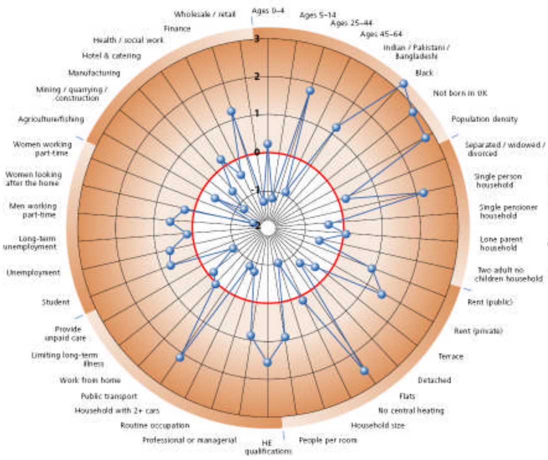
London Suburbs

Range-standardised difference from the UK mean. Positive values show an above average level of the population and negative values show a below average level of the population



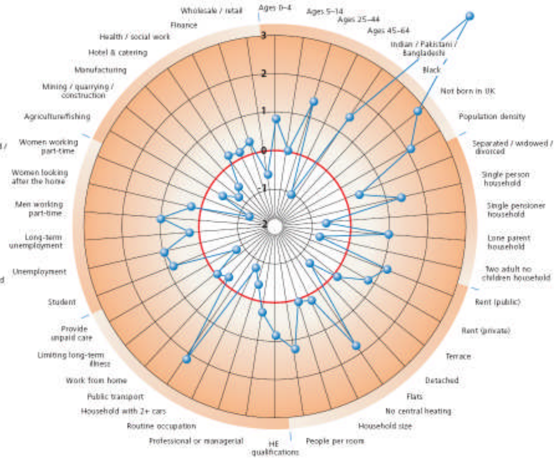
London Centre

Range-standardised difference from the UK mean. Positive values show an above average level of the population and negative values show a below average level of the population



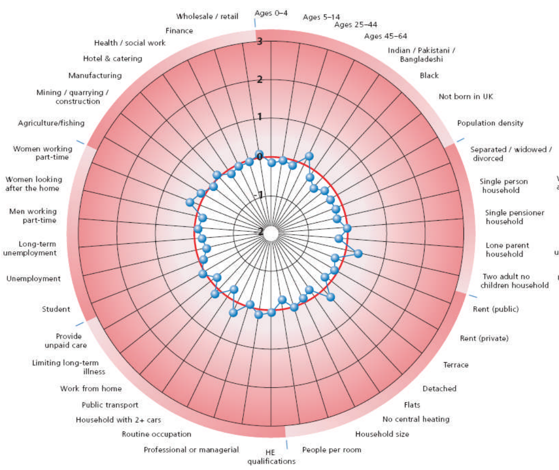
London Cosmopolitan

Range-standardised difference from the UK mean. Positive values show an above average level of the population and negative values show a below average level of the population



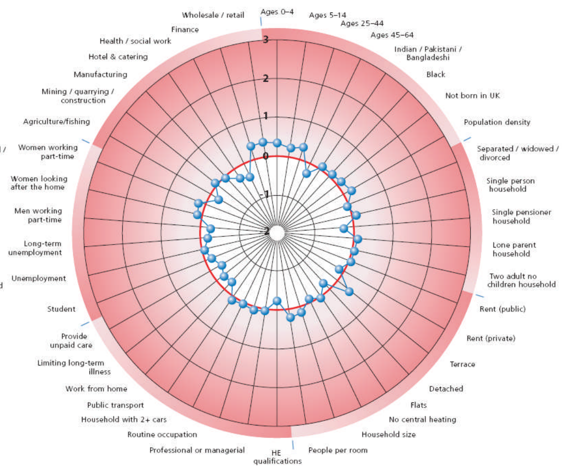
Prospering Smaller Towns

Range-standardised difference from the UK mean. Positive values show an above average level of the population and negative values show a below average level of the population



New and Growing Towns

Range-standardised difference from the UK mean. Positive values show an above average level of the population and negative values show a below average level of the population



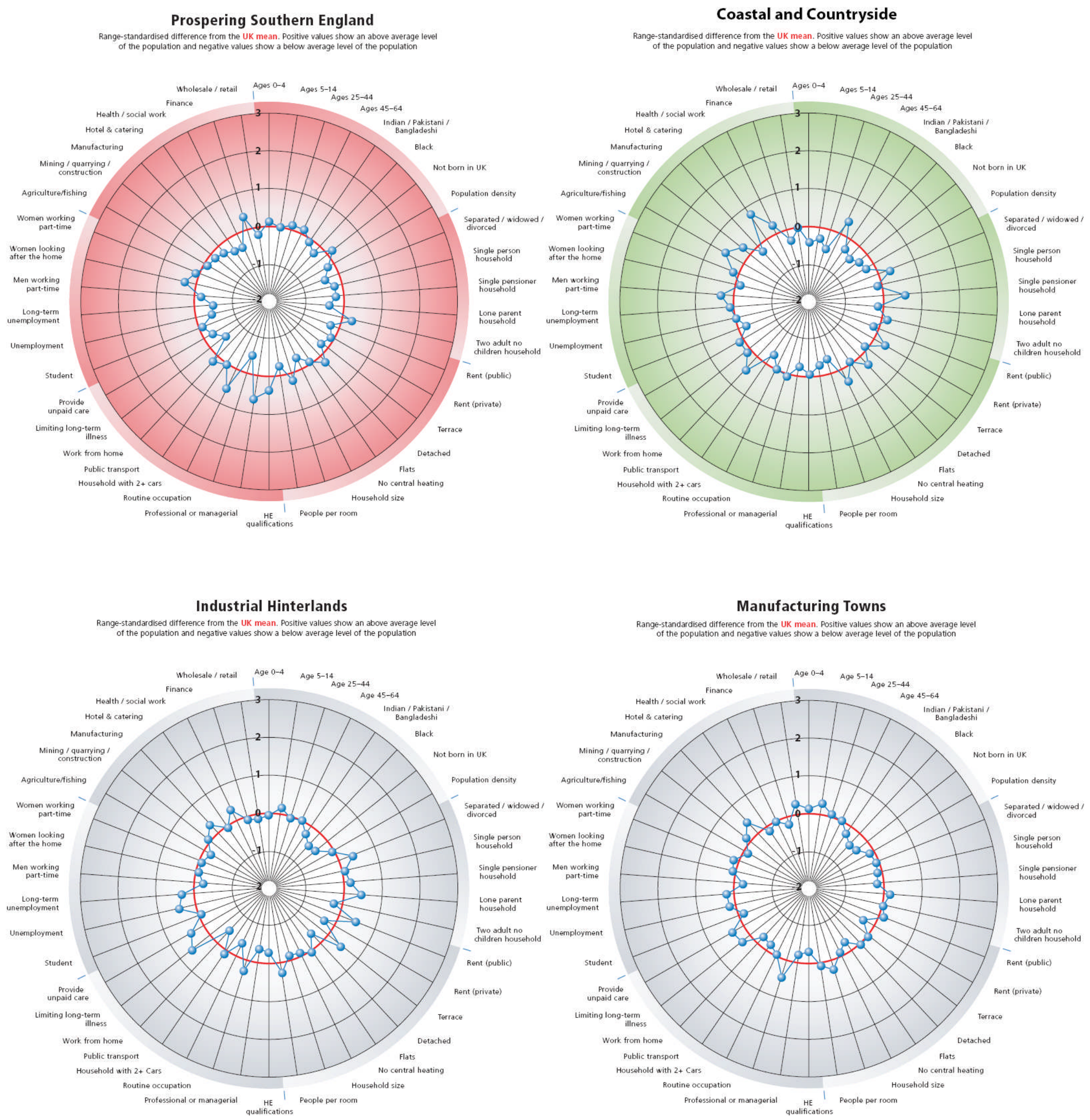


Figure 3-2 Socioeconomic and demographic characteristics of each group in the UK 2001 Area Classification of Local Authorities (Office for National Statistics, 2004)

3.2.4 Areal Socioeconomic Status Measures

Given that there is no information about individual socioeconomic status in Hospital Episode Statistics, areal socioeconomic status measures are used in this study as a proxy to individual measures. Two datasets have been employed to extract areal socioeconomic status measures, including English Indices of Multiple Deprivation 2004 and the England 2001 Census.

English Indices of Multiple Deprivation 2004 including both areal socioeconomic domains and physical deprivation domains covering the whole of England is a valuable and useful areal socioeconomic status data to help investigate whether the effects of areal socioeconomic status are consistent on different types of cardiovascular disease, whether ethnic inequalities in cardiovascular disease could be explained in the perspective of both areal socioeconomic and physical deprivation. This is reported in Chapter Six.

Given that information about socioeconomic status measured across ethnic groups is very limited in the UK, the UK 2001 Census is a significantly important data source of socioeconomic status information about different ethnic groups. Areal socioeconomic status measures are extracted from the UK 2001 Census for different ethnic groups at ward level and local authority level. These areal socioeconomic status measures are used in Chapter Six aiming to investigate the relationships between areal socioeconomic status measured specifically for different ethnic groups and ethnic inequalities in different types of cardiovascular disease, and in Chapter Seven aiming to investigate the effect of areal socioeconomic status measured specifically for different ethnic groups on cardiovascular disease survival, ethnic inequalities in cardiovascular disease survival and severity.

3.2.4.1 English Indices of Multiple Deprivation 2004

English Index of Multiple Deprivation 2004 (IMD 2004) was a Lower Super Output Area (SOA) level measure of multiple deprivation. The underlying idea of indices of multiple deprivation was that the distinct dimensions of deprivation could be recognised and measured separately. The English Index of Multiple Deprivation 2004 was made up of seven SOA level Domain Indices, with sub-domains for some domains. Each Domain contained a number of indicators, totalling 37 overall, based on the selection criteria, such as up to date, could be updated and could measure major features of that deprivation. The domain names, purpose of the domains and sub-domains are shown in the table below.

Domains	Purpose of the Domains	Sub-Domains
Income deprivation	To capture the proportion of the population experiencing income deprivation in an area.	
Employment deprivation	To measure employment deprivation conceptualised as involuntary exclusion of the working age population from the world of work.	
Health deprivation and disability	To identify areas with relatively high rates of people who die prematurely or whose quality of life is impaired by poor health or who are disabled, across the whole population.	
Education, skills and training deprivation	To capture the extent of deprivation in terms of education, skills and training in a local area.	Children/young people
		Skills
Barriers to Housing and Services	To measure barriers to housing and key local services.	Wider Barriers
		Geographical Barriers
Living environment deprivation	To measure the extent of deprivation with respect to the characteristics of the living environment.	The 'indoors' living environment
		The 'outdoors' living environment
Crime	To measure the incidence of recorded crime for four major crime themes, representing the occurrence of personal and material victimisation at a small area level.	

Table 3-4 The English Indices of Multiple Deprivation 2004 Domains

As the lowest geographical level of available ethnic minorities population data is at the ward level (could be extracted from the UK 2001 Census), the English Index of Multiple Deprivation data, which is at super output area (SOA) level, is population-weighted aggregated into higher ward level in Chapter Six.

3.2.4.2 The UK 2001 Census

The UK 2001 Census is the most comprehensive recent survey of the UK population.

Topics in the UK 2001 Census covered directly by questions included demographic and social information about everybody, employment and qualifications of people 16-74, households, housing and additional information collected in communal establishments. The UK 2001 Census also provided information derived from the direct responses to these questions, such as economic activity, socioeconomic classification, overcrowded accommodation (occupancy ratings/persons per room) and shared accommodation. In the census, information about identifiable individuals was never released, but was presented either as simple counts or as figures which related one topic to another at different geographical scales. The most local area was output area, each with around 125 households, based on which larger areas were built, such as wards, local and health authorities, unitary authorities, counties and government office regions. There were three kinds of standard output tables from the 2001 Census in England and Wales, which were Key Statistics, Standard Tables (including theme and Armed Forces tables) and Census Area Statistics (CAS) (including CAS theme tables). The Key Statistics data consisted of a series of 33 tables which provided a summary of the complete results of the 2001 Census. Standard Tables were a set of detailed cross-tabulations providing the output for England and Wales, which were available from national to ward level. Adding more detail to the information provided in Key Statistics and Standard Tables, Census Area Statistics (CAS) tables provided the most local detailed results from the census.

Although the 2001 Census provided comprehensive information about the UK population, information which was measured by ethnic groups was limited at small geographical areas. The table below lists all the standard tables that have socioeconomic status measures by ethnic groups in the UK 2001 Census, from which areal socioeconomic measures, including low socioeconomic class, unemployment, low qualification, living in overcrowded accommodation, living in social rented accommodation and living in shared accommodation, are extracted by ethnic groups as percentages at both Standard Table (ST) wards level and local authority level, where there are a total of 7932 ST wards and 354 local authorities in England.

Table Number	Table Title	Geography
S101	Sex and age by ethnic group	Wards, LADs and higher administrative geographies
S106	Household composition by ethnic group of Household Reference Person (HRP)	Wards, LADs and higher administrative geographies
S107	Sex and age and limiting long-term illness and general health by ethnic group	Wards, LADs and higher administrative geographies
S108	Sex and age and economic activity by ethnic group	Wards, LADs and higher administrative geographies
S109	Sex and occupation by ethnic group	Wards, LADs and higher administrative geographies
S110	Sex and industry by ethnic group	Wards, LADs and higher administrative geographies
S111	Tenure and number of cars or vans by ethnic group of Household Reference Person (HRP)	Wards, LADs and higher administrative geographies
S112	Sex and NS-SeC by ethnic group	Wards, LADs and higher administrative geographies
S117	Age and highest level of qualification by ethnic group	Wards, LADs and higher administrative geographies
S123	Shared /unshared dwelling and central heating and occupancy rating by ethnic group	Wards, LADs and higher administrative geographies
S124	Shared/unshared dwelling and central heating and occupancy rating by ethnic group of Household Reference Person (HRP)	Wards, LADs and higher administrative geographies
S125	Sex and type of communal establishment by resident type and ethnic group	Wards, LADs and higher administrative geographies

Table 3-5 Standard tables that have socioeconomic status measures by ethnic groups

3.3 Methods

3.3.1 Methods for the Missing Data Problem of HES

As introduced at the beginning of this chapter, Hospital Episode Statistics (HES) is a comprehensive and valuable data containing details of all the admissions to NHS hospitals in England. However, there is concern over the use of ethnicity data in HES because the data quality of ethnicity coding is not satisfactory. The percentage of Finished Consultant Episodes (FCEs) with invalid ethnicity codes is at a high level, and varies across data years, geographical regions, primary care trust, sex and age groups. Given its significant potential for research on ethnic inequalities in health and healthcare, HES with incomplete ethnicity code has been studied by a number of authors (Lowdell et al., 2000, Bardsley et al., 2000, Mindell et al., 2007). However, the proportional mortality ratio (PMR) method (or proportional morbidity ratios, proportional admission ratios) they used is doubtful due to the flaw in its underlying assumptions (Bhopal, 2002, Aspinall and Jacobson, 2007), which is discussed in Chapter Four.

Rather than simply ignoring the records with missing ethnicity codes, I have developed two kinds of methods to improve the data quality of ethnicity coding in HES, which are discussed in detail in Chapter Four. Here the two methods are introduced briefly. The first method is the record linking method. Given that more than 12 million episodes were added into HES annually and one person might have more than one episode in HES across many years, the underlying idea of this exact matching method is to restore the missing ethnicity codes by linking the admissions with valid ethnicity codes to the historical admissions without valid ethnicity codes based on the same person's unique identifier HESID. If there is a valid ethnicity code within any of a patient's historical admissions, all the other missing ethnicity codes could be replaced by this valid ethnicity code.

Rather than simply ignoring the records without valid ethnicity codes in HES improved by the record linking method to calculate standardised incidence ratio at local level for each ethnicity-sex group, two different coding rate methods, local area-age-sex coding rate method and local area-sex-ethnicity coding rate method also have been developed to estimate the total number of cardiovascular disease cases for each ethnicity-sex group observed in a certain geographical region. These methods are based on the observed number of cases with valid ethnicity codes and the estimated coding rates of different ethnic groups across regions. The differences between these two coding rate methods are the underlying assumptions. The local area-age-sex coding rate method assumes that there is no ethnic difference in the probability of missing ethnicity code within the same local area-age-sex group, i.e. people from the same local area-age-sex group will have the same chance to be ethnically coded. However, the local area-sex-ethnicity coding rate method acknowledges the ethnic difference in the probability of missing ethnicity code besides the regional difference, age and sex difference in ethnicity code, i.e. people from the same local area-sex-ethnicity group will have the same probability of being ethnically coded in HES. These two coding rate methods are introduced in Chapter Four in detail.

3.3.2 Standardised Incidence Ratio (SIR)

One of the most used methods for comparing disease patterns in different regions or between different populations in the same area, or for the same population over time involves the calculation of incidence rates. However, simply using the crude rate, where the observed number of cases over a given period of time is divided by the population and the time period, may give a misleading result, because of failing to consider the difference in the age structure (Boyle and Parkin, 1991). The comparisons of crude rates between populations with different age and gender structures seem to make no sense. Although it is possible to look at the incidence rate for the specific age to eliminate the age effects, it is a rather cumbersome procedure when comparing several populations. And the results are usually difficult to present (Bland, 1995).

For the purpose of comparing different incidence rates of different populations, a single summary from the age specific rates, which is accomplished by age standardisation, is often useful and calculated. There are two basic methods of age standardisation, direct and indirect methods. (Bland, 1995, Boyle and Parkin, 1991) Both of the two methods use a study population and a reference population, known as *Standard Population,* to generate weighted average age-specific rates, but based on different weighting schemes. And each method has advantages and disadvantages.

(Higham et al., 2005)

In direct standardisation, the directly standardised rate (DSR) is the incidence rate expected in a standard population calculated by multiplying the observed age-specific rates of the study population to the proportion of the population in the standard population and summing the results for all age specific groups. In most circumstances, rather than DSR, the comparative mortality (morbidity) figure (CMF) is used to measure death or incidence of disease. The CMF is the ratio of the number of deaths (or incidences) expected in the standard population when applying the age-specific rates of the study population to the standard population to the number of deaths observed in the standard population.

$$DSR = \sum_{i=1}^{k} \frac{N_i}{N_p} \frac{d_i}{n_i} \tag{3.1}$$

$$CMF = \frac{\text{Expected incidence in standard population}}{\text{Observed incidence in standard population}} \tag{3.2}$$

$$CMF = \frac{\sum_{i=1}^{k} N_i \frac{d_i}{n_i}}{D} \tag{3.3}$$

where

N_i : The number of people in the i^{th} group of the standard population.

N_p : The total number of population in the standard population.

d_i : The number of cases in the i^{th} group of study population.

n_i : The total number of population in the i^{th} group of the study population.

D : The total number of cases in the standard population.

k : The number of groups. (Julious et al., 2001, Higham et al., 2005)

The main advantage of the direct standardisation method is that this method allows the comparisons of groups with different age structure since the rates (or ratios) are standardised to the standard population. So the direct method is generally preferred for comparing different study groups (Julious et al., 2001). However, when calculating the local age-specific rates, if the incidence is very low, the age specific rate will be poorly estimated (Bland, 1995). The standardised rates and ratios will be relatively unstable (Sorlie et al., 1999). This is the case in this study. Minority ethnic groups usually have a relatively small population as well as a relatively small number of cardiovascular disease cases. When disaggregated at local area levels, the numbers of cases for minority ethnic groups will be even smaller, which will result in unreliable local age-specific rates and directly standardised rates.

Compared with direct standardisation, indirect standardisation does not require calculations of local age-specific rates. When dealing with a small number of cases, indirectly standardised rates are less variant and more precise than directly standardised rates. Thus indirect standardisation has advantages in measuring disease with a small number of cases. Furthermore, in most circumstances, incidence data are not available at local area level for calculating local age-specific rates, and indirect standardisation is the only option (Higham et al., 2005). Therefore the indirect standardisation method is the most commonly used technique to compare deaths or incidences of disease between different geographical areas (Julious et al., 2001). The indirect age standardisation method is a comparison or a ratio between the number of cases observed to the number of cases expected in the study population. The expected number is calculated by multiplying the standard age-specific rate by the study population of that age group and summing the results for all specific age groups in the study population, assuming that the risk of disease in the study population would be the same as the standard population. (Bland, 1995) Applied to mortality data, it is known as the standardised mortality ratio (SMR). And when applied to the incidence data, it is commonly known as the standardised incidence ratio (SIR) (Boyle and Parkin, 1991). The ratio is usually multiplied by 100 to get rid of the decimal point. (Bland, 1995) The standardised ratio is expressed as (Julious et al., 2001):

$$Standardized\ Ratio = \frac{Observed\ Number}{Expected\ Number} * 100 \tag{3.4}$$

$$Standardized\ Ratio = \frac{Observed\ Number}{\sum_{i=1}^{K} n_i R_i}$$

$$= \frac{Observed\ Number}{\sum_{i=1}^{K} n_i \frac{D_i}{N_i}} \tag{3.5}$$

where

n_i : The total number of population in the i^{th} group of the study population.

R_i : The standard rate in the i^{th} group of the standard population.

D_i : The total number of cases in the i^{th} group of standard population.

N_i : The total number of population in the i^{th} group of standard population.

However, indirect ratios are not standardised to the standard population but to the study populations with different age structures. For this reason, indirectly standardised ratios are not directly comparable with each other unless the age structures of study populations are similar. And the indirect ratios can only be compared with that of the standard population, which is 100. (Higham et al., 2005) If equal to 100, the ratio implies the rate is the same as the standard rate. A number higher than 100 indicates that there is an excess rate or higher risk of a particular disease than the standard population whereas a number below 100 implies the condition of that disease within the population of interest is better than the standard population.

Given the number of events is large enough, more than 10, the approximated 95% confidence interval is calculated as: (Bland, 1995)

$$Lower\ Limit = 100 * \frac{O}{E} - 1.96 * 100 * \frac{\sqrt{O}}{E} \tag{3.6}$$

$$Upper\ Limit = 100 * \frac{O}{E} + 1.96 * 100 * \frac{\sqrt{O}}{E} \tag{3.7}$$

3.3.3 Empirical Bayes Estimation of Geographical Relative Risk

Standardised incidence ratio is one of the most used methods to compare the relative risks of incidence for different populations (Julious et al., 2001). However, as the spatial analysis of health outcome at the small area level attracts more interest (Richardson et al., 2004), some problems arise in using the pure standardised incidence ratio method for presenting geographical relative risk. Because the standardised incidence ratios are very likely to have extreme values in the sparsely populated areas, particularly for a rare disease, of which the observed number may be still small even the SIR is based on a large number of populations. In this situation, one or two extra cases could occur or be absent purely by chance, but this could give rise to unusually high ratios or return a value of zero, which results in high variations for the ratios. (Langford, 1994) The results, which are likely to be an unknown combination of the true relative risk and random variation caused by the small number, are prone to over-interpret the importance of a small change in the number of cases (Devine et al., 1994). Cardiovascular disease is a very common disease, for this study, there is no such problem at national level for ethnic groups. However, at local area level, the population of ethnic minorities is very small and the incidence is very sparse when disaggregated at small area level, which often return zeros or unusually high value of SIRs. So a method is needed to reduce the random variation of the observed rates and smooth the raw standardised incidence ratios at local area level.

Empirical Bayes estimation is used to smooth the highly variable SIRs occurred in this study. Bayesian inference is a statistical approach to estimate the parameters of interest by taking prior knowledge or belief about that parameter into account. It actually derives the posterior distribution by combining the likelihood function for that data with the prior distribution (Bailey and Gatrell, 1995). The relationship can be expressed as (Langford, 1994):

$$belief \times likelihood\ function = posterior\ belief \tag{3.8}$$

In Bayes estimation, the prior belief of the parameter of interest could be the results from the classical analysis of previous data, or even the background knowledge, intuition, judgement of the analyst (Bailey and Gatrell, 1995).

The SIR for the i th area is defined as $\theta_i = O_i / E_i$, where O_i is the number of observed cases for region i and E_i is the expected number of cases for that region. The estimation of θ_i, $\hat{\theta}_i$, is the true, unknown relative risk for the i th area. Supposing θ_i has a prior probability distribution with mean value $E_\theta(\theta_i) = \gamma_i$ and variance $Var_\theta(\theta_i) = \phi_i$, the best Bayes estimation of θ_i, $\hat{\theta}_i$, could be obtained by combining the prior distribution with the observed rates as (Bailey and Gatrell, 1995):

$$\hat{\theta}_i = w_i\theta_i + (1 - w_i)\gamma_i \tag{3.9}$$

where

$$w_i = \frac{\phi_i}{(\phi_i + \gamma_i / E_i)} \tag{3.10}$$

This is also known as a *shrinkage estimate*, and w_i is a weighting factor (Bailey and Gatrell, 1995). When the observed number of cases is large, i.e. population is relatively large, the weight is close to 1, and more importance is placed on the observed rate θ_i. The empirical Bayes estimation will be little different from the original observed rate. When the observed number of cases is small, i.e. the population is small, the weight is close to 0, and increasing weight is given to the prior belief γ_i .The results will be adjusted or shrunk much towards γ_i , the prior beliefs about the rate (Bailey and Gatrell, 1995, Langford, 1994).

In order to obtain the values for the prior means γ_i and variance ϕ_i , a prior distribution of the rates between areas rather than within areas should be specified from a mathematical perspective. It is plausible to suppose it has a gamma distribution, which describes the amount of space or time required for a number of events to occur (Bailey and Gatrell, 1995). Under Gamma prior distribution on θ_i, firstly, conditional on θ_i, the O_is are independent Poisson random variables with means $E_i\theta_i$; secondly, θ_is are independently as Gamma random variable with shape parameter α and scale parameter β. The mean of this distribution is $E(\theta_i) = \gamma_i = \alpha / \beta$ and the variance is $Var\ (\theta_i) = \phi_i = \alpha / \beta^2$ (Bailey and Gatrell, 1995, Meza, 2003). Given these expressions, the weighting factor w_i in Equation (3.10) can be rewritten as (Bailey and Gatrell, 1995):

$$\hat{w}_i = \frac{\hat{\phi}}{(\hat{\phi} + \hat{\gamma} / E_i)}$$

$$= \frac{\hat{\alpha} / \hat{\beta}^2}{(\hat{\alpha} / \hat{\beta}^2 + \hat{\alpha} / \hat{\beta} E_i)} \tag{3.11}$$

$$= \frac{E_i}{(E_i + \hat{\beta})}$$

And thus the previous Bayes estimation of the rates (Equation (3.9)) could be written as (Bailey and Gatrell, 1995):

$$\hat{\theta}_i = w_i\theta_i + (1 - w_i)\gamma_i$$

$$= w_i\theta_i + \frac{(1 - \hat{w}_i)\hat{\alpha}}{\hat{\beta}} \tag{3.12}$$

$$= \frac{O_i + \hat{\alpha}}{E_i + \hat{\beta}}$$

So the computational problem is therefore equivalent to estimating shape parameter α and scale parameter β. (Bailey and Gatrell, 1995, Langford, 1994) In this empirical Bayes estimation equation, the observed rates are smoothed by the inclusion of α and β. Compared to O_i and E_i in original rates, if the estimates of α and β are relatively large, the Bayes estimation will be largely shrunk towards the overall mean of observed rates (α / β); if the estimates of α and β are relatively small, then the Bayes estimation will be little different from previous observed rates. (Langford, 1994)

Clayton and Kaldor (1987) developed a method to estimate shape parameter α and scale parameter β by combining maximum likelihood (ML) and moments estimators, where

$$\frac{\hat{\alpha}}{\hat{\beta}} = \frac{1}{m}\sum_{i=1}^{m}\frac{O_i + \hat{\alpha}}{E_i + \hat{\beta}} = \frac{1}{m}\sum_{i=1}^{m}\hat{\theta}_i \tag{3.13}$$

$$\frac{\hat{\alpha}}{\hat{\beta}^2} = \frac{1}{m-1}\sum_{i=1}^{m}(1+\frac{\hat{\beta}}{E_i})(\hat{\theta}_i - \frac{\hat{\alpha}}{\hat{\beta}})^2 \tag{3.14}$$

The calculation is an iterative process.

Step 1: a pair of initial values is given to α and β to obtain a starting empirical Bayes estimation.

Step 2: Calculate $\hat{\theta}_i$ according to equation (3.12).

Step 3: Calculate $\frac{\hat{\alpha}}{\hat{\beta}}$ and $\frac{\hat{\alpha}}{\hat{\beta}^2}$ according to equation (3.13) and (3.14).

Step 4: Supposing $\frac{\hat{\alpha}}{\hat{\beta}} = C_0$ and $\frac{\hat{\alpha}}{\hat{\beta}^2} = D_0$, thus the new value of α and β are $\hat{\beta} = C_0 / D_0$ and $\alpha = C_0 \hat{\beta}$.

Repeat steps 2-4, at each stage of iteration, the α and β obtained from the last iteration is used to calculate new empirical Bayes estimation $\hat{\theta}_i$ and new value of α and β, until α and β converge.

Marshall (1991) pointed that Clayton and Kaldor's method required the underlying pattern of θ_i was uniform for convergence, and the iterative procedure was often slow to converge. A moments method to estimate α and β was proposed, which was a non-iterative direct solution, where

$$\hat{\mu} = \frac{\hat{\alpha}}{\hat{\beta}} = \frac{\sum_{i=1}^{m} \hat{\theta}_i E_i}{\sum_{i=1}^{m} E_i} \tag{3.15}$$

$$\sigma^2 = \frac{\hat{\alpha}}{\hat{\beta}^2} = s^2 - \frac{\hat{\mu}}{\frac{1}{m}\sum_{i=1}^{m} E_i} \tag{3.16}$$

$$s^2 = \frac{\sum_{i=1}^{m} E_i (\hat{\theta}_i - \hat{\mu})^2}{\sum_{i=1}^{m} E_i} \tag{3.17}$$

Thus the estimation of α and β are $\alpha = \hat{\mu}^2 / \hat{\sigma}^2$ and $\hat{\beta} = \hat{\mu} / \hat{\sigma}^2$. If the value of σ^2 is negative, it will be truncated at zero (Meza, 2003).

In this study, both of the two methods above have been employed to examine the geographical relative risk of different types of cardiovascular disease for different ethnicity-sex groups, meanwhile to evaluate the application of the two methods in studying spatial health data with ethnic information at small area level. Both of the two methods are accomplished in a SAS programme. The Clayton and Kaldor's method is fitted by translating the MINITAB programme of Langford (1994)'s study into the SAS programme.

3.3.4 Linking the UK 2001 Area Classification to Hospital Episode Statistics

In Chapter Six, the UK 2001 Area Classification of Local Authorities is linked to the cardiovascular disease admissions from the Hospital Episode Statistics to investigate the variations of the standardised incidence ratios of cardiovascular disease for ethnicity-sex groups between geodemographics groups. The process of linking is shown in the below graph. In brief, firstly, the local authority codes of individuals with cardiovascular disease are linked with the geodemographics groups. And then individuals are collated and summarized for each geodemographics groups and for each ethnicity-sex group, acting as observed numbers. We could assume areas with the same geodemographics groups also are merged into a big region, although they may not be geographically connected. The expected numbers of cardiovascular disease are calculated for each big region. Finally, standardised incidence ratios of cardiovascular disease are calculated for each ethnicity-sex group in each geodemographics group.

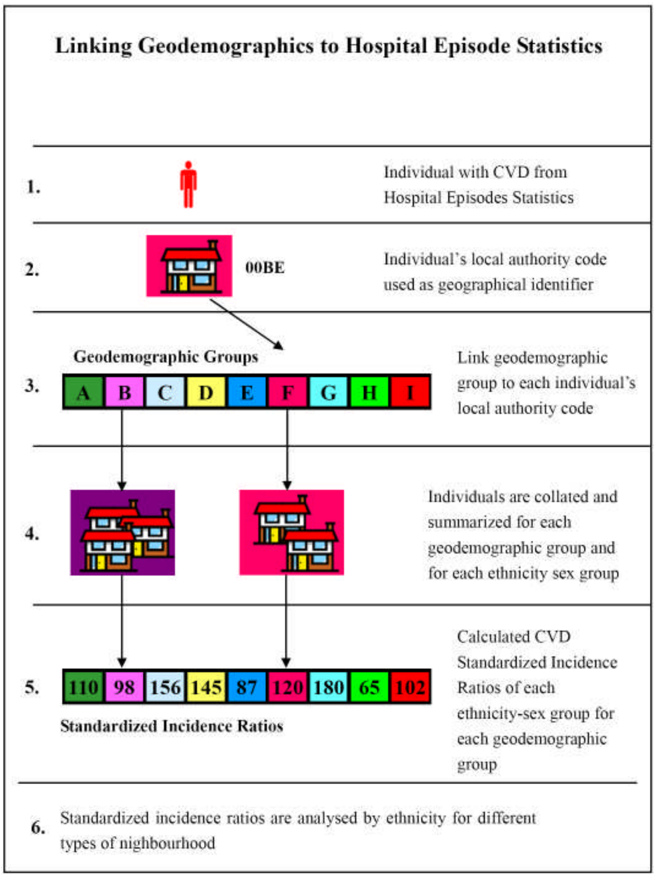


Figure 3-3 Linking THE UK 2001 Area Classification to Hospital Episode Statistics (modified from Ward, 2005, page 22)

3.3.5 Multiple Logistic Regression

In Chapter Five, multiple logistic regression is used to model the relationships between socioeconomic status measured specifically for different ethnic groups and ethnic inequalities in different types of cardiovascular disease. Compared to linear regression, logistic regression has a unique application in analyzing the relationship between discrete responses, i.e. binary responses, ordinal responses and nominal responses, and a set of explanatory variables, where the explanatory variables could be continuous or discrete (Hosmer and Lemeshow, 1989).

In any regression problem, the key quantity is the mean value of the outcome variable (Y) given the values of the independent variables (x), namely conditional mean, which is expressed as

$$E(Y \mid x) \tag{3.18}$$

In linear regression, the conditional mean could be expressed as

$$E(Y \mid x) = \alpha + \beta x \tag{3.19}$$

where it is possible for $E(Y \mid x)$ to take on any value as x ranges from $-\infty$ to $+\infty$. However, in dichotomous data, the conditional mean ranges from 0 to 1, i.e. $0 \le E(Y \mid x) \le 1$. Logistic distribution was proposed for the analysis of data with dichotomous outcome variables. The main reasons are that firstly, logistic distribution is flexible and easily used from a mathematical perspective and secondly, it has a clinically meaningful interpretation. The conditional mean could be expressed as:

$$E(Y \mid x) = \pi(x) = \frac{e^{\alpha+\beta x}}{1+e^{\alpha+\beta x}} \tag{3.20}$$

A transformation of this conditional mean is the logit transformation, which is central to logistic regression and is expressed as

$$1-\pi(x) = \frac{1+e^{\alpha+\beta x}}{1+e^{\alpha+\beta x}} - \frac{e^{\alpha+\beta x}}{1+e^{\alpha+\beta x}} = \frac{1}{1+e^{\alpha+\beta x}} \tag{3.21}$$

$$\frac{\pi(x)}{1-\pi(x)} = e^{\alpha+\beta x} \quad \text{(namely odds in the logistic regression)} \tag{3.22}$$

$$\text{Logit} = \text{log odds} = g(x) = \ln\left[\frac{\pi(x)}{1-\pi(x)}\right] = \alpha + \beta x \qquad (3.23)$$

Thus the logit, g(x), is a linear function of x, which has many desirable properties of a linear regression model and could be continuous or range from $-\infty$ to $+\infty$, depending on x. The unknown parameters β are estimated by Maximum Likelihood Estimation (MLE), which is a statistical method for estimating the coefficients of a model and will not be introduced here in detail. (Hosmer and Lemeshow, 2000)

One of the important uses of logistic regression is to compare the probability of an event occurring in one group with that of another group. For example, in Chapter Five, it is of interest to model the relative risk of different types of cardiovascular disease among different ethnic groups, to quantify whether the risk of a certain type of cardiovascular disease for minority ethnic groups is higher or lower than for the white people. This measure is termed as an odds ratio in logistic regression. When a logistic regression model has been fitted, odds ratios could be calculated as the difference between the logits of different groups, e.g. a, b,

$$\begin{aligned} \log it_a - \log it_b &= \ln(\frac{\hat{\pi}_a}{1-\hat{\pi}_a}) - \ln(\frac{\hat{\pi}_b}{1-\hat{\pi}_b}) \\ \log it_a - \log it_b &= \ln(\frac{\hat{\pi}_a}{1-\hat{\pi}_a} / \frac{\hat{\pi}_b}{1-\hat{\pi}_b}) \qquad (3.24) \\ \log it_a - \log it_b &= odds\ ratio \end{aligned}$$

An odds ratio of 1 indicates that the probabilities of an event occurring are equal in the two groups. An odds ratio greater than 1 indicates the probability of an event occurring is higher in the group of interest than that in the reference group, while an odds ratio less than 1 indicates the probability of an event occurring is higher in the reference group. (Hosmer and Lemeshow, 2000) In Chapter Six, the multiple logistic regression models are fitted using SAS PROC LOGISTIC.

3.3.6 Generalized Linear Mixed Model for Multilevel Modelling

In Chapter Five, multilevel models are fitted based on the generalized linear mixed model to understand the effect of neighbourhood deprivation on different types of cardiovascular disease, and to investigate whether neighbourhood deprivation contributes to the observed ethnic inequalities in cardiovascular disease. The nature of the multilevel modelling and the generalized linear mixed model for multilevel modelling is introduced as follows.

It is very common that data with a hierarchical or clustered structure are used in the social, medical and biological sciences. For example, individuals are nested within neighbourhood and students are nested in the schools. Multilevel modelling is a statistical method to analyze data with a hierarchical or clustered structure by separating individual level effects and effects from higher levels. Given that data with hierarchical structure are subject to intra-class correlation, whereby individuals within the same group are more alike than individuals across groups, traditional multiple regression techniques that fail to recognise hierarchical structures and ignore this intra-class correlation may underestimate the standard error of the regression coefficient of the aggregate risk factor, leading to overestimation of the statistical significance of the risk factors. (Blakely and Woodward, 2000, Li et al., 2006, Browne and Rasbash, 2001) Using multilevel modelling could take hierarchical structure of the data into account by specifying random effects at each level of analysis, and thus result in a more conservative inference for the aggregate effect (Blakely and Woodward, 2000, Li et al., 2006). The multilevel modelling approach thus can bring extra predictive power, description and precision in understanding causal higher level effects (Subramanian, 2004).

In Chapter Five, multilevel logistic regression models with random intercepts are fitted in the generalized linear mixed model (GLMM) to estimate the association between cardiovascular disease and neighbourhood deprivation. A generalized linear mixed model is an extension to the generalized linear models (GLMs) that incorporates normally distributed random effects in addition to the usual fixed effects (Hedeker, 2005, Schabenberger, 2005). The generalized linear model is a flexible generalization of various other statistical models for several types of dependent variables (i.e., continuous, dichotomous, counts), which was first described by McCullagh and Nelder (1989). Common Generalized linear models (GLMs) include linear regression, logistic regression, and Poisson regression. There are three specifications of GLMs (Hedeker, 2005, Schabenberger, 2005):

- a linear predictor η_i that is a linear combination of regression coefficients $\eta_i = x_i^{'}\beta$
- a link function $g(\bullet)$ is specified which converts the expected value μ_i of the outcome variable Y_i (i.e., $\mu_i = E\left[Y_i\right]$) to the linear predictor η_i, $g(\mu_i) = \eta_i$
- a response distribution for Y_i from the exponential family of distributions

Generalized linear models apply when the data are uncorrelated, but are not appropriate for several types of correlated data structures, in particular, for multilevel or hierarchical data, such as clustered data where subjects are nested within larger units and longitudinal data where repeated observations are nested within subjects. For the analysis of the multilevel data, generalized linear mixed models (GLMMs) were developed to account for the correlation of the data by adding random effects to generalized linear models. A very simple random-intercept mixed model is shown in the equation below, assuming that there are j=1,2……n_i observations nested within subject i=1,2,……N,

$$\eta_{ij} = x_{ij}^{'}\beta + v_i \tag{3.25}$$

where v_i is the random effect (one for each subject). Thus the expected value of the outcome variable, which is related to the linear via the link function is given as

$$\mu_{ij} = E\left[Y_{ij} \mid v_i, x_{ij}\right] \tag{3.26}$$

The mixed-effects logistic regression model (or multilevel logistic regression) was developed in the GLMM context, which utilize the logit link, namely

$$g\left(\mu_{ij}\right) = \log it(\mu_{ij}) = \log\left[\frac{\mu_{ij}}{1-\mu_{ij}}\right] = \eta_{ij} \tag{3.27}$$

Since the conditional expectation $\mu_{ij} = E\left[Y_{ij} \mid \nu_i, x_{ij}\right]$ equals to $P\left(Y_{ij} = 1 \mid \nu_i, x_{ij}\right)$ the conditional probability of a response given the random effects, so the model can also be written as

$$P(Y_{ij} = 1 \mid \nu_i, x_{ij}, z_{ij}) = g^{-1}(\eta_{ij}) = \psi(\eta_{ij}) \tag{3.28}$$

where the inverse link function $\psi(\eta_{ij})$ is the logistic cumulative distribution function (cdf), namely

$$\psi(\eta_{ij}) = \left[1 + \exp(-\eta_{ij})\right]^{-1} \tag{3.29}$$

(Hedeker, 2005)

In Chapter Five, multilevel logistic regression models are fitted in the generalized linear mixed model using the SAS (statistical software) GLIMMIX procedure, which offers ease in using the generalized linear mixed models. By allowing the area-level random intercept in the predictor, neighbourhood level effect and individual level effect on cardiovascular disease are simultaneously modelled in SAS and the results are presented in Chapter Five.

3.3.7 Survival Analysis

In Chapter Seven, due to the nature of the cardiovascular disease outcome data extracted from the Hospital Episode Statistics, where the outcome of interest is the time to death, survival analysis is used to investigate ethnic inequalities in cardiovascular disease survival and the relationships between ethnic inequalities in cardiovascular disease survival, areal socioeconomic status measures and geographical distance to treatment sites. Specifically, Kaplan-Meier survival curves are used for simple descriptive analysis and the Cox proportional hazards model is used to examine the relationships between survival and the explanatory variables. In this section, survival function, Kaplan-Meier estimator and Cox proportional hazards model are introduced. The Kaplan-Meier survival curves are plotted using SAS PROC LIFETEST and the Cox proportional hazards models are fitted using SAS PROC

PHREG.

Survival analysis, also known as failure time analysis in engineering and event history analysis in sociology, involves the modelling of time to event data or survival data. Before conducting survival analysis, censoring, which is a missing data problem and common in survival analysis, should be defined. And failure to take censoring into account can produce bias in estimates of the distribution of survival time and related quantities. Censoring refers to the situation where some subjects are not observed because the event of interest does not happen for these subjects before the termination of the study or some subjects are lost to follow up during the study (Altman and Bland, 1998). There are four different types of censoring: right truncation, left truncation, right censoring and left censoring. In this study, only right censoring occurred. Right censoring is the most common censoring in the epidemiology or medical studies, where the event has not occurred during follow-up because the study does not span enough time to observe the event for all the subjects. (Hosmer Jr and Lemeshow, 1999)

In Chapter Seven, as descriptive analysis, survival function of cardiovascular disease estimated by Kaplan-Meier estimator is plotted against time (known as Kaplan-Meier survival curve) to describe the survival experience of different ethnic groups. The survivor function, S(t), is defined as the probability that the survival time T, is greater than or equal to t, i.e.

$$S(t) = \Pr(T > t) \tag{3.30}$$

In the presence of censoring, the survivor function is usually estimated using the Kaplan-Meier estimator (also known as the product limit estimator), as

$$\hat{S}(t) = \prod_{j|t_{(j)} \le t} \left[1 - \frac{d_j}{r_j} \right] \tag{3.31}$$

where $t_{(1)} \le t_{(2)} \le ... \le t_{(n)}$ are the ordered survival times, r_j is the number of individuals at risk just before $t_{(j)}$ (including those censored at $t_{(j)}$) and d_j is the number who experience the event of interest at $t_{(j)}$. (Everitt, 2003)

Rather than plotting the survival probabilities against time, most survival analysis research examines the relationships between survival in the form of the hazard function and explanatory variables (or covariates). Cox proportional hazards models are fitted to assess the effects of explanatory variables on cardiovascular disease survival in Chapter Seven. The Cox proportional hazards model is most commonly used in medical time-to-event studies, which was first introduced by Cox (1972), also known as the Cox regression model and the Cox model. The hazard function is defined as the probability that an individual experiences the event in a small time interval s, given that the individual has survived up to the beginning of the interval, when the size of the time interval approaches zero, which is expressed as:

$$h(t) = \lim_{s \to \infty} \frac{\Pr(t \le T \le t + s \mid T \ge t)}{S} \tag{3.32}$$

In the Cox model,

$$\log h(t) = \log h_0(t) + \beta_1 x_1 + ... + \beta_q x_q \tag{3.33}$$

where $h_0(t)$ is known as the baseline hazard function, which is the hazard function when all explanatory variables are equal to zero. The model also can be written as:

$$h(t) = h_0(t) \exp(\beta_1 x_1 + ... + \beta_q x_q) \tag{3.34}$$

Holding any other explanatory variables constant, the ratio between the predicted hazard for a member of one group and that for a member of the other group, known as hazard ratio, could be written as:

$$\frac{h(t \mid x_1)}{h(t \mid x_2)} = \frac{\exp(\beta' x_1)}{\exp(\beta' x_2)} \tag{3.35}$$

Where x_1 and x_2 are the vectors of the covariate values for two members and β is the vector of regression coefficients, which is estimated by the method of maximum partial likelihood. (Everitt, 2003)

3.4 Summary

This chapter has introduced all the data and the methods used to analyze these data throughout this thesis. Hospital Episode Statistics is the key data, which has been linked to other data for further study, including Population Estimates by Ethnic Group 2004, The UK 2001 Area Classification, The UK 2001 Census and English Indices of Multiple Deprivation 2004. Standardised incidence ratio (SIR) is used to examine ethnic inequalities in cardiovascular disease incidence. Multiple logistic regression and Generalized Linear Mixed Models (GLMM) for multilevel modelling are used to investigate whether socioeconomic status measures contribute to ethnic inequalities in cardiovascular disease incidence. And survival analysis is employed to examine ethnic inequalities in cardiovascular survival and the effect of socioeconomic status on ethnic inequalities in cardiovascular disease survival. Ethnic inequalities in cardiovascular disease severity/treatment and the effect of socioeconomic status on ethnic inequalities in cardiovascular disease severity/treatment are examined using multiple logistic regression.

However, beyond the normal procedures of these analyses, there are two practical difficulties in analyzing ethnic data using the HES. Firstly, there are a high percentage of the HES records without valid ethnicity coding, which can't be simply ignored in the analysis. Before analyzing the HES, two methods are developed by me to improve the data qualities in the HES ethnic data, which is briefly introduced in this chapter and is going to be introduced in detail in Chapter Four. Secondly, studying geographical ethnic inequalities in cardiovascular disease is subject to the small number problems caused by the small size of population of minority ethnic groups at small areas. The empirical Bayes estimation method is employed to alleviate this problem. Two estimation methods are used to examine the geographical relative risk of cardiovascular disease for ethnic groups. This is reported in Chapter Five.

Chapter Four: Improving Quality of Ethnic Codes in HES

4.1 Introduction

The previous chapter introduced all the data and methods employed to achieve the research objectives in this study. Hospital Episode Statistics (HES), which is one of the only 10 routinely collected data that are ethnically coded in the English regions (Aspinall and Jacobson, 2007), is the key data used throughout this thesis. Given the large number of events, detailed classification of ethnicity, geographically national coverage, fine geographical scale, and comprehensive clinical information, the HES data has substantial potential for further understanding ethnic inequalities in cardiovascular disease as well as other disease. However, concern over the use of ethnicity data arises because the data quality is not satisfactory. The percentage of Finished Consultant Episodes (FCEs) with invalid ethnicity codes is at a high level.

Despite the incomplete ethnicity codes, the HES haven't been neglected by research on ethnic inequalities in health and healthcare. There are a number of previous studies using the Hospital Episode Statistics to derive ethnic disparities in health. However, the main method they used, the proportional mortality ratio or proportional morbidity ratio (PMR), is of doubtful accuracy.

There are few studies in the UK that validate the ethnicity codes or supply additional ethnic information in the data (Aspinall and Jacobson, 2007). Rather than simply ignoring the records with missing ethnicity codes in the analysis, two methods have been developed in this chapter, including the record linkage method and the coding rate method, to improve the data quality of ethnicity codes.

The record linkage method validates the ethnicity codes by linking the FCEs with valid ethnicity codes to the historical admissions without valid ethnicity codes based on the same person's unique identifier. After applying the record linkage method, the data quality of ethnicity codes has been significantly improved. However, the record linkage method can't restore the ethnicity codes for patients with none of their historical FCEs with valid ethnicity codes.

To enable the calculation of the standardised incidence ratios of cardiovascular disease for ethnic groups, the coding rate method is then developed to estimate the total number of cases for ethnic groups within a region based on the observed number of cases with valid ethnicity codes and the estimated coding rates for that region. Two coding rates methods, including local area-age-sex coding rate method and local area-sex-ethnicity coding rate method, have been developed. The first one assumes there is no ethnic difference in the coding rates for local area-age-sex groups. The latter one allows the coding rates vary across local area-sex groups. However, the local area-sex-ethnicity coding rate method is subject to the small number problem. And finally, the local area-age-sex coding rate method is selected to further adjust the cardiovascular disease data.

4.2 How Good is HES Ethnicity Coding?

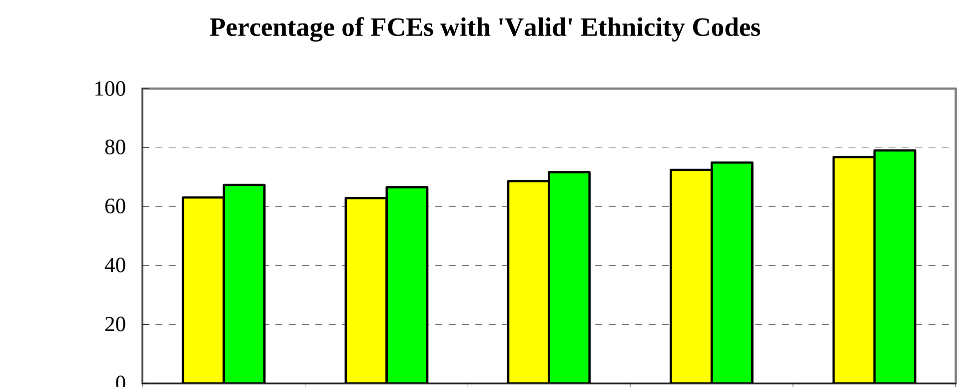
The high level of incompleteness in ethnicity codes has limited the wide use of the Hospital Episode Statistics in identifying ethnic inequalities in health and healthcare. This section is going to introduce how good is the data quality of ethnicity coding in the HES by examining the trends in the percentages of Finished Consultant Episodes (FCEs) with valid ethnicity codes by data years, Government Office Regions, Primary Care Trusts, sex and age groups.

4.2.1 National Coding Rates

On April 1st 1995, the Department of Health introduced the mandatory collection of ethnic information on all inpatients in Hospital Episode Statistics (Aspinall, 2000).

The overall percentage of Finished Consultant Episodes (FCEs) with missing ethnicity data has fluctuated over data years, which was 52 per cent in 1996/97, and stabilized at around 37 per cent in 2000/01 and 2001/02 (HESonline, 2004b). This number decreased to 31.35 per cent in 2002/03.

In recent years, the quality of ethnicity data was steadily improving by about 4 per cent annually. In 2004/05, about 76.8 per cent of Finished Consultant Episodes had valid ethnicity codes. In the most recent data year 2005/06, the percentage of FCEs with valid ethnicity codes reached about 80 per cent (Aspinall and Jacobson, 2006, Georghiou and Thorlby, 2007). A similar pattern has been observed in cardiovascular FCEs. However, the overall percentage of cardiovascular FCEs with valid ethnicity codes was about 3 per cent higher than the national average.



	2000/01	2001/02	2002/03	2003/04	2004/05
All FCEs	63.08	62.96	68.65	72.45	76.81
CVD FCEs	67.3	66.61	71.71	74.96	79.07

Figure 4-1 Percentage of FCEs with valid ethnicity codes by data years

4.2.2 Government Office Region Level Coding Rates

The incompleteness of HES ethnicity data varies across not only data years but also regions. Significant difference in data qualities has been observed at Government Office Regions (GOR). In the data year 2004/05, the North East achieved the best completeness of HES ethnicity data, which was about 90 per cent. However, the percentage of FCEs with valid ethnicity codes in the Yorkshire and the Humber was 16 per cent lower than that of the North East, which was around 64 per cent. For cardiovascular disease episodes, the completeness of ethnicity data was still slightly better than the national average. The highest percentage of FCEs with valid ethnicity codes reached 92 per cent in the North East. However, most of the others were still lower or even much lower than 85 per cent.

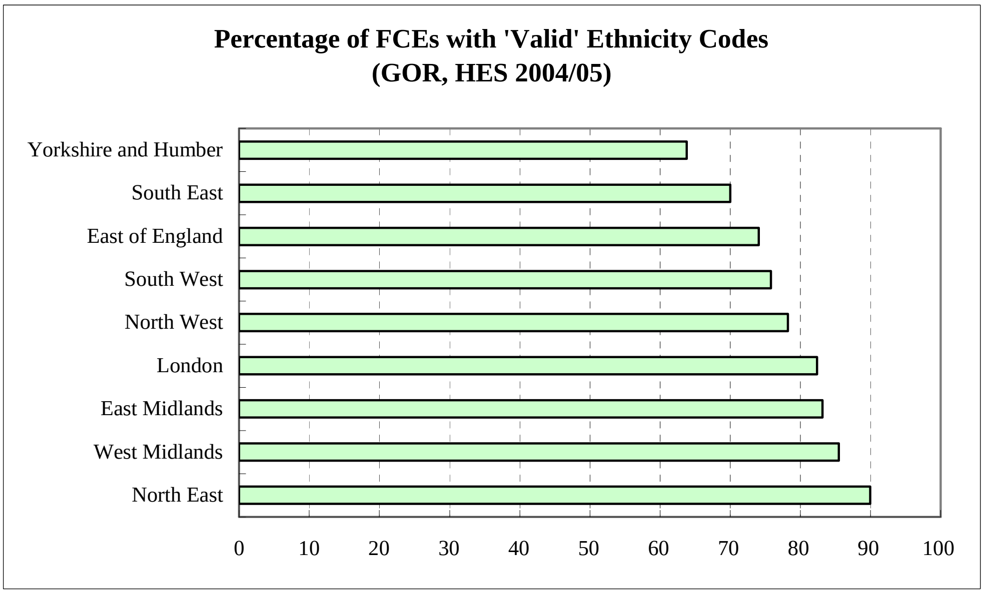


Figure 4-2 Percentage of FCEs with valid ethnicity codes by GORs

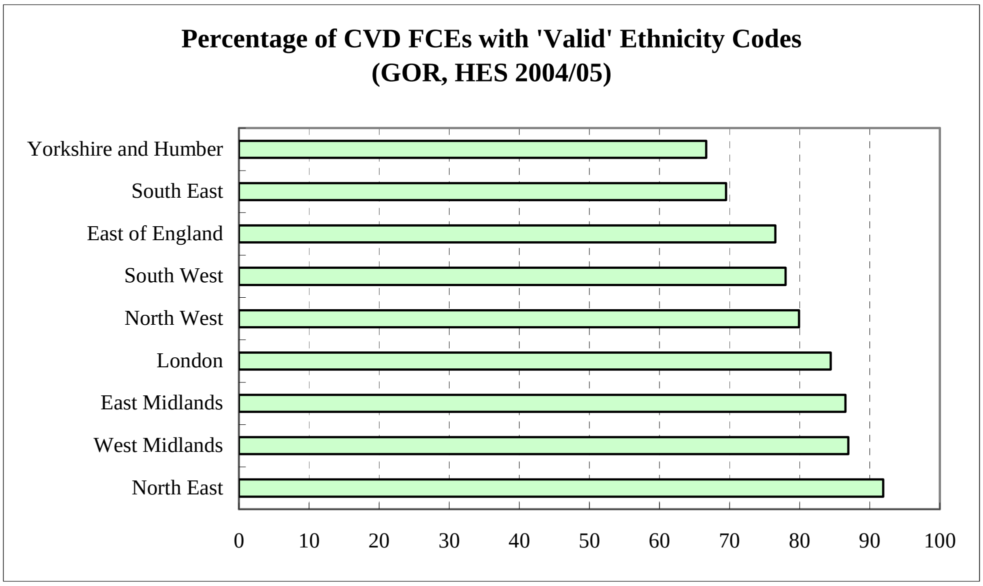
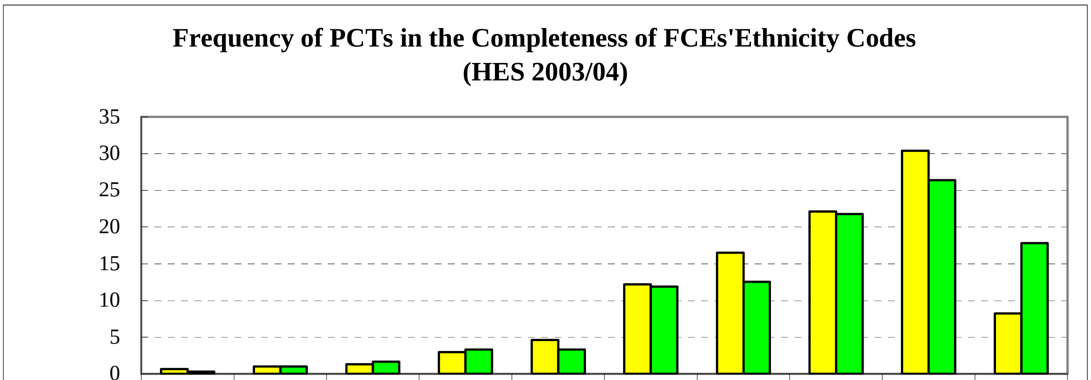


Figure 4-3 Percentage of CVD FCEs with valid ethnicity codes by GORs

4.2.3 Primary Care Trusts Level Code Rates

Variations of quality of HES ethnicity coding also have been observed across Primary Care Trusts (PCT). The graph below based on the 2003/04 FCEs shows there were significant differences in the quality of ethnicity coding between different NHS hospital trusts. Less than 50 per cent of FCEs were ethnically coded in the bottom 10 per cent of all the PCTs. Nearly half of the PCTs had the completeness of FCEs' ethnicity codes between 50 per cent and 80 per cent. The average per cent of FCEs with valid ethnicity codes was between 80 and 90 per cent in the upper 30 per cent of PCTs. Only less than 10 per cent of PCTs achieved completeness of ethnicity coding higher than 90 per cent. The data quality of CVD FCEs was particularly better than the national average in the 90 to 100 per cent completeness group. More than 40 per cent of PCTs have percentages of CVD FCEs with valid ethnicity codes higher than 80 per cent.



	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
All FCEs	0.66	0.99	1.32	2.97	4.62	12.21	16.50	22.11	30.36	8.25
CVD FCEs	0.33	0.99	1.65	3.30	3.30	11.88	12.54	21.78	26.40	17.82

Percentage of FCEs with 'Valid' Ethnicity Codes

Figure 4-4 Percentage of FCEs with valid ethnicity codes by PCTs

4.2.4 Coding Rates by Gender and Age Groups

At the national level, little difference in ethnicity data quality has been observed between male and female patients, although the completeness of ethnicity data among female patients was slightly better than male. For both male and female patients, the data quality of CVD FCEs was a little better.

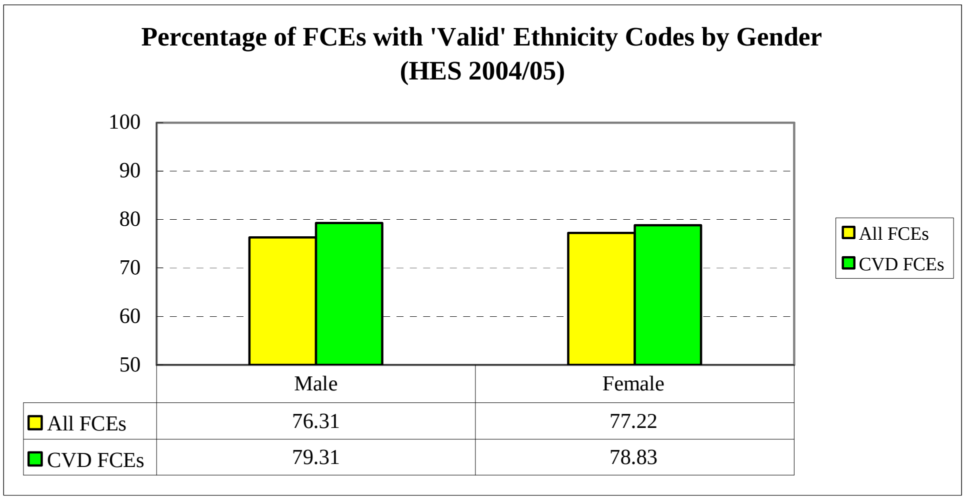


Figure 4-5 Percentage of FCEs with valid ethnicity codes by gender

However, there exists much difference in ethnicity coding in different age groups at the national level. The young people (0-19 years old) seemed to be most poorly coded. The percentage of FCEs with valid ethnicity codes across the 20 to 59 years age ranges stabilized at around 76 per cent. And then the percentage of completeness increased with age. The highest percentage of valid ethnicity codes, which was about 79 per cent, was for older people (70 to 84 years old). The CVD FCEs' completeness in ethnicity codes was better than the national average in all the age groups, particularly for young people. And the difference in ethnicity coding between different age groups was not as wide as the national average.

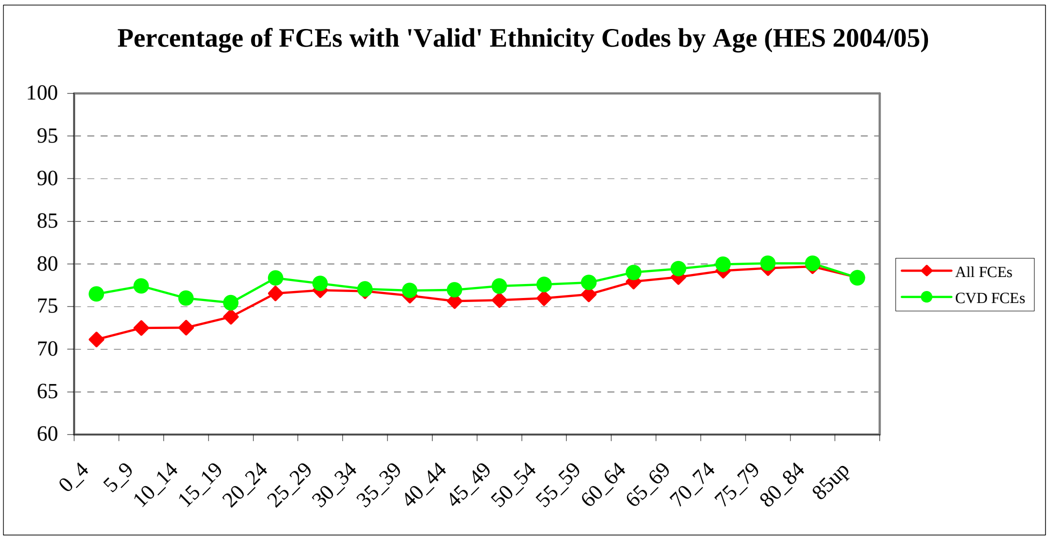


Figure 4-6 Percentage of FCEs with valid ethnicity codes by age group

4.2.5 Coding Rates by Ethnicity

As the ethnicity coding in the HES is incomplete, there is no true total number of patients for each ethnic group. Thus it is impossible to examine the exact coding rates for ethnic groups. However, a study has been conducted by researchers from HESonline to investigate whether there are discrepancies in coding rates across ethnic groups by comparing the observed ethnic distribution of 2002-03 Finished Consultant Episodes by trust to the expected ethnic distribution estimated based on Census ethnic data (HESonline, 2004a). This research assumed the ethnic distribution of FCEs in a certain trust was consistent with the ethnic distribution of the population in that trust. The results showed that the comparison of ethnicity distribution between HES 2002/03 and the 2001 Census was fair at national level, suggesting that there was no ethnic group that was widely misrepresented in HES data. And for a large number of NHS hospital trusts, the ethnic data coding was fairly consistent with that of their patient population, although some large discrepancies have been observed in a number of trusts. However, there was a limitation in the assumption. The ethnic distribution of FCEs might not always be consistent with the ethnic distribution in the census, because people from different ethnic groups and age groups have varying risk of hospitalisation, which hasn't been considered in this research.

4.3 Previous Research Using HES Ethnicity Data

Although the overall data quality is not very satisfactory, the HES data haven't been neglected from the research on ethnic inequalities in health and healthcare. Lowdell et al. (2000) attempted to look at the distribution of causes of admission of people aged 65 and over across ethnic groups using Hospital Episode Statistics (1997/1998), acknowledging that about 31% of all the admissions didn't have valid ethnicity codes. By ignoring the uncoded cases, Bardsley et al. (2000) have examined the proportional hospital admission rates for heart operation by ethnic groups in London, which has been rarely undertaken before on a London wide basis. Including ethnicity information of new born children, Hospital Episode Statistics was identified and recommended as a potential data source for analyzing generational differences in fertility among ethnic groups (Haskey and Huxstep, 2002). For example, it was used to analyse the ethnic difference in fertility in London by calculating Age-Specific Fertility Rate structures (ASFRs) and Total Period Fertility Rate (TPFR) for different ethnic groups, which has developed a more robust fertility projection methodology in London (Klodawski, 2003). In order to compare the proportion of all hospital admissions in each ethnic group, proportional admission ratios have been calculated for coronary heart disease, revascularization, diabetes and cataracts for ethnic groups using Hospital Episode Statistics across English regions (Fitzpatrick et al., 2005). Mindell et al. (2007) examined the ethnic difference in coronary revascularization procedures in London to further measure ethnic inequalities in access to health services using the proportional ratios method, concluding that even if the data was not perfect, the analysis can identify inequalities that warrant further investigation. In addition, Mann et al. (2008) have investigated the difference in age-standardised morbidity and mortality ratios and morbidity and mortality odds ratios of hepatitis C-related end-stage liver disease in ethnic minorities in England using Hospital Episode Statistics from 1997/98 to 2004/05 and the 2001 Census. These previous studies using the ethnicity data from Hospital Episode Statistics did provide importantly further analysis about health and healthcare among ethnic groups, indicating that although the Hospital Episode Statistics is imperfect in ethnicity coding, as the data quality improves over time, the Hospital Episode Statistics with valuable information about ethnic groups is attracting more and more public health interest

In most previous research using the HES ethnicity data, it is the proportional mortality ratio (PMR) method (or proportional morbidity ratios, proportional admission ratios) that make it possible to derive ethnic disparities in health from Hospital Episode Statistics with incomplete ethnicity codes (Lowdell et al., 2000, Bardsley et al., 2000, Mindell et al., 2007). A proportional mortality ratio (PMR) measures whether the proportional mortality of the study population from a certain cause is higher or lower than the proportional mortality due to that cause in the standard or general population, where the proportional mortality or morbidity (PM) can be calculated as the ratio between the number of cases due to that cause and the total number of cases (Fitzpatrick et al., 2005). In addition, it is possible to make the denominator (total number of causes) cause specific in the PMR method. For example, the deaths from a certain kind of disease could be examined as a proportion of deaths from similar causes rather than all the causes (Aspinall and Jacobson, 2007). The PM and PMR can be expressed as follows (Aspinall and Jacobson, 2006):

$$\text{Proportional Mortality or Morbidity (PM)} = \frac{\text{Number of Cases due to Cause X}}{\text{Total Number of Cases}} \tag{4.1}$$

$$\text{Proportional Mortality or Morbidity Ratio (PMR)} = \frac{\text{PM in Population A (the Study Population)}}{\text{PM in Population B (the Standard or Reference Population)}} \tag{4.2}$$

The proportional mortality (morbidity) ratio method is particularly useful when the underlying population at risk can't be accurately measured, since this method doesn't require appropriate population denominators as in the age-standardised rates method (Mindell et al., 2007). The ethnicity information is poorly recorded in the HES data and it is difficult to measure the true corresponding population for the cases with valid ethnicity codes. So the proportional mortality ratio (PMR) method was widely used in previous research conducted using the incomplete HES data. The use of the PMR method is also strengthened in the following situations. For some NHS hospital trusts, it is hard to estimate the population for a hospital catchment area, because their catchments are not discrete geographical areas and usually overlap with neighbourhood trusts (Aspinall and Jacobson, 2006). In addition, given three or five years of data are frequently used in epidemiological analysis, the ethnic group population data, which is mainly derived from the decennial census could only be accurate several years beyond the census. PMR was recommended to be more widely used by NHS organizations to monitor the health of the population (Aveyard, 1998).

Although it is argued that the bias of PMR is small and of no practical importance (Aveyard, 1998), the accuracy of the PMR method is doubtful. Firstly, this ratio depends not only on the number of cases from the disease under study but also on the number of cases of the reference disease (Bhopal, 2002). The fundamental assumption is that the distribution of cases from other causes rather than the one of interest is the same in the population of interest and reference population, which is unlikely to hold (Bhopal, 2002).So the proportional mortality (morbidity) ratio is more likely to be an overestimate when overall mortality rate is low and underestimate mortality (morbidity) if the overall rate of the comparison group is high. Secondly, another underlying assumption of using the PMR method to analyze the HES ethnicity data is that the records with no ethnicity codes that have been ignored should have a similar ethnic mix to those records that have a valid ethnicity code at the geographical or aggregated level of study, which is inappropriate and might not be true for most of the cases. Otherwise, ignoring the records with missing ethnicity codes will introduce bias and uncertainties. So users of the PMR method should be aware of the flaws and the results need to be interpreted with caution (Aspinall and Jacobson, 2007).

Given that the Hospital Episode Statistics are particularly useful and the PMR method is flawed by the underlying assumptions, rather than simply ignoring the records with missing ethnicity codes, two methods have been developed by me, including the record linking method and the coding rate method. The aim of the first one is to improve the data quality of ethnicity codes in the HES. And the latter one is to adjust the total number of cardiovascular cases within regions based on the observed number of cases with valid ethnicity codes and the estimated coding rates across regions.

4.4 Record Linkage Method

4.4.1 Introduction to the Record Linkage Method

The record linkage method, which links different data by their common variables, such as name, sex and date of birth, is a reliable method to restore the missing data. By linking with other data, the data of interest also can be enriched with additional variables. Two main record linkage methods are available, namely deterministic matching and probabilistic matching methods. Deterministic matching is an exact matching method, which links different data by their unique identifier. However, for reasons of confidentiality, the data may not contain such high quality identifiers, which make this method frequently not possible. The probabilistic matching method is used when a combination of information (such as age, sex and date of birth) about the same person rather than a unique identifier is available in both data (Aspinall and Jacobson, 2007).

There is some previous research which links administrative records to surveys and other administrative data using the record linkage method. For example, in the English Longitudinal Study, the 1971-2001 Censuses have been linked together along with other vital events for 1% of the population of England and Wales based on individual personal detail (Blackwell et al., 2003). The HES data have been linked to the mortality data for England from 1998/99 to the present by the University of Oxford, based on which a series of papers about mortality rates after hospital admission for myocardial infarction, stroke and diabetes have been published (Roberts and Goldacre, 2003, Roberts et al., 2004, Goldacre et al., 2004). Other examples include linking the Pupil Level Annual School Census with the National Pupil Database, Millennium Cohort Study and The Avon Longitudinal Study of Parents and Children. However, there are few studies in the UK that validate the ethnicity codes or supply additional ethnic information in the data, with an exception of the linkage between the Scottish 2001 Census and the Scottish NHS Community Health Index used in Scottish Longitudinal Study (Aspinall and Jacobson, 2007).

In this study, the deterministic matching method, which is an exact matching method, is used to improve the quality of ethnicity codes in the HES. Unlike other applications of the record linkage method that involve different data, this deterministic matching only relies on the HES historical data itself. The underlying idea of this exact matching method is to restore the missing ethnicity codes by linking the admissions with valid ethnicity codes to the historical admissions without valid ethnicity codes based on the same person's unique HESID. The deterministic matching is realized upon two characteristics of the HES data, the unique HESID and the historical readmissions. Firstly, in the HES, each episode has been assigned a HESID, which is generated by matching records for the same patient using a combination of NHS Number, local patient identifier, sex and date of birth. If two episodes have the same HESID, they are believed to belong to the same patient. (HESonline) Therefore, uniquely identifying a patient across all data years, HESID could act as the unique identifier in the deterministic matching method. Second, the HES is a data warehouse containing all the NHS hospital admissions across many years, from 1998/1999 over 12 million records have been added into the HES per year, and from 2003/2004, this number has reached more than 14 millions. During the data years, one person may come to hospital for more than one time, which could be identified by the patient's unique HESID. If there is a valid ethnicity code within any of the historical admissions belonging to one person, all the other missing ethnicity codes could be replaced by this valid ethnicity code.

The potential of this method is that, as the data quality is better and better, there will be more and more episodes with valid and accurate ethnicity codes, which could be used to restore previous missing ethnicity information. There is evidence that some trusts with the worst ethnicity coding before have achieved almost complete coding in subsequent years (Mindell et al., 2007). So it is reasonable to believe that not only the data quality of future years will be better, but also the quality of ethnicity codes in the historical data will be better. In addition, by linking the historical admissions in different years, it is possible to trace individuals' vital medical information and events during the life course, such as birth, diagnosis, operations, and death and so on. The HES data itself could be a specific longitudinal data about health, as long as the hospital admissions are recorded continuously.

This method is based on the assumption that each patient has only one valid ethnicity code across the whole HES data. This is true for 98.5 per cent of all the patients with at least one valid ethnicity code. They have been assigned to the only ethnic group that has been recorded in their historical admissions, which is a true match for their records. However, inconsistency of valid ethnicity coding has been observed for some patients. About 1.5 per cent of all the patients with at least one valid ethnicity code have been recorded to multiple ethnic groups in the historical admissions. And 98% per cent of these patients have two different valid ethnic groups. There are several possible reasons.

a) Ethnicity classification reason. The England 2001 Census has introduced the new ethnicity classification system. However, HES has continued to accept the old codes as well as the new codes for the 2001/02 and 2002/03 data years. There is some inconsistency between the old and new ethnicity coding, particularly for the mixed blood population. As there was no "Mixed" group in the old coding system, people who described themselves as mixed blood population in new classification in the later years had to choose one single ethnic group in their earlier admissions, which caused inconsistent ethnicity codes for them.

b) Organization or institutional reason. Although it is mandatory for NHS hospital trusts to collect ethnicity information about patient, in the early years, some trusts didn’t perform well on it. Staff might record patients’ ethnicity simply by guessing or they might simply assign ‘Other’ ethnic group to the patients. There is some evidence that white patients have been coded as ‘Other’ in some trusts (HESonline, 2004b). Recently, as ethnicity monitoring has been paid more attention, the patients who were simply assigned to ‘Other’ ethnic group before are more likely to have been assigned to their representative ethnicity in the data. So these patients usually have two valid ethnic groups in the records, ‘Other’ group and another valid ethnicity.

c) Personal reason. Some people would feel it difficult to describe their ethnicity, especially the people who have mixed origins. They might describe themselves as Mixed group sometimes, but sometimes they might prefer one of their origins. In addition, some people from minority ethnic groups might be reluctant to describe themselves as minorities in some cases, so they might not provide their true ethnicity in the records.

Given the above possible reasons, some criteria have been set according to their historical admissions to assign a ‘most likely’ ethnic group to the patients with multiple ethnic groups recorded.

1). If a certain valid ethnic group occurs more than 80 per cent of all the records with valid ethnicity codes, this person is more likely to belong to this ethnic group.

2). If no one ethnic group accounts more than 80 per cent of all the records with valid ethnicity codes, if ‘mixed’ is among the valid ethnic groups, this person is more likely to belong to the ‘mixed’ population.

3). If no one ethnic group accounts for more than 80 per cent of all the records with valid ethnicity codes, if 'Other' is among the valid ethnic groups, this person is more likely to belong to the other valid ethnicity code rather than the 'Other' group. (About 98% per cent of the patients with more than one valid ethnic group codes only have two different valid ethnic groups)

4). If one patient's ethnicity code distribution doesn't follow any above criteria, then the most recent valid recorded ethnicity group will be assigned to this person, since generally the most recent HES data are more accurate and have better data quality than previous data.

As this record linkage method is based on the historical hospital admissions with valid ethnicity codes, there is a possibility that people who are generally sicker that have more historical hospital admissions are more likely to have been recorded with valid ethnicity codes. Thus the cardiovascular disease admissions with invalid ethnicity codes belonging to these people are more likely to be restored with valid ethnicity codes, which might introduces bias. However, it seems reasonable to assume that this will be true of all ethnic groups and therefore there will be no bias when making comparisons between ethnic groups.

4.4.2 Results of the Record Linkage Method

After applying the record linkage method discussed above to the HES data, the data quality of ethnicity codes has been significantly improved. This section presents to what extent the data quality has been improved by comparing the coding rates of validated ethnicity codes with that of the original ethnicity codes at national level, GOR level, PCT level and for sex and age groups.

4.4.2.1 New Overall Coding Rates

As shown in the graphs below, the overall coding rates of ethnicity codes validated by the record linkage method increase significantly in recent data years, particularly for the earlier data years. There are about 14 per cent more FCEs that have been restored with valid ethnicity codes in the data year 2000/01. The most complete ethnicity codes are in 2004/05, which is about 84 per cent, 7 per cent higher than the old one. Similar pattern has been observed in the CVD FCEs. However, the overall coding rates of CVD FCEs are better than the national average in recent data years. Nearly 88 per cent of the CVD FCEs have valid ethnicity codes in data year 2004/05.

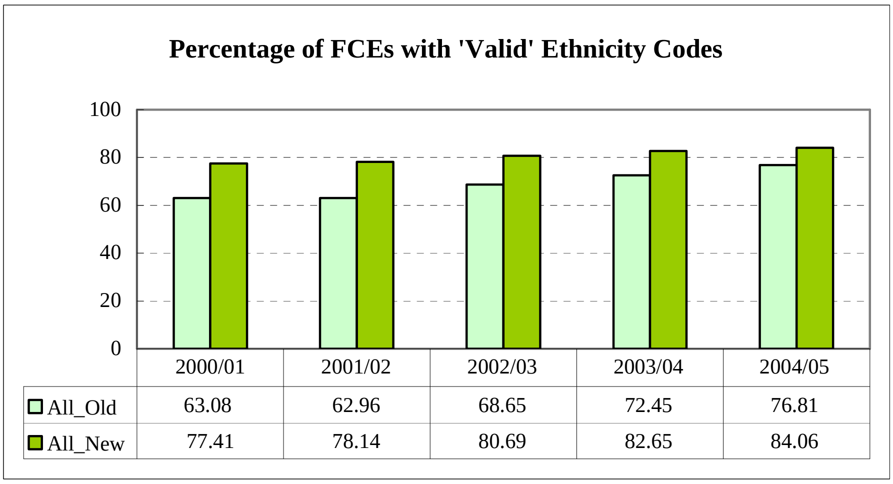


Figure 4-7 New percentage of FCEs with valid ethnicity codes by data years

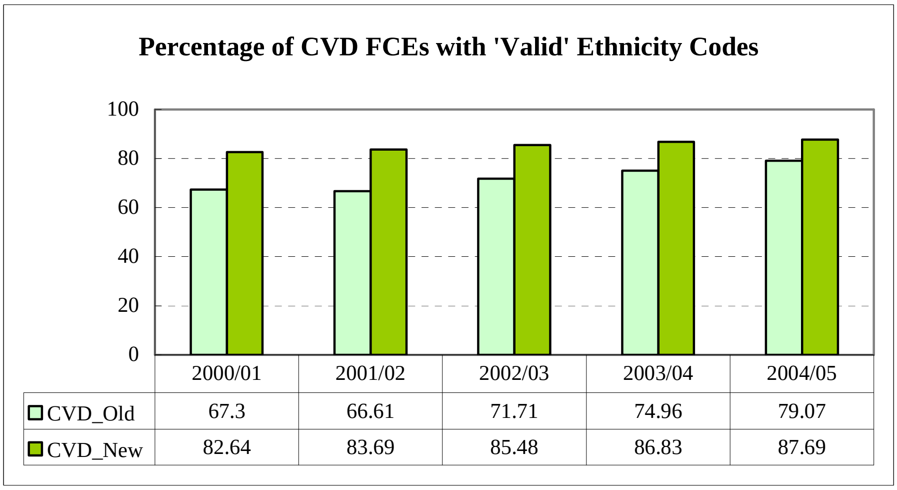


Figure 4-8 New percentage of CVD FCEs with valid ethnicity codes by data years

4.4.2.2 New Coding Rates by Government Office Regions

The significant improvement of the data quality of ethnicity codes has been found in Government Office Regions after applying the record linkage method. As shown in the graphs below, nearly all the GORs have the completeness of ethnicity codes above 80 per cent in data year 2004/05, particularly the West Midlands and the North East. About 94 per cent of FCEs have valid ethnicity codes in the North East. The data quality in the Yorkshire and Humber is still the worst. However, the completeness of ethnicity codes has increased by more than 10 per cent there. For the CVD FCEs, the percentage of FCEs with valid ethnicity codes is more than 90 per cent in the top five GORs. The North East has the highest completeness of ethnicity codes, which is more than 95 per cent.

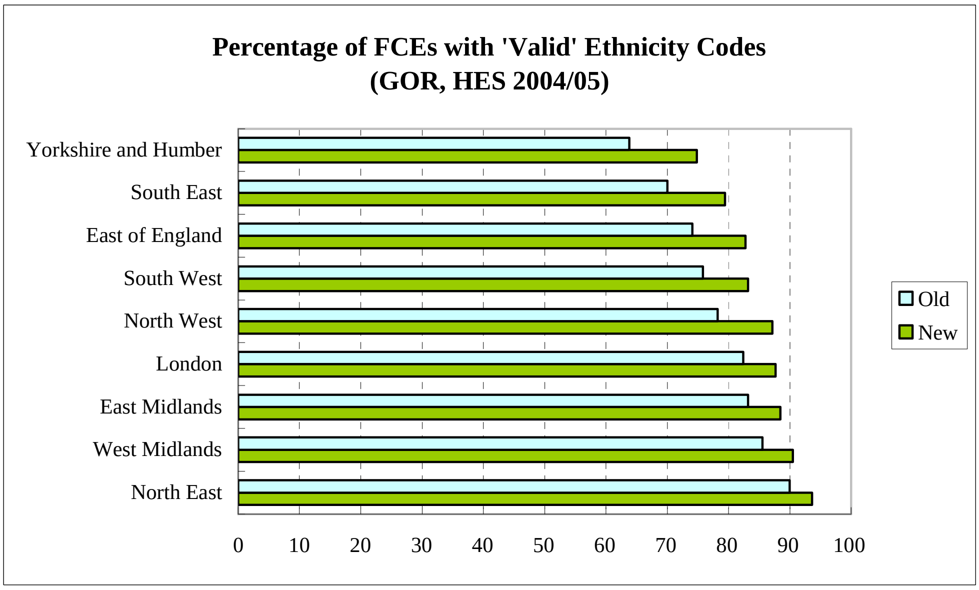


Figure 4-9 New percentage of FCEs with valid ethnicity codes by GORs

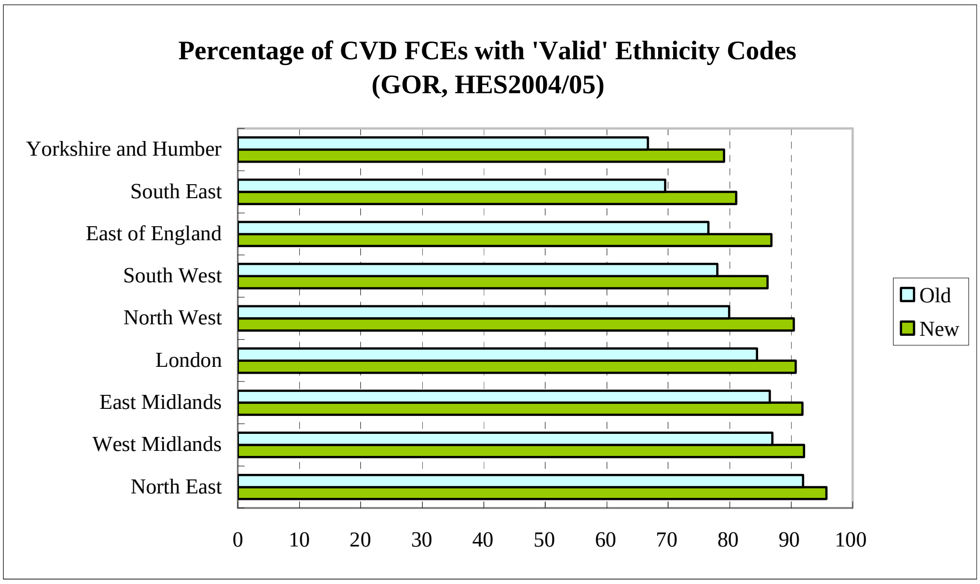
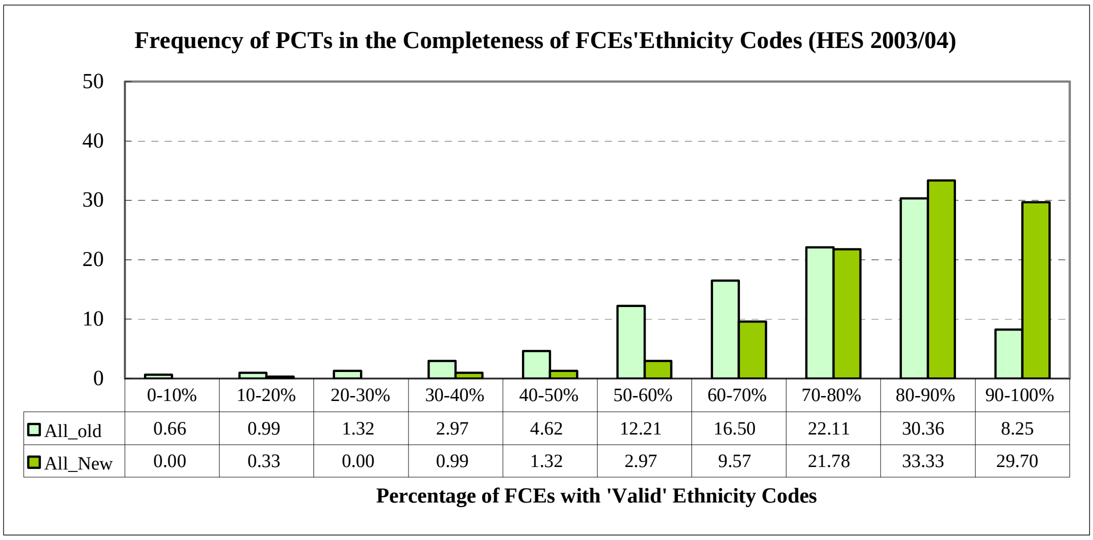


Figure 4-10 New percentage of CVD FCEs with valid ethnicity codes by GORs

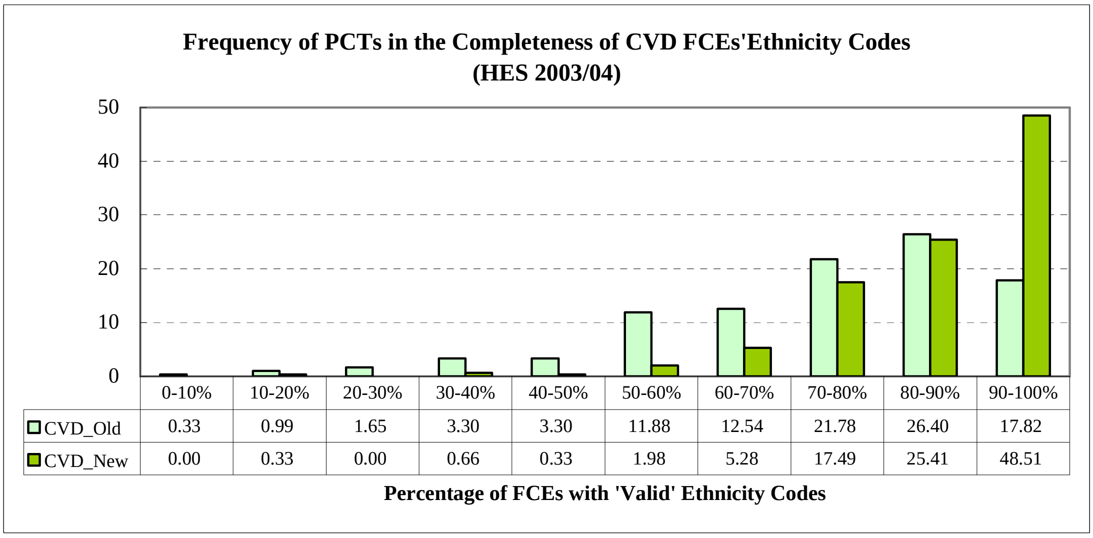
4.4.2.3 New Coding Rates by Primary Care Trusts

The graphs below show to what extent the data quality of ethnicity codes has been improved for Primary Care Trusts. After validating ethnicity codes using the record linkage method, the percentage of PCTs with lower completeness of ethnicity codes (below 70 per cent) has largely decreased, despite a small number of PCTs with very low completeness. Significant increase of percentage of PCTs that have above 90 per cent of FCEs with valid ethnicity codes has been observed. Compared with 8 per cent before applying the record linkage method, nearly 30 per cent of PCTs have more than 90 per cent completeness of ethnicity codes. For the CVD FCEs, nearly half the PCTs have the completeness of ethnicity codes higher than 90 per cent. Another one quarter of PCTs have 80-90 per cent of FCEs with valid ethnicity codes. The data quality for the other quarter of PCTs is still not satisfactory.



	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
All_old	0.66	0.99	1.32	2.97	4.62	12.21	16.50	22.11	30.36	8.25
All_New	0.00	0.33	0.00	0.99	1.32	2.97	9.57	21.78	33.33	29.70

Figure 4-11 New percentage of FCEs with valid ethnicity codes by PCTs



	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
CVD_Old	0.33	0.99	1.65	3.30	3.30	11.88	12.54	21.78	26.40	17.82
CVD_New	0.00	0.33	0.00	0.66	0.33	1.98	5.28	17.49	25.41	48.51

Figure 4-12 New percentage of CVD FCEs with valid ethnicity codes by PCTs

4.4.2.4 New Coding Rates by Gender

The graphs below show how the data quality of ethnicity codes has been improved for gender groups.

About 8 per cent more FCEs have valid ethnicity codes for both gender groups in the HES 2004/05. Little difference has been observed in the completeness of ethnicity codes between male and female patients. The CVD FCEs have similar pattern to the general FCEs in the percentage of FCEs with valid ethnicity codes for sex groups.

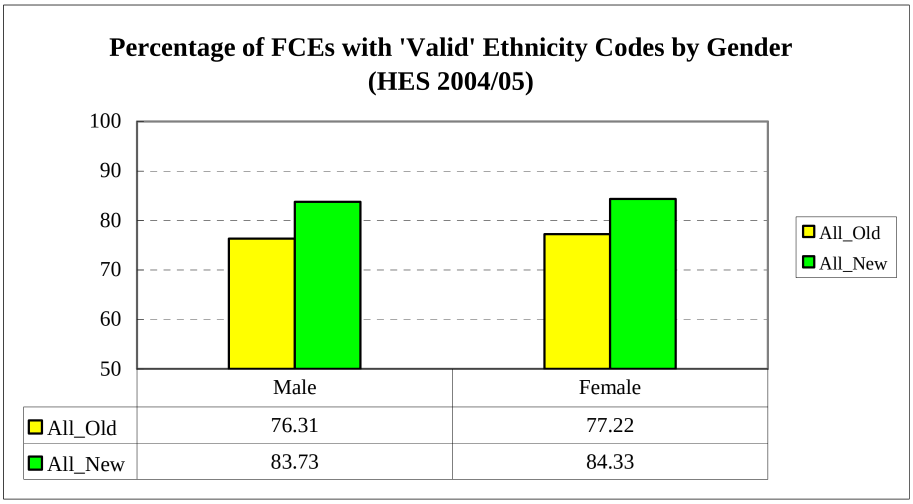


Figure 4-13 New percentage of FCEs with valid ethnicity codes by gender

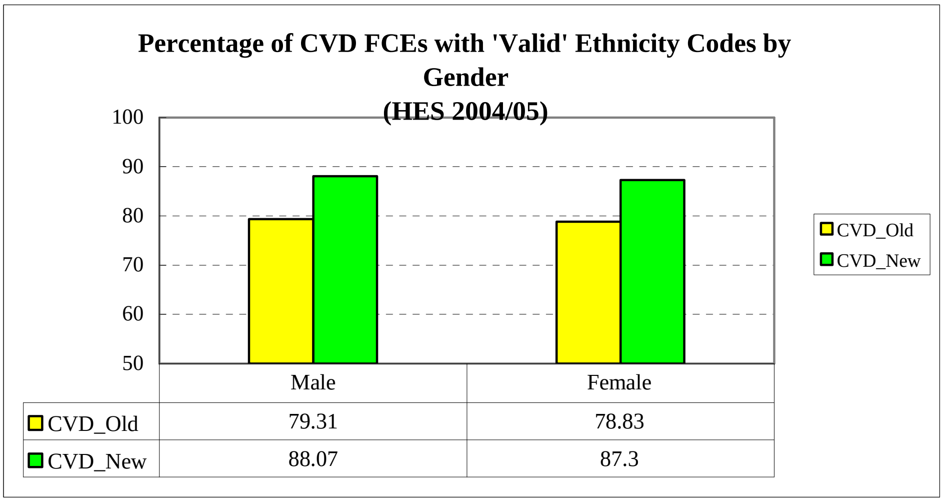


Figure 4-14 New percentage of CVD FCEs with valid ethnicity codes by gender

4.4.2.5 New Coding Rates by Age Group

As shown in the graphs below, significant improvement of completeness of ethnicity codes has been made for age groups after applying the record linkage method. Young age groups (0-24) still have poorer data quality. And then the percentages of FCEs with valid ethnicity codes increase with age groups. The completeness of ethnicity codes is higher among older age groups (above 55), which is above 85 per cent. For

CVD FCEs, the difference between age groups in ethnicity coding is relatively small. Nearly all the age groups have completeness scores above 85 per cent, except for the age group 15-19. People aged 0-4 and above 50 are most ethnically coded.

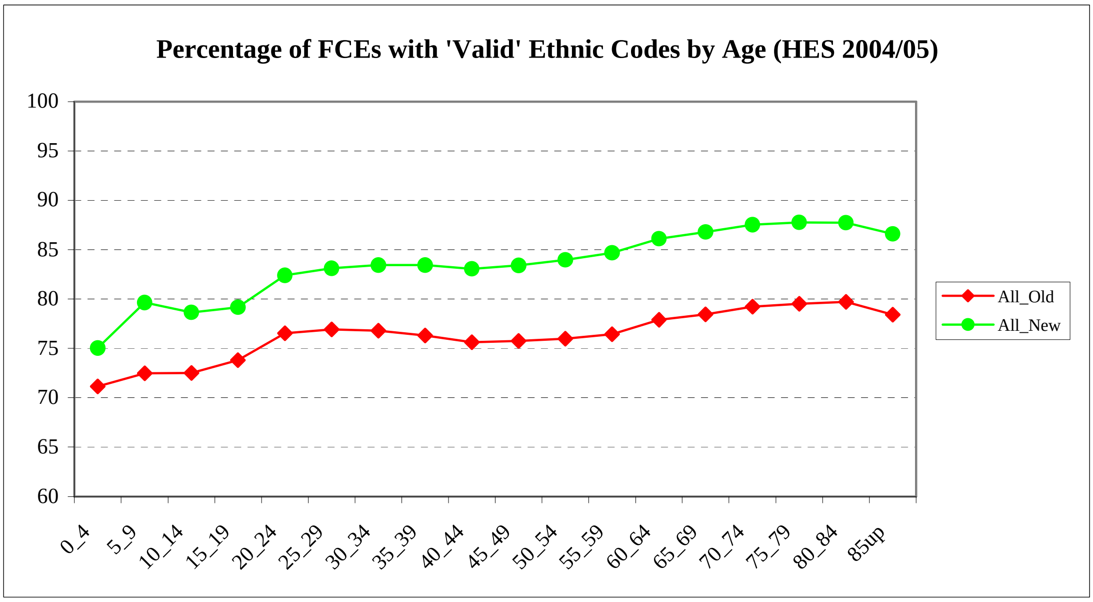


Figure 4-15 New percentage of FCEs with valid ethnicity codes by age groups

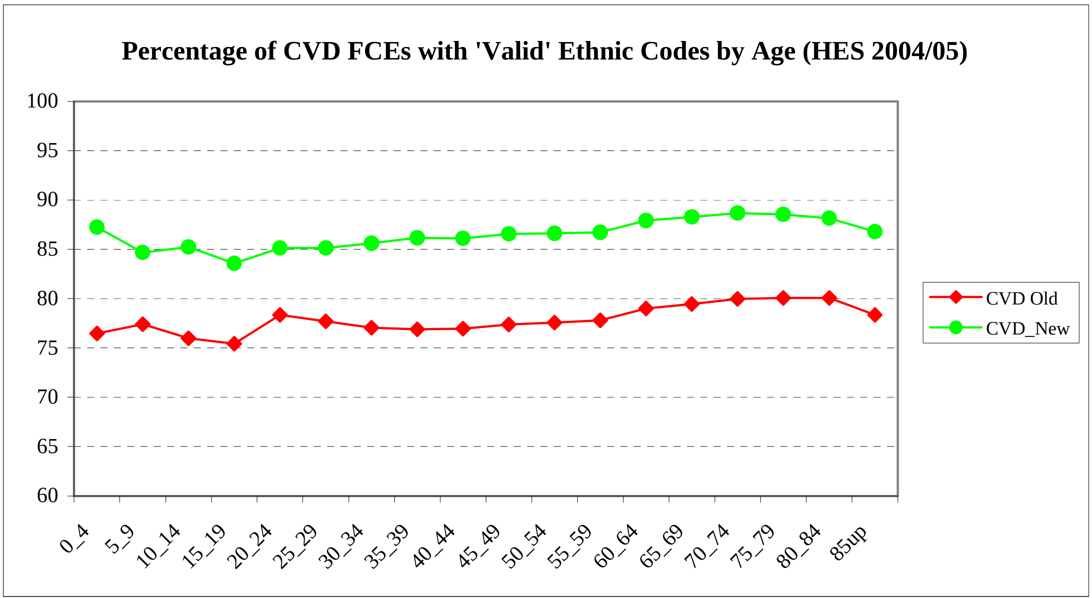
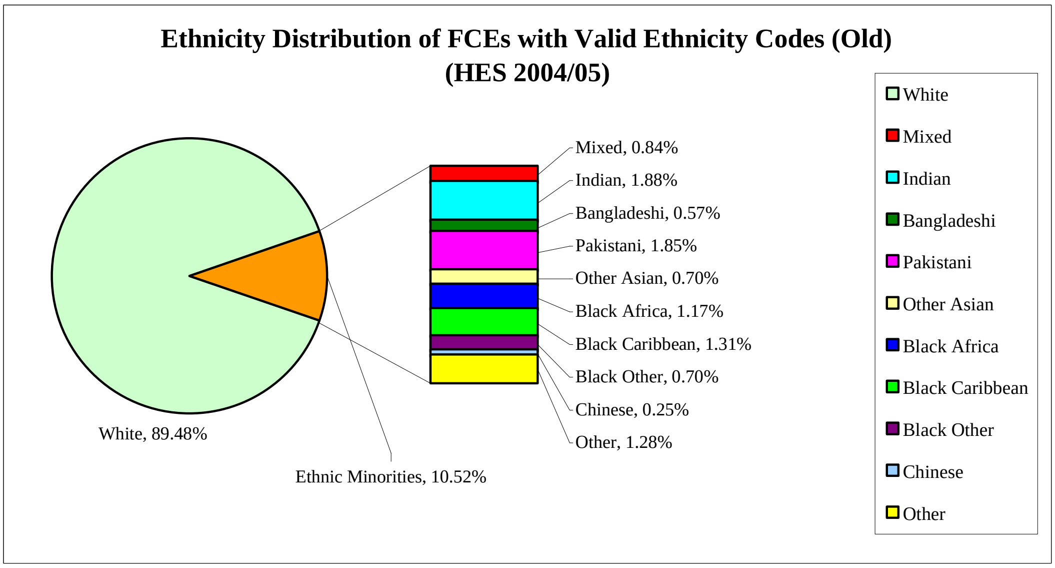


Figure 4-16 New percentage of CVD FCEs with valid ethnicity codes by age groups

4.4.2.6 Ethnicity Distribution Comparison

The ethnicity distribution in the FCEs that have been validated by the record linkage method has been compared with the old ethnicity distribution. Here the ethnicity distribution is based on number of episodes or admissions of different ethnic groups rather than the number of patients of ethnic groups. If there is little difference between the ethnicity distributions in the FCEs before and after applying the record linkage method, we can say the FCEs that have been restored with valid ethnicity codes have the same ethnicity distribution as the FCEs that already have valid ethnicity codes before. If so, at the national level no ethnic groups are more or less likely to be ethnically coded in the FCEs with new restored valid ethnicity codes. Thus it is perhaps reasonable to say that the ethnicity codes of these FCEs are missing by chance.

As shown in the graphs below, for both general FCEs and CVD FCEs, there is little difference between the new and old ethnicity distributions, indicating that at the national level, no ethnic groups are more or less likely to be ethnically coded in the FCEs with new restored valid ethnicity codes. Although this might not be applicable to the whole missing data, however, it actually supports the assumption that ethnicity distributions are consistent in the FCEs with valid ethnicity codes and the FCEs without valid codes, i.e. no ethnic groups are much more or less likely to be ethnically coded at the national level.



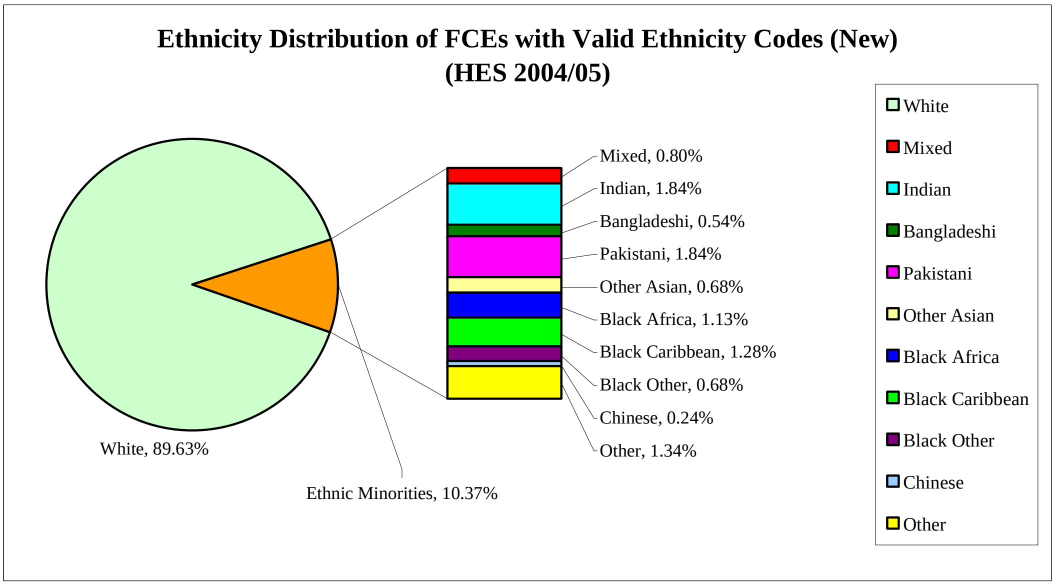
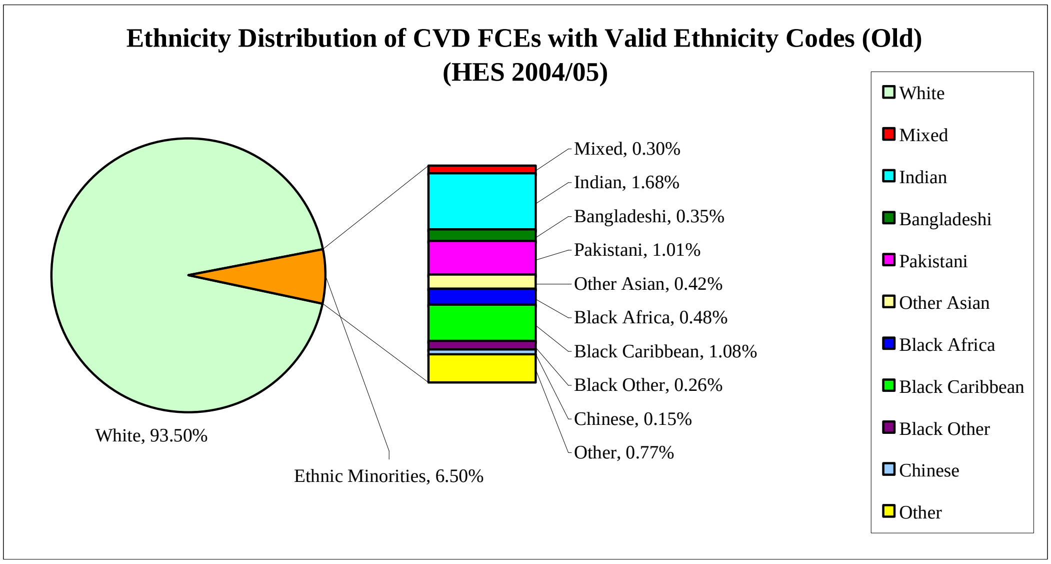


Figure 4-17 Comparison of ethnicity distribution of FCEs with valid ethnicity codes



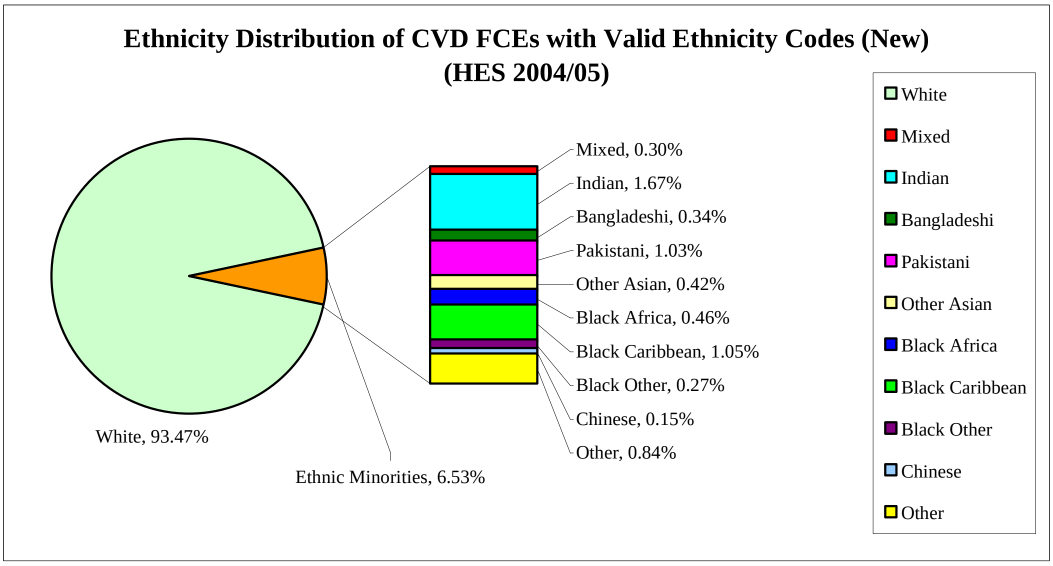


Figure 4-18 Comparison of ethnicity distribution of CVD FCEs with valid ethnicity codes

4.5 Coding Rate Methods

The record linkage method works well for restoring the missing ethnicity codes of the episodes if at least one record of a patient's historical admissions has a valid ethnicity code. However, it is not possible to restore the missing ethnicity codes if the ethnicity code of all the historical admissions of that person is 'unknown'. Rather than simply ignoring the records without valid ethnicity codes after validating ethnicity codes using the record linkage method, two coding rates methods, a local area-age-sex coding rate method and a local area-sex-ethnicity coding rate method, have been developed to adjust the total number of cases within regions based on the observed number of cases with valid ethnicity codes and the estimated coding rates across regions. The main strength of this method is that the result obtained here is the estimated total number of cases for each ethnicity-sex group occurring in a certain geographical region, of which the total underlying population at risk is available either in the census or other administrative data. So it is possible to employ the standardised incidence ratio method to investigate the ethnic disparities in health rather than using the proportional mortality method, which is flawed by its underlying assumptions discussed before.

4.5.1 Local Area-Age-Sex Coding Rate Method

The main procedure of the coding rate method is to calculate the coding rates of ethnicity codes. The coding rates could be calculated at the national level. However, given that there are significant variations in the data quality of ethnicity coding across regions and PCTs, and no relationship between density of ethnic minority population within regions and the completeness of the HES ethnicity data has been observed, organizational factors seem to be the main reason for the observed variations (Aspinall and Jacobson, 2007, Walsh, 2006). So it is more reasonable to calculate the coding rates at local area level, assuming that the probabilities of being ethnically coded for patients are more similar within hospitals or regions than across regions. In addition, as discussed in the previous section, the difference in the percentage of FCEs with valid ethnicity codes has been observed in different age groups. Age difference should also be considered in calculating the coding rates, assuming that people in the same age groups will also have similar probabilities of being ethnically coded. Furthermore, although there is little difference in the data quality of ethnicity coding observed at the national level between male and female, sex variations in ethnicity coding might also exist at local level. In summary, according to the available evidence, calculating the coding rates depend not only on where the episodes occurred, but also on patients' age, sex and ethnic groups.

If we further assume that the missing ethnicity coding is not related to people's ethnicity, then people in the same region, with the same age group and sex will have the similar probabilities of missing ethnicity coding, no matter which ethnic groups they are belonging to. Thus, the ethnicity coding rates could be calculated based on local area-age-sex groups.

The next step is to find a disease in the HES data as a base to calculate the coding rates. Ideally, the patients of this disease could represent the general population rather than being more likely to come from certain ethnic groups. The risk of this disease should be similar for people from different ethnic groups. And people from different ethnic groups have similar probabilities to come to hospitals. Otherwise there will be selection bias of ethnic groups in calculating the coding rates. So this disease should not be affected by socioeconomic status, particularly ethnicity. It is difficult to find such a disease, since most disease is associated with socioeconomic status to some extent. Attempt were made to examine fracture, screening, accident and so on, finally cataract was chosen to help to estimate the coding rate. Cataract is the main cause of reversible blindness in the UK, and there is no proven preventive measure for it. The only treatment is surgical extraction and intraocular lens insertion. In the UK, there were 153,000 cataract operations conducted by National Health Service in 1997/98.(Stocks et al., 2002) And this number was projected to be 250,000 in 2003 by the Department of Health (NHS, 2000). Few studies have investigated the relationships between cataract and socioeconomic status. Klein et al. (1994) has demonstrated a relationship between cataract and socioeconomic position. However, this was mainly based in the US. In the UK, in the research conducted by Stocks et al. (2002), there was no statistically significant association between social class and the presence or absence of any form of cataract, even after adjusting for age. So cataract was selected to estimate the coding rates.

The local area-age-sex coding rate is then calculated as the ratio of the number of cataract patients with valid ethnicity coding to the total number of cataract patients for each local authority-age-sex group. The rate is then applied to the observed number of cardiovascular cases for each ethnic group in the same local authority-age-sex group to obtain the ‘true’ total number of cardiovascular disease.

4.5.2 Local Area-Sex-Ethnicity Coding Rate Method

The above method that calculates the coding rates for local area-age-sex groups assumes that there is no ethnic difference in the probability of not being ethnically coded within the same local area-age-sex group, i.e. people from the same local area-age-sex group will have the same chance to be ethnically coded. However, this might not be true for every local area-age-sex group. The coding rates might vary across ethnic groups in local areas. For example, for some areas with a very high percentage of white population, ‘White’ might not be coded but be regarded as the default ethnicity. For some areas with a relatively large number of ethnic minorities, the hospitals might pay more attention to the coding for people from minority ethnic groups. So the ideal assumption for calculating the coding rates is to acknowledge the ethnic difference in the probability of missing ethnicity codes besides the regional, age and sex variations in ethnicity coding.

Local area-sex-ethnicity coding method is developed by considering the ethnic difference in the coding rate calculation. In theory the coding rate should be calculated as a ratio between the number of cases with valid ethnicity codes and the total number of cases in that local area-sex-ethnicity group. However, the true total number of cases for each local area-sex-ethnicity group is unknown due to incomplete ethnicity coding. Given that cataract is not related to socioeconomic status, then the ‘true’ total number of cataract here is estimated as the expected number of cases within each local authority-sex-ethnicity group, assuming that there is no other geographical difference in cataract risk. Being similar to the standardised incidence ratio method, this method first calculates the national standard rate of cataract for each age group, and then applies this rate to each local authority to obtain the expected number of cataract cases for each ethnicity-sex group in that area. So the coding rate for each local authority-sex-ethnicity group can be calculated as the ratio of the total number of observed ethnically coded cataract cases to the expected number of cataract cases for that local authority-sex-ethnicity group.

When applying the coding rates to the cardiovascular disease data to adjust the total number of cardiovascular disease for each local authority-sex-ethnicity group, three scenarios have been tested.

(1) Using the crude local authority-sex-ethnicity coding rates

The first method is to apply the crude coding rates directly to the cardiovascular disease data to adjust the total number of cases of cardiovascular disease for each local authority-sex-ethnicity group.

However, because the numbers of cataract cases from minority ethnic groups are usually small when disaggregated at local authority level, the crude coding rates for minority ethnic groups in some local authorities are subject to the small number problem. As introduced in Chapter Three, in this situation, one or two extra cases that occur or be absent purely by chance would give rise to unusually high ratios or return a value of zero because the denominators are very small, which results in high variations for the coding rates. And the high variations may be passed to the adjustment of the cardiovascular disease data. Empirical Bayes estimation is then used to alleviate the small number problem.

(2) Using the local authority-sex-ethnicity coding rates that have been shrunk towards the national coding rate by empirical Bayes estimation

In the empirical Bayes estimation, all the local authority level coding rates for a certain ethnicity-sex group are moved towards the national coding rate for that ethnicity-sex group, assuming that the local coding rates are not systematically biased from the national coding rate. Finally the adjusted ethnicity coding rates are applied to the cardiovascular disease data to calculate standardised incidence ratios.

(3) Using the local authority-sex-ethnicity coding rates that have been shrunk towards the Government Office Region level coding rates by empirical Bayes estimation

Since ethnic minorities are usually clustered in some regions, moving the local authority-sex-ethnicity coding rate towards the national coding rate for that ethnicity-sex group is somewhat equivalent to moving the coding rates of small population areas towards those of the ethnic minorities clusters (for example, London).

In addition, as organization is the main factor for missing ethnicity code, moving towards the national coding rate might reduce the importance of the organizational factors. So it might be more reasonable to shrink the local estimates to the regional level coding rate rather than the national coding rate. In this method, the local authority-sex-ethnicity coding rates are shrunk towards the coding rate at the government office region (GOR) level for that ethnicity-sex group.

4.5.3 Discussion about the Coding Rate Methods

The coding rate methods are developed to estimate the total number of cardiovascular disease cases for each ethnicity-sex group occurring in a region by the coding rates, which enable calculation of the standardised incidence ratios for ethnic groups. The coding rates are calculated under two different assumptions separately. The local area-age-sex coding rate method assumes that there is no ethnic difference in the coding rates for local area-age-sex groups. And the local area-sex-ethnicity method allows the coding rates to vary across ethnic groups for each local area-sex group. In theory, the local area-sex-ethnicity coding rate method is superior to the local area-age-sex coding rate method, allowing variations of the coding rates across ethnic groups. However, in practice, the local area-sex-ethnicity coding rate method is more likely to be subject to the small number problem.

The local area-age-sex coding rate method rather than the local area-sex-ethnicity coding rate method is finally selected to adjust the cardiovascular disease data. The selection is mainly based on two criteria. Firstly, the selection is based on whether the assumption made for the method is sensible, and could be supported by the available evidence. Secondly, the selection is based on whether the ethnic inequalities in cardiovascular disease obtained from the adjusted data could generally reflect well known knowledge about the ethnic disparities in cardiovascular disease. Here the ethnic inequalities are measured as the standardised incidence ratios.

The first part of this section is about why the local area-sex-ethnicity coding rate method failed, and why the local area-age-sex coding rate method was selected is discussed in the second part.

4.5.3.1 Why the Local Area-Sex-Ethnicity Coding Rate Method Failed

The assumption of this method, which allows the coding rates to vary across ethnic groups for each local area-sex group, is even superior to that of the local area-age-sex coding rate method. However, in practice, calculating the local area-sex-ethnicity coding rates is subject to the small number problem. The coding rates here are calculated as the ratio between the observed number of cases to the expected number of cases for ethnicity-sex groups at local authority level. As the population size of ethnic minorities is usually small at local level, thus the expected numbers of cataracts are even smaller. The local authority-sex-ethnicity coding rates for ethnic minorities are more likely to have extreme values. As one or two cataract cases could occur purely by chance for minority ethnic groups, this situation results in high variations of the coding rates. So the crude coding rates are poorly estimated because of the small number problem. The empirical Bayes estimation, also known as a shrinkage method, is employed to reduce the variations of the coding rates. Although the empirical Bayes estimation could largely reduce the variations of the coding rates, some extreme values occur at local authority level for minority ethnic groups. For example, the table below shows the top 10 and bottom 10 coding rates for male people from Mixed ethnic group at local authority level. Normally, the coding rates are supposed to have a mean value less than 1 or 100 per cent. However, the coding rates below are either extremely high or extremely low. When applying these extreme values to the cardiovascular disease data, the estimated total number of cardiovascular disease will be much shrunk or enlarged.

Local Authority	Coding Rate
00HX	0.00013290
00HC	0.00015853

Local Authority	Coding Rate
15UH	200.2661142
15UD	42.45681091

23UD	0.00021616	29UL	36.5685155
00HH	0.00023504	16UD	35.94320635
46UD	0.00027590	29UN	26.06724945
19UD	0.00029395	29UB	25.60222421
46UC	0.00031407	00BZ	24.8057228
46UB	0.00032591	15UF	24.21986951
23UC	0.00036927	15UC	23.76801994
19UJ	0.00066934	30UF	20.51121699

Table 4-1 Extreme values in local area-sex-ethnicity coding rates

Generally, in the UK, previous research found that South Asians (including Indian, Pakistani and Bangladeshi people) have a higher risk of cardiovascular disease than the white population (Cappuccio, 1997, Nazroo, 1997, Nazroo, 2001, Aspinall and Jacobson, 2004), and the relative risk is low for people born in Caribbean and West African groups (Wild and McKeigue, 1997, Bardsley et al., 2000). However, when applying the local area-sex-ethnicity coding rates to adjust the cardiovascular disease data, compared with previous studies, much inconsistency has been found in the ethnic inequalities in cardiovascular disease based on the adjusted cardiovascular disease data, as shown in graphs below.

The graphs below shows the standardised incidence ratios for ethnic groups based on the cardiovascular disease data adjusted by the crude local area-sex-ethnicity coding rates. The evidence of inconsistency is that all the ethnicity-sex groups except for white men have lower risk of cardiovascular disease than the general population, particularly South Asians.

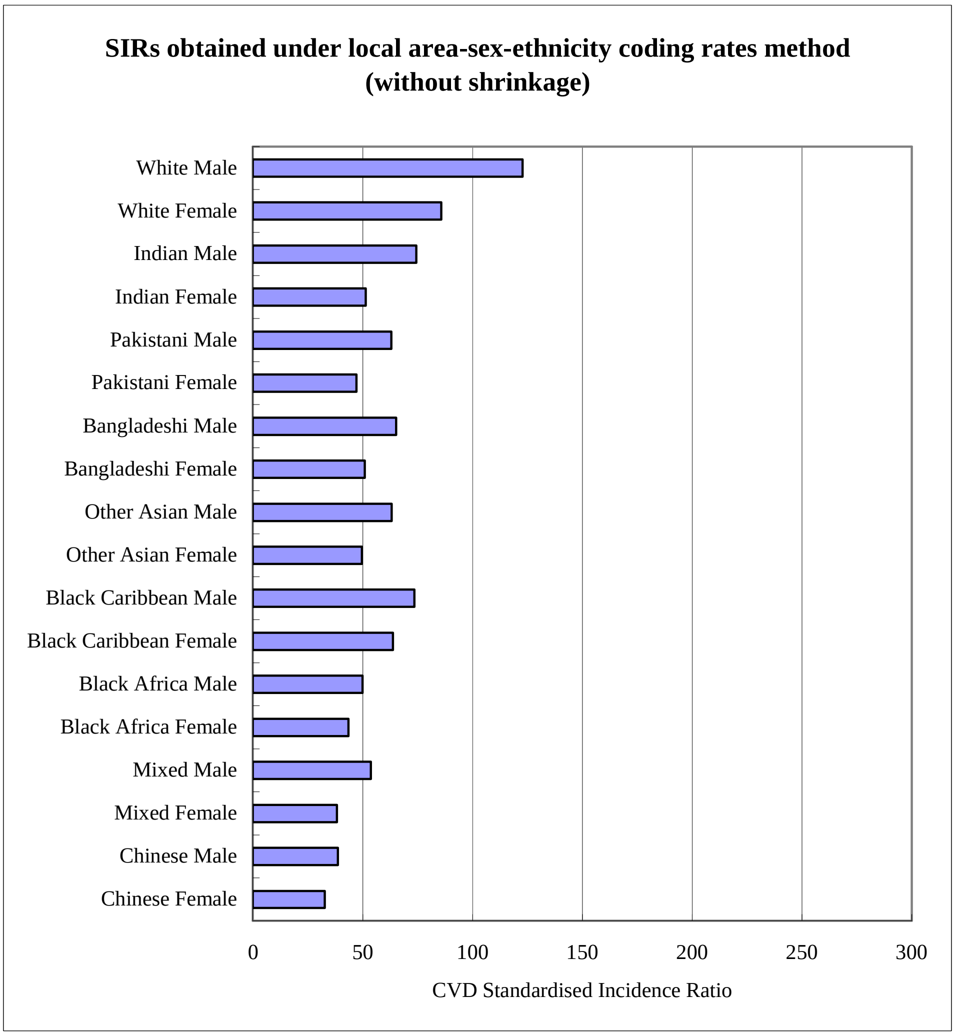


Figure 4-19 SIRs obtained under local area-sex-ethnicity coding rates method (without shrinkage)

The graphs below shows the standardised incidence ratios for ethnic groups based on the cardiovascular disease data adjusted by the local area-sex-ethnicity coding rates that have been shrunk towards the national coding rate by empirical Bayes estimation. The evidence of inconsistency is that the SIRs of Indian men and women are close to or lower than the general population, and much lower than that of white people. And Black Africa people are found to be in the highest risk.

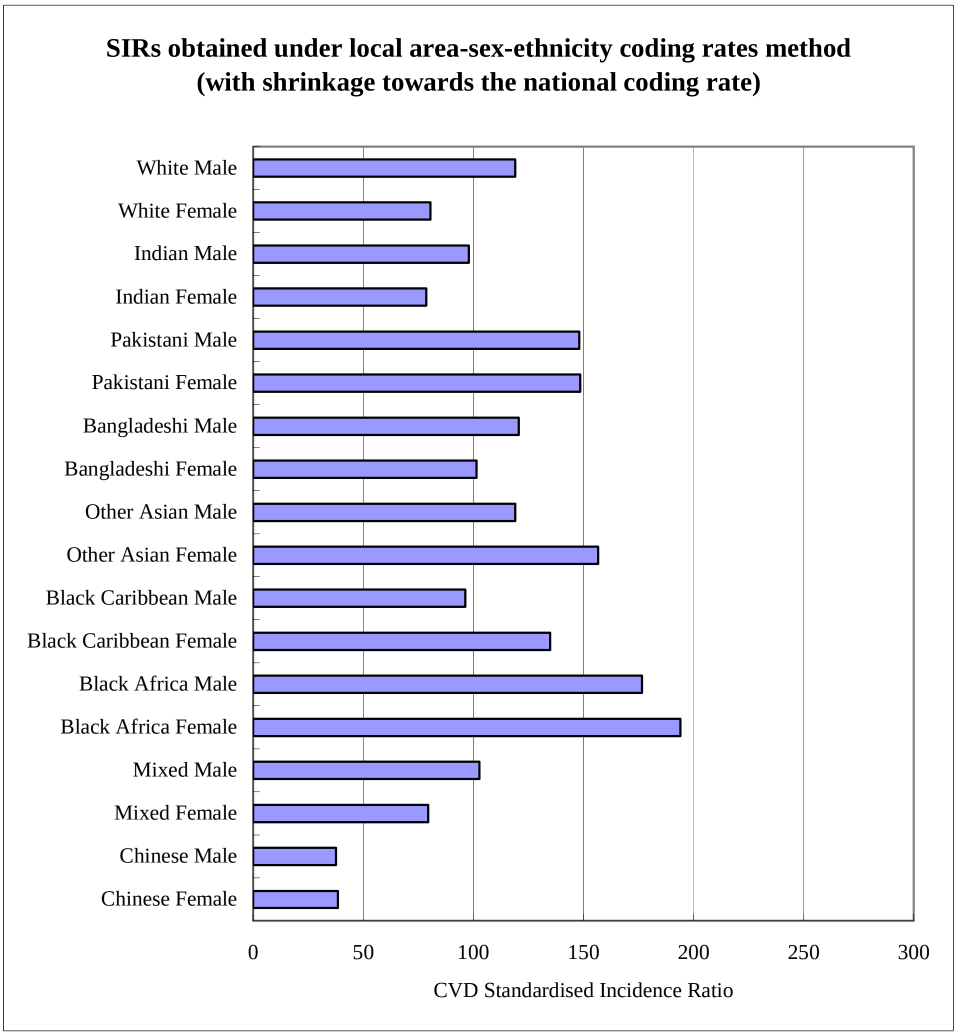


Figure 4-20 SIRs obtained under local area-sex-ethnicity coding rates method (with shrinkage towards the national coding rate)

The graphs below shows the standardised incidence ratios for ethnic groups based on the cardiovascular disease data adjusted by the local area-sex-ethnicity coding rates that have been shrunk towards the GOR level coding rate by the empirical Bayes estimation. The evidence of inconsistency is that the Indian, Pakistani and Bangladeshi groups, who were found to have a higher risk of cardiovascular disease before, are found to have lower or much lower risk than the general population and the white population. Although there is no previous evidence about the relative risk of cardiovascular disease among people from Mixed group, the standardised incidence ratios for both men and women from Mixed group are found to be the highest, particularly for men, who have a value of about 2000 (excluded from the graph for presentation). This is clearly overestimated.

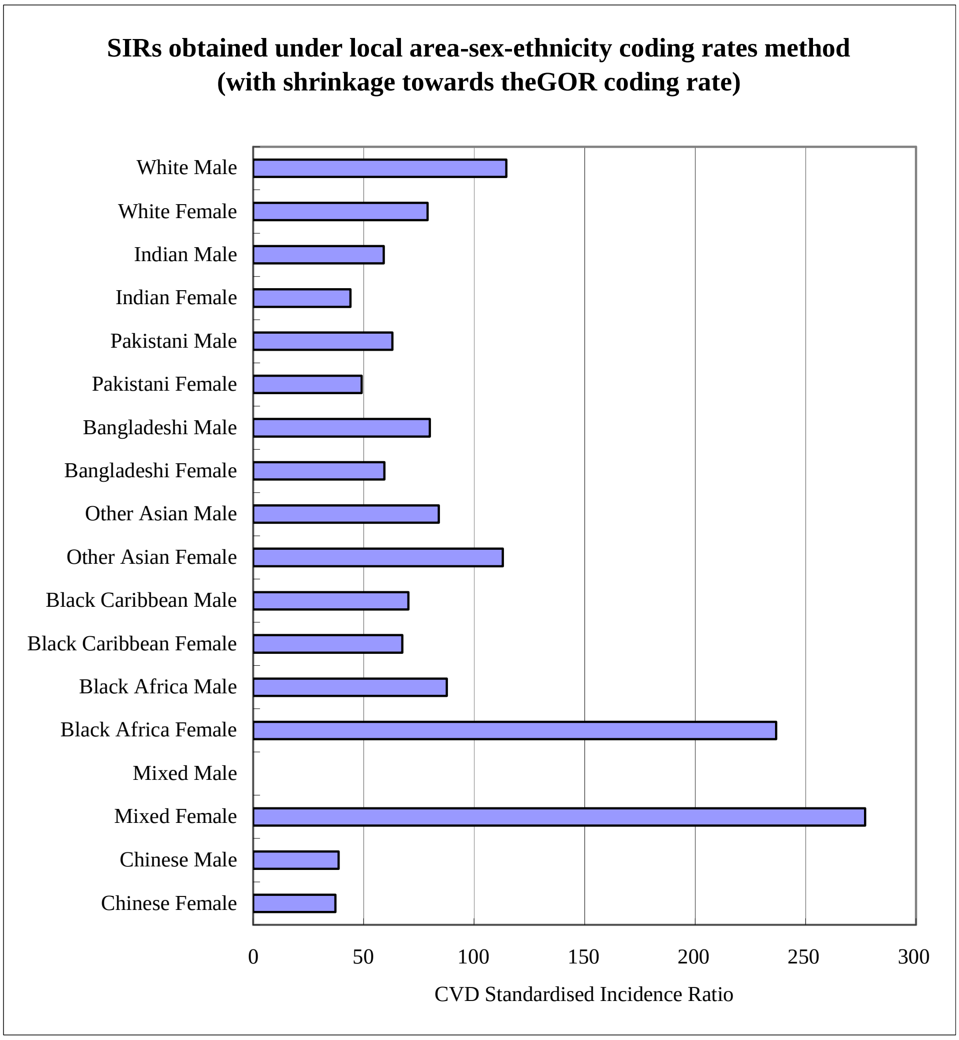


Figure 4-21 SIRs obtained under local area-sex-ethnicity coding rates method (with shrinkage towards the GOR coding rate)

4.5.3.2 Why was the Local Area-Age-Sex Coding Rate Method Selected?

Although the assumption of the local area-age-sex coding rate method that doesn't allow ethnic difference in the coding rates at local level is not perfect, it seems to be sensible and is supported by some available evidence.

Firstly, organizational factors are suggested to be the main reason for missing ethnicity coding in the HES (Aspinall and Jacobson, 2007). The low priority of policy on collecting ethnicity information in the HES in some Primary Care Trusts may affect all the HES records rather than particularly influence episodes of people from certain ethnic groups. Researchers in HESonline have conducted a comparison between the observed ethnic distribution of 2002-03 Finished Consultant Episodes by trust and the expected ethnic distribution estimated based on Census ethnic data to investigate whether there are discrepancies in coding rates across ethnic groups by trusts (HESonline, 2004a). Most trusts were found to have a less than 5 per cent discrepancy between observed and expected aggregated ethnic group distributions, and the mean average was 4.7 per cent (with a median of 2.0 per cent), implying there were no ethnic groups that are far more or far less likely to be ethnically coded at the local area level.

Secondly, from the graphs about the comparison between the ethnicity distributions of FCEs with valid ethnicity codes before and after being validated by the record linkage method presented in the previous section, little difference in the ethnicity distribution has been found, indicating that no ethnic groups are more likely or less likely to be ethnically coded in the Finished Consultant Episodes (FCEs) with invalid ethnicity codes before that have been restored with valid ethnicity codes by the record linkage method. Although this might not be applicable to the whole missing data, at least this evidence also supports the assumption of the local area-age-sex coding rate method which assumes that there is no ethnic difference in the coding rate for each local area-age-sex group.

Furthermore, in practice, the pattern of the standardised incidence ratios of cardiovascular disease for ethnicity-sex groups obtained based on the cardiovascular disease data adjusted by the local area-age-sex coding rate method is consistent with general knowledge of ethnic inequalities in cardiovascular disease identified by previous research, as shown in the graph below. South Asian people, particularly for the male people, are found to have a relatively higher risk than the general population.

The risk of Black Caribbean and Black Africa people is very close to the national average. There is little evidence about the relative risk of cardiovascular disease among Other Asian group before. However, given that, among the Asian British, most are second and third generation descendants of Pakistani, Bangladeshi and Indian migrants, it is not a surprise that Other Asian people have a higher risk of cardiovascular disease. So generally, the data adjusted by the local area-age-sex coding rate method could reflect well known knowledge about ethnic inequalities in cardiovascular disease at the national level.

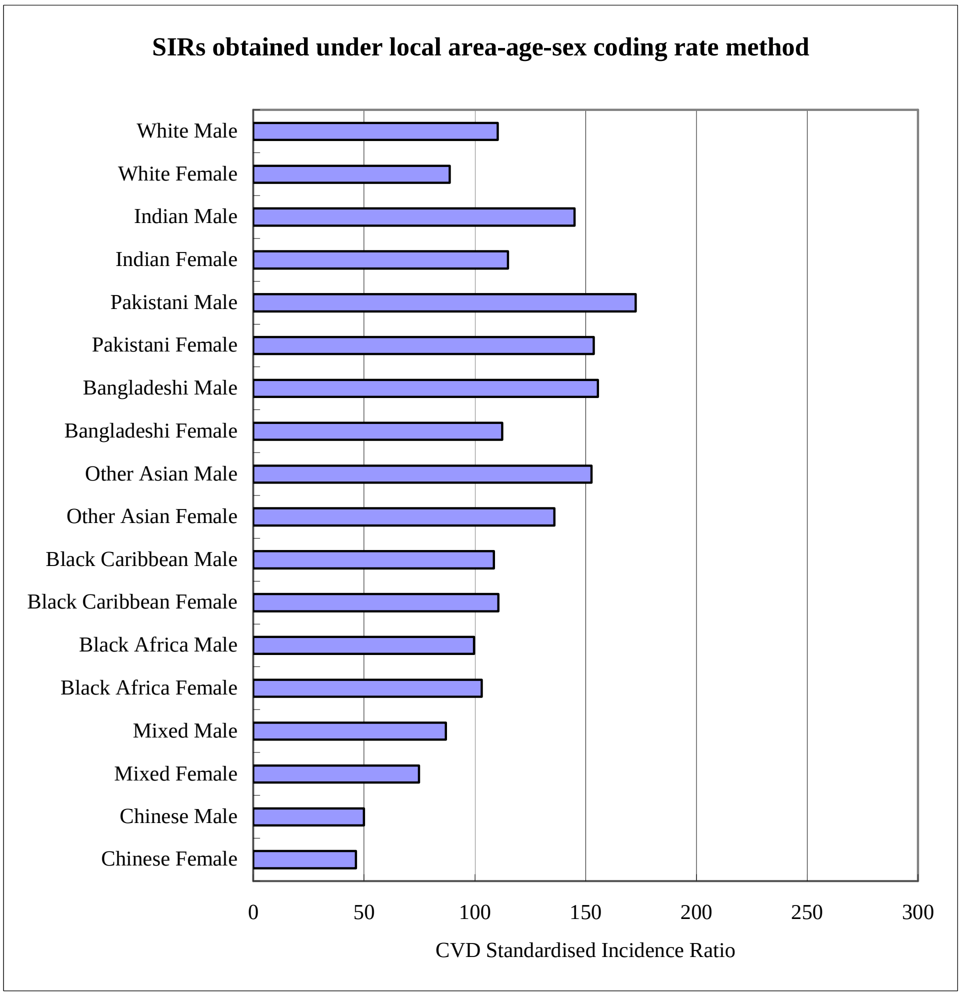


Figure 4-22 SIRs obtained under local area-age-sex coding rate method

4.6 Conclusion

Given the significant potential of Hospital Episode Statistics for research on ethnic inequalities in cardiovascular disease and the data quality of ethnicity codes in the HES is not satisfactory, in this chapter, two methods have been developed to improve the data quality of ethnicity codes, including the record linkage method and the coding rate method.

The record linkage method restores the missing ethnicity codes by linking the episodes without valid ethnicity codes to the historical episodes with valid ethnicity codes for the same person. This method assumes that each patient has only one valid ethnicity code across the whole HES data. However, there are about 1.5 per cent of all the patients with valid ethnicity codes have been recorded to multiple ethnic groups. In this situation, an algorithm has been developed to assign a ‘most likely’ ethnic group to those patients. After applying the record linkage method, the data quality of ethnicity codes has been significantly improved. There are a large proportion of CVD FCEs have been restored with valid ethnicity codes. In 2004/05, the overall coding rate of CVD FCEs is increased to about 88 per cent from 79 per cent.

The coding rate method is then developed to estimate the total number of cardiovascular disease cases for ethnic groups at regional level to enable the calculating of the standardised incidence ratios. The coding rates at local level have been calculated in two ways. The local area-age-sex coding rate method assumes there is no ethnic difference in coding rates; however, the local area-sex-ethnicity coding rate method allows the coding rates to vary across ethnic groups at local authority level. The local area-age-sex coding rate method is finally used to adjust the cardiovascular disease data, mainly because the adjusted data could generally reflect well known knowledge about ethnic inequalities in cardiovascular disease and currently there is available evidence that support its assumption. However, the local area-sex-ethnicity coding rate method failed because it is greatly affected by the small number problem.

Chapter Five: Ethnic Inequalities in Cardiovascular Disease

5.1 Introduction

The Hospital Episode Statistics have significant potential for further examining ethnic inequalities in cardiovascular disease due to the large number of events, detailed classification of ethnicity, geographically national coverage, fine geographical scale, and comprehensive clinical information. This chapter is going to examine the extent to which there are ethnic inequalities in different types of cardiovascular disease at both the English national and the local authority levels using the Hospital Episode Statistics.

As introduced in Chapter One, previous research on ethnic inequalities in cardiovascular disease in the UK is limited by the availability of health data with ethnicity information. Firstly, previous studies usually concentrate on general cardiovascular disease, coronary heart disease and stroke due to lack of clinical information. Secondly, as the sample size of observations from minority ethnic groups is usually small in some surveys, minority ethnic groups with similar pattern of disease of interest have to be combined into one group for analysis, which will lose the heterogeneities between these ethnic groups. Thirdly, most studies conduct research on ethnic inequalities in cardiovascular disease in relatively large areas, such as London and Birmingham, or in individual small study areas. There is no research that has examined geographical variations of ethnic inequalities in cardiovascular disease either in Britain or elsewhere.

The first aim of this chapter is to further examine ethnic inequalities in different types of cardiovascular disease at English national level employing the standardised incidence ratio (SIR) method as introduced in Chapter Three. The base population for calculating the SIRs are extracted from the mid-2004 local authority population estimates by ethnicity-sex groups in England from Office for National Statistics. Six different cardiovascular diseases have been studied, namely general cardiovascular disease, coronary heart disease, stroke, hypertensive heart disease, rheumatic heart disease and heart failure. The standardised incidence ratios of different cardiovascular disease for ethnic groups are presented in two ways in this chapter. On one hand, the SIRs are presented by cardiovascular disease types, showing the relative risk of the same cardiovascular disease for different ethnic groups. On the other hand, the SIRs are presented by ethnic groups, indicating which ethnic groups are more or less likely to get what kind of cardiovascular disease, compared to the general population.

The other aim of this chapter is to investigate and present geographical relative risk of cardiovascular disease for ethnic groups. The geographical unit used here is the local authority.

Geographical relative risk presentation, or disease mapping, is a method to understand the spatial variations of disease risk or geographical distribution of disease across small areas (Clayton and Kaldor, 1987, Meza, 2003). By projecting the health indicators on the maps, disease mapping makes it possible to identify geographical areas with excess or low risk of disease; to compare maps of health indicators with maps of potential risk factors, which might give some clues about the etiology of a particular disease (English, 1992, Elliott et al., 2000); to examine the temporal effects of health indicators, if data at different times are available (G´omez-Rubio and L´opez-Qu´ılez, 2006). Thus examining the geographical relative risk of disease is useful for national government agencies to allocate resources, for local government agencies to target people at risk, customize local health policy and conduct local health promotions.

It is often proposed that the standardised mortality ratio (SMR) or standardised incidence ratio (SIR) be computed and mapped in disease mapping studies (Lawson et al., 2000). The SIR is a widely used measure of relative risk, which is defined as the ratio between the observed number of cases for a group and the expected number of cases for that group in the same region, as introduced in Chapter Three. The SMR is a reliable method for large geographical regions. However, mapping SIRs at small area level is problematic (Meza, 2003). Firstly, the SIR method is subject to the small number problem in areas with very low population, where only few observed cases could produce extreme and unreliable estimates (Lawson et al., 2000, Wakefield, 2007). Secondly, the SMR will be zero if there are no observed cases in regions, making no difference between regions with different population size and different expected numbers of cases (Lawson et al., 2000, Wakefield, 2007). This is the case in this study, although cardiovascular disease is a common disease. The sparse population of minority ethnic groups in a large proportion of the local authorities in England and the rarity of cardiovascular disease in those areas for ethnic minorities will make the SIRs unstable.

An alternative method is to map the statistical significance of local deviations of risk from the overall rates, i.e. p-values, which has been adopted in some disease atlases attempting to overcome the extreme value problem of SMR or SIR (Clayton and Kaldor, 1987, Langford, 1994). However, it is argued that the p-values method is even less informative than mapping SIRs (Wakefield, 2007). P-values tend to be more extreme in areas with large populations, such as urban areas, where the SIRs are more statistically significant due to large sample size (Langford, 1994). Furthermore, very small increase of relative risk in regions with high population may result in a high level of statistical significance, which has little biological importance (Langford, 1994, Clayton and Bernardinelli, 1992, Nicholson et al., 2000).

Both the two approaches discussed above might misrepresent the geographical distribution of relative risk. Alternative methods for disease mapping were proposed in different research to overcome their problems, which have been broadly classified into four categories by Lawson et al (2000) as follows:

- Smoothing models (for examples, non-parametric regression)
- Linear Bayes methods, which are based on a linear function of the SMR
- Bayesian models, which assume that the relative risks are realizations from some distribution
- Empirical Bayes models, which are similar to Bayesian models but which estimate the prior distribution for the relative risks from the observed data.

In this study, the empirical Bayes estimation method is used to examine the geographical relative risk of cardiovascular disease among ethnic groups. Empirical Bayes estimation can be seen as a compromise between SIR and p-values (Langford, 1994), based on the underlying theory that the posterior distribution of the parameters of interest can be derived by combining the likelihood function for that data with the prior distribution (Bailey and Gatrell, 1995, Langford, 1994). The empirical Bayes estimation is referred as ‘shrinkage estimate’ of SIRs (Nicholson et al., 2000). As introduced in Chapter Three, when the local population is relatively large, more importance is placed on the observed SIR. The empirical Bayes estimation will be little different from the original observed rate. When the local population is small, increasing weight is given to the prior belief, the national average. The results will be adjusted or shrunk much towards the overall mean of local area level SIRs (Bailey and Gatrell, 1995, Langford, 1994).

This approach seems to be first used for disease rates by Efron and Morris (1975). With the development of estimation methods, empirical Bayes estimation is widely used in epidemiology. For example, it was used to map the geographical variation in breast cancer in all the health care districts of Sardinia (Bernardinelli and Montomili, 1992). Schlattmann and Bohning (1993) employed mixed model within an empirical Bayes framework to map hepatitis B data in Berlin. In the UK, Martuzzi and Elliott (1996) proposed an empirical Bayes method to estimate the prevalence of non-rare conditions, which modelled the geographical distribution of the prevalence of respiratory symptoms in schoolchildren across 71 small areas in Huddersfield, Northern England. And Saunderson and Langford (1996) studied the geographical distribution of suicide rates in England and Wales using empirical Bayes estimation. Rigby and Gatrell (2000) examined the spatial patterns in breast cancer incidence in north-west Lancashire at a variety of spatial scales using empirical Bayes estimation. The empirical Bayes estimation was also proposed by the UK Office of National Statistics as a potential smoothing method of the ward-level standardised mortality ratios (Carrington et al., 2007).

Clayton and Kaldor (1987) developed empirical Bayes estimation procedures by combining maximum likelihood (ML) and moments estimators. However Marshall (1991) suggested the iterative procedure of this method was often slow to converge and proposed an empirical Bayes estimator with parameters simply estimated by moments, which was a non-iterative direct solution. According to equations (3.13) and (3.15) in Chapter Three, the main difference of these two methods is that the first method shrinks the local SIRs towards the overall mean of local area level SIRs, however, the latter method shrinks the local SIRs towards the national SIR for that group.

Both of these two empirical Bayes estimation methods are employed to estimate the geographical relative risk of cardiovascular disease for ethnic groups, in order to examine the uncertainties of the estimation of geographical relative risk for ethnic groups, particularly for minority ethnic groups. In the final part of this chapter, firstly, the crude standardised incidence ratios and the empirical Bayes estimation of cardiovascular disease relative risk estimated using the two methods above have been compared to examine the extent to which the empirical Bayes estimation methods reduce the variations of the standardised incidence ratios. Secondly, the empirical Bayes estimation of geographical relative risk of cardiovascular disease obtained using the two estimation methods is presented in maps. Difference of results from these two estimation methods are highlighted and discussed.

5.2 National Standardised Incidence Ratio by CVD Types

The standardised incidence ratios (SIR) of different cardiovascular disease for ethnicity-sex groups at English national level are presented in radar charts as follows, where each ethnicity-sex group has a separate axis. All the male people are located in the left half of the radar charts and female people are in the right half of the charts. Figures for males tend to be higher than figures for females. The red circle in the radar chart highlights the national average SIR, which is 100. The national average is computed from data for both sexes together. Being equal to 100, the ratio implies the rate for that ethnicity-sex group is the same as the national average. A value higher than 100 indicates that there is an excess rate or higher risk of cardiovascular disease for that ethnicity-sex group whereas a number under 100 implies the condition of cardiovascular disease within the population of interest is better than the general population.

5.2.1 General Cardiovascular Disease

The radar chart below shows the national standardised incidence ratios (SIRs) of general cardiovascular disease for both men and women among different ethnic groups.

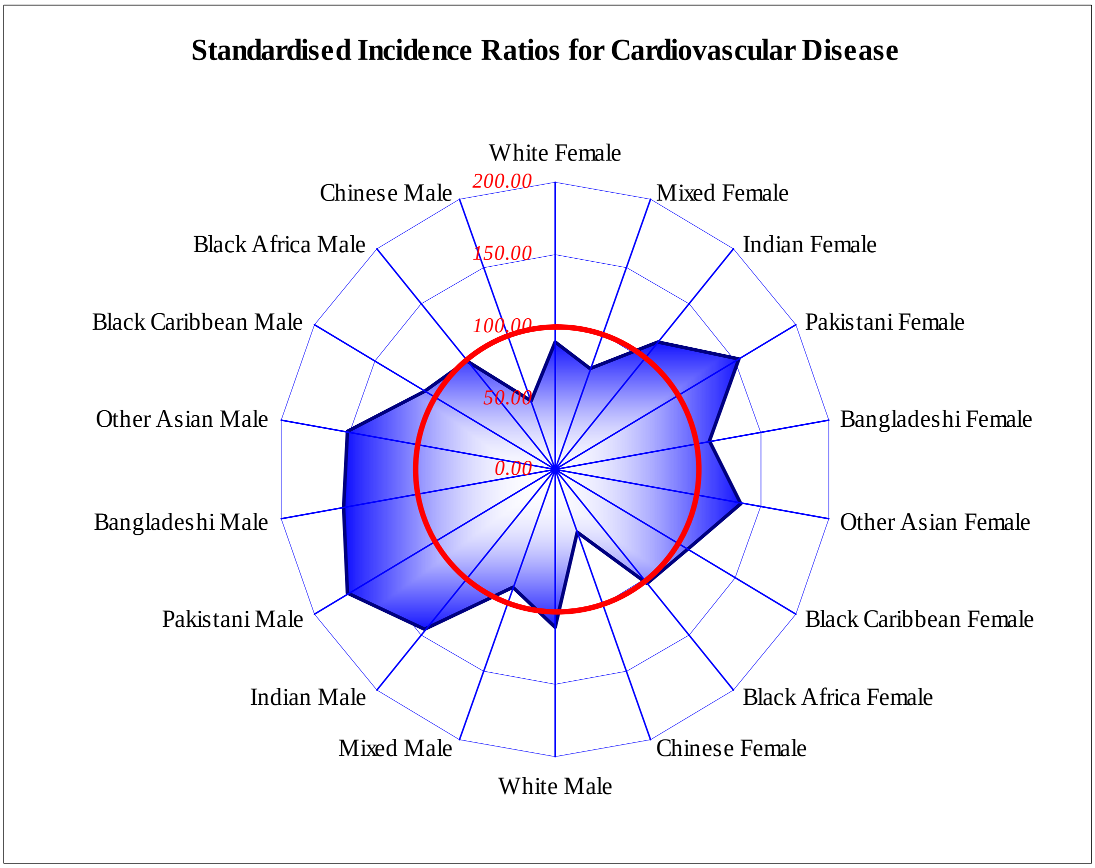


Figure 5-1 Standardised Incidence Ratios for General Cardiovascular Disease

In men, white men have a slightly higher ratio (110) for cardiovascular disease than the general population. Whereas as expected, the standardised incidence ratios of South Asian men are significantly high, among which the ratio of Pakistani men (around 170) is the highest, followed by Bangladeshi men (155) and Indian men (145). Other Asian men, which are less studied in previous research, are found to have importantly high ratio (152). The ratios of both Black Africa men (99) and Black Caribbean men (108) are close to the national average. Chinese men (50) and Mixed men (86) have the lowest ratios, implying their lower risk of cardiovascular disease.

In women, white women with a ratio (88) below the national average are relatively healthy in cardiovascular disease. The ratios of South Asian women are not as high as those of South Asian men, but Pakistani women have the highest ratio (153) among women, followed by Other Asian women (135). Indian women (114) and Bangladeshi women (112) also have higher ratios than the general population. Black Caribbean women have a moderately higher ratio (110) than the general population, while the ratio of Black Africa women (103) is very close to the national average. Mixed women (74) and Chinese women (46) are still the healthiest people in general cardiovascular disease.

5.2.2 Coronary Heart Disease

The radar chart below shows the national standardised incidence ratios of coronary heart disease for both men and women among different ethnic groups. The ethnic disparities in coronary heart disease are more remarkable than those found in general cardiovascular disease.

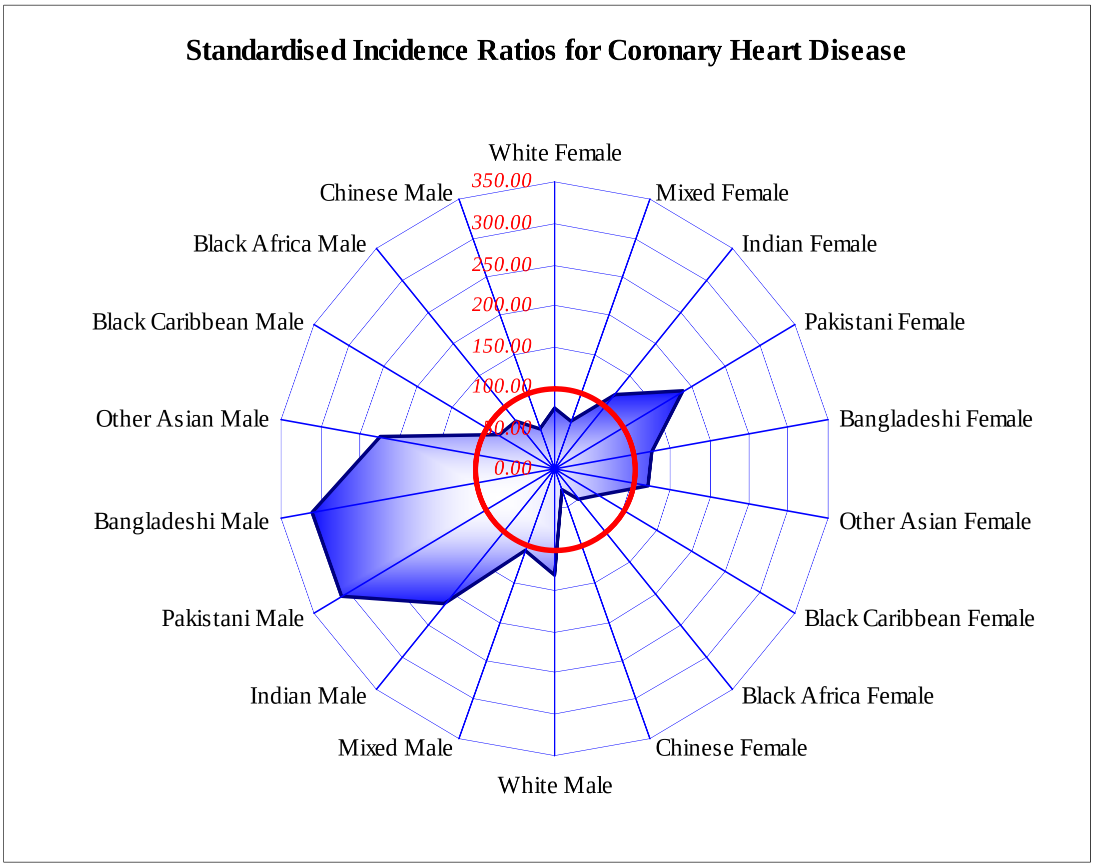


Figure 5-2 Standardised Incidence Ratios for Coronary Heart Disease

In men, the ratio of white male population (128) actually is much higher than the national average, but not as high as South Asians. All the South Asian men have extremely high ratios. Pakistani men (310) and Bangladeshi men (310) are at three times higher risk than the general population in coronary heart disease. Indian men's ratio (210) is two times higher than the national average. The ratio of Other Asian men (222) is also strikingly high. However, there is an obvious drop in the ratios of Black Caribbean men (79) and Black Africa men (75), indicating that black people are among the healthiest groups in coronary heart disease. The coronary heart disease condition of Mixed men (107) is similar to the general population. Chinese men (50) have significantly lower risk of coronary heart disease.

In women, white women are less likely to have coronary heart disease, with a ratio of 74. Indian women (117) and Bangladeshi women (125) have experienced a relatively lower rate of coronary heart disease than their men, but are still moderately higher than the general population. And Other Asian women (119) have a similar incidence ratio to Indian and Bangladeshi women. Pakistani women's ratio (187), which is nearly two times greater than the national average, appears to be the highest in women. In striking contrast, being within the red circle, Black Caribbean women (62), Black Africa women (47), Mixed women (63) and Chinese women (27) are among the healthier female groups in coronary heart disease.

5.2.3 Stroke

The radar chart below shows the national standardised incidence ratios of stroke for both men and women among different ethnic groups.

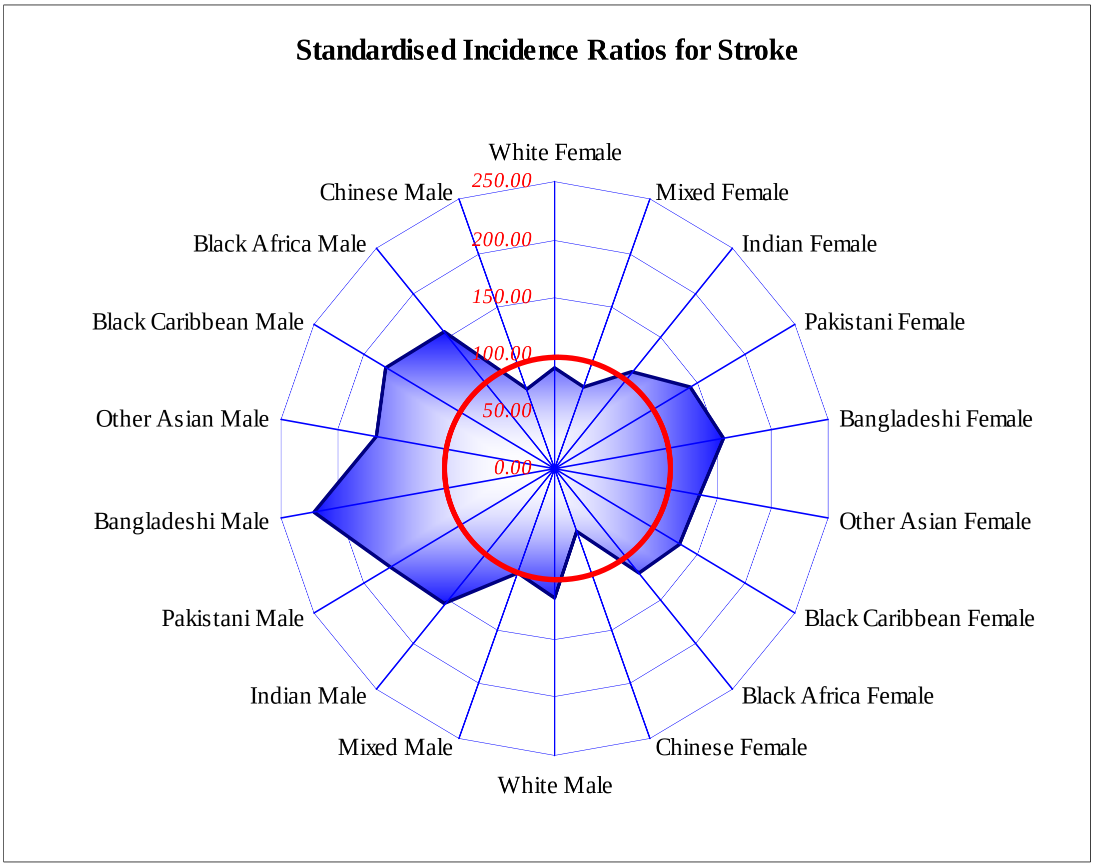


Figure 5-3 Standardised Incidence Ratios for Stroke

In men, white men have a slightly greater incidence ratio (112) in stroke than the general population. South Asian men remain the highest ones in stroke standardised incidence ratios. This is particularly true for Bangladeshi men (219), which are the unhealthiest among all the ethnic groups, followed by Pakistani men (170) and Indian men (153). Higher standardised incidence ratios of stroke are also found in Other Asian men (163), Black Africa men (156) and Black Caribbean (175) men, which have at least 1.5 times higher ratio than the general population. The incidence ratio of Mixed men population (97) is very close to the national average. And Chinese men (73) are healthier in stroke.

In women, women generally have lower stroke incidence ratios than men. White women's incidence ratio (87) is lower than the national average. Although the stroke conditions for South Asian women are less serious than South Asian men, all the ratios are still obviously high. Bangladeshi women (153) have experienced the highest ratio of stroke in female groups, followed by Pakistani women (140). The Indian women seem a little better (109) in stroke. Other Asian women (130), Black Caribbean women (131) and Black Africa women (119) are also found to be less healthy in stroke. However, the health status in stroke among Mixed women (75) and Chinese women (58) is much better.

5.2.4 Hypertensive Heart Disease

The radar chart below shows the national standardised incidence ratios of hypertensive heart disease for both men and women among different ethnic groups.

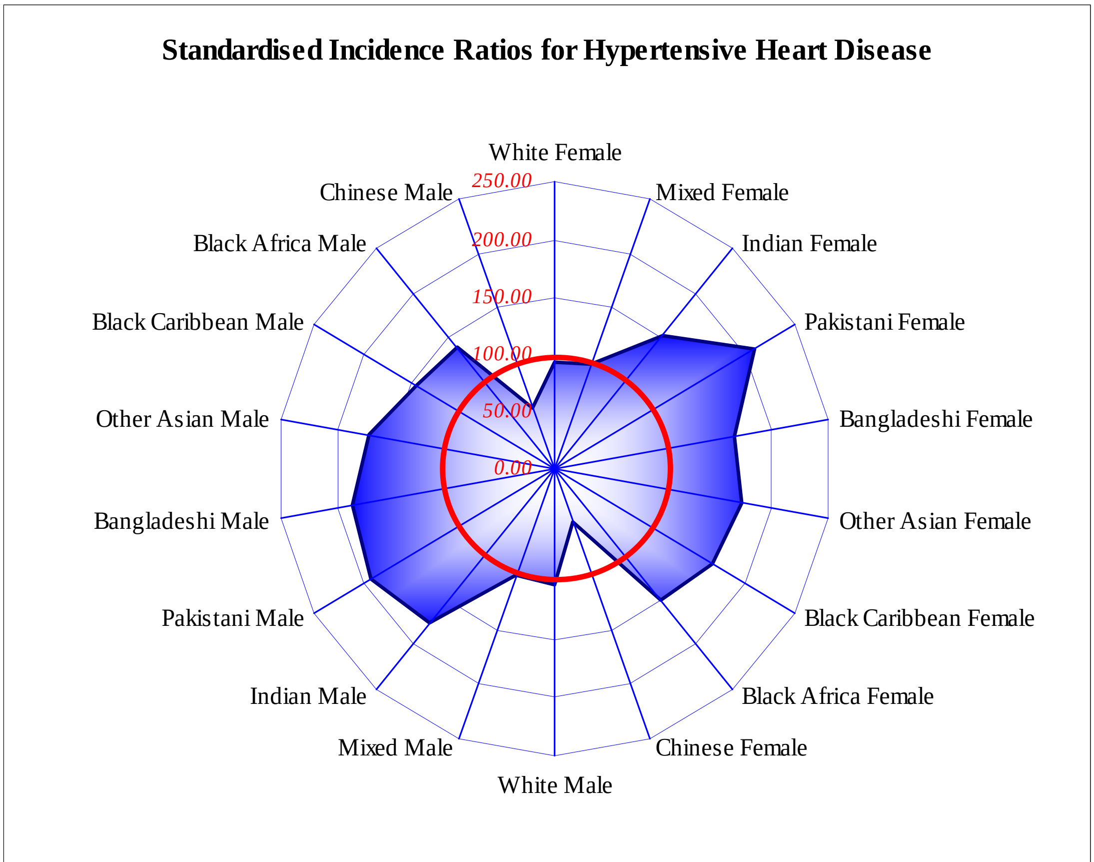


Figure 5-4 Standardised Incidence Ratios for Hypertensive Heart Disease

In men, the incidence ratio of white men (101) is very close to the national average. However, all the South Asian men have significantly higher standardised incidence ratios than the general population, which are about 1.5-2 times greater than the national average. In particular, Pakistani men (189) have got the highest incidence ratio in hypertensive heart disease among men. Other Asian men (170), as well as Black Caribbean men (143) and Black Africa men (137) are also found to be less healthy. The situation in hypertensive heart disease among Mixed men (99) is quite similar to the general population. Chinese men remain the healthiest group in hypertensive heart disease.

In women, white women (93) are a little healthier in hypertensive heart disease, as well as Mixed women. The ratio of Pakistani women (209) is the highest among all the ethnicity-sex groups, which is about two times higher than the national average. Indian women (152), Bangladeshi women (164), Other Asian women (172), Black Caribbean women (164) and Black Africa women (148) are found to have strikingly greater standardised incidence ratios of hypertensive heart disease than the general population. Chinese women (46) are much healthier than these groups.

5.2.5 Rheumatic Heart Disease

The radar chart below shows the national standardised incidence ratios of rheumatic heart disease for both men and women among different ethnic groups. It is surprising that generally women have higher ratios of rheumatic heart disease than men, which completely reverses the general knowledge about cardiovascular disease that men are usually more likely to get heart disease than women.

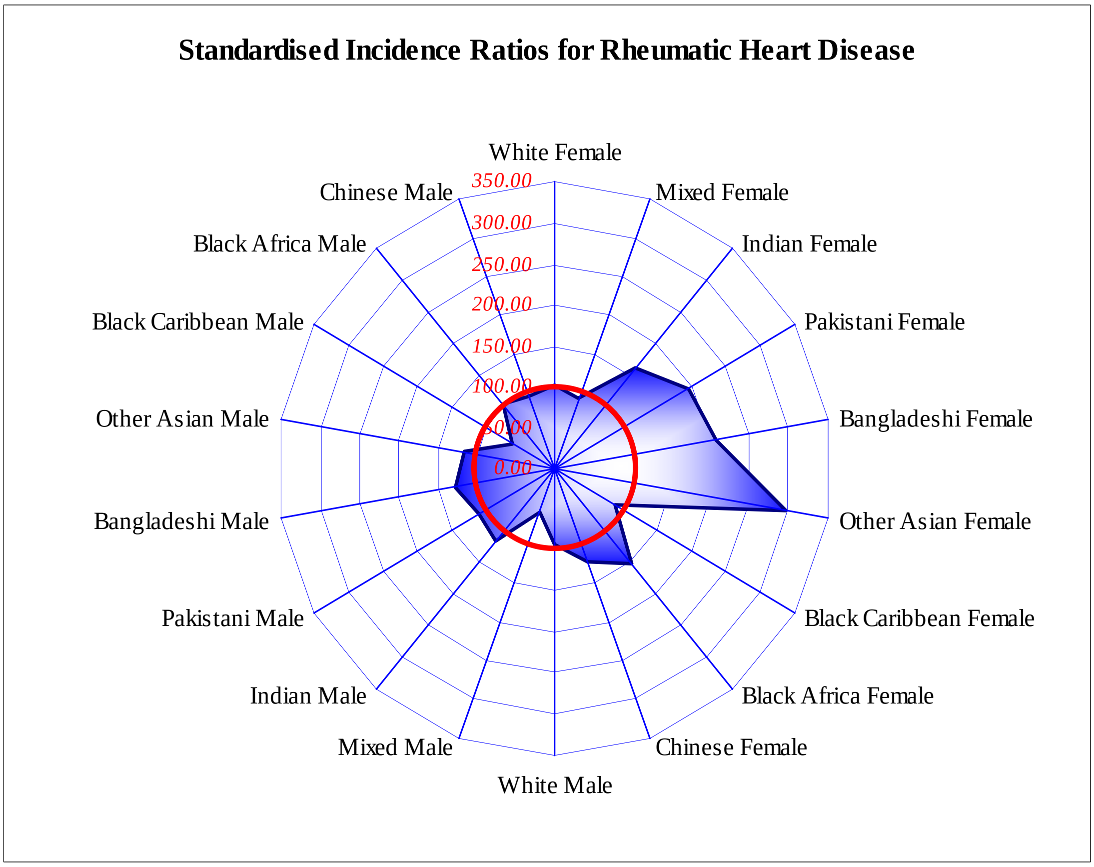


Figure 5-5 Standardised Incidence Ratios for Rheumatic Heart Disease

In men, white men with a ratio of 93 are a little healthier than the general population. The ratio of Indian men (114) and Pakistani men (108) are slightly high. Bangladeshis (128) are the unhealthiest group in men, followed by Other Asian men (115). The ratio of Black Africa men (102) is very close to the national average. Black Caribbean men (60), Mixed men (56) and Chinese men (91) are among the healthiest groups in rheumatic heart disease.

In women, the incidence ratio of white women (101) is very close to the national average. However, among South Asian women, Bangladeshi women are the unhealthiest, with an incidence ratio of 206, followed by Pakistani women (193) and Indian women (160). Other Asian women, seem to be a more important group in rheumatic heart disease, with an extremely high ratio of 297, nearly three times higher than the national average. In rheumatic heart disease, Chinese woman (121) is no longer the healthier group. The difference between the general population and Black Africa men (102) in incidence ratio is little. And Mixed women and Black Caribbean women are the healthiest groups in terms of rheumatic heart disease.

5.2.6 Heart Failure

The radar chart below shows the national standardised incidence ratios of heart failure for both men and women among different ethnic groups.

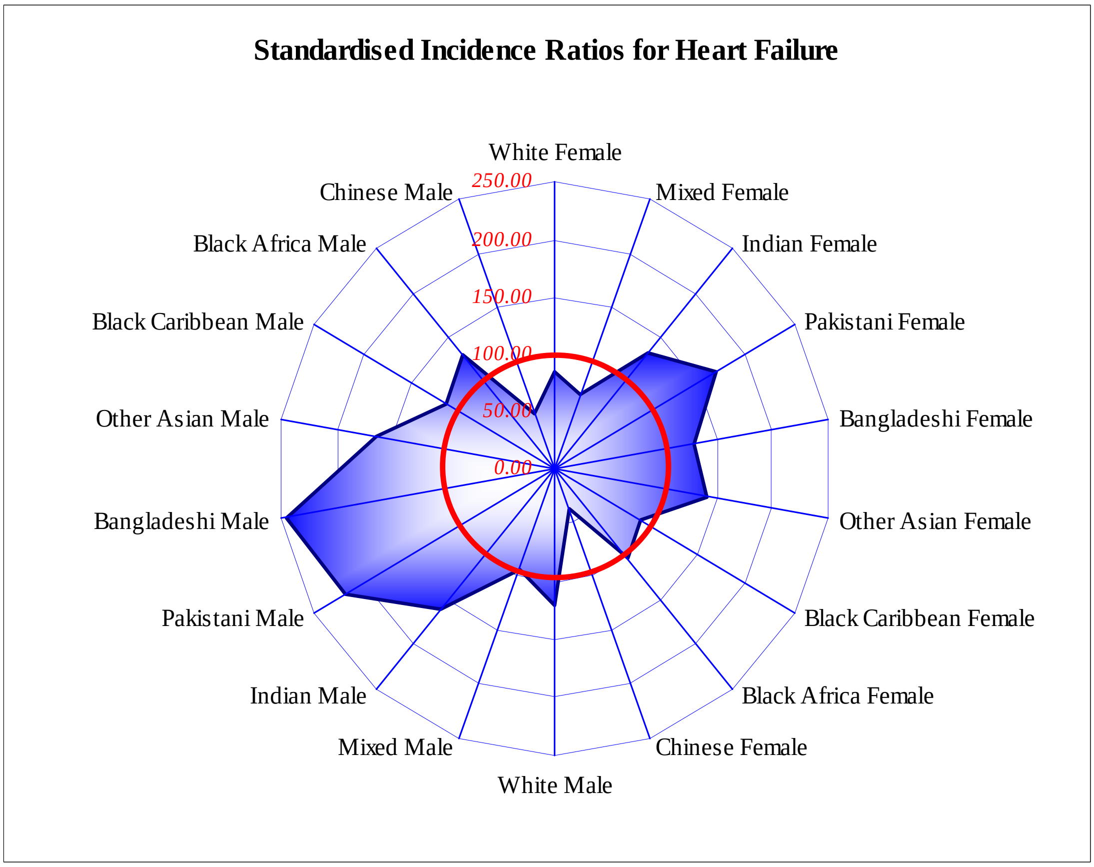


Figure 5-6 Standardised Incidence Ratios for Heart Failure

In men, the incidence ratio of white men (119) is moderately higher than the national average. Bangladeshi men (245) have experienced the highest ratio among all the male groups, nearly 2.5 times greater than the general population. Pakistani men (218) and Indian men (158) appear to be significantly high in ratios. Other Asian men are also found to have obviously high standardised incidence ratios (164). Black Africa men (129) and Black Caribbean men (113) are also less healthy in heart failure than the general population. However the incidence ratio of Black Caribbean men is a little lower than white men. Both Chinese men (51) and Mixed men (92) are among the healthier groups in heart failure.

In women, white women with a ratio of 84 are one of the healthiest ethnic groups in heart failure. The standardised incidence ratios of South Asian women are remarkably high. This is particularly true for Pakistani women (168), which is the unhealthiest ethnic group among women, followed by Indian women (130) and Bangladeshi women (128). Other Asian women (139) appear to have much higher standardised incidence ratios than the general population as well. The health status of heart failure among Black Africa women (102), Black Caribbean women (89), Mixed women (67) and Chinese women (36) is close or much better than the general population.

5.3 National Standardised Incidence Ratio by Ethnicity

The national standardised incidence ratios of cardiovascular disease for different ethnic groups have been examined and presented by types of cardiovascular disease in the previous section. In this section, the same standardised incidence ratios are presented by ethnic groups to examine which ethnic groups are more or less likely to get what kind of cardiovascular disease than the general population.

5.3.1 White People

The graph below about national standardised incidence ratios for white people shows the extent to which the white people are more or less likely to get certain kinds of cardiovascular disease than the general population.

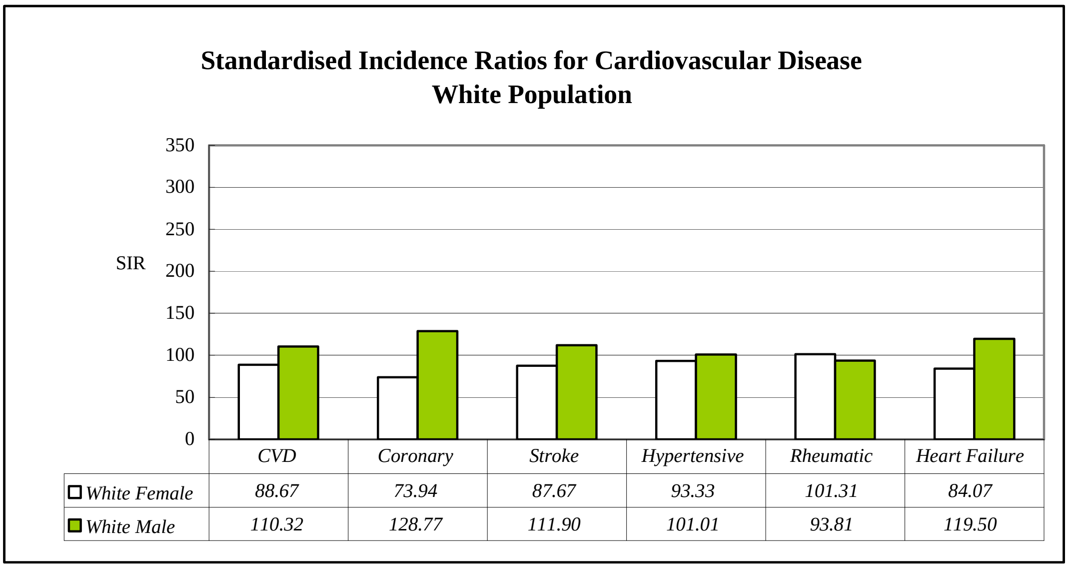
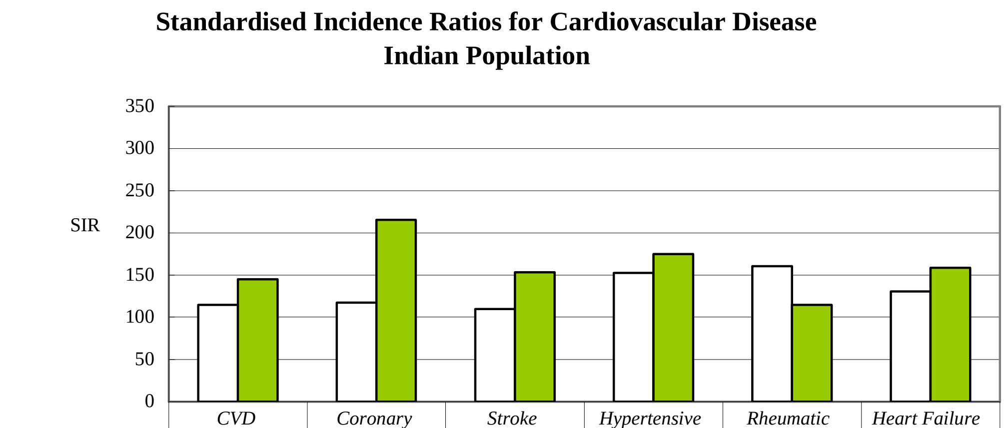


Figure 5-7 Standardised Incidence Ratios for White People

Being regarded as the general population, the white people are usually chosen as reference people in most studies of ethnic inequalities in cardiovascular disease. However, white men actually are more likely to get some kinds of cardiovascular disease than the general population, such as coronary heart disease, stroke and heart failure. The most obvious clinical difference between the general population and the white people lies in coronary heart disease and heart failure. The white men have about 1.2 times higher standardised incidence ratios of these two heart diseases than the general population. For the general cardiovascular disease, the ratio of the white men is faintly high. However, generally, the health status of the white women is better than the white men in most cardiovascular diseases except for rheumatic heart disease. The white women are healthier in most cardiovascular diseases than the general population.

5.3.2 Indian People

The graph below about national standardised incidence ratios for Indian people shows the extent to which the Indian people are more or less likely to get certain kinds of cardiovascular disease than the general population.



	CVD	Coronary	Stroke	Hypertensive	Rheumatic	Heart Failure
Indian Female	114.87	117.21	109.57	152.67	160.54	130.54
Indian Male	145.08	215.28	153.33	175.07	114.86	158.49

Figure 5-8 Standardised Incidence Ratios for Indian People

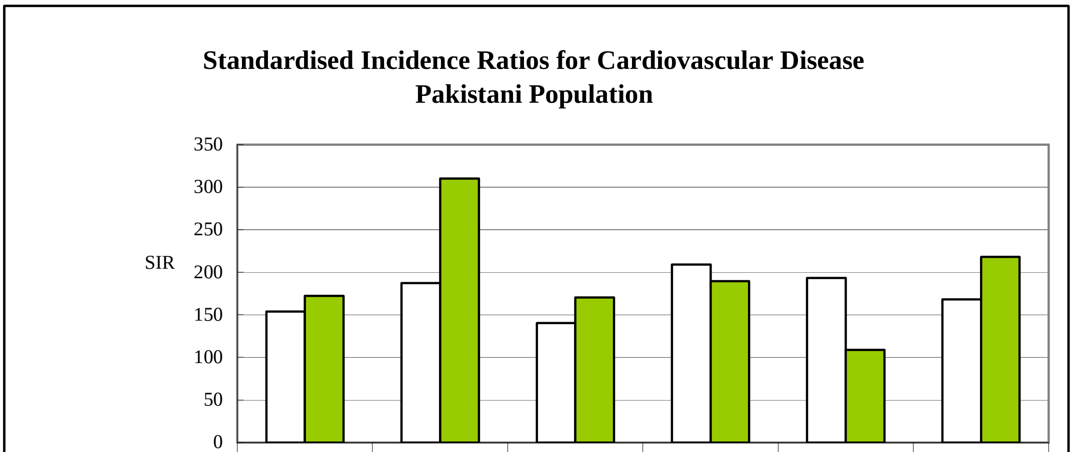
The Indian group is a relatively large ethnic minority in the UK and has been examined in many studies of ethnic difference in cardiovascular disease (Wild and McKeigue, 1997, Nazroo, 1997, Primatesta and Brooks, 2001).

It is obvious that the Indian men have about 1.5-2.1 times higher standardised incidence ratios than the general population in all the types of cardiovascular disease studied here except for rheumatic heart disease. The ratios of coronary heart disease and hypertensive heart disease are particularly high, implying their much worse health status in these heart diseases.

For the Indian women, the standardised incidence ratios for general cardiovascular disease, coronary heart disease and stroke are moderately higher than the general population. And the Indian women appear to be much more likely to get hypertensive heart disease, rheumatic heart disease and heart failure than the general population. Rheumatic heart disease is the only disease where the Indian women have higher standardised incidence ratios than the Indian men.

5.3.3 Pakistani People

The graph below about national standardised incidence ratios for Pakistani people shows the extent to which the Pakistani people are more or less likely to get certain kinds of cardiovascular disease than the general population.



	CVD	Coronary	Stroke	Hypertensive	Rheumatic	Heart Failure
Pakistani Female	153.70	187.57	140.39	209.26	193.58	168.25
Pakistani Male	172.56	310.20	170.53	189.82	108.72	217.98

Figure 5-9 Standardised Incidence Ratios for Pakistani People

As a major ethnic group among South Asians, the Pakistanis group is one of the most important themes in many studies on ethnic inequalities in cardiovascular disease (Wild and McKeigue, 1997, Nazroo, 1997, Primatesta and Brooks, 2001). It looks as if the Pakistani people have even worse health status in cardiovascular disease than the Indian people.

The Pakistani men appear to be much less healthy than the general population in coronary heart disease, stroke, hypertensive heart disease and heart failure. The ratio of coronary heart disease for the Pakistani men is extremely high, which is about 3.1 times higher than the national average. However, in striking contrast, the health status of the Pakistani men in rheumatic heart disease is as good as the general population.

For the Pakistani women, compared to the general population they have remarkably higher standardised incidence ratios for all the subtypes of cardiovascular, particularly in hypertensive heart disease (2.1 times higher), rheumatic heart disease (1.9 times higher) and coronary heart disease (1.8 times higher). In addition, their ratios are even higher than the Pakistani men in hypertensive heart disease and rheumatic heart disease, indicating that the Pakistani women are more likely to get these two heart disease than the Pakistani men.

5.3.4 Bangladeshi People

The graph below about national standardised incidence ratios for Bangladeshi people shows the extent to which the Bangladeshi people are more or less likely to get certain kinds of cardiovascular disease than the general population.

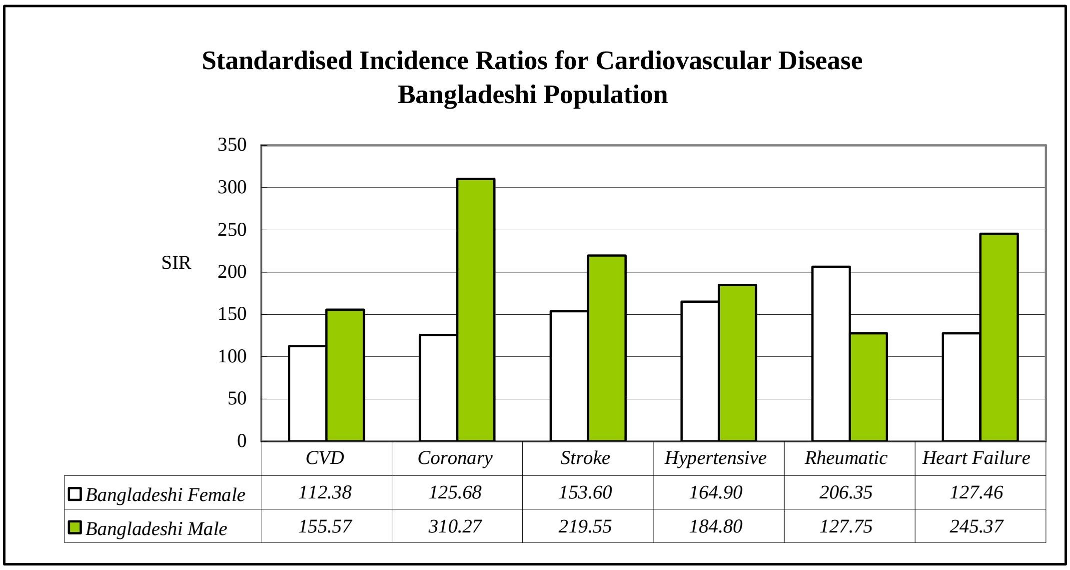


Figure 5-10 Standardised Incidence Ratios for Bangladeshi People

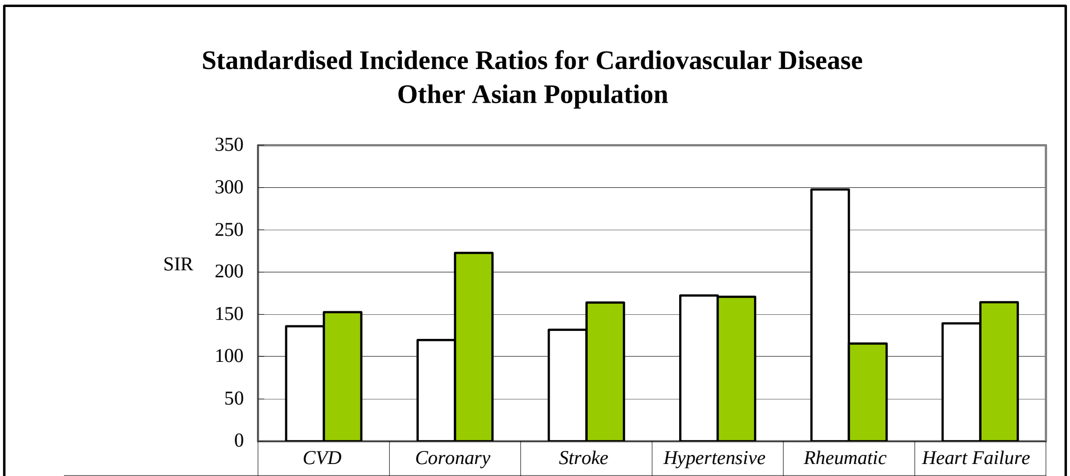
Being similar to the Pakistani people in cardiovascular disease risk, the Bangladeshi people also have been paid much attention in many studies on ethnic inequalities in cardiovascular disease (Balarajan and Raleigh, 1997, Bhopal et al., 2005b, Bhopal et al., 2005a, Gill et al., 2002).

The situation of the Bangladeshi men in general cardiovascular disease is much worse than the national average. Extremely high standardised incidence ratios for Bangladeshi men have been found in coronary heart disease, heart failure, stroke and hypertensive heart disease, being about 1.8-3.1 times higher than the national average. Compared to other subtypes, rheumatic heart disease seems relatively rare in Bangladeshi men. But the ratio is still higher than the national average.

The Bangladeshi women are found to have strikingly high standardised incidence ratios of rheumatic heart disease, hypertensive heart disease and stroke, and moderately high standardised incidence ratios in coronary heart disease and heart failure. The Bangladeshi women are less healthy in rheumatic heart disease than the Bangladeshi men. In summary, the Bangladeshi group is one of the unhealthiest ethnic groups in cardiovascular disease in the UK.

5.3.5 Other Asian People

The graph below about national standardised incidence ratios for Other Asian people shows the extent to which the Other Asian people are more or less likely to get certain kinds of cardiovascular disease than the general population.



	CVD	Coronary	Stroke	Hypertensive	Rheumatic	Heart Failure
Other Asian Female	135.89	119.67	131.84	172.36	297.53	139.38
Other Asian Male	152.66	222.55	163.89	170.66	115.43	164.20

Figure 5-11 Standardised Incidence Ratios for Other Asian People

The Other Asian is a combined group of Asian British (32 per cent), Sri Lanka (24 per cent), Middle East (16 per cent) and Other groups(Gardener and Connolly, 2005). Among the Asian British, most are second and third generation descendants of the Pakistani, the Bangladeshi and the Indian migrants (Gardener and Connolly, 2005), which might be the reason for the fact that the Other Asian group is much less healthy than the general population in cardiovascular disease. Generally speaking, there are a lot of similarities between the Other Asian people and South Asian people in the incidence of cardiovascular disease.

In general cardiovascular disease, the standardised incidence ratios for both the Other Asian men and women are significantly higher than the national average.

The Other Asian men seem to be one of the unhealthiest ethnic groups in all the subtypes, except for rheumatic heart disease. The ratios for the Other Asian men are clearly higher than the national average in coronary heart disease, hypertensive heart disease, heart failure and stroke.

The Other Asian women are also found to have remarkably high standardised incidence ratios in the subtypes of cardiovascular disease, except for coronary heart disease. Other Asian woman is the unhealthiest ethnic group in rheumatic heart disease in the UK.

5.3.6 Black Caribbean People

The graph below about national standardised incidence ratios for Black Caribbean people shows the extent to which the Black Caribbean people are more or less likely to get certain kinds of cardiovascular disease than the general population.

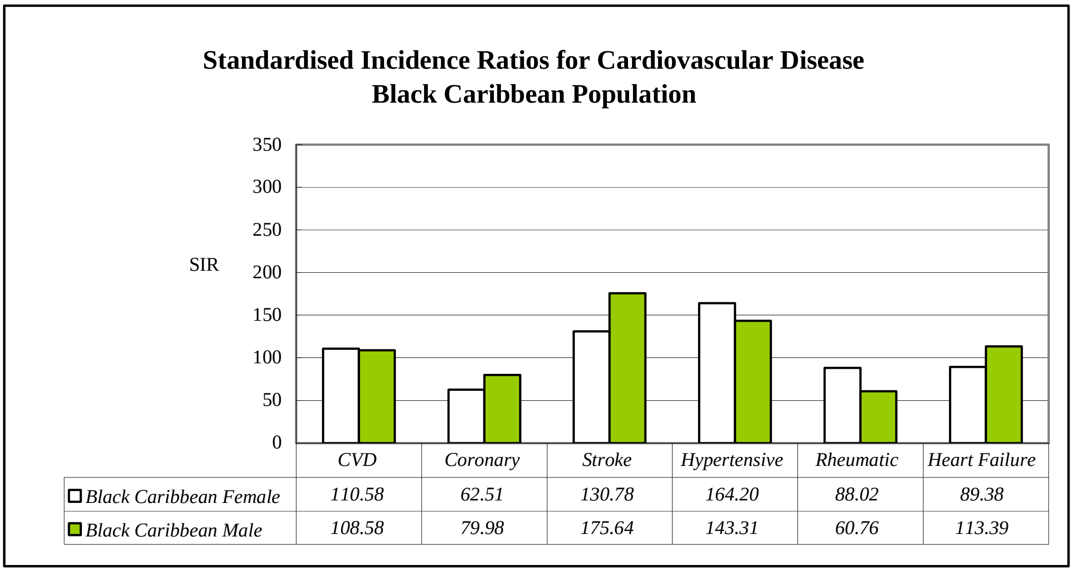
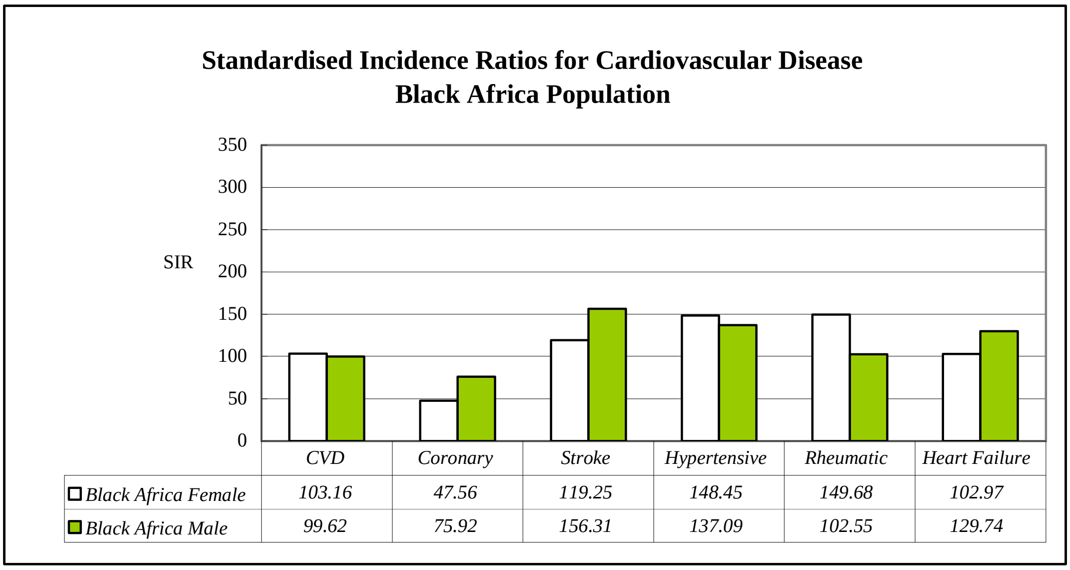


Figure 5-12 Standardised Incidence Ratios for Black Caribbean People

Black Caribbean people seem to be much healthier in some kinds of cardiovascular disease but less healthy in other subtypes. In general cardiovascular disease, both the Black Caribbean men and women have slightly high standardised incidence ratios, implying that the health status in cardiovascular disease of the Black Caribbean people is generally not too bad. In the subtypes of cardiovascular disease, both the Black Caribbean men and women are found to have significantly lower standardised incidence ratios than the general population in coronary heart disease and rheumatic heart disease, but remarkably higher ratios in stroke and hypertensive heart disease. Black Caribbean women are healthier in heart failure, whereas the Black Caribbean men are a little less healthy in heart failure.

5.3.7 Black Africa People

The graph below about national standardised incidence ratios for Black Africa people shows the extent to which the Black Africa people are more or less likely to get certain kinds of cardiovascular disease than the general population.



	CVD	Coronary	Stroke	Hypertensive	Rheumatic	Heart Failure
Black Africa Female	103.16	47.56	119.25	148.45	149.68	102.97
Black Africa Male	99.62	75.92	156.31	137.09	102.55	129.74

Figure 5-13 Standardised Incidence Ratios for Black Africa People

The Black Africa group is one of the most diverse ethnic groups in terms of country of origin. In terms of general cardiovascular disease, both the Black Africa men and women have similar standardised incidence ratios to the general population, implying that the health conditions of the Black Africa people in cardiovascular disease are at the national average level. Both the Black Africa men and women are even healthier than the general population in coronary heart disease.

The Black Africa men have particularly higher incidence ratio in stroke. In addition, the Black Africa men are also less healthy in hypertensive heart disease and heart failure. The ratio of the Black Africa men in rheumatic heart disease is at the national average level, which is much lower than that of the Black Africa women.

Higher incidence ratios were found in hypertensive heart disease and rheumatic heart disease among the Black Africa women. The Black Africa women also have a moderately high incidence ratio in stroke, and their ratio of heart failure is at the national average level.

5.3.8 Mixed People

The graph below about national standardised incidence ratios for people from the Mixed group shows the extent to which people from the Mixed group are more or less likely to get certain kinds of cardiovascular disease than the general population.

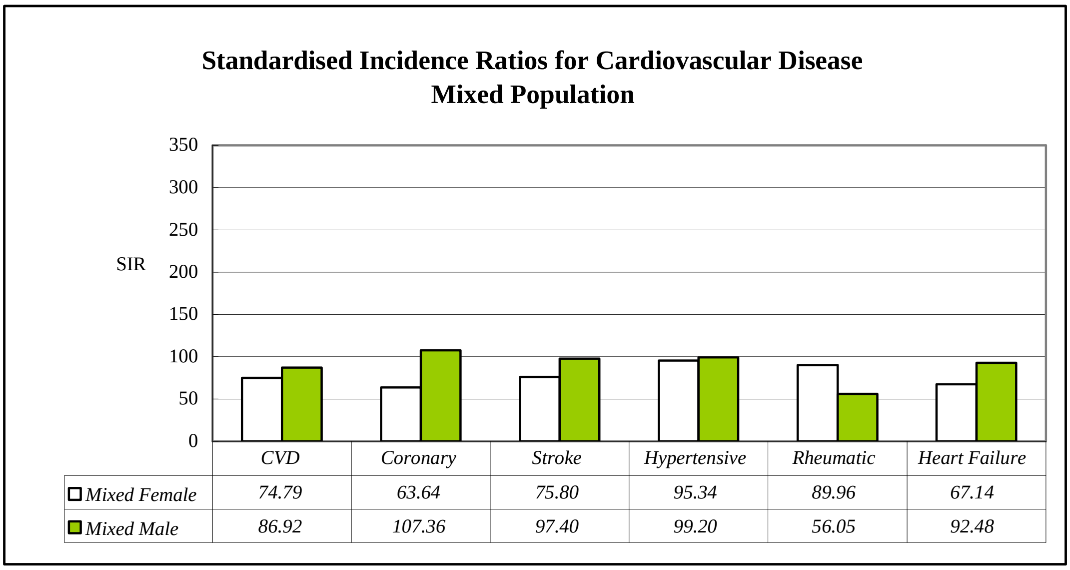


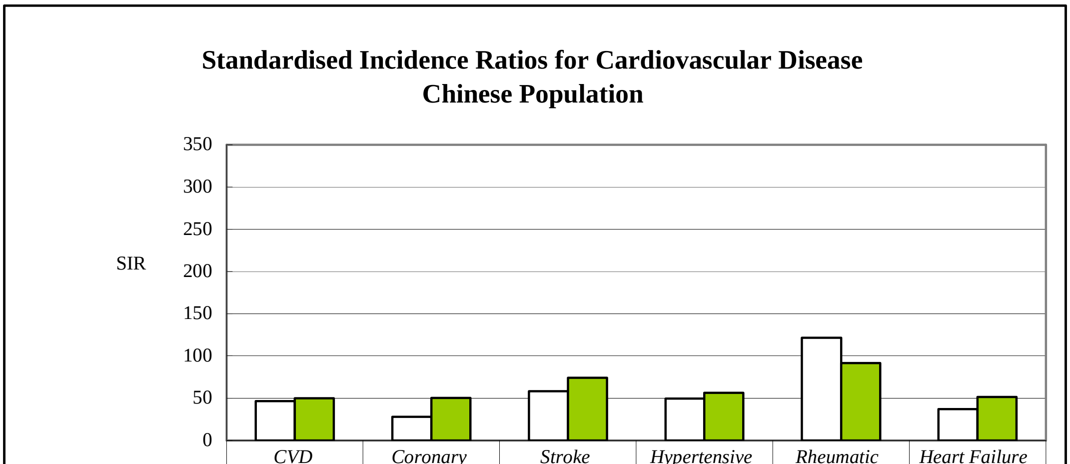
Figure 5-14 Standardised Incidence Ratios for Mixed People

Mixed group, including four subgroups White and Black Caribbean, White and Black African, White and Asian and Other Mixed, was introduced for the first time in the

UK 2001 Census and hasn't been well studied in research on ethnic inequalities in cardiovascular disease. Generally speaking, the Mixed group is one of the healthiest ethnic groups in cardiovascular disease. All the standardised incidence ratios of general cardiovascular disease and the subtypes among both the Mixed men and women are lower or significantly lower than the national average, with the exception of the ratio of coronary heart disease for the Mixed man group, which is slightly higher than the national average. Compared to the Mixed women, the Mixed men are somewhat less healthy in most cardiovascular diseases except for rheumatic heart disease.

5.3.9 Chinese People

The graph below about national standardised incidence ratios for Chinese people shows the extent to which the Chinese people are more or less likely to get certain kinds of cardiovascular disease than the general population.



	CVD	Coronary	Stroke	Hypertensive	Rheumatic	Heart Failure
Chinese Female	46.35	27.88	58.02	49.66	121.53	36.84
Chinese Male	50.03	50.27	73.88	56.42	91.66	51.45

Figure 5-15 Standardised Incidence Ratios for Chinese People

The Chinese people can be regarded as the healthiest ethnic group in cardiovascular disease. In terms of general cardiovascular disease, the ratios for both Chinese men and women are about half of the national average. The Chinese people are also much healthier in subtypes of cardiovascular disease than the general population, with the exception of rheumatic heart disease. It is noticeable that the Chinese women have a ratio of 121, which is about 1.2 times higher than the national average. Rheumatic heart disease is also the only disease where Chinese men health condition is better than Chinese women.

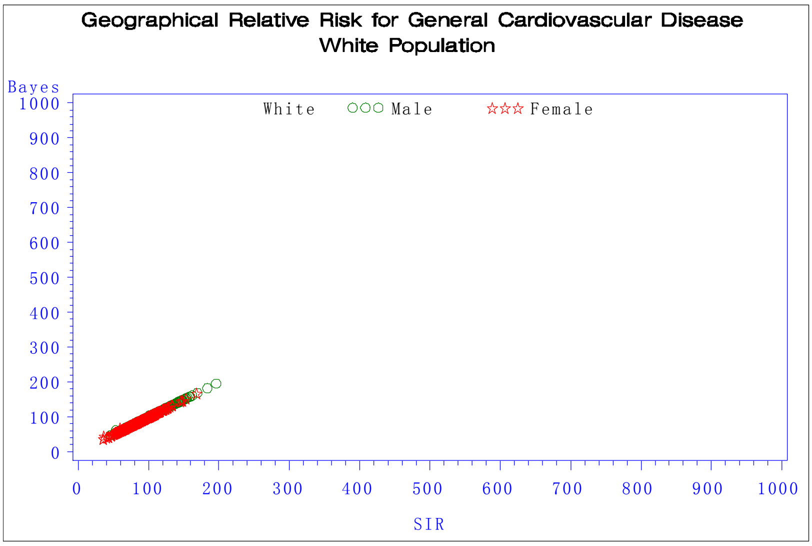
5.4 Geographical Relative Risk of Cardiovascular Disease

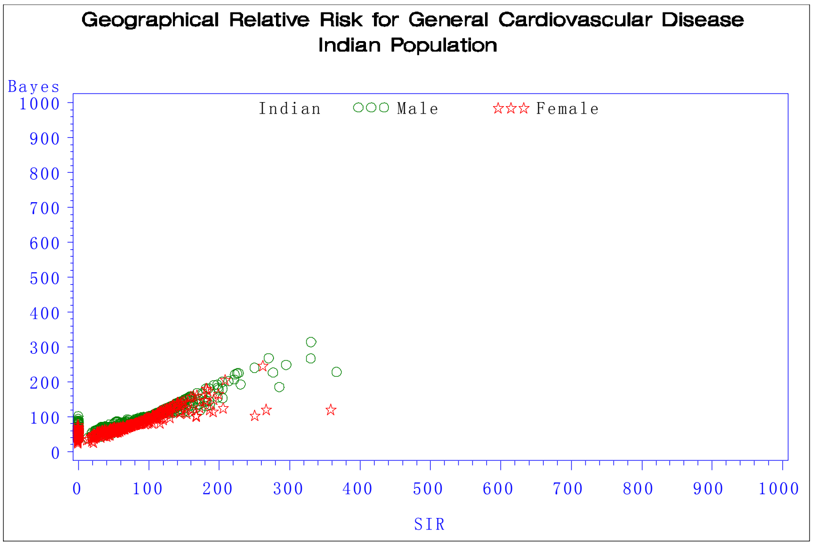
As introduced before, two empirical Bayes estimation methods have been employed to estimate the geographical relative risk of cardiovascular disease for ethnicity-sex groups for the 345 local authorities in England. The empirical Bayes estimation method developed by Clayton and Kaldor (1987) estimates the local relative risk based a combination of maximum likelihood (ML) and the moments estimators, which shrinks the local relative risk towards the overall mean of the local relative risk. However, Marshall (1991) proposed a simple estimation using moments estimator, which moves the local relative risk towards the national SIR for the same group. Before mapping the geographical relative risk of cardiovascular disease, the empirical Bayes estimation is compared with the crude standardised incidence ratios of cardiovascular disease for ethnicity-sex groups to examine the extent to which the empirical Bayes estimation reduces the variations of the standardised incidence ratios of cardiovascular disease. And then the geographical relative risk of cardiovascular disease estimated by the two empirical Bayes estimation methods are presented in maps with discussion about the pattern of the geographical relative risk of cardiovascular disease for ethnic groups as well as the uncertainties in the estimation of geographical relative risk using different estimation methods..

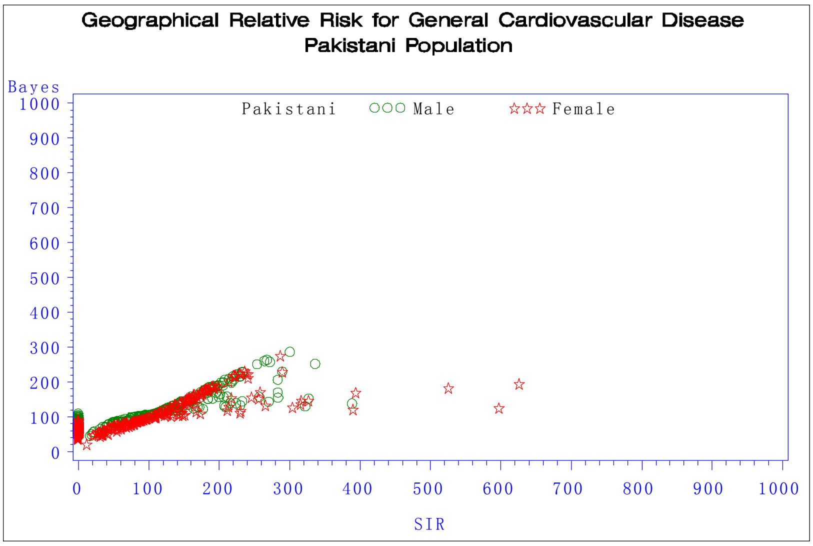
5.4.1 Comparison between the SIRs and the Empirical Bayes Estimation

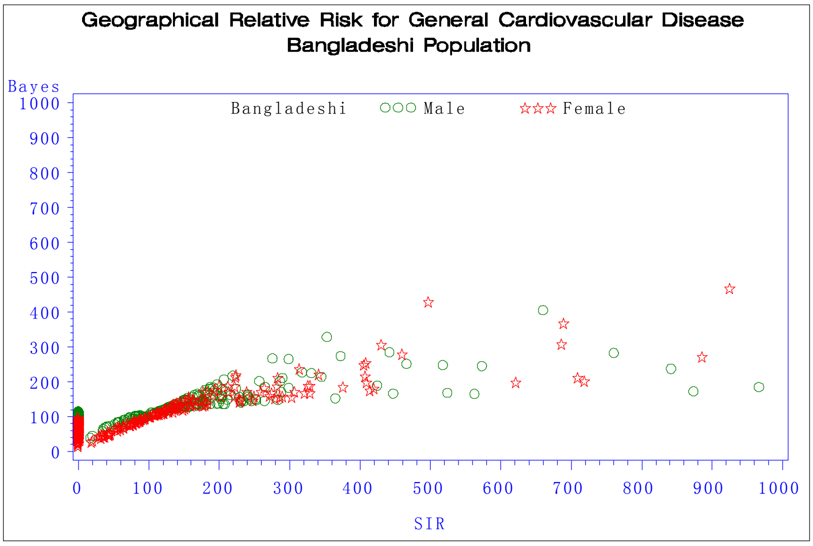
Both the crude standardised incidence ratios and the empirical Bayes estimation of geographical relative risk of cardiovascular disease are plotted in the graphs for ethnicity-sex groups. The first series of graphs below are the comparison between the SIRs and the empirical Bayes estimation of geographical relative risk obtained using the method developed by Clayton and Kaldor (1987). And the second series of graphs are the comparison between the SIRs and the estimation of local relative risk obtained using the empirical Bayes estimation method proposed by Marshall (1991). There is obvious difference between the standardised incidence ratios of cardiovascular disease and the empirical Bayes estimation of the geographical relative risk of cardiovascular disease for all the ethnicity-sex groups except for white population, as shown in the graphs below.

The graphs below show the empirical Bayes estimation of general cardiovascular disease for ethnicity-sex groups using the Clayton and Kaldor (1987) method.

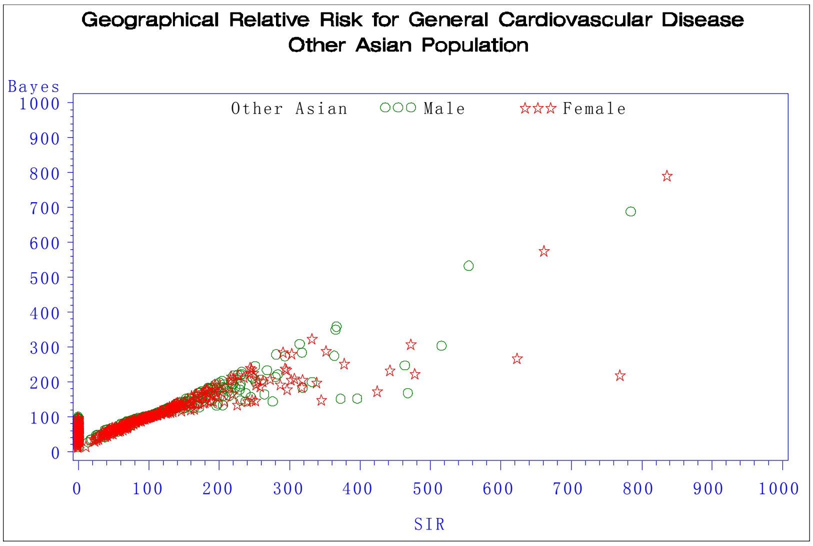




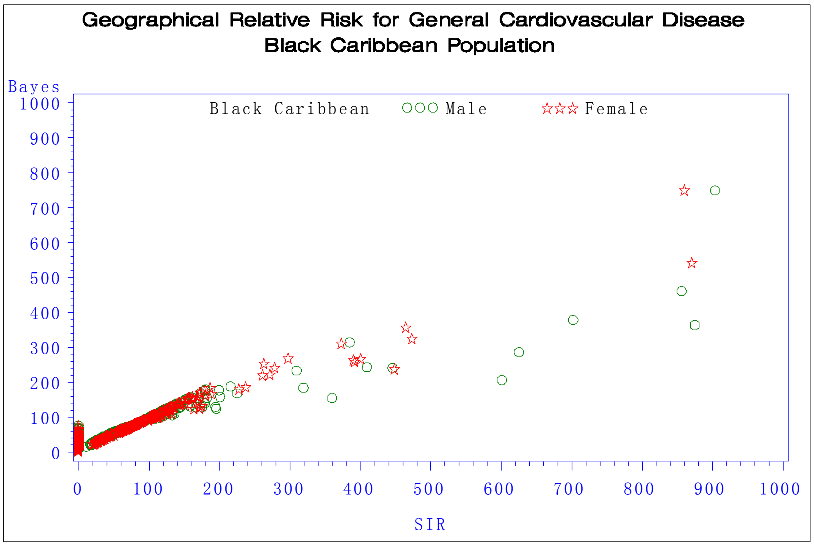




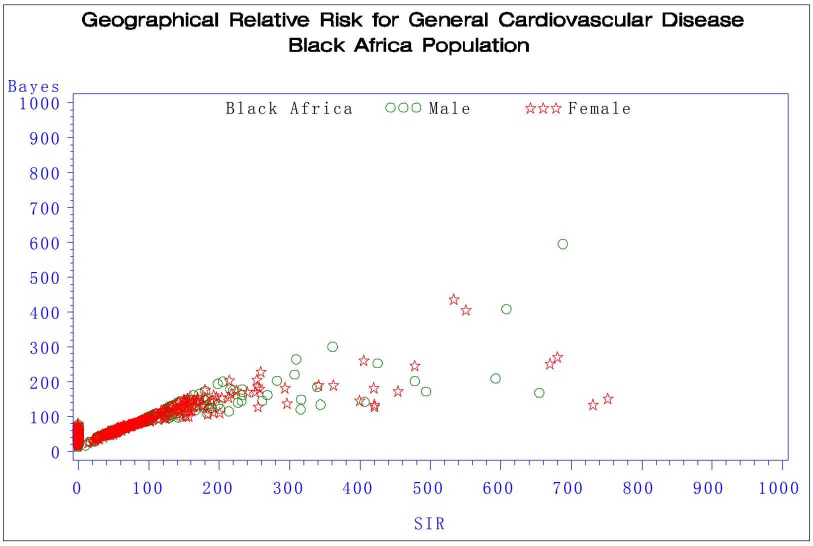
Geographical Relative Risk for General Cardiovascular Disease
Bangladeshi Population
Bayes
Bangladeshi
Male
Female
SIR

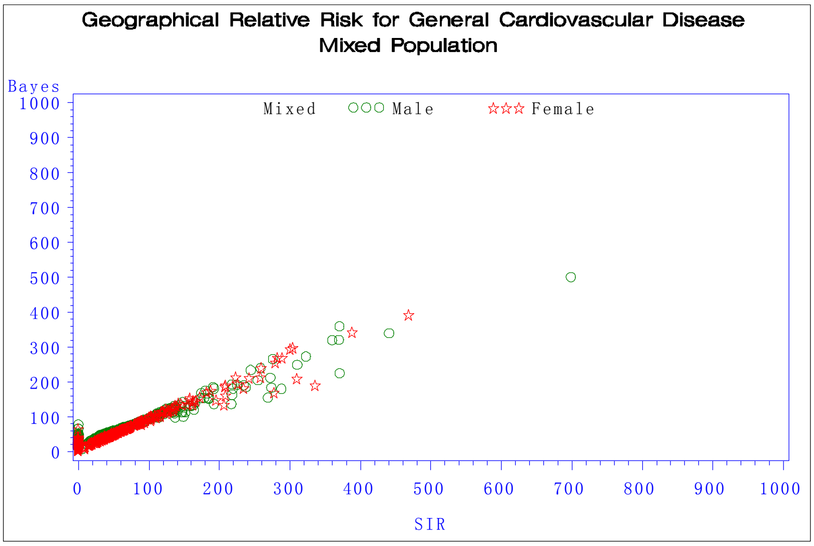


Geographical Relative Risk for General Cardiovascular Disease
Other Asian Population
Bayes
Other Asian
Male
Female
SIR



Geographical Relative Risk for General Cardiovascular Disease
Black Caribbean Population
Bayes
Black Caribbean
Male
Female
SIR





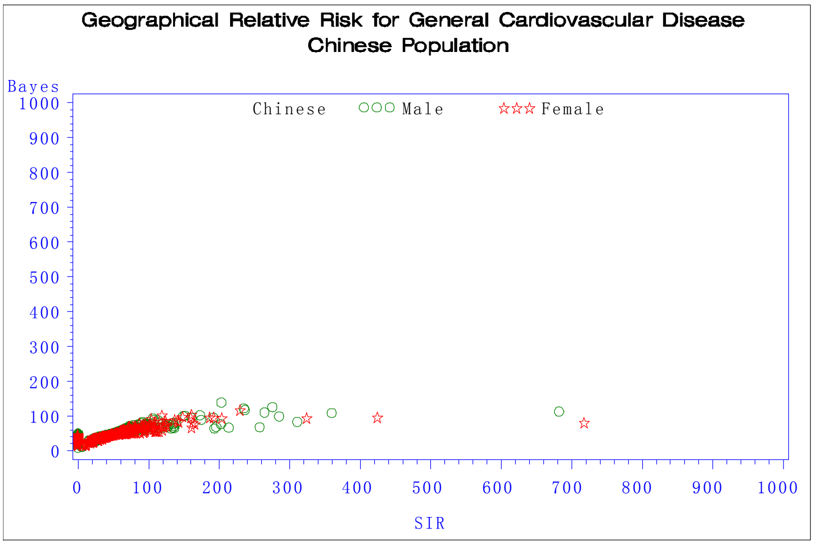
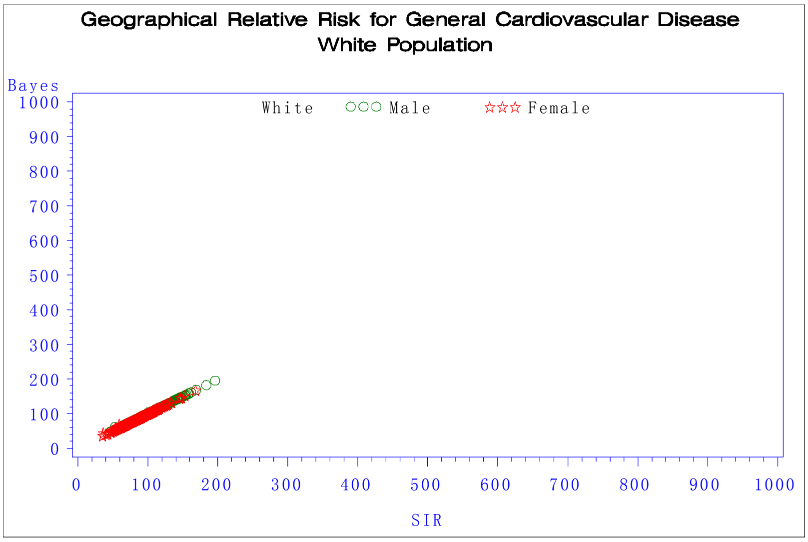
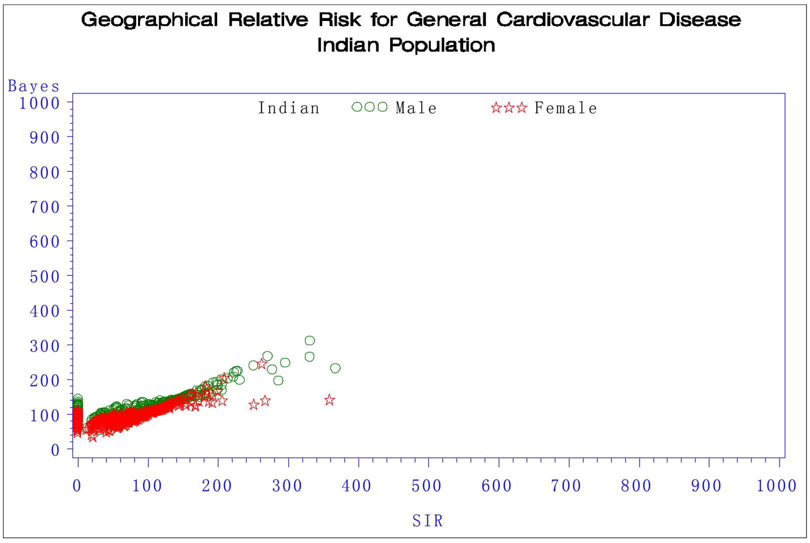
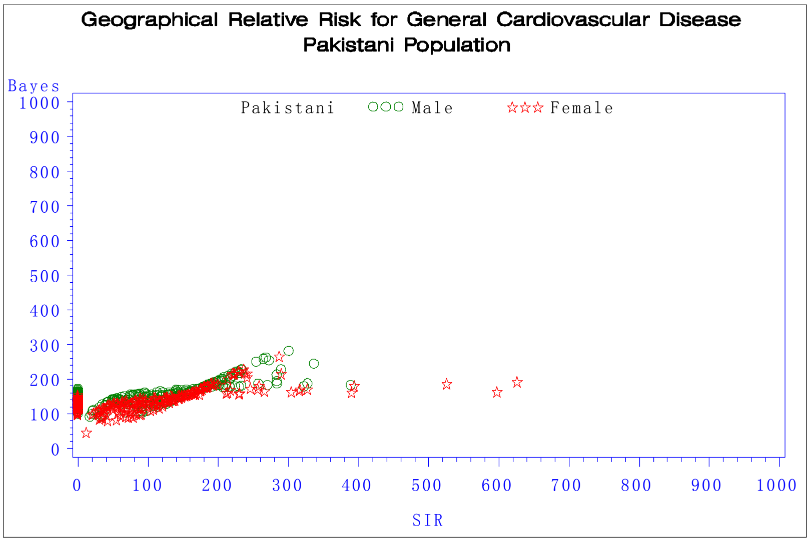


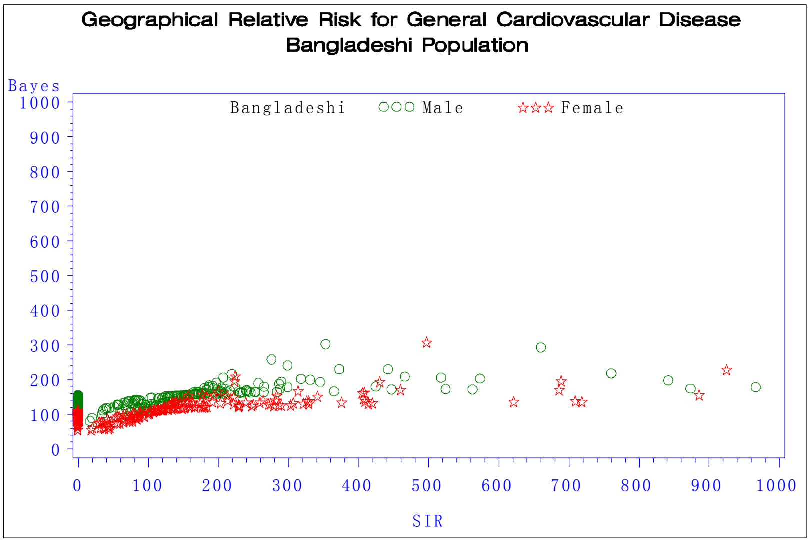
Figure 5-16 Empirical Bayes estimation of general cardiovascular disease (Clayton and Kaldor (1987) method using Maximum Likelihood and Moments estimators)

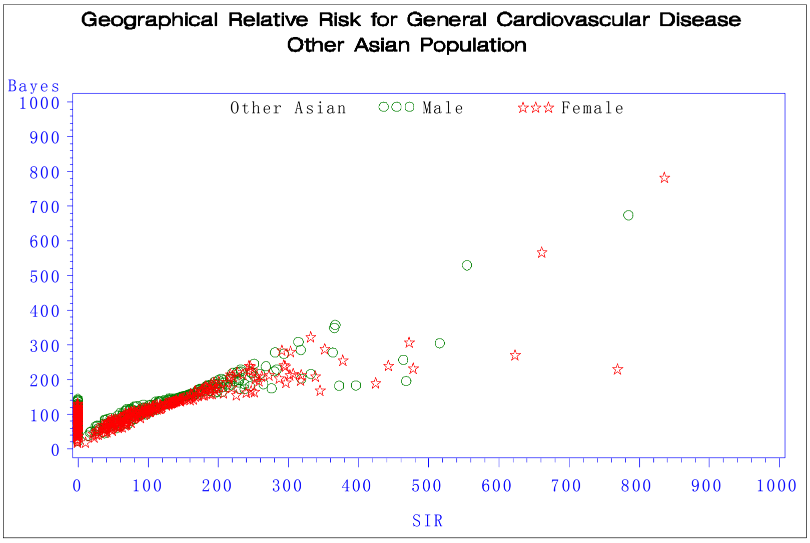
The graphs below show the empirical Bayes estimation of general cardiovascular disease for ethnicity-sex groups using the Marshall (1991) method.

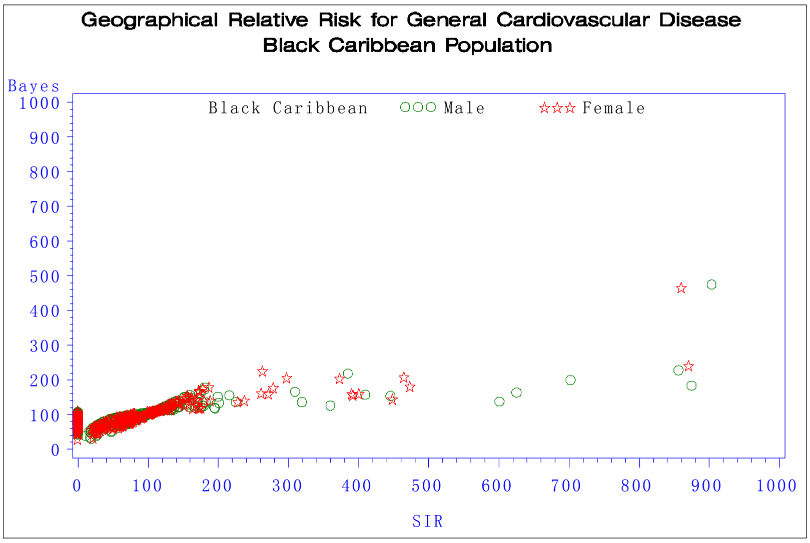







Geographical Relative Risk for General Cardiovascular Disease
Bangladeshi Population
Bayes
Bangladeshi Male Female
SIR
0
100
200
300
400
500
600
700
800
900
1000


Geographical Relative Risk for General Cardiovascular Disease
Other Asian Population
Bayes
Other Asian Male Female
SIR
0
100
200
300
400
500
600
700
800
900
1000


Geographical Relative Risk for General Cardiovascular Disease
Black Caribbean Population
Bayes
Black Caribbean Male Female
SIR
0
100
200
300
400
500
600
700
800
900
1000

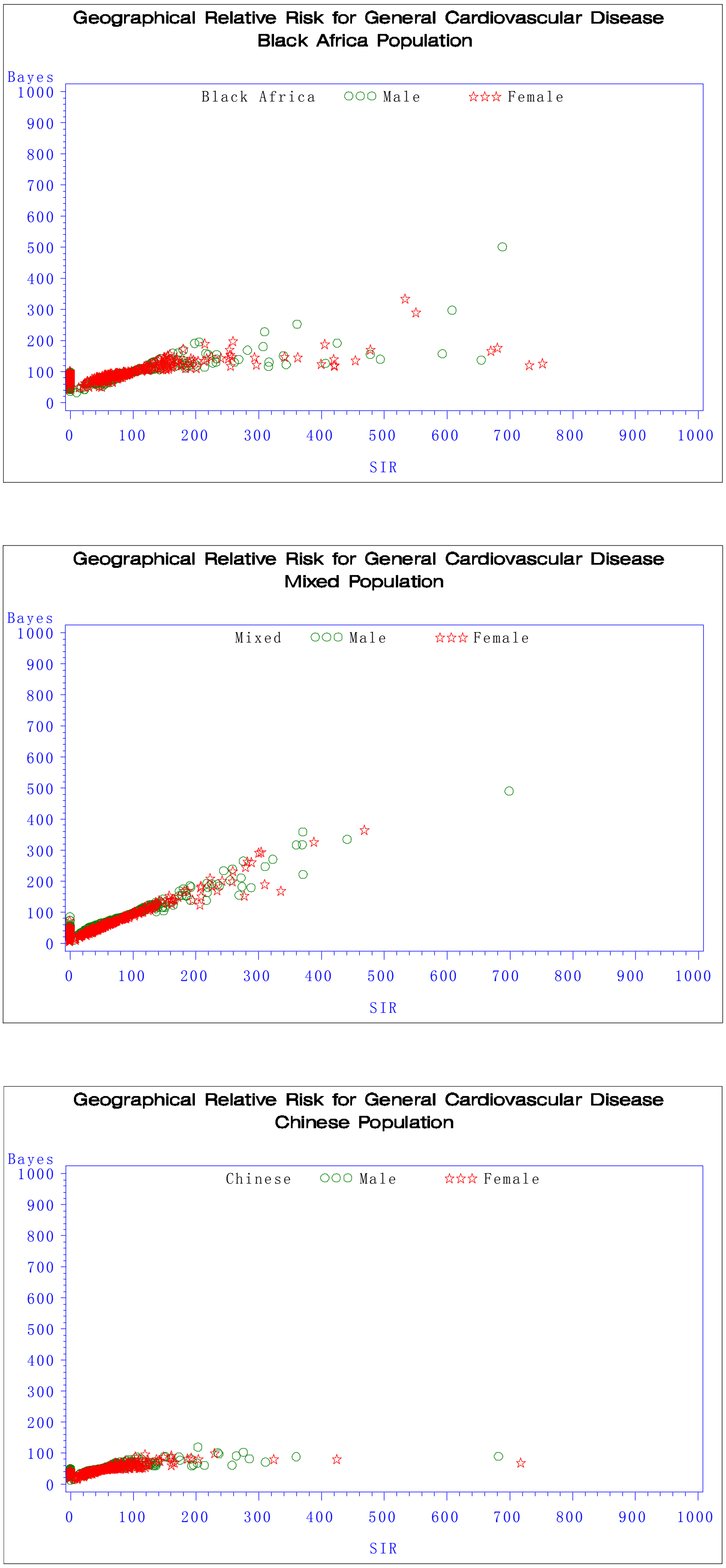


Figure 5-17 Empirical Bayes estimation of general cardiovascular disease (Marshall (1991) method using Moments estimator)

Firstly, both of the two empirical Bayes estimation methods have reduced the high variations of the crude SIRs for minority ethnic groups. As expected, the SIRs for minority ethnic groups tend to be extremely high in the areas where the populations are sparse and the cases occurred by chance. Most very high SIRs for Bangladeshi, Other Asian, Black groups and Chinese groups have been shrunk towards either the overall mean or their national SIRs to a large extent in the empirical Bayes estimation, indicating the two empirical Bayes estimation methods work well for most unstable ratios and some high crude SIRs for these groups are clearly overestimated. However, the empirical Bayes estimation methods haven't shrunk so much for the very high SIRs for Indian, Pakistani and Mixed groups. The SIRs for these three ethnic groups are more stable, probably because the local populations for those areas are relatively large or more cases of clinical importance have been observed there. As introduced in Chapter Two, Indian, Pakistani and Mixed ethnic groups have the largest size of population among ethnic minorities. For white group, there is even no difference between the SIRs and the empirical Bayes estimation due to its large population, indicating that the geographical relative risk of white people is much more stable and reliable than those for minority ethnic groups.

Secondly, the geographical relative risk of areas with no observation of cardiovascular disease for minority ethnic groups has been estimated by both of the empirical Bayes estimation methods. In the SIRs, the geographical relative risk of areas with zero observation will return a ratio of zero. However, the values of zero can't reflect the underlying relative risk for these areas with different non-zero expected number of cardiovascular disease cases. Both of the two empirical Bayes estimation methods have moved these zeros towards either the overall mean or their national SIR for minority ethnic groups by taking different expected number of cases of those areas into account. The larger the expected number of cases, the less the relative risk of those areas will be moved. In addition, in the empirical Bayes estimation, the relative risk of areas with zero population, particularly for minority ethnic groups, has been moved to either the overall mean or their national SIR, assuming that if there are population, they will share the average relative risk.

Both of the two empirical Bayes estimation methods work well in dealing with the small number problem and zero observation problem of the standardised incidence ratio method, however, there is a difference between the results of these two methods, which is discussed and highlighted in maps in the following section.

5.4.2 Map Presentation

The empirical Bayes estimation of the geographical relative risk of cardiovascular disease for ethnicity-sex groups has been projected on the maps. The maps adopt the traffic lights colour scheme to make the legend epidemiologically meaningful. The green colour means “low relative risk”, “healthy”. The darker the green colour, the lower the relative risk. The yellow colour represents “higher relative risk’. And the red colour indicates “significantly high relative risk”. The darker the red colour, the higher the relative risk.

The results from both the two empirical Bayes estimation methods are projected on the maps. For each ethnicity-sex group, the map on the left side is the result of the Clayton and Kaldor (1987) method using Maximum Likelihood (ML) and moments estimators. And the map on the right side is the result of the Marshall (1991) method using moments estimator. Generally, there is little difference between the maps for White, Mixed and Chinese groups. However, the geographical relative risk of cardiovascular disease obtained using the two methods for Indian, Pakistani, Bangladeshi and Other Asian groups is significantly different. For example, for Pakistani male, Pakistani female and Bangladeshi male groups, most local authorities are covered with yellow colour in the Marshall (1991) method, indicating significantly high relative risk. However, in the Clayton and Kaldor (1987) method, they are in green colour, implying relatively low relative risk of cardiovascular disease. The difference between the maps for Black Caribbean and Black Africa groups is not so significant, but still observable.

The reason for the difference is that these two methods move the local relative risk of cardiovascular disease towards different average relative risk. The Clayton and Kaldor (1987) method shrinks the local relative risk towards the overall mean of the local SIRs. However, the Marshall (1991) method moves the local relative risk towards the national SIR for that group. As presented in the previous section, the national standardised incidence ratios of cardiovascular disease for South Asians are remarkably high. Thus, being moved towards these remarkably high national SIRs, the local relative risk is also significantly high in the Marshall (1991) method.

For white male and female groups, there has been little shrinkage in either of the two methods due to the large size of the white population, so there is little difference between the two methods in risk of cardiovascular disease. However, for Mixed and Chinese male and female groups, probably because there is little difference between their overall mean of local SIRs and the national SIRs, the difference in their geographical relative risk is small.

As there are clear difference in the relative risk of cardiovascular disease at national level for male and female groups, even for the same ethnic group, as presented in the previous section, there is clear difference in the empirical Bayes estimation of the local relative risk between male and female groups in the same ethnic group when using the Marshall (1991) method. As shown in the maps, Indian, Pakistani and Bangladeshi male groups generally have higher geographical relative risk of cardiovascular disease than their female groups. However, the results of the Clayton and Kaldor (1987) method haven’t shown such difference, probably because there is less difference between the overall mean of local relative risk for their male and female groups due to a large proportion of the local authorities with a standardised incidence ratio of zero.

Although difference of geographical relative risk of cardiovascular disease has been observed for minority ethnic groups when using the two empirical Bayes estimation methods, the difference is mainly occurred in the process of “shrinkage”, which is more likely to happen to areas with small size of population and unstable standardised incidence ratios. For areas with relatively large size of populations of minority ethnic groups, where the crude standardised incidence ratios are relatively stable, little shrinkage has been made for them even using different empirical Bayes estimation methods. Thus whichever empirical Bayes estimation method is used, the local relative risk of cardiovascular disease in areas with large population remains either high or low. As shown in the maps, there are some areas that remain the same colour when using different empirical Bayes estimation methods, although the estimation values might be a little different. For example, in London, little difference has been observed for minority ethnic groups in the two methods, indicating the geographical relative risk of cardiovascular disease in London is more stable and reliable for all the ethnic groups.

Generally, the geographical relative risk of cardiovascular disease for White, Mixed and Chinese are lower or much lower than the general population in most local authorities. As expected, a large proportion of local authorities have higher relative risk of cardiovascular disease for Indian, Pakistani and Bangladeshi population, particularly for their male groups. The Other Asian group, which hasn’t been studied in previous studies, is found to have significantly high relative risk in a large number of local authorities, particularly in London area. For Black Caribbean and Black Africa groups, whose national SIRs are close to the general population, their local relative risk of cardiovascular disease is higher in some local authorities, but below the national average in most regions.

London is of particular interest in studying geographical relative risk of cardiovascular disease because nearly half of the UK ethnic minority population concentrate there. The patterns of the geographical relative risk of cardiovascular disease for ethnic groups are summarized in the table below, followed by the map presentations of the geographical relative risk of cardiovascular disease for ethnic groups. In particular, the risk of cardiovascular disease for minority ethnic groups, particularly South Asians and Other Asians is significantly high in local authorities located in London.

Ethnicity		**London**	
		Extremely High (>200)	**Significantly High (>150, <200)**
White	Male	None	None
	Female	None	None
Indian	Male	Hounslow, Ealing, Barking and Dagenham	Waltham Forest, Hillingdon, Newham, Harrow, Redbridge, Greenwich
	Female	None	Ealing, Hounslow, Waltham Forest
Pakistani	Male	Waltham Forest, Hillingdon, Newham, Redbridge, Barking and Dagenham, Harrow, Greenwich	Ealing, Lambeth, Hounslow, Haringey, Tower Hamlets, Croydon, Islington, Lewisham, Hackney,Southwark
	Female	Redbridge, Hounslow, Waltham Forest	Ealing, Hillingdon, Harrow, Newham, Barking and Dagenham, Hammersmith and Fulham, Enfield, Greenwich
Bangladeshi	Male	Waltham Forest, Westminster, Lewisham, Newham, Tower Hamlets	Redbridge, Croydon, Lambeth, Enfield, Barking and Dagenham, Islington, Hackney, Greenwich, Camden, Southwark
	Female	Redbridge, Waltham Forest	Lewisham, Croydon, Newham, Harrow
Other Asian	Male	Waltham Forest, Westminster, Lewisham, Newham, Tower Hamlets	Redbridge, Croydon, Lambeth, Enfield, Barking and Dagenham, Islington, Hackney, Greenwich, Camden, Southwark
	Female	Wandsworth, Hounslow, Newham, Lambeth, Camden, Brent, Hackney	Ealing, Kensington and Chelsea, Merton, Hammersmith and Fulham, Southwark, Richmond upon, Thames, Hillingdon, Redbridge, Westminster
Black Caribbean	Male	None	Hounslow, Westminster, Ealing
	Female	None	Hounslow, Waltham Forest
Black Africa	Male	Richmond upon Thames, Hounslow	Westminster, Ealing
	Female	Richmond upon Thames	Westminster, Croydon, Ealing, Hounslow
Mixed	Male	Wandsworth, Merton	Waltham Forest, Newham
	Female	Merton, Wandsworth	None
Chinese	Male	None	None
	Female	None	None

Table 5-1 Pattern of geographical relative risk of CVD for ethnic groups in London

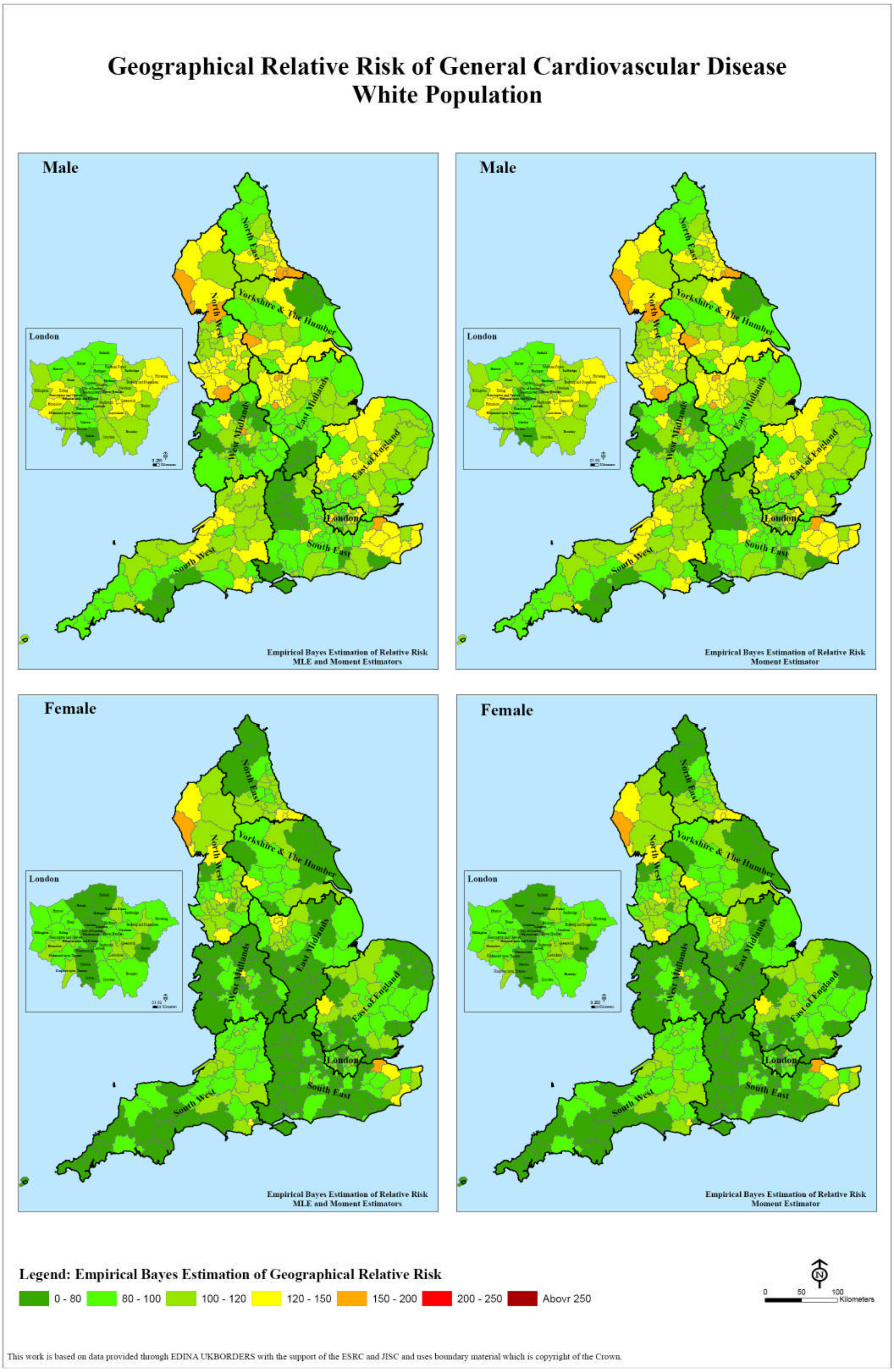


Figure 5-18 Geographical relative risk of cardiovascular disease for White population

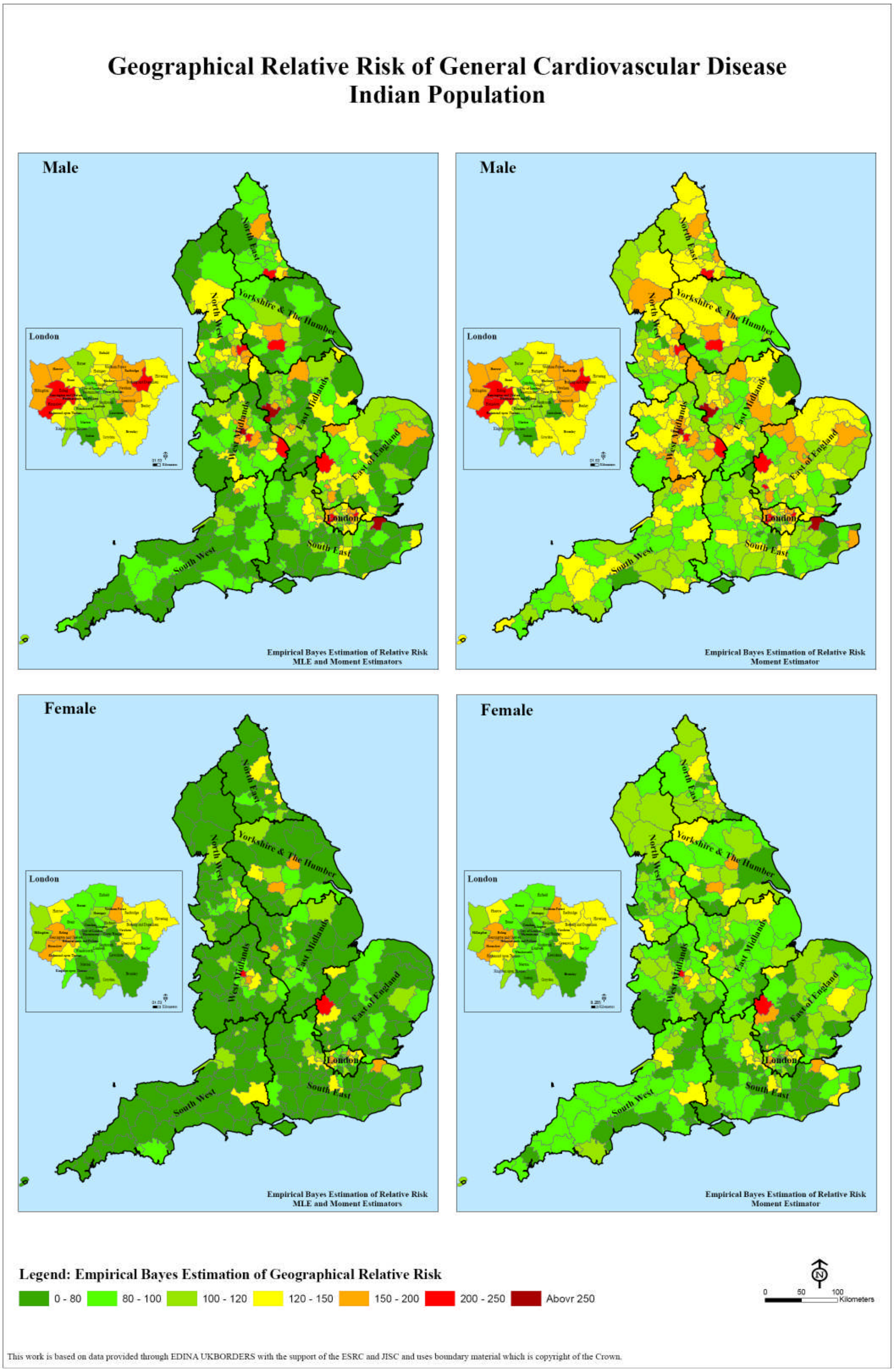


Figure 5-19 Geographical relative risk of cardiovascular disease for Indian population

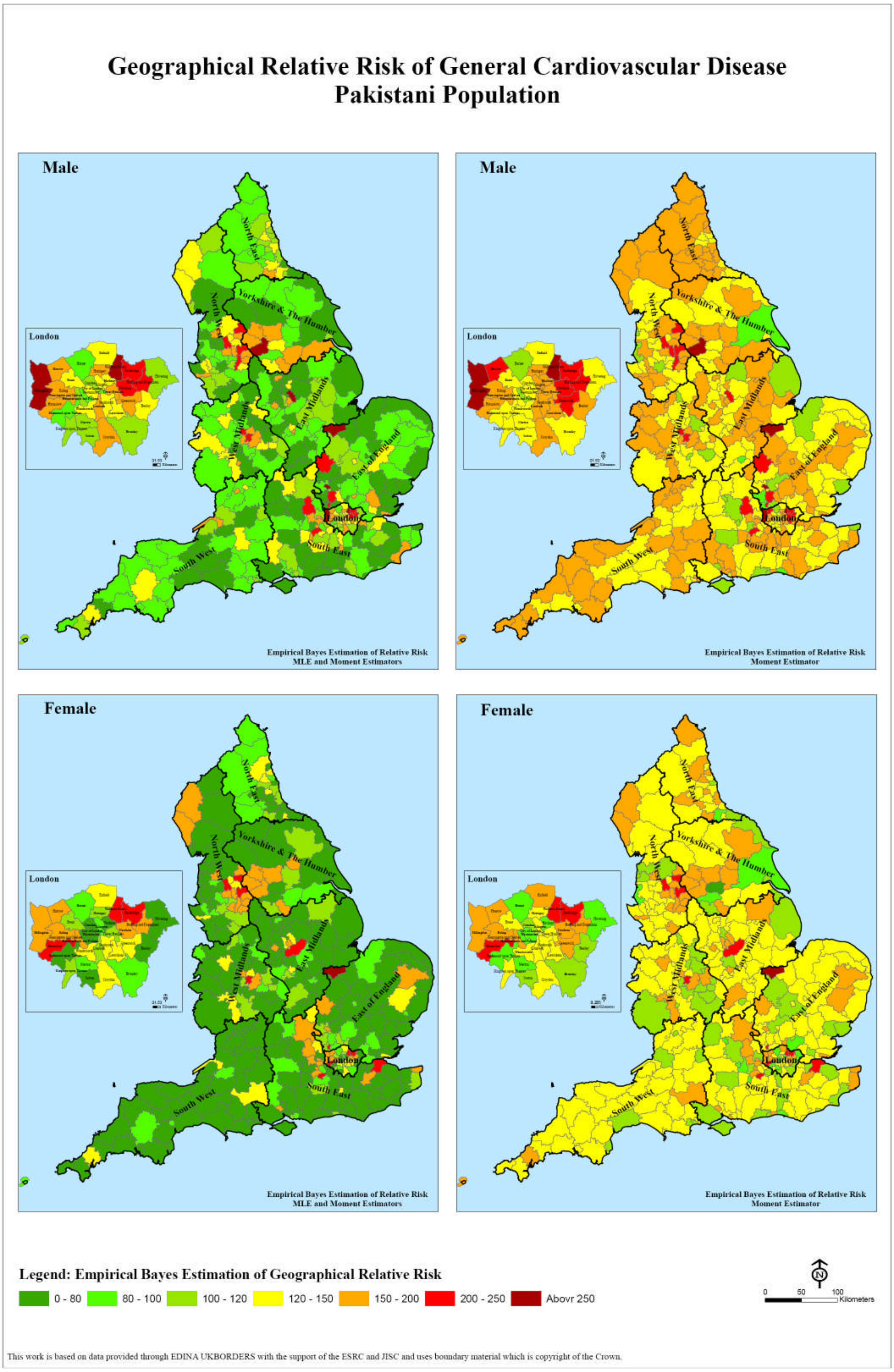


Figure 5-20 Geographical relative risk of cardiovascular disease for Pakistani population

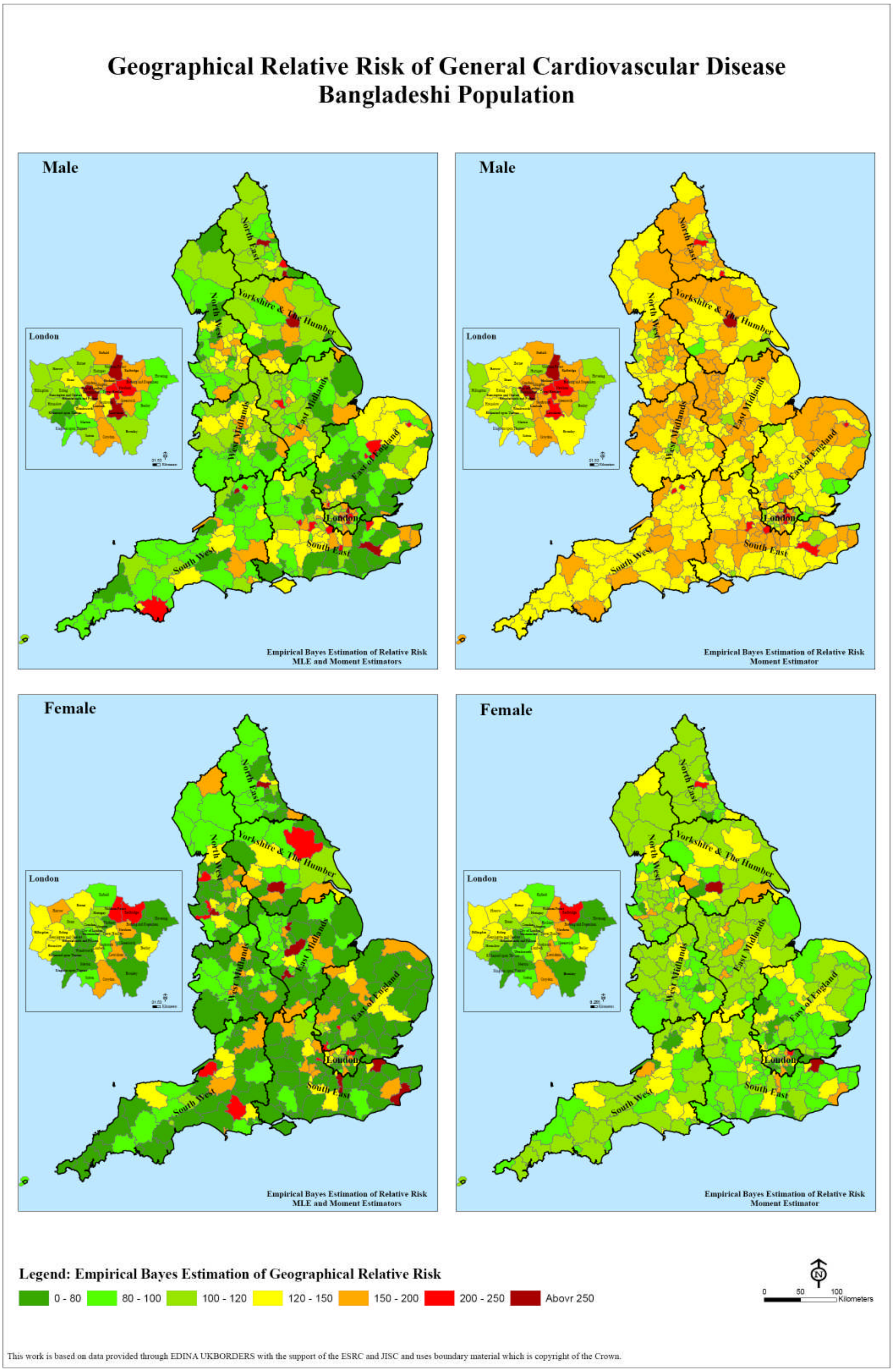


Figure 5-21 Geographical relative risk of cardiovascular disease for Bangladeshi population

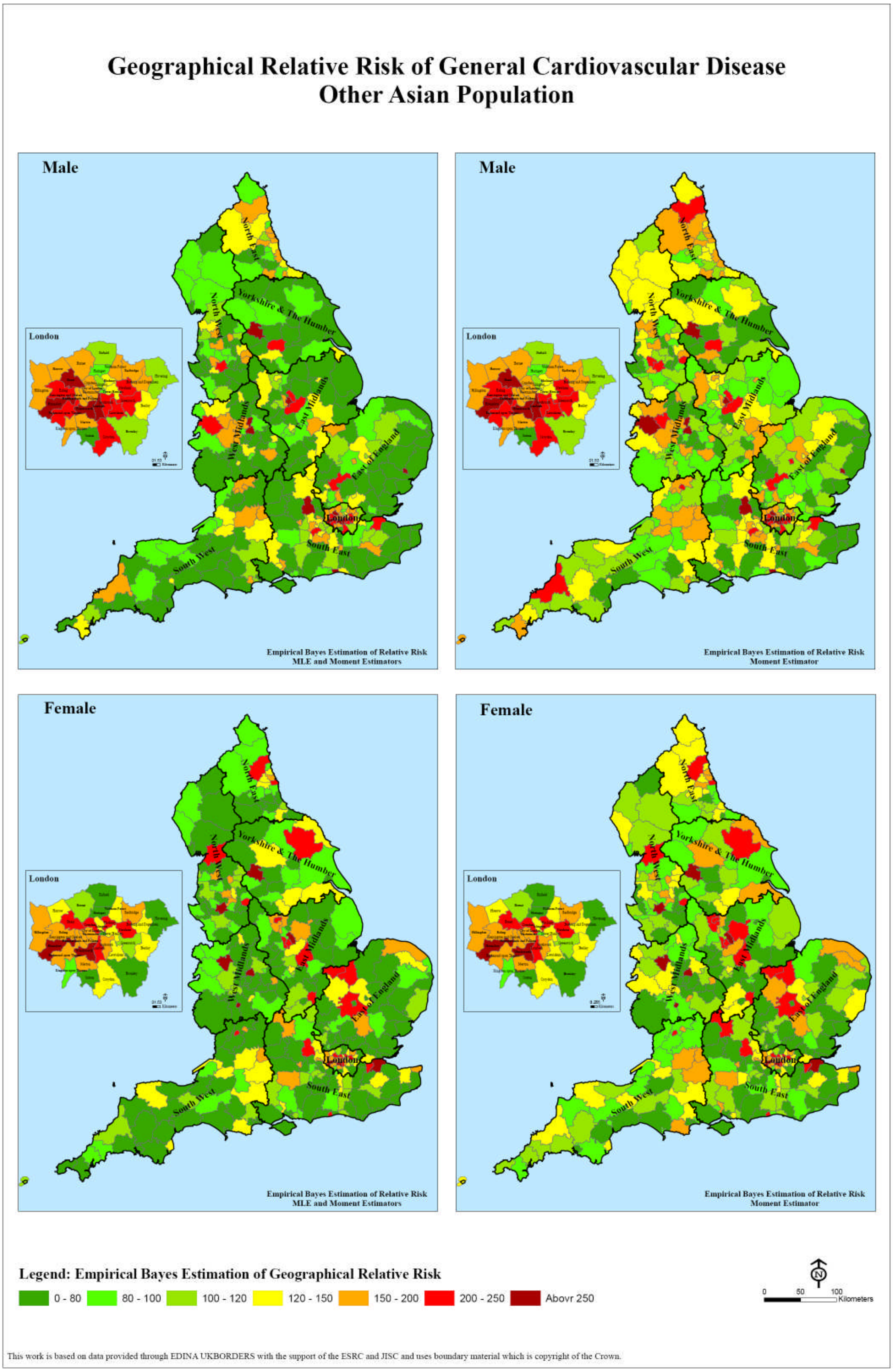


Figure 5-22 Geographical relative risk of cardiovascular disease for Other Asian population

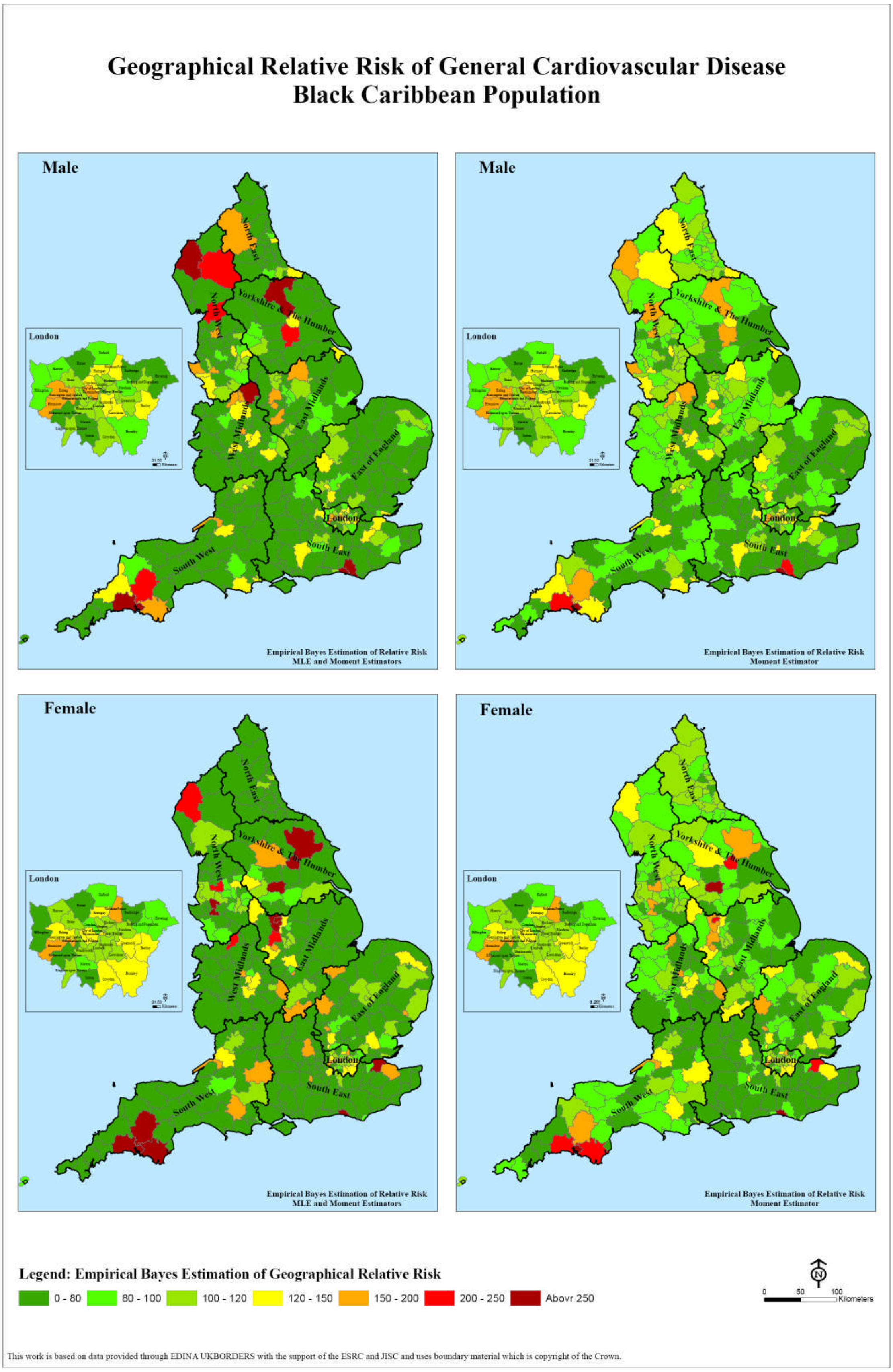


Figure 5-23 Geographical relative risk of cardiovascular disease for Black Caribbean population

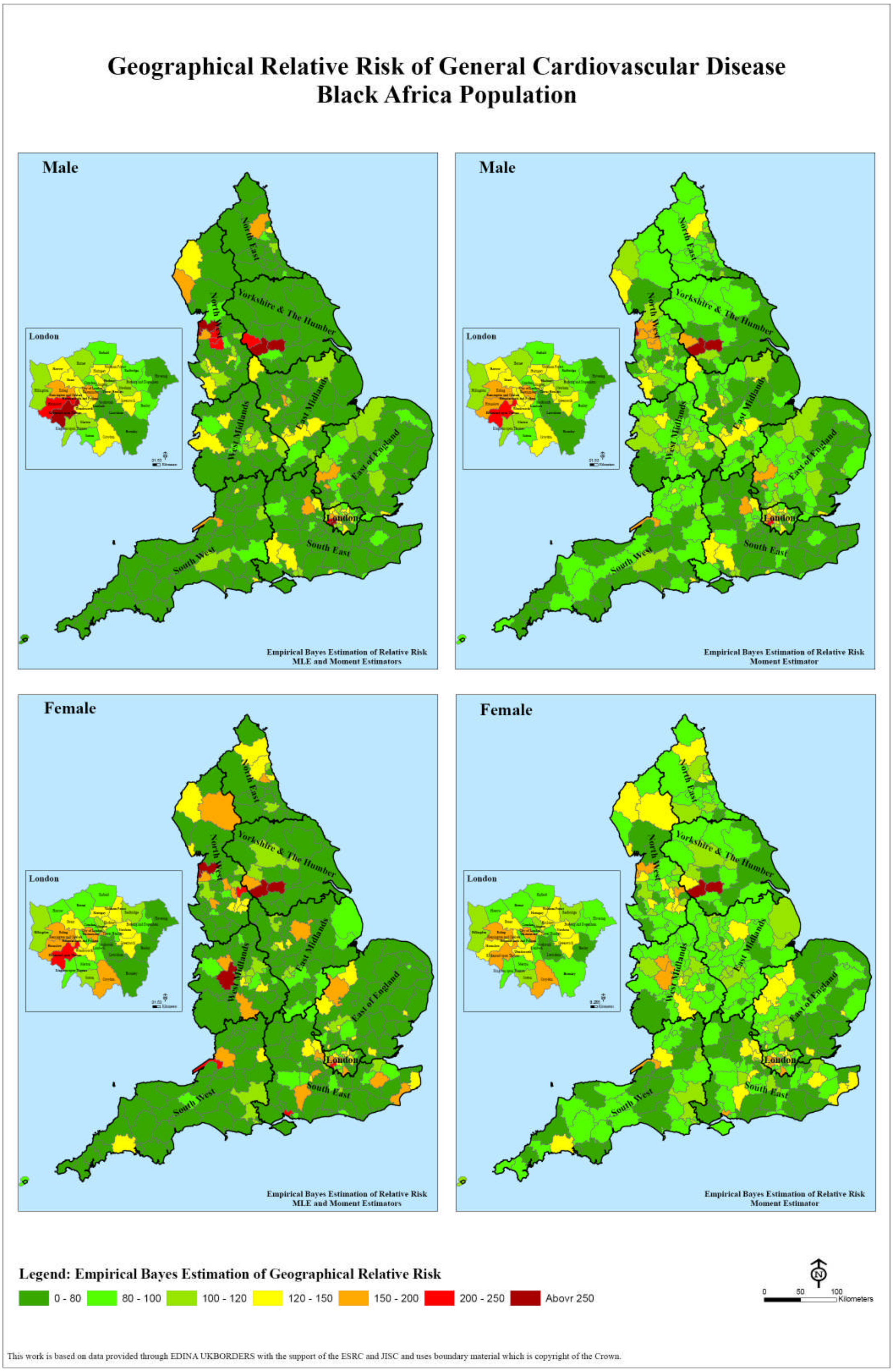


Figure 5-24 Geographical relative risk of cardiovascular disease for Black Africa population

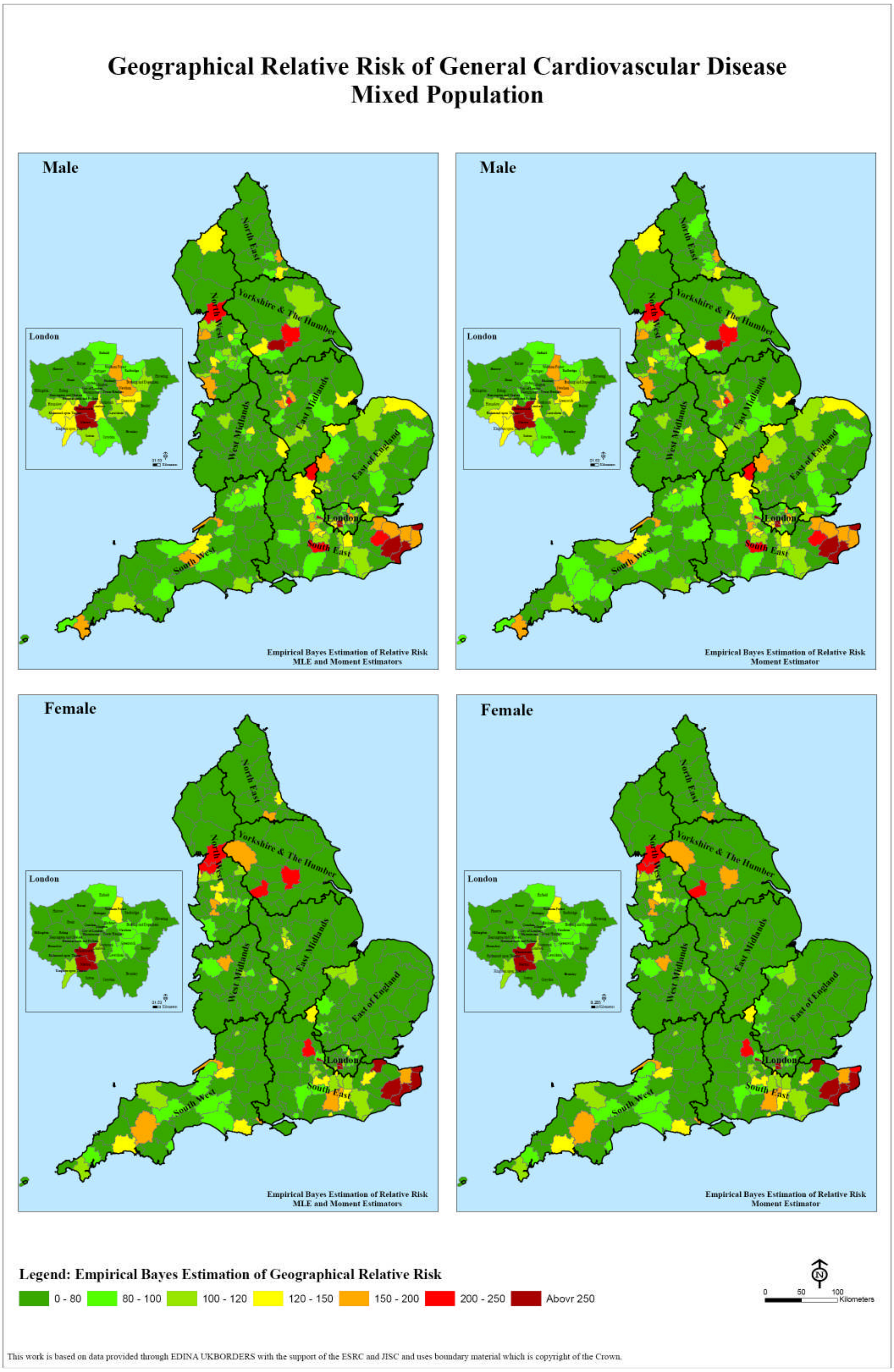


Figure 5-25 Geographical relative risk of cardiovascular disease for Mixed population

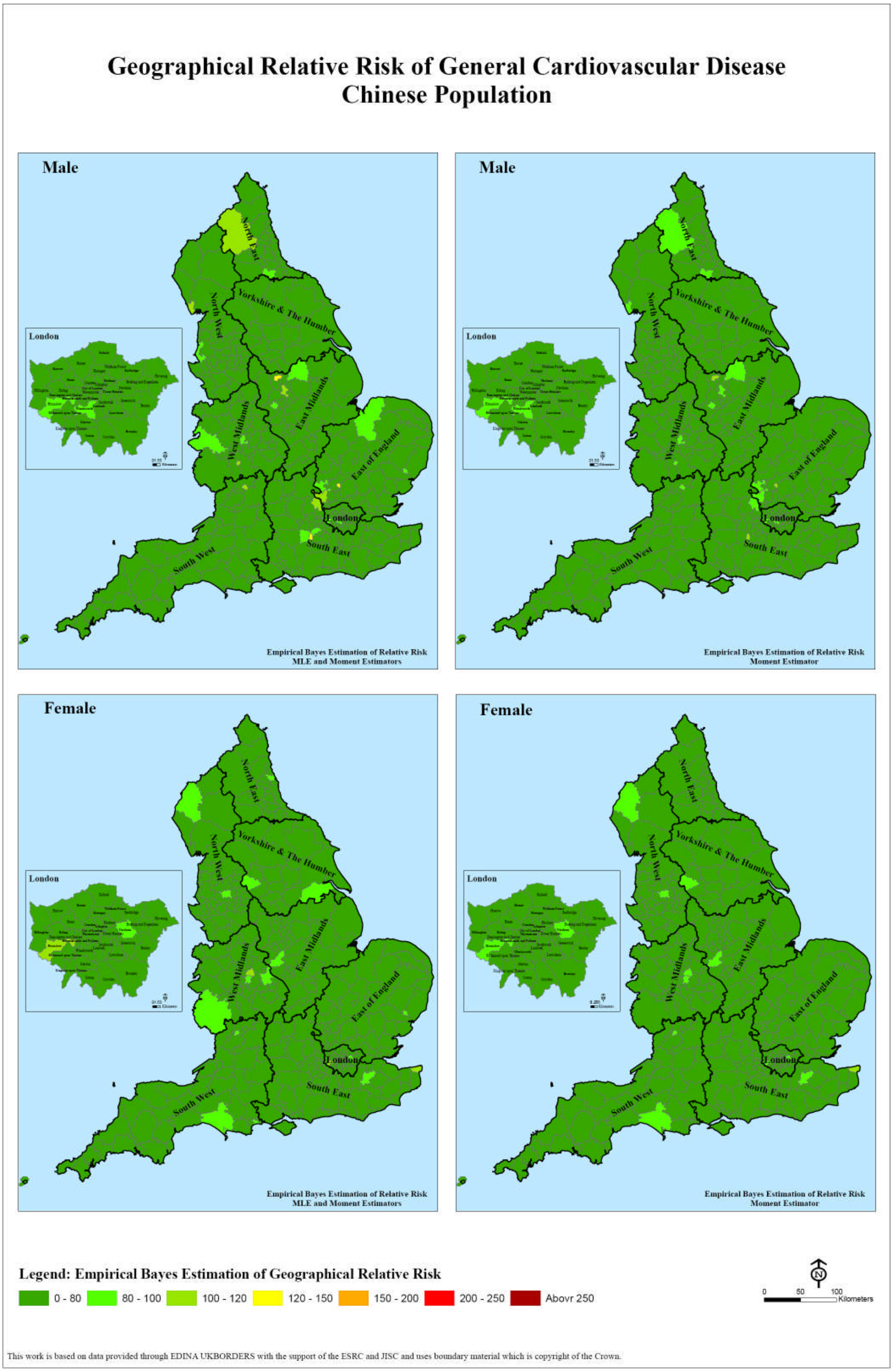


Figure 5-26 Geographical relative risk of cardiovascular disease for Chinese population

5.5 Discussion

Ethnic inequalities in cardiovascular disease in the UK have been highlighted in some national surveys and previous studies. More specifically, this study has further examined ethnic inequalities in cardiovascular disease, using a more detailed classification of ethnicity, a larger geographical coverage and a finer geographical scale.

Compared with the ethnic inequalities in cardiovascular disease identified in the Fourth National Survey of Ethnic Minorities (1993 to 1994) (Nazroo, 1997), the Health Survey for England 1999 (Primatesta and Brooks, 2001) and the Health Survey for England 2004 (Mindell and Zaninotto, 2005), the patterns of the standardised incidence ratios of cardiovascular disease for ethnicity-sex groups in England based on the Hospital Episode Statistics 2004 indicate that the pattern of ethnic inequalities in cardiovascular disease in the UK has changed little over 10 years. In brief, South Asian people have highly excess standardised incidence ratios in all the cardiovascular diseases studied, particularly Bangladeshi and Pakistani people. Both Black Africa and Black Caribbean people are healthier in most cardiovascular diseases, but have higher prevalence of stroke and hypertensive heart disease. Significant lower prevalence of cardiovascular disease is found among Chinese and Mixed populations. This study also examined ethnic inequalities in heart failure and rheumatic heart disease.

One of the notable findings is that Other Asian people, for which group little research on cardiovascular disease has been done, are found to have a significantly high risk of most cardiovascular diseases than the general population. The Other Asian group was first introduced in the ethnicity classification of the 2001 England/Wales Census. The increased risk of cardiovascular disease for the Other Asian group might be because a large proportion of Other Asians have a South Asian origin. According to the 2001 Census, 31 per cent of people describing themselves as Other Asian were born in the

United Kingdom, 24 per cent were born in Sri Lanka, 16 per cent were born in a Middle East country and 11 per cent were born in an African country. In terms of region of birth, around 36 per cent were born in South Asian. In addition, for the Other Asians born in the UK (31 per cent of Other Asian people), most are second and third generation descendants of Pakistani, Bangladeshi and Indian migrants. (Gardener and Connolly, 2005) Given that South Asians have a significantly high risk of cardiovascular disease, it is not surprising that the standardised incidence ratios for Other Asians are particularly high in most cardiovascular diseases.

However, it is difficult to explain the lower risk of all types of cardiovascular disease for Mixed groups in terms of the ethnic origins of people classifying themselves as Mixed ethnicity. Mixed ethnicity is a group of great diversity of ethnic origins. The main Mixed ethnic groups are Mixed White and Black Caribbean, Mixed White and Black African, Mixed White and Asian and Other Mixed (Bradford, 2006). As there are many countries in Africa and Asia, there are a great number of identities in the Mixed group. It should be acknowledged that people classifying themselves into Mixed groups may share none of the attributes that define an ethnic group, such as physical appearance, subjective identification, cultural and religious affiliation, national and regional origins, and language etc (Bradford, 2006). Thus the risk of cardiovascular disease for individuals from Mixed group with distinct background may be much less homogeneous than that for individuals from other ethnic groups, such as Black Caribbean, Indian and Chinese. Although Mixed people on average have lower risk of most cardiovascular diseases than the general population, there might be significant variations of the risk of cardiovascular disease between sub groups of Mixed ethnicity.

Apart from the national standardised incidence ratios, the geographical relative risk of cardiovascular disease in 354 local authorities in England also has been examined for ethnic groups. Two empirical Bayes estimation methods, i.e. the Clayton and Kaldor (1987) method and the Marshall (1991) method, are employed to overcome the small number problem for ethnic minorities. However, when studying geographical relative risk of cardiovascular disease, particularly for minority ethnic groups, we should be aware of the uncertainties of the results when using different methods. Difference has been observed in the results of the two methods for minority ethnic groups, because these two methods shrink the local relative risk towards different “average relative risk”, i.e. overall mean of local relative risk in the Clayton and Kaldor (1987) method and the national SIRs for that group in the Marshall (1991) method. Compared with the overall mean of local relative risk, moving the local relative risk towards the national SIRs seems more sensible for minority ethnic groups. This method also can retain the gender difference in the relative risk of cardiovascular disease.

Whichever method is used, the geographical relative risk of cardiovascular disease is reliable in areas with large ethnic minority populations. In particular, the risk of cardiovascular disease for minority ethnic groups, particularly South Asians and Other Asians, is stably significantly high in local authorities located in London, where nearly half the ethnic minorities are living. There is a theory about ethnic density effect on health, which suggests that living in an area with a relatively high proportion of a person’s own ethnic group has a protective effect on ethnic minorities’ health, because ethnic concentration enhances social support, releases chronic stressors, such as racial harassment and encourages healthy behaviour (Smaje, 1995). However, it seems that the ethnic density effect is great on mental health (Halpern and Nazroo, 2000, Whitley et al., 2006), but not on cardiovascular disease, or has been offset by the effect of socioeconomic status.

The higher ratios for South Asians, Other Asian and Black population in local authorities located in London are probably mainly due to the low socioeconomic status of ethnic minorities in London, particularly for Bangladeshi and Pakistani Londoners. According to the Annual Population Survey for 2006, the employment rate of BAME (Black, Asian and Minority Ethnicity) Londoners was 58 per cent, compared with the employment rate for White Londoners (75 per cent). In particular, the employment rate of persons at working age excluding full-time students was 42 per cent for Bangladeshi Londoner, 54 per cent for Pakistani Londoner and 66 per cent for Black Africa and Other Asian Londoners (Greater London Authority, 2008), which were also much lower than the national average employment rates of these groups. The national employment rates for Bangladeshi, Pakistani, Other ethnic group, and Black African groups were around 85 per cent (Office for National Statistics, 2005). In addition, Bangladeshi, Pakistani and Black Caribbean Londoners have a high level of overcrowding, living in social rented accommodation, low qualification and low social class (Piggott, 2004, Piggott, 2005, Cameron, 2008). However, low socioeconomic status might not be an explanation of Indian Londoners' higher ratios. Indian Londoners show a relatively high rate of employment, 75 per cent (Greater London Authority, 2008). Indian Londoners also have a higher level of high qualifications (Cameron, 2008).

Chapter Six: Ethnic Inequalities in CVD and SES

6.1 Introduction

There have been consistent findings about ethnic inequalities in cardiovascular disease, such as the notable national surveys, the Fourth National Survey of Ethnic Minorities, the Health Survey for England 1999 and the Health Survey for England 2004. In the previous chapter, ethnic inequalities in cardiovascular disease have been further investigated using the Hospital Episodes Statistic data, which include information about more specific cardiovascular disease, more detailed classification of ethnicity, larger geographical coverage and finer geographical scale. Significant ethnic disparities have been identified in different types of cardiovascular disease at English national level as well as in the geographical relative risk of cardiovascular disease. In general, South Asian and Other Asian people have particularly high standardised incidence ratios in all the cardiovascular diseases studied, particularly Bangladeshi and Pakistani people. Black Africa and Black Caribbean people are less healthy in stroke and hypertensive heart disease than other ethnic groups. Chinese people and people from Mixed group have the lowest standardised incidence ratios in most cardiovascular diseases.

Although a large number of papers have tried to explain ethnic inequalities in cardiovascular disease from the perspective of classical risk factors (Cappuccio et al., 1997, Ehtisham et al., 2005, Teers, 2001), novel risk factors (Bhatnagar et al., 1995, Danesh et al., 2004, Forouhi and Sattar, 2006), gene-environment interactions (Bhatnagar et al., 1995, Khunti and Samani, 2004, Patel et al., 2006) and racial discrimination (Williams et al., 2003, Virdee, 1997, Nazroo, 2003b), particularly for South Asians, little is known to what extent these factors contribute to the observed ethnic inequalities in cardiovascular disease. Showing higher level of these cardiovascular risk factors doesn’t necessarily mean higher incidence and mortality from cardiovascular disease. The presence and severity of risk factors did not seem to fully explain ethnic inequalities in cardiovascular morbidity and mortality.

Given the association between socioeconomic status and cardiovascular disease, and the generally low socioeconomic position of some ethnic minority groups, socioeconomic status inequalities across ethnic groups might be the main determinant of ethnic inequalities in cardiovascular disease. However, few studies examined to what extent socioeconomic status contribute to ethnic inequalities in cardiovascular disease.

This chapter is going to examine the relationships between socioeconomic status and the ethnic inequalities in cardiovascular disease, investigating to what extent socioeconomic status inequalities contribute to ethnic inequalities in cardiovascular disease. The first aim of this chapter is to further examine to what extent there are ethnic inequalities in cardiovascular disease between neighbourhoods with different socioeconomic status profiles by linking the Hospital Episode Statistics to the geodemographics data, the UK 2001 Area Classification. The second aim of this chapter is then, given that there is no individual socioeconomic status measures in the HES, to explore the effect of areal socioeconomic status on the ethnic inequalities in different types of cardiovascular disease, to investigate whether the effect on cardiovascular disease is constant for different ethnic groups, to examine whether the effect of areal socioeconomic status measures is constant when the areal socioeconomic status is measured in different ways and at different geographical scales.

6.1.1 Geodemographics for Ethnic Inequalities in CVD

Geodemographics is “the analysis of people by where they live” (Sleight, 1997), which classifies small geographical areas into groups according to the similar characteristics of interest within them, or according to the 'type' of people who live there (Batey and Brown, 1994, Brown et al., 2000, Webber, 2004a), originating from research commissioned by the Office for Population Census and Surveys (now the Office for National Statistics - ONS) and the Department of Environment in the late 1970s. By clustering a large number of small areas into a handful of groups which share similar properties, understanding of the areas is greatly enhanced (Vickers and Rees, 2007).

Geodemographics is continuously and widely adopted and extended in business since it was developed, in order to support decision making about branch openings, closures, and company mergers (Birkin and Clarke, 1998, Malley, 1995), in order to profile and target customers and generate new business (Mitchell, 1994, Sleight, 1997, Harris et al., 2005). Geodemographics is also increasingly used by geographers and social scientists who are interested in the spatial patterning of social behaviours, such as crime (Ashby, 2004), pupil’s performance (Farr, 2006) and general elections (Webber, 2006). However, evidence of effectiveness of geodemographics in the public health setting is less developed. Geodemographics has not been extensively explored in relation to health outcomes (Dedman et al., 2006).

Geodemographics is of potential for public health. Geodemographics is useful in identifying potential groups or areas for designing disease prevention, health campaigns and promotion. By linking geodemographics with health-related data, it will be possible to understand what type of neighbourhoods show a higher incidence rate of a certain disease or higher propensity towards unhealthy lifestyles, and where these neighbourhoods are. It is also possible to gain insight about residents within a target neighbourhood, such as their probable income, education, housing type, consumption patterns etc. from the detailed descriptive data for each geodemographics group. Disease prevention, health campaigns and promotion activities can be focused on the residents living in these neighbourhoods (Ward, 2005, Jones et al., 2006).

Studies on application of geodemographics in health are growing. Webber (2004b) summarised the key difference between hospital admission rates and Mosaic types, which is the most widely used postcode classification in the UK, by linking the Mosaic codes to the Hospital Episode Statistics. He also suggested that geodemographics may be also efficient in assessing health care need at highly local level, besides in targeting specific health campaigns. Dedman et al. (2006) used the same data, but identified neighbourhood types with particularly high (or low) rates of emergency admissions for violence, alcohol-related hospital admissions and hip replacement operations. By linking life style survey to geodemographics classification, Jones et al. (2006) explored the use of geodemographics data in capturing differential life style behaviours and suggested the results could not only help to target population groups in health promotion but also provide a measure to evaluate the appropriateness of resource allocation.

Despite the potential of geodemographics for health studies and the discriminatory power in targeting health promotion and allocating recourse, there are some potential limitations and uncertainties around their use. Flowerdew and Leventhal, (1998) pointed out that there was no formal proof and no ‘theory of geodemographics’ either, only the concept that ‘birds of a feather flock together’. In addition, the reliance of geodemographics on the relationships between areal characteristics and people behaviour make it very susceptible to the modifiable areal unit problem (MAUP) and the ecological fallacy (Debenham et al., 2001). Geodemographers were also concerned that the construction of the typology arbitrariness and lack of validation (Vickers, 2006). This is because running a cluster analysis requires a series of steps, i.e. select input variables and select weight, where each step is usually made according to experience rather than stable rules (Dedman et al., 2006). This will bring some uncertainties to geodemographics classifications.

In this chapter, geodemographics is used to identify the ethnic inequalities in cardiovascular disease in neighbourhoods with different socioeconomic status profiles by linking the UK 2001 Areal Classification to the Hospital Episode Statistics. The process of the linking has been introduced in Chapter Three: Data and Methods. In brief, all the local authorities that belong to the same geodemographics group have been conceptually aggregated. And the standardised incidence ratios of cardiovascular disease are calculated for each ethnicity-sex group in each geodemographics group using the Hospital Episode Statistics. And the results are presented in section 6.2.

6.1.2 Measuring the Effect of Areal Socioeconomic Status

The second aim of this chapter is to measure the effect of socioeconomic status on ethnic inequalities in different types of cardiovascular disease. However, given that individual socioeconomic status measures are not available in the HES, areal socioeconomic status measures are used as proxy for individual socioeconomic status.

Individual socioeconomic status measures are good predictors of health; however, they are often not available for analysis, but the same measures are only available at aggregate levels. In some studies, purpose-designed individual level survey data have been collected, however, they often lack sufficient sample size to analyse small subgroups effectively or to allow geographical disaggregation (Fieldhouse and Tye, 1996). An alternative method is to use areal socioeconomic status to substitute individual socioeconomic status, termed as ecological study, by cautiously linking individual's geographical variables to census or other information-rich data. This is the case in this study. Assuming that the characteristics of socioeconomic status within the geographical area are stable and homogeneous, the aggregate data substitute for individual socioeconomic status in the form of means or percentage of the unavailable individual level variables at a specified geographical level, which is assigned to each individual in the analysis. Defined to be comparable to individual socioeconomic status, the aggregate variables would hypothetically get the similar estimate as the individual socioeconomic status in models (Geronimus, 2006).

6.1.2.1 Measuring Areal Socioeconomic Status for Ethnic Groups

Before exploring the effect of areal socioeconomic status on ethnic inequalities in cardiovascular disease, areal socioeconomic status should be measured for ethnic groups. Normally, in studies on the effect of areal socioeconomic status on population health, areal socioeconomic status is measured generally for the whole population within the neighbourhood, assuming that all the residents within the same neighbourhood will have the same level of areal socioeconomic status. As shown in the figure below, for this study, residents living in the same neighbourhood, no matter which ethnic groups they are belonging to, are supposed to experience similar areal socioeconomic deprivation. English Indices of Multiple Deprivation 2004, which has been introduce in Chapter Three, is a good data source of areal socioeconomic status measures for ethnic groups, covering England with seven domains, including Income Domain, Employment Domain, Education, Skills and Training Domain, Barriers to Housing and Services Domain, The Living Environment Domain and Crime Domain.

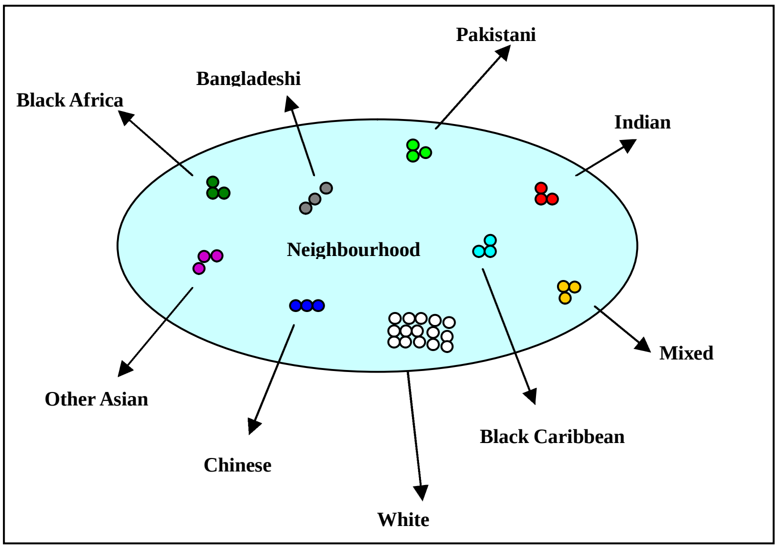


Figure 6-1: Measurement of areal socioeconomic status for ethnic groups-method one

However, compared to the general population, people from certain ethnic minority groups are usually of low socioeconomic status. Areal measures based on the whole population might not be able to reflect the actual area deprivation of different ethnic groups. It is more sensible to measure the areal socioeconomic status specifically for different ethnic groups. As shown in the figure below, in this hierarchical structure, a neighbourhood could be conceptually divided into different ethnic groups or ethnic communities. Individuals within the same ethnic group in the same neighbourhood will have the same level of area measures. And people from different ethnic groups even within the same neighbourhood will experience different level of deprivation. Even the measurement is based on the aggregation of individuals from the same ethnic groups, it must be acknowledged that the aggregation will omit the heterogeneity of socioeconomic status between individuals in the same ethnic group. The UK 2001 Census is the only data source in the UK that has collected socioeconomic status measures by ethnic groups at small area level, which has been employed in this chapter.

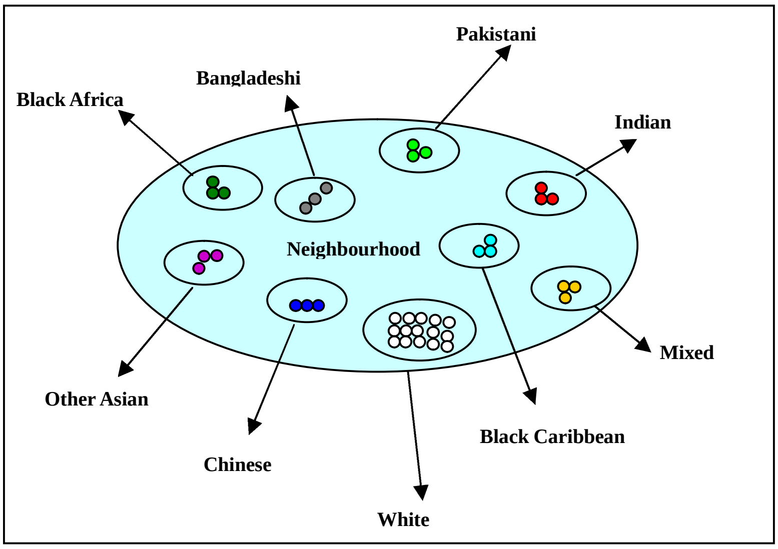


Figure 6-2: Measurement of areal socioeconomic status for ethnic groups-method two

In order to examine the influence of measurement methods of areal socioeconomic status for ethnic groups on the effect of areal socioeconomic status on the ethnic inequalities in cardiovascular disease, both the English Indices of Multiple Deprivation 2004 and the 2001 Census are employed as areal socioeconomic status measures in this study.

In addition, measuring areal socioeconomic status is subject to the Modifiable Areal Unit Problem (MAUP), which refers to the phenomenon that statistical results defined over a set of essentially arbitrary areal units vary according to at which geographical scale the analysis is conducted and how the geographical boundaries are drawn at that scale (Flowerdew et al., 2001) The Modifiable Areal Unit Problem has two fundamental issues, a scale problem and an aggregation (or zonation) problem (Openshaw and Taylor, 1979, Wong and Amrhein, 1996). On one hand, when data at basic units are aggregated to a large geographical scale, much of the geographical variation is lost, although this will provide more stable rate or percentage. On the other hand, more geographical variations will be kept when aggregated to a relatively small level. However, this might result in an unreliable rate because the denominator population is small. An aggregation problem is variation resulting from grouping small areas into large units, particularly when there are many different possible ways for aggregation. Although most geographical studies are likely to aggregate units within a certain geographical boundary, it is possible to aggregate units which are not necessarily spatially connected but are based on some other criterion. (Openshaw and Taylor, 1979, Wong and Amrhein, 1996)

In this study, the effect of areal socioeconomic status measured at different geographical scales on the ethnic inequalities in different types of cardiovascular disease is investigated. Areal socioeconomic status is measured at both Standard Table (ST) ward level and local authority level. ST ward is geographic unit used in the UK 2001 Census Standard Tables. There are a total of 7932 ST wards and 354 local authorities in England.

6.1.2.2 Method for the Small Population Problem

Multiple logistic regression and multilevel logistic regression have been employed to model the relationships between areal socioeconomic status and ethnic inequalities in different types of cardiovascular disease. These two methods have been introduced in detail in Chapter Three and will not be introduced here. Both of the multiple logistic regression models and the multilevel logistic regression models are fitted in *Event*/*Trial* format rather than *0/1* binary response format. And the number of the events should be less than or equal to the number of the trials, since there is no reason that the number of events is greater than the number of trials. In this study, *Event* is the number of cardiovascular disease cases observed in a local area-age-sex-ethnicity group, which can be extracted from the Hospital Episode Statistics. *Trial* is the population for that local area-age-sex-ethnicity group, which is available in the UK 2001 Census. So the number of cardiovascular disease cases for a local area-age-sex-ethnicity group should be less or equal to the population for that local area-age-sex-ethnicity group.

In the UK 2001 Census, in order to prevent disclosure of individual information, the Office for National Statistics has eliminated all 1s and 2s in census tables to be produced by rounding the number to either zero or a multiple of 3 (Office for National Statistics, 2002). In terms of the population tables, the rounding is much more likely to occur to minority ethnic groups, because the size of population is very small at small area level, particularly when disaggregated into age-sex groups. Thus a large proportion of either ST ward-age-sex-ethnicity or local authority-age-sex-ethnicity groups for minority ethnic groups have population of either 0 or 3. However, it is often the case that one or two cardiovascular disease cases have been recorded in the HES for those local area-age-sex-ethnicity groups. In this situation, all these observations have to be deleted in the logistic regression models because the number of trials is less than the number of events. As nearly all the observations that have to be deleted are from minority ethnic groups, this introduces bias to the results by underestimating the relative risk of cardiovascular disease for minority ethnic groups.

A method has been developed to overcome this small population problem by aggregating all the local area-age-sex-ethnicity groups that have population either 0 or 3 according to their geodemographics groups in the UK 2001 Area Classification. The

UK 2001 Area Classification grouped together geographic areas with more similar characteristics, mainly socioeconomic and demographic characteristics. By aggregating the local area-age-sex-ethnicity groups with similar socioeconomic status profiles into area classification-age-sex-ethnicity groups, the small population problem could be overcome and the socioeconomic status profiles for those local area-age-sex-ethnicity groups have been maintained as well. In this study, in the two separate models conducted at ST ward level or local authority level, the local area-age-sex-ethnicity groups that have population either 0 or 3 have been aggregated into either ST ward level area classification groups or local authority level area classification groups for analysis.

6.1.2.3 The Ecological Fallacy

As this study uses areal socioeconomic measure alone to make inference about individual-level relationships, it is acknowledged that it can introduce bias, known as the ecological fallacy (Selvin, 1958, Firebaugh, 1978).

The ecological fallacy was first explained formally in 1950 by William Robinson (Robinson, 1950). It arises from assuming that the effects of the variables obtained at group level are the same or similar at individual level. Although relations found among aggregated level variables do not mean the same relations will be observed among individual variables, there is evidence based on individual level supporting the conclusion that ecological correlations between socioeconomic deprivation and health could reflect associations among the relevant variables in individuals (MacRae, 1994). Substantial ecological studies have been widely conducted in health studies (Firebaugh, 1978, Schwartz, 1994, McLoone and Boddy, 1994, McCarron et al., 1994, Stewart and Kuulasmaa, 1994, Fieldhouse and Tye, 1996, Diez-Roux et al., 2000, Whitley et al., 1999, Franco et al., 2004, Geronimus, 2006, Wheeler et al., 2008). Geronimus (2006) concluded that as long as health data offer few other options, social researcher will continue to use areal socioeconomic measures to proxy for unavailable individual socioeconomic variables, with careful interpretation of study results.

6.2 Ethnic Inequalities in CVD between Geodemographics Groups

Ethnic inequalities in cardiovascular disease between geodemographics groups with different socioeconomic status profiles have been examined by linking a geodemographics dataset, the UK 2001 Area Classification, to the Hospital Episode Statistics. As shown in the following graphs, the standardised incidence ratios of cardiovascular disease for ethnicity-sex groups vary significantly between geodemographics groups with different socioeconomic status profiles, which provides some evidence that socioeconomic status might explain ethnic inequalities in cardiovascular disease to some extent.

6.2.1 White Population

The figure below shows how the standardised incidence ratios of cardiovascular disease for white population vary between geodemographics groups with different socioeconomic status profiles.

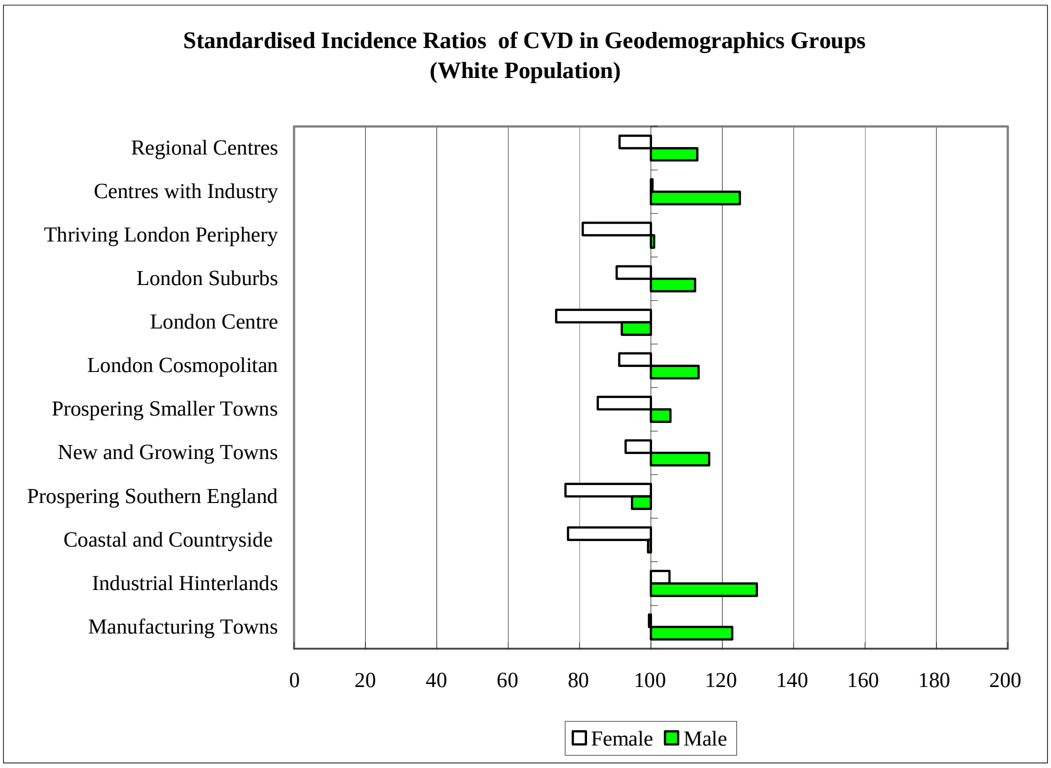


Figure 6-3: SIRs of CVD between geodemographics groups for White population

For white men, the standardised incidence ratios are above the national average in most geodemographics groups. They are relatively high in Centre with Industry, Industrial Hinterlands and Manufacturing Towns, but are relatively low in Thriving London Periphery, London Centres, Prospering Southern England, and Coastal and Countryside. Particularly for London Centre and Prospering Southern England, the standardised incidence ratios are moderately below the national average.

For white women, nearly all geodemographics groups have standardised incidence ratios below the national average, particularly London Centre, Prospering Southern England and Coastal and Countryside, with the exception of Industrial Hinterlands.

6.2.2 Indian Population

The figure below shows how the standardised incidence ratios of cardiovascular disease for Indian population vary between geodemographics groups with different socioeconomic status profiles.

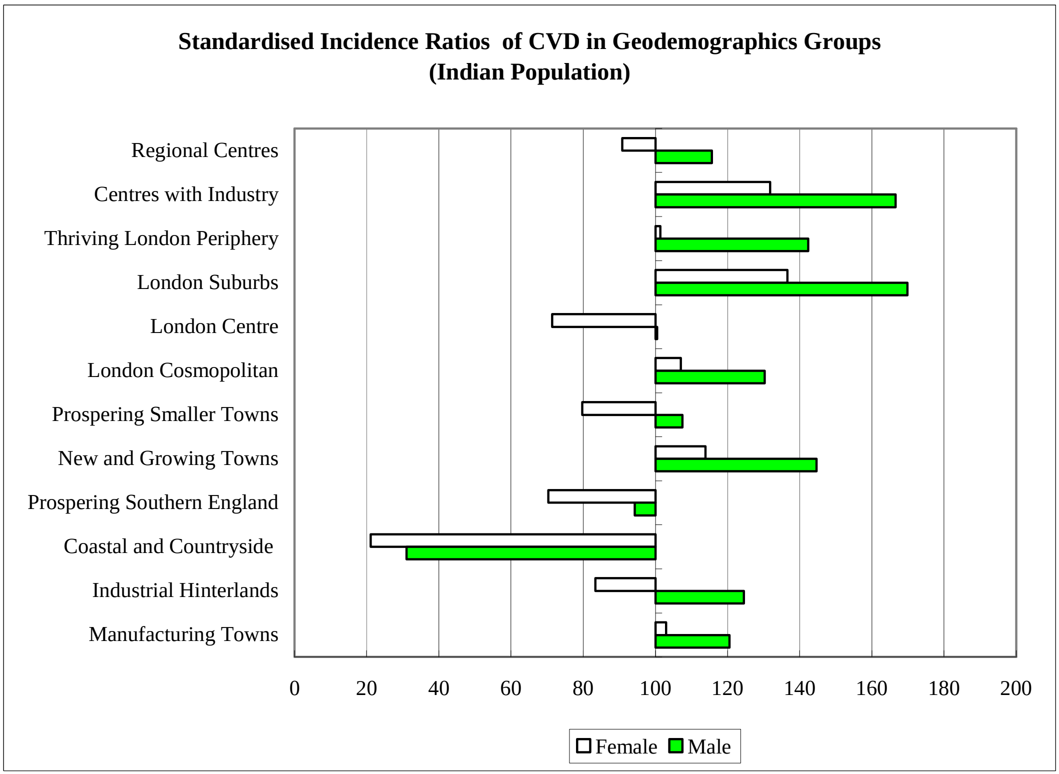


Figure 6-4: SIRs of CVD between geodemographics groups for Indian population

For Indian men, there are clear variations in the standardised incidence ratios among geodemographics groups. The standardised incidence ratios are particularly high in Centres with Industry, London Suburbs, Thriving London Periphery and New and Growing Towns, but relatively low in Coastal and Countryside, Prospering Southern England and London Centre.

For Indian women, they don't have similar patterns to Indian men. Although Indian people generally have a higher risk of cardiovascular disease, the standardised incidence ratios are only found relatively high in Centres with Industry and London Suburbs. The standardised incidence ratios are below the national average in Regional Centres, London Centre, Prospering Smaller Towns, Prospering Southern England, and Coastal and Countryside.

6.2.3 Pakistani Population

The figure below shows how the standardised incidence ratios of cardiovascular disease for Pakistani population vary between geodemographics groups with different socioeconomic status profiles.

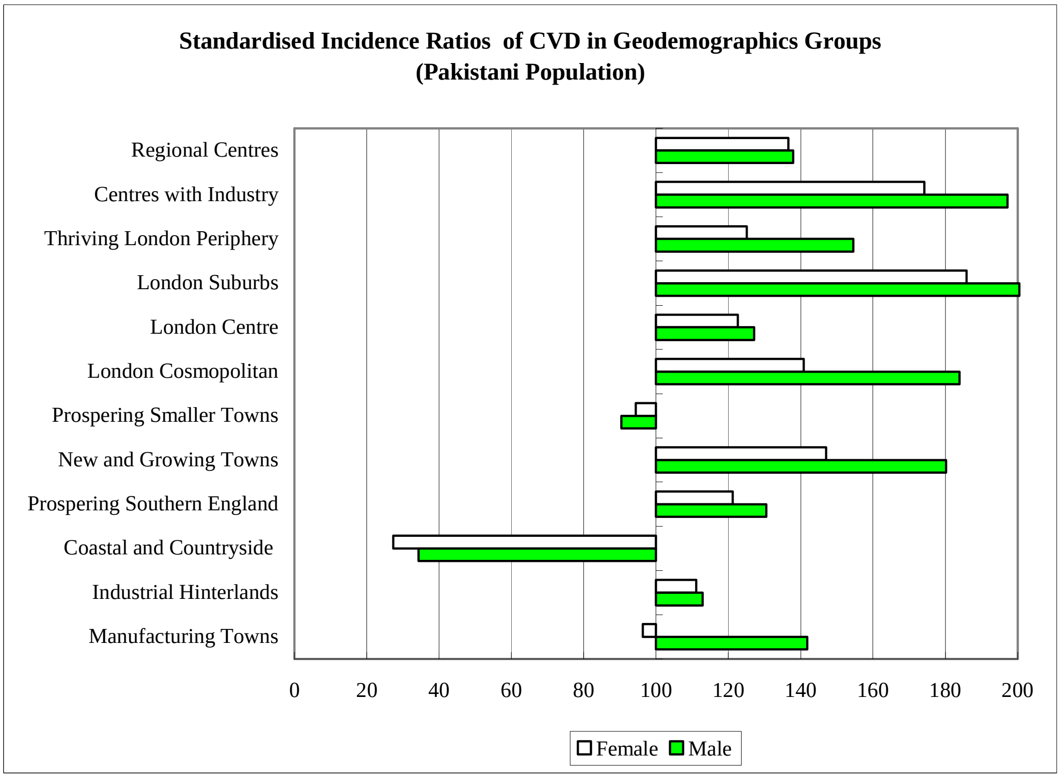


Figure 6-5: SIRs of CVD between geodemographics groups for Pakistani population

For Pakistani men, the standardised incidence ratios are extremely high in Centres with Industry, London Suburbs, London Cosmopolitan and New and Growing Towns. Compared with Pakistani men in these geodemographics groups, Pakistani men in London Centre, Prospering Southern England and Industrial Hinterlands are relatively healthy. The standardised incidence ratios in Prospering Smaller Towns and Coastal and Countryside are below the national average.

For Pakistani women, they have very similar patterns of the standardised incidence ratios between geodemographics groups to Pakistani men, although their standardised incidence ratios are not as high as those of Pakistani men. One exception is that the incidence ratio of Pakistani women in Manufacturing Towns is below the national average.

6.2.4 Bangladeshi Population

The figure below shows how the standardised incidence ratios of cardiovascular disease for Bangladeshi population vary between geodemographics groups with different socioeconomic status profiles.

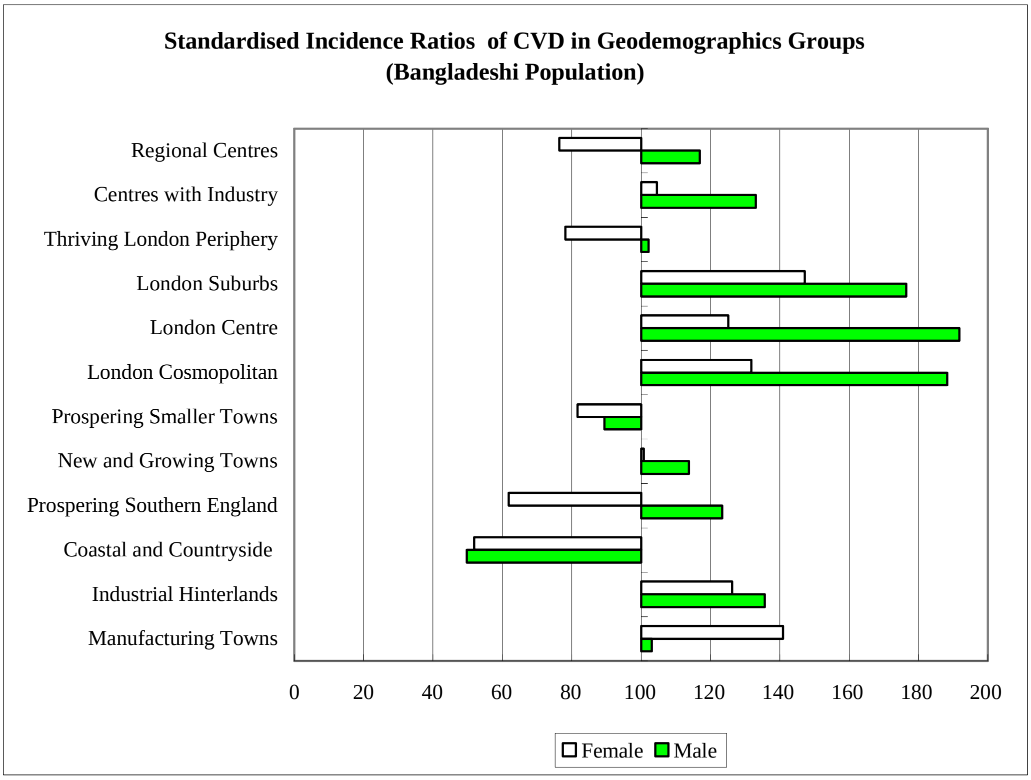


Figure 6-6: SIRs of CVD between geodemographics groups for Bangladeshi population

For Bangladeshi men, the geodemographics groups with extremely high standardised incidence ratios are London Suburbs, London Centre and London Cosmopolitan, which are all located in London. However, in contrast, all the other geodemographics groups don't have so high standardised incidence ratios. The standardised incidence ratios are relatively low in Thriving London Periphery, Prospering Smaller Towns, Coastal and Countryside, and Manufacturing Towns. It is surprising for Manufacturing Towns to have relatively low incidence ratio.

For Bangladeshi women, the standardised incidence ratios are relatively high in London Suburbs, London Centre, London Cosmopolitan, Industrial Hinterlands and Manufacturing Towns. For the other geodemographics groups, the standardised incidence ratios are either close to or lower than the national average, particularly for Prospering Southern England and, Coastal and Countryside.

6.2.5 Other Asian Population

The figure below shows how the standardised incidence ratios of cardiovascular disease for Other Asian population vary between geodemographics groups with different socioeconomic status profiles.

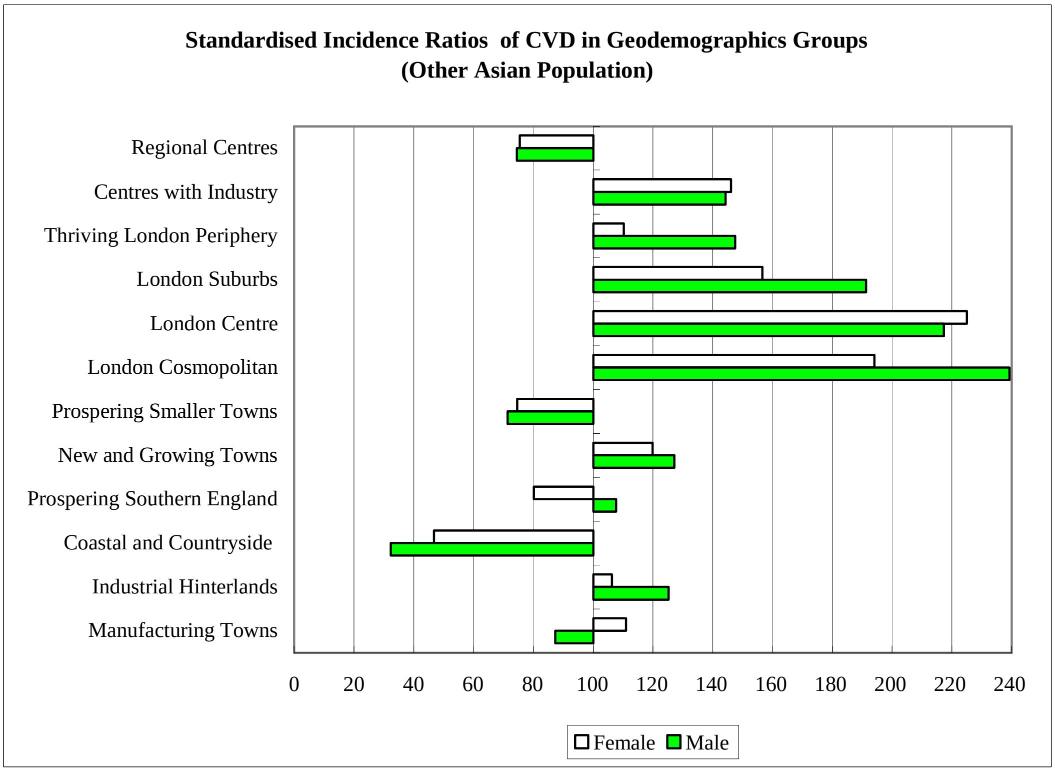


Figure 6-7: SIRs of CVD between geodemographics groups for Other Asian population

For Other Asian men, the standardised incidence ratios are relatively high in Centres with Industry and Thriving London Periphery, but are extremely high in London Suburbs, London Centre and London Cosmopolitan, which are all located in London. However, Other Asian men are relatively healthy in Regional Centres, Prospering

Smaller Towns, Coastal and Countryside and Manufacturing Towns.

For Other Asian women, there is a similar pattern of standardised incidence ratios in geodemographics groups to Other Asian men. Significantly high ratios are found in Centres with Industry and London areas, but lower in Regional Centres, Prospering Smaller Towns, Prospering Southern England, and Coastal and Countryside.

6.2.6 Black Caribbean Population

The figure below shows how the standardised incidence ratios of cardiovascular disease for Black Caribbean population vary between geodemographics groups with different socioeconomic status profiles.

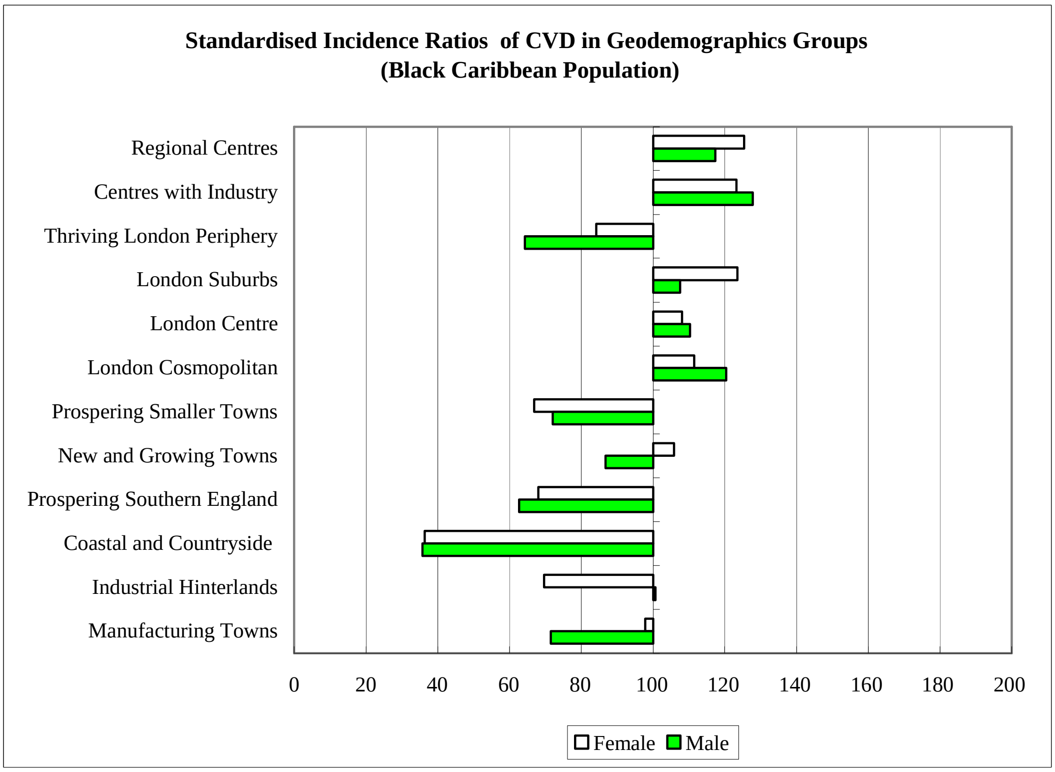


Figure 6-8: SIRs of CVD between geodemographics groups for Black Caribbean population

For Black Caribbean men, relatively high standardised incidence ratios are observed in Regional Centres, Centres with Industry and London Cosmopolitan. However, most other geodemographics groups have standardised incidence ratios lower than the national average. The standardised incidence ratios in Thriving London Periphery, Prospering Smaller Towns, Prospering Southern England, and Coastal and Countryside are significantly low.

For Black Caribbean women, they have relatively high standardised incidence ratios in Regional Centres, Centres with Industry and London Suburbs, but significantly low standardised incidence ratios in Prospering Smaller Towns, Prospering Southern England, Coastal and Countryside, and Industrial Hinterlands.

6.2.7 Black Africa Population

The figure below shows how the standardised incidence ratios of cardiovascular disease for Black Africa population vary between geodemographics groups with different socioeconomic status profiles.

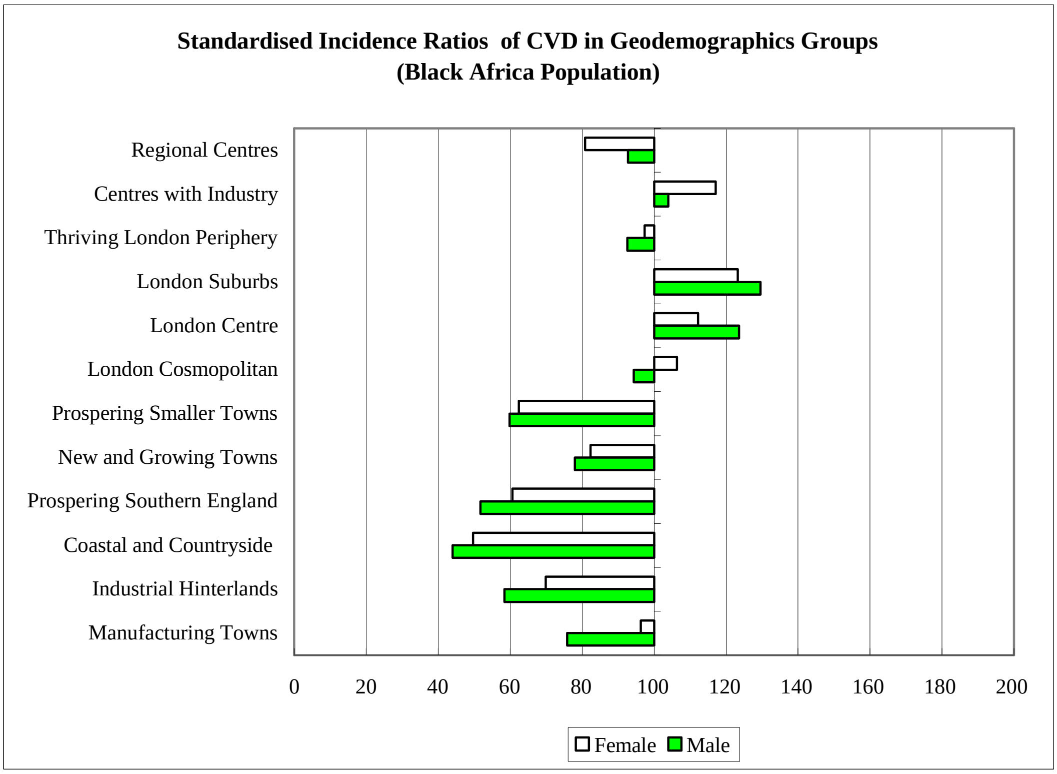


Figure 6-9: SIRs of CVD between geodemographics groups for Black Africa population

For Black Africa men, relatively high ratios are found in London Suburbs and London Centre. However, all the other geodemographics groups have standardised incidence ratios close to or lower than the national average. The standardised incidence ratios in Prospering Smaller Towns, Prospering Southern England, Coastal and Countryside, and Industrial Hinterlands are particularly low.

For Black Africa women, relatively high ratios are found in Centres with Industry, London Suburbs, London Centre and London Cosmopolitan. The standardised incidence ratios in all the other types are below the national average, particularly in Prospering Smaller Towns, Prospering Southern England, and Coastal and Countryside.

6.2.8 Mixed Population

The figure below shows how the standardised incidence ratios of cardiovascular disease for Mixed population vary between geodemographics groups with different socioeconomic status profiles.

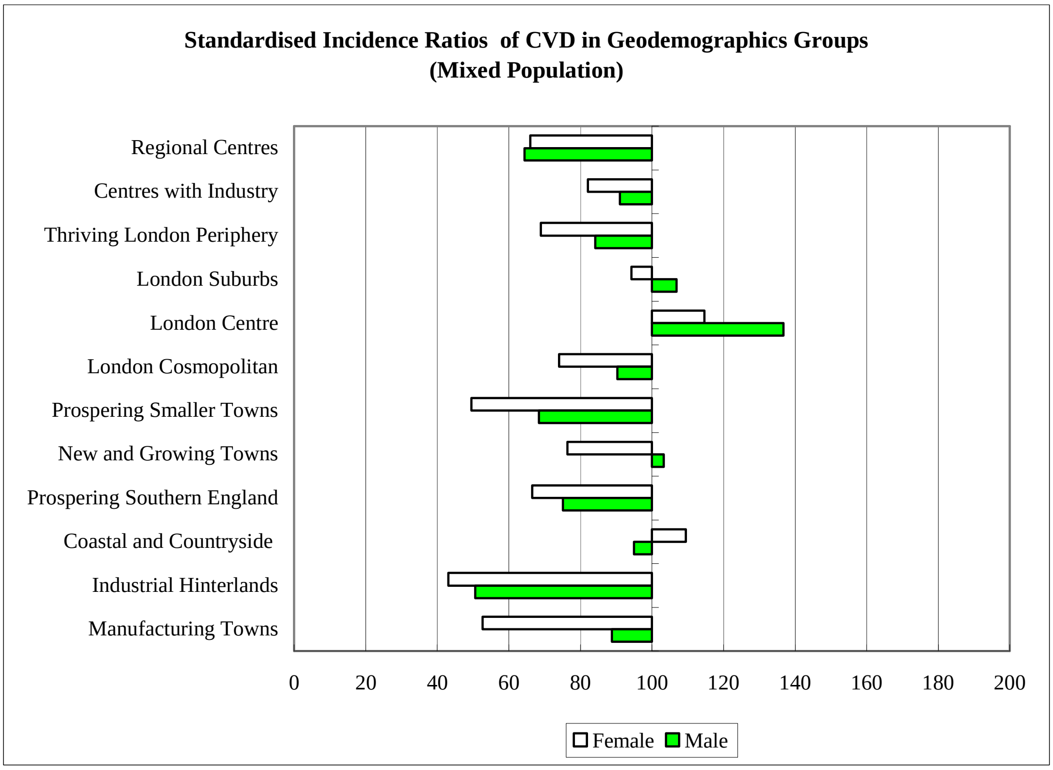


Figure 6-10: SIRs of CVD between geodemographics groups for Mixed population

For Mixed men, most geodemographics groups have lower standardised incidence ratios than the national average, particularly Regional Centres, Prospering Smaller Towns and Industrial Hinterlands. The geodemographics groups that need more attention are London Centre, where the ratio for Mixed men is particularly high.

For Mixed women, low standardised incidence ratios are observed in most geodemographics groups, particularly in Prospering Smaller Towns, Industrial Hinterlands and Manufacturing Towns. However, Mixed women living in London Centre, and Coastal and Countryside are found to be less healthy than Mixed women in other geodemographics groups and the general population.

6.2.9 Chinese Population

The figure below shows how the standardised incidence ratios of cardiovascular disease for Chinese population vary between geodemographics groups with different socioeconomic status profiles.

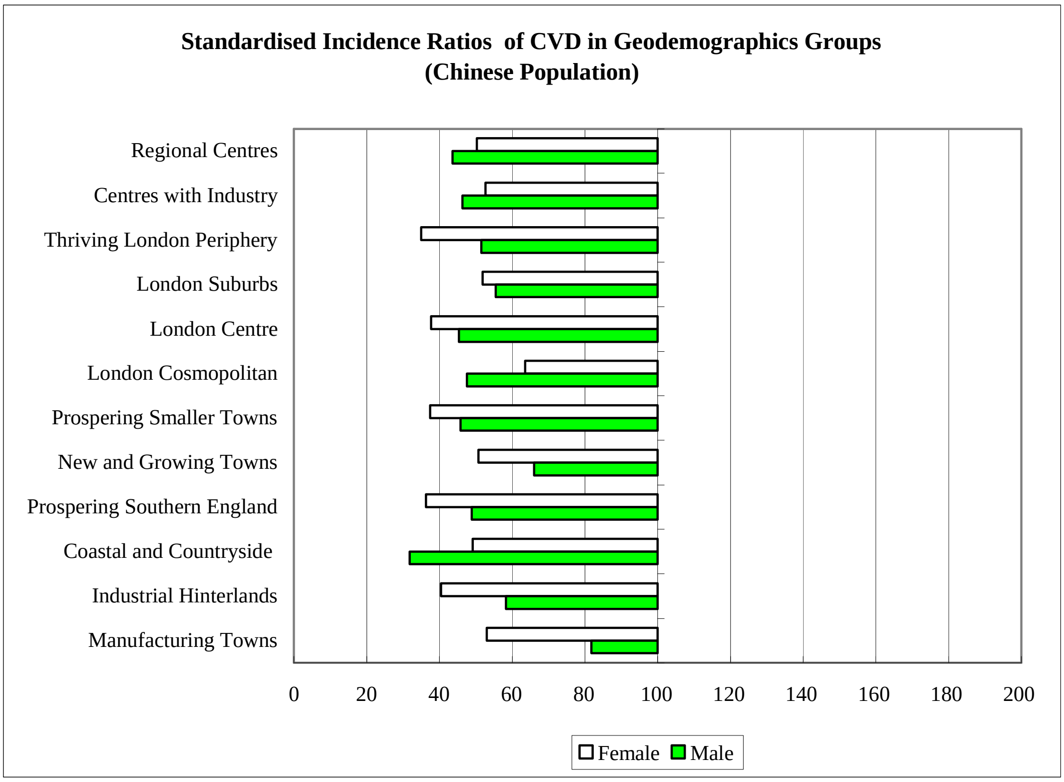


Figure 6-11: SIRs of CVD between geodemographics groups for Chinese population

Generally speaking, Chinese people in all geodemographics groups have lower or much lower standardised incidence ratios than the general population. However, compared with Chinese people in other geodemographics groups, Chinese men in Manufacturing Towns are a little less healthy.

6.2.10 Summary

Generally, people living in affluent or prospering geodemographics groups are expected to be healthier than people from industrial areas or manufacturing towns. The standardised incidence ratios of cardiovascular disease are more likely to be lower in prospering geodemographics groups, such as Prospering Smaller Towns and Prospering Southern England, but higher in industrial and manufacturing regions, such as Centres with Industry, Industrial Hinterlands and Manufacturing Towns. This is the case for White population. However, for minority ethnic groups, particularly Indian, Pakistani, Bangladeshi and Other Asian groups, the pattern of the standardised incidence ratios is different. They are more likely to have significantly high standardised incidence ratios of cardiovascular disease in geodemographics groups located in London, such as London Suburbs, London Centre and London Cosmopolitan. In contrast, their standardised incidence ratios in Industrial Hinterlands and Manufacturing Towns are not that high. The reason for the difference might be that the classification of neighbourhoods is based on the areal socioeconomic status of the general population, a very large proportion of whom are white people. However, the socioeconomic status for minority ethnic groups is different from that of the white people in the same neighbourhood.

6.3 Ethnic Inequalities in CVD and Areal Socioeconomic Status

The previous section has examined how the standardised incidence ratios of cardiovascular disease for ethnicity-sex groups vary between geodemographics groups with different socioeconomic status profile, which has provided some evidence that socioeconomic status contributes to the ethnic inequalities in cardiovascular disease. This section is going to quantify to what extent areal socioeconomic status measures contribute to the ethnic inequalities in different types of cardiovascular disease, to examine the different effect of areal socioeconomic status on cardiovascular disease for different ethnic groups. The cardiovascular disease examined in this study includes general cardiovascular disease, coronary heart disease, hypertensive heart disease, stroke, heart failure and rheumatic heart disease.

As introduced in the previous section, areal socioeconomic status for ethnic groups could be measured in different ways. In this study, the effect of areal socioeconomic status for ethnic groups measured in different ways on the ethnic inequalities in cardiovascular disease has been explored. Two main datasets have been used, the English Indices of Multiple Deprivation 2004 (IMD) and the UK 2001 Census. The difference between these two data is that in the IMD data, areal socioeconomic status is measured based on the general population with no difference between ethnic groups in the same neighbourhood; however, in the UK 2001 Census, areal socioeconomic status can be measured specifically for different ethnic groups. In addition, in order to examine the effect of areal socioeconomic status measured in different geographical scales, areal socioeconomic status has been extracted at both ST ward level and local authority level from the UK 2001 Census for analysis.

The table below introduces the data, methods and variables that have been used for the analysis.

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Aims	Data	Methods	Variables		
Aim I: Examine the effect of areal socioeconomic status measured for the general population on ethnic inequalities in different types of cardiovascular disease	The English Indices of Multiple Deprivation 2004 Hospital Episode Statistics	Multilevel Logistic Regression	**Age** 16-34 35-44 45-54 55-64 65-74 75-84 **Sex** Male Female	**Ethnicity** Indian Pakistani Bangladeshi Other Asian Black Caribbean Black Africa Mixed Chinese White	**Areal Socioeconomic Status** Income Domain Employment Domain Education, Skills and Training Domain Barriers to Housing and Services Domain Living Environment Domain Crime Domain
Aim II: Examine the effect of areal socioeconomic status measured specifically for different ethnic groups at different geographical scales on ethnic inequalities in different types of cardiovascular disease	The UK 2001 Census Hospital Episode Statistics	Multiple Logistic Regression	**Age** 16-34 35-44 45-54 55-64 65-74 75-84 **Sex** Male Female	**Ethnicity** Indian Pakistani Bangladeshi Other Asian Black Caribbean Black Africa Mixed Chinese White	**Areal Socioeconomic Status** Low Qualification Low Social Class Unemployment Living in Overcrowded Accommodation Living in Social Rented Accommodation (measured at both ST ward level and local authority level)

Table 6-1 Introduction to the models for measuring the effect of areal socioeconomic status

Logistic regression has been employed to model the relationships between areal socioeconomic status measures and ethnic inequalities in cardiovascular disease. The odds ratio from logistic regression is an indicator of relative risk. An odds ratio being greater than 1 implies higher risk of cardiovascular disease than the reference group and an odds ratio being less than 1 implies lower risk of cardiovascular disease than the reference group. In all the regression models, the White group is the reference group.

In the process of modelling, firstly, models are only fitted with age, sex and ethnicity in order to obtain the uncontrolled relative risk (odds ratios) of cardiovascular disease to the white population for minority ethnic groups. And then the areal socioeconomic status measures are included into the models to obtain the controlled relative risk of cardiovascular disease for minority ethnic groups. To what extent areal socioeconomic status measures contribute to the ethnic inequalities in cardiovascular disease could be identified by comparing the uncontrolled odds ratios with the controlled odds ratios.

6.3.1 Ethnic Inequalities in CVD and the IMD

This section discusses the effect of areal socioeconomic status measured for the general population on the ethnic inequalities in cardiovascular disease. Multilevel models are fitted based on the generalized linear mixed model to explore the relationships between areal socioeconomic status measures extracted from the English Indices of Multiple Deprivation 2004 and the ethnic inequalities in different types of cardiovascular disease. However, due to the intensive computation of the multilevel modelling process, the study area has been limited to London, where more than half of the UK ethnic minority populations are living.

The tables below show the odds ratios of the model without and with deprivation domains of the English Indices of Multiple Deprivation 2004. The areal socioeconomic measures are found significant in the models. The influence of areal socioeconomic status measures varies between different types of cardiovascular disease. After controlling for the six domains, Employment Domain and Education, Skills and Training Domain are found to be significantly associated with general cardiovascular disease, coronary heart disease and hypertensive heart disease. For stroke and heart failure, it is noticeable that the Crime Domain is significant in the model, although it is less important than the Employment Domain. However, for rheumatic heart disease, only the Education, Skills and Training Domain is found significant.

Significant difference in the relative risk of cardiovascular disease for ethnic groups in London has been observed. Compared to the White population, South Asians have significantly high relative risk of all the cardiovascular diseases studied. In particular, Pakistani and Bangladeshi population are at least two times higher risk of most cardiovascular diseases than the White population, especially in coronary heart disease, hypertensive heart disease and rheumatic heart disease. The Other Asian group, which was first introduced in the ethnicity classification in the 2001 UK Census and has been less studied in research on ethnic inequalities in cardiovascular disease, are found to be at a particularly higher risk of all the types of cardiovascular disease than the white population. Both Black Caribbean and Black Africa population have lower risk of coronary heart disease than the White population, however, the risk of hypertensive heart disease and stroke for these two groups is much higher than that of the White population. The risk of all types of cardiovascular disease for Mixed groups is very close to that of the White group. And Chinese population have a lower risk of most cardiovascular diseases than the White population.

For each cardiovascular disease, the odds ratios obtained from the models controlled by the deprivation domains have been compared with the odds ratios in the models without deprivation measures. However, there is little difference between the controlled and uncontrolled odds ratios, indicating that the areal socioeconomic status measures used here don’t seem to contribute to high relative risk of cardiovascular disease of ethnic minorities, although these areal socioeconomic status measures are associated with cardiovascular disease. However, this might be because the deprivation domains don’t reflect the areal socioeconomic status inequalities across ethnic groups in the neighbourhoods.

General Cardiovascular Disease (London)

Variable	Odds Ratio Estimates (95% Confidence Limits)	
	Model I: Model with Age, Sex and Ethnicity	**Model II:** Model with the English Indices of Multiple Deprivation (IMD)
Age		
16-34	0.013 (0.013, 0.013)	0.013 (0.013, 0.013)
35-44	0.044 (0.043, 0.045)	0.044 (0.043, 0.045)
45-54	0.115 (0.113, 0.116)	0.115 (0.113, 0.117)
55-64	0.264 (0.261, 0.268)	0.264 (0.261, 0.268)
65-74	0.536 (0.529, 0.543)	0.536 (0.529, 0.543)
75-84	1	1
Sex		
Male	1.365 (1.351, 1.378)	1.365 (1.351, 1.378)
Female	1	1
Ethnicity		
Indian	1.656 (1.622, 1.692)	1.661 (1.626, 1.696)
Pakistani	2.033 (1.960, 2.109)	2.035 (1.962, 2.111)
Bangladeshi	2.035 (1.948, 2.125)	2.009 (1.924, 2.099)
Other Asian	2.176 (2.104, 2.251)	2.179 (2.107, 2.254)
Black Caribbean	1.261 (1.232, 1.291)	1.255 (1.226, 1.285)
Black Africa	1.426 (1.382, 1.471)	1.418 (1.375, 1.463)
Mixed	1.035 (0.987, 1.084)	1.033 (0.986, 1.083)
Chinese	0.624 (0.580, 0.671)	0.623 (0.579, 0.670)
White	1	1
IMD		
Income Domain		
Employment Domain		5.067 (2.967, 8.653)
Education, Skills and Training Domain		1.008 (1.006, 1.010)
Barriers to Housing and Services Domain		
Living Environment Deprivation Domain		
Crime Domain		
Fit Statistics		
2 Res Log Pseudo-Likelihood	234571.4	234570.2
Generalized Chi-Square	96845.98	96977.48
Gener. Chi-Square / DF	1.78	1.78

Table 6-2 Odds ratios of the model with the IMD for general cardiovascular disease

Coronary Heart Disease (London)

Variable	Odds Ratio Estimates (95% Confidence Limits)	
	Model I: Model with Age, Sex and Ethnicity	**Model II:** Model with the English Indices of Multiple Deprivation (IMD)
Age		
16-34	0.002 (0.002, 0.002)	0.002 (0.002, 0.002)
35-44	0.022 (0.021, 0.023)	0.022 (0.021, 0.023)
45-54	0.101 (0.098, 0.104)	0.101 (0.098, 0.104)
55-64	0.277 (0.271, 0.284)	0.277 (0.271, 0.284)
65-74	0.579 (0.567, 0.591)	0.578 (0.566, 0.591)
75-84	1	1
Sex		
Male	2.098 (2.062, 2.134)	2.097 (2.062, 2.134)
Female	1	1
Ethnicity		
Indian	2.258 (2.187, 2.331)	2.276 (2.204, 2.349)
Pakistani	3.435 (3.265, 3.614)	3.449 (3.278, 3.629)
Bangladeshi	3.462 (3.260, 3.677)	3.379 (3.183, 3.588)
Other Asian	2.831 (2.688, 2.980)	2.844 (2.701, 2.994)
Black Caribbean	0.844 (0.805, 0.885)	0.834 (0.795, 0.874)
Black Africa	0.847 (0.788, 0.912)	0.836 (0.777, 0.899)
Mixed	1.103 (1.016, 1.199)	1.099 (1.012, 1.195)
Chinese	0.481 (0.415, 0.558)	0.480 (0.413, 0.557)
White	1	1
IMD		
Income Domain		
Employment Domain		4.053 (2.213, 7.421)
Education, Skills and Training Domain		1.012 (1.010, 1.015)
Barriers to Housing and Services Domain		
Living Environment Domain		
Crime Domain		
Fit Statistics		
2 Res Log Pseudo-Likelihood	309457.6	309831.5
Generalized Chi-Square	88880.38	89372.05
Gener. Chi-Square / DF	1.65	1.66

Table 6-3 Odds ratios of the model with the IMD for coronary heart disease

Hypertensive Heart Disease (London)

Variable	Odds Ratio Estimates (95% Confidence Limits)	
	Model I: Model with Age, Sex and Ethnicity	**Model II:** Model with the English Indices of Multiple Deprivation (IMD)
Age		
16-34	0.004 (0.004, 0.004)	0.004 (0.004, 0.004)
35-44	0.027 (0.026, 0.028)	0.027 (0.026, 0.028)
45-54	0.101 (0.099, 0.104)	0.101 (0.099, 0.104)
55-64	0.260 (0.255, 0.265)	0.260 (0.255, 0.265)
65-74	0.563 (0.554, 0.573)	0.563 (0.554, 0.573)
75-84	1	1
Sex		
Male	1.166 (1.151, 1.182)	1.166 (1.151, 1.182)
Female	1	1
Ethnicity		
Indian	2.120 (2.065, 2.176)	2.124 (2.069, 2.180)
Pakistani	2.626 (2.509, 2.748)	2.628 (2.511, 2.750)
Bangladeshi	2.882 (2.728, 3.045)	2.853 (2.700, 3.014)
Other Asian	2.712 (2.598, 2.831)	2.716 (2.602, 2.835)
Black Caribbean	1.837 (1.786, 1.889)	1.830 (1.779, 1.882)
Black Africa	2.229 (2.145, 2.316)	2.218 (2.135, 2.305)
Mixed	1.268 (1.193, 1.349)	1.267 (1.191, 1.347)
Chinese	0.703 (0.637, 0.776)	0.702 (0.637, 0.775)
White	1	1
IMD		
Income Domain		
Employment Domain		4.243 (1.842, 9.770)
Education, Skills and Training Domain		1.010 (1.006, 1.014)
Barriers to Housing and Services Domain		
Living Environment Domain		
Crime Domain		
Fit Statistics		
2 Res Log Pseudo-Likelihood	267423.3	267454.9
Generalized Chi-Square	90549.31	90633.73
Gener. Chi-Square / DF	1.67	1.67

Table 6-4 Odds ratios of the model with the IMD for hypertensive heart disease

Stroke (London)

Variable	Odds Ratio Estimates (95% Confidence Limits)	
	Model I: Model with Age, Sex and Ethnicity	**Model II:** Model with the English Indices of Multiple Deprivation (IMD)
Age		
16-34	0.005 (0.004, 0.006)	0.005 (0.004, 0.006)
35-44	0.019 (0.018, 0.021)	0.019 (0.018, 0.021)
45-54	0.052 (0.049, 0.055)	0.052 (0.049, 0.055)
55-64	0.153 (0.146, 0.160)	0.153 (0.146, 0.160)
65-74	0.405 (0.390, 0.421)	0.405 (0.390, 0.420)
75-84	1	1
Sex		
Male	1.466 (1.421, 1.513)	1.465 (1.420, 1.512)
Female	1	1
Ethnicity		
Indian	1.373 (1.276, 1.477)	1.366 (1.270, 1.470)
Pakistani	1.737 (1.520, 1.986)	1.708 (1.495, 1.952)
Bangladeshi	2.535 (2.237, 2.872)	2.372 (2.094, 2.688)
Other Asian	2.130 (1.903, 2.384)	2.123 (1.897, 2.376)
Black Caribbean	1.612 (1.507, 1.724)	1.544 (1.443, 1.651)
Black Africa	1.773 (1.604, 1.960)	1.701 (1.539, 1.881)
Mixed	1.085 (0.929, 1.267)	1.066 (0.913, 1.245)
Chinese	0.840 (0.674, 1.046)	0.827 (0.664, 1.030)
White	1	1
IMD		
Income Domain		
Employment Domain		21.254 (9.103, 49.622)
Education, Skills and Training Domain		
Barriers to Housing and Services Domain		
Living Environment Domain		
Crime Domain		1.081 (1.005, 1.163)
Fit Statistics		
2 Res Log Pseudo-Likelihood	354874.9	356885
Generalized Chi-Square	81253.59	82754.57
Gener. Chi-Square / DF	1.52	1.55

Table 6-5 Odds ratios of the model with the IMD for stroke

Heart Failure (London)

Variable	Odds Ratio Estimates (95% Confidence Limits)	
	Model I: Model with Age, Sex and Ethnicity	**Model II:** Model with the English Indices of Multiple Deprivation (IMD)
Age		
16-34	0.002 (0.001, 0.002)	0.002 (0.001, 0.002)
35-44	0.007 (0.007, 0.008)	0.007 (0.007, 0.008)
45-54	0.029 (0.027, 0.031)	0.029 (0.027, 0.031)
55-64	0.105 (0.099, 0.110)	0.105 (0.099, 0.110)
65-74	0.349 (0.336, 0.362)	0.349 (0.336, 0.362)
75-84	1	1
Sex		
Male	1.562 (1.512, 1.613)	1.561 (1.511, 1.613)
Female	1	1
Ethnicity		
Indian	1.753 (1.636, 1.880)	1.767 (1.649, 1.894)
Pakistani	2.328 (2.055, 2.637)	2.318 (2.046, 2.625)
Bangladeshi	2.552 (2.228, 2.924)	2.345 (2.047, 2.687)
Other Asian	2.324 (2.068, 2.613)	2.334 (2.076, 2.624)
Black Caribbean	1.201 (1.108, 1.302)	1.152 (1.062, 1.249)
Black Africa	1.705 (1.516, 1.918)	1.631 (1.449, 1.835)
Mixed	1.110 (0.939, 1.313)	1.092 (0.923, 1.291)
Chinese	0.467 (0.339, 0.645)	0.459 (0.333, 0.634)
White	1	1
IMD		
Income Domain		2.600 (1.599, 4.226)
Employment Domain		
Education, Skills and Training Domain		1.007 (1.004, 1.011)
Barriers to Housing and Services Domain		
Living Environment Domain		
Crime Domain		1.085 (1.009, 1.166)
Fit Statistics		
2 Res Log Pseudo-Likelihood	387152.4	388528.3
Generalized Chi-Square	84718.02	85583.18
Gener. Chi-Square / DF	1.59	1.6

Table 6-6 Odds ratios of the model with the IMD for heart failure

Rheumatic Heart Disease (London)

Variable	Odds Ratio Estimates (95% Confidence Limits)	
	Model I: Model with Age, Sex and Ethnicity	**Model II:** Model with the English Indices of Multiple Deprivation (IMD)
Age		
16-34	0.015 (0.012, 0.019)	0.015 (0.012, 0.019)
35-44	0.049 (0.040, 0.060)	0.049 (0.040, 0.060)
45-54	0.075 (0.061, 0.091)	0.075 (0.061, 0.092)
55-64	0.212 (0.182, 0.247)	0.212 (0.182, 0.248)
65-74	0.482 (0.424, 0.549)	0.482 (0.424, 0.548)
75-84	1	1
Sex		
Male	0.747 (0.673, 0.830)	0.747 (0.673, 0.830)
Female	1	1
Ethnicity		
Indian	1.807 (1.476, 2.213)	1.828 (1.492, 2.240)
Pakistani	2.441 (1.701, 3.502)	2.452 (1.709, 3.519)
Bangladeshi	2.948 (2.046, 4.248)	2.871 (1.990, 4.141)
Other Asian	3.452 (2.599, 4.585)	3.486 (2.625, 4.631)
Black Caribbean	0.797 (0.587, 1.081)	0.789 (0.582, 1.071)
Black Africa	2.095 (1.574, 2.789)	2.069 (1.554, 2.754)
Mixed	1.050 (0.636, 1.733)	1.051 (0.637, 1.734)
Chinese	1.080 (0.582, 2.004)	1.082 (0.583, 2.007)
White	1	1
IMD		
Income Domain		
Employment Domain		
Education, Skills and Training Domain		1.007 (1.000,1.013)
Barriers to Housing and Services Domain		
Living Environment Domain		
Crime Domain		
Fit Statistics		
2 Res Log Pseudo-Likelihood	455989.4	456313.5
Generalized Chi-Square	76142.04	76361.78
Gener. Chi-Square / DF	1.43	1.44

Table 6-7 Odds ratios of the model with the IMD for rheumatic heart disease

6.3.2 Ethnic Inequalities in CVD and the UK 2001 Census

This section is going to examine the effect of areal socioeconomic status measured specifically for different ethnic groups on the ethnic inequalities in different types of cardiovascular disease. Multiple logistic regression models are fitted to model the relationships between ethnic inequalities in cardiovascular disease and the areal socioeconomic status measures for ethnic groups extracted from the UK 2001 Census at both ST ward level and local authority level. For each type of cardiovascular disease, three logistic regression models have been fitted, Model I without socioeconomic status measures, Model II with socioeconomic status measured at ST ward level and Model III with socioeconomic status measured at local authority level. All the models are built based on parsimonious criteria, trying to use the most parsimonious set of predictors to explain the most variation in the response variable. The odds ratios obtained from these three models are then compared.

6.3.2.1 General Cardiovascular Disease

The table below shows the odds ratios (relative risk) of general cardiovascular disease for ethnic groups in the models uncontrolled and controlled by areal socioeconomic status measured specifically for different ethnic groups, where white population is the reference group.

After controlling for age and sex, South Asians and Other Asians have a remarkably higher relative risk of general cardiovascular disease than the white people. The risk for Pakistani people is the highest, which is nearly double that of the white people. Both Black Africa people and Black Caribbean people have a higher risk than the white people. However, the relative risk of Mixed and Chinese groups is below the white people.

There is little difference between the odds ratios in the models controlled by the ST ward level socioeconomic status measures and the local authority level socioeconomic status measures, indicating the effect of areal socioeconomic status measures is consistent at different geographical scales. The relative risk of cardiovascular disease for Bangladeshi people, Black Africa people and Black Caribbean people, who had a higher risk than the white people in the model without areal socioeconomic status measures, has significantly dropped a level close to that of the white people, indicating their higher relative risk is related to these areal socioeconomic status measures. However, the relative risk of Pakistani people is still significantly high, implying these areal socioeconomic status measures contribute little to their higher relative risk. The relative risk of Indian people and Other Asian people changed in a reverse way, increased a little, which means these socioeconomic status measures couldn't explain their higher relative risk of cardiovascular disease at all. The relative risk of Mixed and Chinese groups changes little, still below the white people.

General Cardiovascular Disease

Variable	Odds Ratio Estimates (95% Wald Confidence Limits)		
	Model I: Model without Socioeconomic Status (ST Ward)	**Model II:** Model with Socioeconomic Status Measured at ST Ward Level	**Model III:** Model with Socioeconomic Status Measured at Local Authority Level
Age			
16-34	0.016 (0.016, 0.016)	0.016 (0.016, 0.016)	0.016 (0.016, 0.016)
35-44	0.051 (0.050, 0.051)	0.051 (0.050, 0.051)	0.051 (0.051, 0.051)
45-54	0.111 (0.111, 0.112)	0.112 (0.111, 0.112)	0.112 (0.111, 0.112)
55-64	0.269 (0.267, 0.270)	0.269 (0.268, 0.270)	0.269 (0.267, 0.270)
65-74	0.519 (0.517, 0.521)	0.517 (0.515, 0.520)	0.518 (0.516, 0.520)
75-84	1	1	1
Sex			
Male	1.330 (1.325, 1.335)	1.335 (1.330, 1.340)	1.323 (1.317, 1.328)
Female	1	1	1
Ethnicity			
Indian	1.620 (1.600, 1.641)	1.684 (1.659, 1.710)	1.737 (1.713, 1.761)
Pakistani	2.141 (2.106, 2.177)	1.864 (1.825, 1.905)	1.878 (1.841, 1.916)
Bangladeshi	1.787 (1.733, 1.842)	1.273 (1.229, 1.319)	1.253 (1.212, 1.294)
Other Asian	1.899 (1.851, 1.948)	1.960 (1.905, 2.017)	1.967 (1.916, 2.019)
Black Caribbean	1.266 (1.245, 1.287)	1.055 (1.036, 1.073)	1.013 (0.995, 1.031)
Black Africa	1.473 (1.437, 1.511)	1.342 (1.303, 1.382)	1.288 (1.253, 1.324)
Mixed	0.984 (0.956, 1.013)	0.928 (0.900, 0.955)	0.872 (0.847, 0.899)
Chinese	0.633 (0.606, 0.661)	0.715 (0.684, 0.747)	0.724 (0.693, 0.757)
White	1	1	1
Socioeconomic Status			
Low Qualification		1.006 (1.006, 1.007)	1.006 (1.005, 1.006)
Low Social Class		1.008 (1.007, 1.008)	1.007 (1.006, 1.007)
Unemployment		1.008 (1.007, 1.008)	1.012 (1.011, 1.013)
Overcrowded Accommodation		1.001 (1.001, 1.002)	
Social Rented Accommodation		1.003 (1.003, 1.003)	1.004 (1.004, 1.004)
Goodness of Fit			
Akaike Information Criterion (AIC)	10368631	10336800	10354225
Schwarz's Bayesian Criterion (SBC)	10368863	10337109	10354519
-2LOGL	10368601	10336760	10354187

Table 6-8 Odds ratios of the models with the areal socioeconomic status measured at different geographical scales for general cardiovascular disease

6.3.2.2 Coronary Heart Disease

The table below show the odds ratios of coronary heart disease for ethnic groups in the models uncontrolled and controlled by areal socioeconomic status measured specifically for different ethnic groups, where White population is the reference group.

After controlling for age and sex, South Asians have particularly high relative risk than the white people. In particular, Pakistanis have the highest risk of coronary heart disease. The relative risk of Other Asians is very close to that of the Pakistani people. However, all the other minority ethnic groups have a lower relative risk of coronary heart disease than the white people.

There is little difference between the odds ratios in the models controlled by the ST ward level socioeconomic status measures and the local authority level socioeconomic status measures, indicating the effect of areal socioeconomic status measures is consistent at different geographical scales.

The controlled odds ratio of coronary heart disease for Bangladeshi people has largely dropped, indicating socioeconomic status is an important determinant of their higher relative risk. After controlling for areal socioeconomic status measures, the relative risk for Pakistani people decreases a little and is still the highest, which indicates these socioeconomic status measures could explain little about their higher relative risk. However, the relative risk of Indian people and Other Asian people has increased to some extent after controlling by socioeconomic status, implying the socioeconomic status measures used here don’t contribute their higher relative risk at all.

Coronary Heart Disease

Variable	Odds Ratio Estimates (95% Wald Confidence Limits)		
	Model I: Model without Socioeconomic Status (ST Ward)	**Model II:** Model with Socioeconomic Status Measured at ST Ward Level	**Model III:** Model with Socioeconomic Status Measured at Local Authority Level
Age			
16-34	0.002 (0.002, 0.002)	0.002 (0.002, 0.002)	0.002 (0.002, 0.002)
35-44	0.022 (0.022, 0.023)	0.022 (0.022, 0.023)	0.022 (0.022, 0.023)
45-54	0.090 (0.090, 0.091)	0.091 (0.090, 0.092)	0.091 (0.090, 0.091)
55-64	0.262 (0.260, 0.264)	0.263 (0.261, 0.265)	0.262 (0.260, 0.264)
65-74	0.548 (0.545, 0.552)	0.547 (0.543, 0.550)	0.547 (0.543, 0.550)
75-84	1	1	1
Sex			
Male	1.937 (1.926, 1.948)	1.958 (1.945, 1.970)	1.958 (1.945, 1.971)
Female	1	1	1
Ethnicity			
Indian	2.041 (2.003, 2.080)	2.294 (2.249, 2.339)	2.380 (2.332, 2.429)
Pakistani	3.257 (3.181, 3.334)	2.956 (2.879, 3.034)	2.958 (2.874, 3.044)
Bangladeshi	2.945 (2.824, 3.072)	1.994 (1.908, 2.083)	1.775 (1.696, 1.858)
Other Asian	2.232 (2.146, 2.322)	2.564 (2.463, 2.669)	2.532 (2.430, 2.637)
Black Caribbean	0.783 (0.757, 0.810)	0.619 (0.598, 0.641)	0.566 (0.546, 0.586)
Black Africa	0.870 (0.820, 0.922)	0.843 (0.794, 0.896)	0.757 (0.712, 0.806)
Mixed	0.997 (0.948, 1.049)	0.956 (0.908, 1.006)	0.905 (0.859, 0.953)
Chinese	0.498 (0.457, 0.542)	0.614 (0.563, 0.669)	0.639 (0.586, 0.697)
White	1	1	1
Socioeconomic Status			
Low Qualification		1.010 (1.010, 1.011)	1.010 (1.010, 1.011)
Low Social Class		1.009 (1.009, 1.010)	1.010 (1.009, 1.011)
Unemployment		1.006 (1.005, 1.007)	1.007 (1.005, 1.008)
Overcrowded Accommodation			
Social Rented Accommodation		1.005 (1.005, 1.006)	1.008 (1.008, 1.009)
Goodness of Fit			
Akaike Information Criterion (AIC)	4635529.8	4611559.7	4623225.2
Schwarz's Bayesian Criterion (SBC)	4635761.6	4611853.3	4623518.9
-2LOGL	4635499.8	4611521.7	4623187.2

Table 6-9 Odds ratios of the models with the areal socioeconomic status measured at different geographical scales for coronary heart disease

6.3.2.3 Stroke

The table below show the odds ratios of stroke for ethnic groups in the models uncontrolled and controlled by areal socioeconomic status measured specifically for different ethnic groups, where White population is the reference group.

After controlling for age and sex, all the ethnic groups except for Chinese and Mixed groups have significantly higher relative risk of stroke than the white people. In particular, Bangladeshi people have the highest risk of stroke. And the risk for Pakistani, Other Asian and Black Africa groups is double that that of the white group.

The difference between the odds ratios in the models controlled by the ST ward level socioeconomic status measures and the local authority level socioeconomic status measures has been observed. The odds ratios are slightly higher for South Asians and Other Asians in the model conducted at the local authority level, indicating the effect of local authority level socioeconomic status is slightly lower. However, there is little difference between the odds ratios for other ethnic groups.

For Bangladeshi, Black Africa and Black Caribbean people, whose relative risk is significantly high before controlling for socioeconomic status, their relative risk has largely reduced to a level slightly higher than that of the white people, implying their higher relative risk could be mostly explained by socioeconomic status measures. The relative risk of Pakistani and Other Asian people also decreases to some extent, but still obviously higher than the white people. However, inconsistent finding about the odds ratios for Indian people have been observed in the models conducted at different geographical scales. Whatever, given that there is little change in these odds ratios, these socioeconomic status measures contribute little to their higher relative risk of stroke.

Stroke

Variable	Odds Ratio Estimates (95% Wald Confidence Limits) **Model I:** Model without Socioeconomic Status (ST Ward)	**Model II:** Model with Socioeconomic Status Measured at ST Ward Level	**Model III:** Model with Socioeconomic Status Measured at Local Authority Level
Age			
16-34	0.006 (0.006, 0.006)	0.006 (0.006, 0.006)	0.006 (0.006, 0.006)
35-44	0.022 (0.022, 0.023)	0.022 (0.022, 0.023)	0.022 (0.022, 0.023)
45-54	0.055 (0.054, 0.057)	0.056 (0.054, 0.057)	0.055 (0.054, 0.057)
55-64	0.146 (0.144, 0.149)	0.147 (0.145, 0.150)	0.147 (0.144, 0.149)
65-74	0.374 (0.369, 0.379)	0.374 (0.369, 0.379)	0.374 (0.369, 0.379)
75-84	1	1	1
Sex			
Male	1.394 (1.378, 1.410)	1.387 (1.370, 1.404)	1.370 (1.351, 1.388)
Female	1	1	1
Ethnicity			
Indian	1.589 (1.521, 1.661)	1.457 (1.384, 1.534)	1.662 (1.588, 1.739)
Pakistani	1.993 (1.878, 2.114)	1.462 (1.360, 1.572)	1.637 (1.528, 1.754)
Bangladeshi	2.606 (2.378, 2.855)	1.352 (1.214, 1.506)	1.467 (1.330, 1.618)
Other Asian	1.939 (1.776, 2.117)	1.604 (1.456, 1.767)	1.858 (1.698, 2.032)
Black Caribbean	1.759 (1.677, 1.846)	1.205 (1.143, 1.270)	1.149 (1.089, 1.213)
Black Africa	1.960 (1.803, 2.130)	1.205 (1.096, 1.326)	1.270 (1.163, 1.388)
Mixed	1.036 (0.936, 1.147)	0.838 (0.755, 0.929)	0.840 (0.757, 0.932)
Chinese	0.872 (0.759, 1.003)	0.825 (0.715, 0.950)	0.937 (0.814, 1.078)
White	1	1	1
Socioeconomic Status			
Low Qualification			
Low Social Class		1.011 (1.010, 1.012)	1.009 (1.008, 1.010)
Unemployment		1.014 (1.012, 1.017)	1.021 (1.017, 1.024)
Overcrowded Accommodation		1.006 (1.005, 1.007)	
Social Rented Accommodation		1.004 (1.003, 1.004)	1.008 (1.007, 1.009)
Goodness of Fit			
Akaike Information Criterion (AIC)	1432131.2	1428454.9	1430128.5
Schwarz's Bayesian Criterion (SBC)	1432363	1428748.5	1430406.7
-2LOGL	1432101.2	1428416.9	1430092.5

Table 6-10 Odds ratios of the models with the areal socioeconomic status measured at different geographical scales for stroke

6.3.2.4 Hypertensive Heart Disease

The table below show the odds ratios of hypertensive heart disease for ethnic groups in the models uncontrolled and controlled by areal socioeconomic status measured specifically for different ethnic groups, where White population is the reference group.

After controlling for age and sex, all the ethnic groups except for Chinese and Mixed groups have significantly higher relative risk of hypertensive heart disease than the white people. In particular, Pakistani people have the highest risk of stroke. And the risk for Indian, Bangladeshi, Other Asian and Black Africa groups is two times higher that that of the white group.

There is little difference between the odds ratios in the models controlled by the ST ward level socioeconomic status measures and the local authority level socioeconomic status measures, indicating the effect of areal socioeconomic status measures is consistent at different geographical scales.

The controlled relative risk of hypertensive heart disease for Bangladeshi and Black Caribbean people has decreased by a large proportion, indicating these socioeconomic status measures significantly contribute to their higher relative risk. For Pakistani and Black Africa people, the relative risk doesn't reduce that much, and is still obviously high, implying areal socioeconomic status measures are not the main reason for their higher relative risk of hypertensive heart disease. Give the controlled relative risk of Indian and Other Asian people changes in an opposite way, increases a little; socioeconomic status used here can't explain their high relative risk at all.

Hypertensive Heart Disease

Variable	Odds Ratio Estimates (95% Wald Confidence Limits)		
	Model I: Model without Socioeconomic Status (ST Ward)	**Model II:** Model with Socioeconomic Status Measured at ST Ward Level	**Model III:** Model with Socioeconomic Status Measured at Local Authority Level
Age			
16-34	0.006 (0.005, 0.006)	0.006 (0.005, 0.006)	0.006 (0.005, 0.006)
35-44	0.033 (0.033, 0.034)	0.033 (0.033, 0.034)	0.033 (0.033, 0.034)
45-54	0.104 (0.103, 0.105)	0.104 (0.104, 0.105)	0.104 (0.103, 0.105)
55-64	0.282 (0.281, 0.284)	0.283 (0.281, 0.285)	0.283 (0.281, 0.285)
65-74	0.567 (0.564, 0.571)	0.566 (0.563, 0.569)	0.566 (0.563, 0.570)
75-84	1	1	1
Sex			
Male	1.134 (1.129, 1.139)	1.140 (1.135, 1.146)	1.130 (1.124, 1.136)
Female	1	1	1
Ethnicity			
Indian	2.102 (2.070, 2.135)	2.209 (2.168, 2.252)	2.298 (2.260, 2.338)
Pakistani	2.656 (2.600, 2.714)	2.387 (2.321, 2.454)	2.430 (2.367, 2.494)
Bangladeshi	2.374 (2.284, 2.469)	1.742 (1.664, 1.823)	1.724 (1.653, 1.797)
Other Asian	2.310 (2.235, 2.387)	2.429 (2.341, 2.520)	2.447 (2.365, 2.531)
Black Caribbean	1.852 (1.817, 1.888)	1.591 (1.558, 1.624)	1.530 (1.497, 1.563)
Black Africa	2.188 (2.121, 2.258)	2.068 (1.992, 2.146)	2.001 (1.933, 2.071)
Mixed	1.206 (1.160, 1.253)	1.164 (1.119, 1.210)	1.115 (1.071, 1.159)
Chinese	0.715 (0.674, 0.758)	0.805 (0.758, 0.855)	0.825 (0.778, 0.876)
White	1	1	1
Socioeconomic Status			
Low Qualification		1.007 (1.007, 1.008)	1.007 (1.006, 1.008)
Low Social Class		1.006 (1.005, 1.006)	1.004 (1.004, 1.005)
Unemployment		1.004 (1.003, 1.005)	1.008 (1.006, 1.009)
Overcrowded Accommodation		1.002 (1.001, 1.002)	
Social Rented Accommodation		1.003 (1.003, 1.003)	1.005 (1.004, 1.005)
Goodness of Fit			
Akaike Information Criterion (AIC)	6306704.4	6291581.9	6300075.6
Schwarz's Bayesian Criterion (SBC)	6306936.2	6291891	6300369.2
-2LOGL	6306674.4	6291541.9	6300037.6

Table 6-11 Odds ratios of the models with the areal socioeconomic status measured at different geographical scales for hypertensive heart disease

6.3.2.5 Heart Failure

The table below show the odds ratios of heart failure for ethnic groups in the models uncontrolled and controlled by areal socioeconomic status measured specifically for different ethnic groups, where White population is the reference group.

After controlling for age and sex, South Asians and Other Asians show a significantly high relative risk of heart failure, particularly Bangladeshi and Pakistani people. The relative risk of Black Africa people is also obviously high. However, the relative risk for other ethnic groups is close to or below that of the white people.

The odds ratios for South Asians and Other Asians obtained in the model conducted at local authority level are slightly higher, indicating the effect of areal socioeconomic status measures is slightly lower in the local authority level. However, there is little difference between the odds ratios for other ethnic groups in the models conducted at ST ward level and local authority level.

After controlling for socioeconomic status, the relative risk of heart failure for Bangladeshi and Black Africa has dropped by a large proportion, indicating socioeconomic status measures contribute most to their higher relative risk, particularly for Bangladeshi people. The relative risk of Pakistani people has decreased to some extent, but is still particularly high. However, for Indian and Other Asian people, their high relative risk has not been alleviated by controlling for socioeconomic status measures, implying socioeconomic status measures used here can’t explain their higher relative risk of heart failure at all.

Heart Failure

Variable	Odds Ratio Estimates (95% Wald Confidence Limits)		
	Model I: Model without Socioeconomic Status (ST Ward)	**Model II:** Model with Socioeconomic Status Measured at ST Ward Level	**Model III:** Model with Socioeconomic Status Measured at Local Authority Level
Age			
16-34	0.002 (0.002, 0.002)	0.002 (0.002, 0.002)	0.002 (0.002, 0.002)
35-44	0.007 (0.007, 0.008)	0.007 (0.007, 0.008)	0.007 (0.007, 0.008)
45-54	0.027 (0.026, 0.028)	0.027 (0.027, 0.028)	0.027 (0.026, 0.028)
55-64	0.101 (0.099, 0.103)	0.101 (0.100, 0.103)	0.101 (0.099, 0.103)
65-74	0.327 (0.323, 0.331)	0.327 (0.323, 0.331)	0.326 (0.322, 0.330)
75-84	1	1	1
Sex			
Male	1.605 (1.588, 1.623)	1.629 (1.610, 1.649)	1.621 (1.599, 1.643)
Female	1	1	1
Ethnicity			
Indian	1.808 (1.734, 1.885)	1.808 (1.720, 1.901)	1.954 (1.869, 2.044)
Pakistani	2.568 (2.433, 2.711)	2.089 (1.949, 2.239)	2.244 (2.104, 2.393)
Bangladeshi	2.615 (2.378, 2.877)	1.533 (1.370, 1.716)	1.643 (1.485, 1.819)
Other Asian	1.988 (1.817, 2.175)	1.942 (1.759, 2.144)	2.095 (1.910, 2.298)
Black Caribbean	1.192 (1.126, 1.263)	0.893 (0.840, 0.949)	0.856 (0.804, 0.912)
Black Africa	1.663 (1.507, 1.835)	1.332 (1.194, 1.487)	1.348 (1.213, 1.498)
Mixed	0.970 (0.871, 1.080)	0.874 (0.784, 0.976)	0.878 (0.787, 0.980)
Chinese	0.513 (0.426, 0.619)	0.558 (0.462, 0.675)	0.608 (0.504, 0.734)
White	1	1	1
Socioeconomic Status			
Low Qualification		1.006 (1.005, 1.007)	1.004 (1.003, 1.006)
Low Social Class		1.012 (1.011, 1.014)	1.013 (1.012, 1.015)
Unemployment		1.006 (1.004, 1.009)	1.011 (1.008, 1.014)
Overcrowded Accommodation		1.004 (1.003, 1.005)	
Social Rented Accommodation		1.004 (1.003, 1.005)	1.006 (1.005, 1.007)
Goodness of Fit			
Akaike Information Criterion (AIC)	1441208.1	1435993	1438755.5
Schwarz's Bayesian Criterion (SBC)	1441440	1436302	1439049.2
-2LOGL	1441178.1	1435953	1438717.5

Table 6-12 Odds ratios of the models with the areal socioeconomic status measured at different geographical scales for heart failure

6.3.2.6 Rheumatic Heart Disease

The table below show the odds ratios (relative risk) of rheumatic heart disease for ethnic groups in the models uncontrolled and controlled by areal socioeconomic status measured specifically for different ethnic groups, where White population is the reference group.

After controlling for age and sex, except for Black Caribbean and Mixed groups, all the minority ethnic groups show a higher relative risk of rheumatic heart disease. In particular, the risk of rheumatic heart disease for Bangladeshi and Other Asian groups is more than two times higher than that of the white people.

There is little difference between the odds ratios in the models controlled by the ST ward level socioeconomic status measures and the local authority level socioeconomic status measures, with an exception for Other Asian and Black Africa groups, indicating the effect of areal socioeconomic status measures is consistent at ST ward level and local authority level.

After controlling for socioeconomic status, no significant change has been identified in the controlled relative risk for minority ethnic groups. The relative risk of Bangladeshi has decreased a little, implying socioeconomic status is a determinant of their high relative risk. However, for Indian, Pakistani, Other Asian and Black Africa people, no decrease of the relative risk has been made by the inclusion of socioeconomic status, indicating that socioeconomic status used here doesn’t contribute their higher risk of rheumatic heart disease at all.

Rheumatic Heart Disease

Variable	Odds Ratio Estimates (95% Wald Confidence Limits)		
	Model I: Model without Socioeconomic Status (ST Ward)	**Model II:** Model with Socioeconomic Status Measured at ST Ward Level	**Model III:** Model with Socioeconomic Status Measured at Local Authority Level
Age			
16-34	0.013 (0.011, 0.014)	0.013 (0.011, 0.014)	0.013 (0.011, 0.014)
35-44	0.030 (0.028, 0.033)	0.030 (0.028, 0.033)	0.030 (0.028, 0.033)
45-54	0.069 (0.064, 0.074)	0.069 (0.065, 0.074)	0.069 (0.064, 0.074)
55-64	0.206 (0.196, 0.216)	0.206 (0.197, 0.216)	0.206 (0.196, 0.216)
65-74	0.506 (0.487, 0.526)	0.506 (0.487, 0.525)	0.506 (0.487, 0.525)
75-84	1	1	1
Sex			
Male	0.917 (0.888, 0.947)	0.937 (0.907, 0.969)	0.953 (0.922, 0.985)
Female	1	1	1
Ethnicity			
Indian	1.726 (1.535, 1.940)	1.828 (1.622, 2.061)	1.788 (1.588, 2.013)
Pakistani	1.871 (1.580, 2.215)	1.844 (1.557, 2.186)	1.887 (1.593, 2.234)
Bangladeshi	2.252 (1.720, 2.949)	1.961 (1.493, 2.577)	1.966 (1.490, 2.593)
Other Asian	2.715 (2.207, 3.341)	3.026 (2.457, 3.728)	2.921 (2.374, 3.595)
Black Caribbean	0.863 (0.714, 1.044)	0.800 (0.660, 0.971)	0.770 (0.632, 0.938)
Black Africa	1.792 (1.414, 2.271)	1.909 (1.492, 2.444)	1.724 (1.347, 2.207)
Mixed	0.938 (0.697, 1.261)	0.962 (0.715, 1.295)	0.949 (0.705, 1.278)
Chinese	1.547 (1.159, 2.066)	1.820 (1.361, 2.433)	1.793 (1.342, 2.397)
White	1	1	1
Socioeconomic Status			
Low Qualification		1.005 (1.002, 1.008)	
Low Social Class		1.011 (1.007, 1.014)	1.018 (1.015, 1.022)
Unemployment			
Overcrowded Accommodation			
Social Rented Accommodation		1.002 (1.000, 1.003)	1.002 (1, 1.004)
Goodness of Fit			
Akaike Information Criterion (AIC)	241733.59	241448.98	241589.58
Schwarz's Bayesian Criterion (SBC)	241965.41	241727.15	241852.31
-2LOGL	241703.59	241412.98	241555.58

Table 6-13 Odds ratios of the models with the areal socioeconomic status measured at different geographical scales for rheumatic heart disease

6.4 Discussion

This chapter has conducted population based research to examine the relationships between socioeconomic status and ethnic inequalities in cardiovascular disease.

The first aim of this chapter is to examine to what extent there are ethnic inequalities in cardiovascular disease between geodemographics groups with different socioeconomic status profiles. Geodemographics has a discriminatory power in targeting health promotion and disease prevention initiatives and allocating resources to tackle ethnic inequalities in cardiovascular disease. In this study, geodemographics groups with particularly high standardised incidence ratio of cardiovascular disease have been identified for each ethnicity-sex group. However, there are significant variations of the patterns of the standardised incidence ratio across ethnic groups.

Given the well established association between neighbourhood socioeconomic environment and cardiovascular disease (Diez-Roux et al., 2001b, Sundquist et al., 2004, Leyland, 2005), it is not surprising that white male population have relatively high ratios in the geodemographics groups of Centre with Industry, Industrial Hinterlands and Manufacturing Towns, but lower ratios in London Centres and Prospering Southern England. However, most minority ethnic groups, namely South Asians, Other Asian and Black population, are found to have particularly higher standardised incidence ratios in geodemographics groups located in London, particularly London Suburbs, London Centre and London Cosmopolitan. This is probably because minority ethnic groups in London are on average associated with lower socioeconomic status, compared with white Londoners and their peers in other parts of the UK, which has been discussed in Chapter Five before.

It is noticeable that nearly all the ethnicity-sex groups have lower standardised incidence ratios of cardiovascular disease than the general population in the geodemographics group of Coastal and Countryside, particularly for South Asians and

Other Asians. Although the standardised incidence ratio for white people in Coastal and Countryside is also lower than the national average, the ratio is not as significantly low as those for South Asians and Other Asians. In the Coastal and Countryside geodemographics group, the variables with a proportion far above the national average are Working from home, Working part-time for both men and women, Working in hotel & catering and People Aged 45–64 (Office for National Statistics, 2004). It is less likely that white people have lower ratios due to their high socioeconomic status. However, the lower ratios for South Asians and Other Asians might be because people from these groups living in Coastal and Countryside are really wealthy and affluent. As the UK 2001 Area Classification is based on the general population, the really wealthy status of minority ethnic groups hasn't been captured in the area classification.

A disadvantage of using geodemographics data to examine ethnic inequalities in cardiovascular disease must be acknowledged. It is easy to describe the characteristics of geodemographics groups showing very high standardised incidence ratio of cardiovascular disease according to the names of the geodemographics groups. However, when examining the standardised incidence ratio of cardiovascular disease between geodemographics groups for minority ethnic groups, the results are misleading. Geodemographics groups with low socioeconomic status, such as Centre with Industry, Industrial Hinterlands and Manufacturing Towns, are expected to have higher standardised incidence ratios of cardiovascular disease. However, the results show that Bangladeshi and Other Asian male population have significantly low ratios in Manufacturing Towns than other geodemographics groups. And Pakistani and Black Caribbean male population have lower ratios in Industrial Hinterlands. This is because the geodemographics classification used in this study, the UK 2001 Area Classification, is built based on the demographic and socioeconomic characteristics of the general population, the majority of which are white population. However, minority ethnic groups don't have a consistent spatial distribution of demographic and socioeconomic characteristics with white people. Ethnic minorities in a wealthy geodemographics group might be relatively poor. However, they might be of high socioeconomic status in geodemographics groups with high levels of unemployment and low qualification. Unfortunately there is no geodemographics classification that considers ethnic difference in demographic and socioeconomic characteristics.

The second aim of this chapter is to examine to what extent areal socioeconomic status inequalities could explain the ethnic inequalities in different types of cardiovascular disease, as there is no information about individual socioeconomic status in the HES. Given that residents of minority ethnic groups tend to live in more deprived areas in terms of environmental characteristics and service provision (Smaje, 1995), Nazroo (1998) suggested that ecological effect produced by the concentration of ethnic minority groups in deprived residential areas might be an important factor that determines their poor health. Karlsen et al. (2002) explored the contribution of ward level characteristics to ethnic inequalities in self-reported fair or poor health in the UK based on the Fourth National Survey of Ethnic Minorities (1993-1994). However, none of the ward level indicators, including the quality of the local environment, the provision of local amenities and local problems of crime and nuisance, was statistically and significantly associated with self-reported health among ethnic groups. There is a similar finding in this study. Although areal socioeconomic status measured in the English Index of Multiple Deprivation 2004 is statistically and significantly associated with cardiovascular disease, however, these measures don’t contribute to the ethnic inequalities in cardiovascular disease at all.

However, when areal socioeconomic status is measured specifically for ethnic groups, socioeconomic status inequalities significantly contribute to some ethnic groups’ higher relative risk of cardiovascular disease, although not fully. And the effect of areal socioeconomic status is consistent when the areal socioeconomic status is measured at different geographical scales. The effect of socioeconomic status inequalities on different types of cardiovascular disease varies across ethnic groups. The particularly high relative risk of Bangladeshi people in most cardiovascular diseases decreases by a large proportion after controlling for socioeconomic status, indicating socioeconomic status is an important determinant of their high relative risk. Socioeconomic status also has a substantial effect on general cardiovascular disease, stroke and heart failure for Black Caribbean and Black Africa people. The socioeconomic effect on Pakistani people's high relative risk is moderate for most cardiovascular diseases. However, given little change in the relative risk of different types of cardiovascular disease for Indian and Other Asian people after controlling for socioeconomic status, socioeconomic status explain their high relative risk hardly at all.

As this research is conducted at the ecological level, there is a possibility, termed the ecological fallacy, that the relationships found at aggregated level will not be the same relationships as found at individual level. However, there is evidence that the findings in this study are consistent with the relationships between individual level socioeconomic status and ethnic inequalities in health. Nazroo (2001) reported that after controlling for socioeconomic status indicators, particularly standard of living, the higher risk of reporting heart disease for Pakistani and Bangladeshi individuals was largely reduced. However, there was little difference between the uncontrolled and controlled risk for Indian people. A similar pattern of the effect of individual socioeconomic status on ethnic groups was also observed in reporting fair or bad general health. Socioeconomic status is found to account for a large proportion of the inequalities in self-reported health among Black Caribbean, Pakistani and Bangladeshi groups, but not Indian groups (Cooper, 2002, Nazroo, 2003b). However, the ecological fallacy might have a great impact on Other Asian and Mixed groups. As discussed in Chapter Five, Other Asian and Mixed groups are less likely to be socially stratified due to the great diversity of ethnic origins within each group, particularly Mixed group. People from these two groups don't share the attributes that define an ethnic group. There might be greater heterogeneity between individuals' socioeconomic status than that between individuals from other ethnic groups, such as Bangladeshi and Indian. Thus areal socioeconomic status might not be a proper indicator of individuals' socioeconomic status, which results in the ecological fallacy.

These findings about the contribution of socioeconomic status to the ethnic inequalities in cardiovascular disease raise a question about why socioeconomic status measures could explain part of the difference in cardiovascular disease risk? Given that people from minority ethnic groups generally have lower socioeconomic status, particularly Bangladeshi and Pakistani people, and that lower socioeconomic status is significantly associated with cardiovascular disease, people from these ethnic groups have increased risk of cardiovascular disease. Though the mechanisms through which socioeconomic status influences health outcomes are not well understood (McNeill et al., 2006), socioeconomic status may be unlikely to have a direct effect on health but serve to stimulate other determinants (Angell, 1993), including health behaviours, biological stress, physical environment and access to and use of health care, which have more immediate effects on health (Adler and Newman, 2002).

Firstly, individuals of lower socioeconomic status are more likely to engage in unhealthy behaviours than those with higher socioeconomic positions (Lindstrom et al., 2001). Low socioeconomic status is associated with more sedentary lifestyle and lower consumption of fibre and fresh fruits and vegetables (KrebsSmith et al., 1995, Adler and Newman, 2002). In contrast, individuals in higher socioeconomic status tend to adopt health promoting behaviours and reduce unhealthy behaviours at a faster rate than poor people (Institute of Medicine US, 2001).

Secondly, people of lower socioeconomic status have greater stressors, including financial strain, stressful living and working environment, low control at work, social exclusion, housing, unfair treatment and other stressors, which can affect health both directly and indirectly through its effect on unhealthy behaviours, and might be amplified as depression (Adler and Newman, 2002, Macinko et al., 2003, McNeill et al., 2006).

Thirdly, individuals in lower socioeconomic status are more likely to live and work in worse physical environments, exposed to air pollution, lead, carbon dioxide, and industrial waste. This kind of poor physical environment is very harmful to population health. In addition, as housing quality is relatively poor for low socioeconomic status families, individuals with lower socioeconomic status are more likely to experience residential overcrowding and noise, which appear to be more problematic for health (Richardson et al., 2002, Harris, 1999, Evans and Saegert, 2000, Evans, 1997). Furthermore, they may be more likely to live in neighbourhoods with poor recreational facilities, fewer stores selling fresh produce and more advertisement for tobacco and alcohol (Adler and Newman, 2002), which in turn affect their health behaviours.

Last but not least, access to and use of health care also vary by socioeconomic status. There was research showing that poverty reduces access to health care resources, which in turn results in poor health (Baum et al., 1999, Shi et al., 1999), although access to health care can only explain part or even relatively little of the difference in health status among social groups (Wood et al., 1999, Adler and Newman, 2002). People with less income and education do not use health services in the same way that their wealthier, better-educated counterparts do (Dunlop et al., 2000).

Socioeconomic status is an important determinant of ethnic inequalities in cardiovascular disease. However, the findings of this study suggest that socioeconomic status inequality can’t fully explain the ethnic inequalities in cardiovascular disease. The possible reasons might be that:

Firstly, although people from certain ethnic groups are not born with a higher risk, their traditional lifestyle, language, diet, culture and religion, which are not necessarily related to socioeconomic status, would promote their unhealthy behaviour, reduce access to health care, affect their attitude and perception towards cardiovascular disease, and thus as a combination put them at higher CVD risk. And these risk factors tend to cluster.

For example, South Asian food is high in saturated fat. Ghee, which is composed almost entirely of saturated fat, is used a lot in South Asian daily cooking, causing high levels of lipids in the blood. People from minority ethnic groups speak different language. They may not be able to speak or understand English, which is a barrier for them to utilize health care service, to communicate with doctors and to present their symptoms in an English speaking country. In South Asian culture, being fat is not a problem, but a sign of health, wealth and success (Naqvi, 2003). However, obesity, particularly central fat, is a major risk factor of cardiovascular disease. In addition, South Asian women are restricted from mixed-sex activities outside the home for cultural reasons, which keeps them away from outdoor physical activities. South Asian women, particularly older women, even perceived recreational physical activity beyond daily work as a selfish activity, because in their culture women are supposed to be dedicated to do all the house work (Sriskantharajah and Kai, 2007). Furthermore, religion may affect people's attitude and perception towards CVD. Muslims feel that suffering is part of Allah's will and is a test of their faith in Allah. They may not want to change it. Thus when they have been given a diagnosis of CVD or recommendations for prevention, they take it less seriously than non-South Asians, or even just ignore it (Naqvi, 2003).

Secondly, racial discrimination is another important dimension that directly relates to ethnicity, which would promote biological stress and psychological problems that increase risk of cardiovascular disease. Racial discrimination refers to personally perceived bias because of their ethnicity that occurs between individuals, or discriminatory policies or practices of organizations that result in differential access to resources and societal opportunities (Williams et al., 2003, Karlsen and Nazroo, 2002, Krieger, 2000), the latter of which has resulted in the economic and social deprivation of ethnic minorities (Nazroo, 2003b, Williams, 1999). Adjusting for demographic and socioeconomic status, a higher level of discrimination is associated with a higher level of mental illness, self reported 'not good' health, cardiovascular disease, high blood pressure and low birth weight (Williams et al., 2003). In addition, people who suffered discrimination are also at increased risk of unhealthy behaviours, such as smoking and alcohol use (Krieger, 2000). However, one practical problem of studying racial discrimination is that the extent of racial discrimination is still difficult to measure. But racial discrimination does happen to people from minority ethnic groups and is likely contribute to their risk of cardiovascular disease.

Chapter Seven: Ethnic Inequalities in CVD Survival, Severity and Treatment

7.1 Introduction

The previous chapter has investigated the relationships between ethnic inequalities in cardiovascular disease incidence and areal socioeconomic status. This chapter firstly examines ethnic inequalities in cardiovascular disease survival, and then investigates the contribution of areal socioeconomic status, distance to treatment sites and cardiovascular disease severity and treatment to the ethnic inequalities in cardiovascular survival. This chapter also examines ethnic disparities in cardiovascular disease severity and treatment, and explores the relationships between socioeconomic status and these inequalities.

Ethnic inequalities in cardiovascular disease incidence have been well studied and documented in previous research worldwide, particularly in the United Kingdom and the United States. Given that the mortality rates of cardiovascular disease for ethnic minorities, such as South Asians in the UK and black Americans in the US, are usually higher than that of white people, it would seem that overall survival is poorer in the ethnic minorities. However, there is inconsistent evidence in cardiovascular disease survival between ethnic minorities and white people in the US and the UK.

In the United States, black American people have higher cardiovascular disease mortality rates than white people. Compared to white and Asians, African Americans were more likely to be rehospitalized for congestive heart failure; however, it is surprising that they were less likely to die within a 12-month follow up period (Alexander et al., 1999). In the population-based Northern Manhattan Stroke Study, where 980 patients with first ischemic stroke were followed for 3 years, although the unadjusted Kaplan-Meier analysis shows a non-significant five year survival advantage in Caribbean Hispanics and black Americans compared with white people, black people have a lower proportion of incident stroke-related early deaths than white people (Hartmann et al., 2001). However, in another population based study conducted in the Greater Cincinnati/Northern Kentucky region, no significant difference between black people and white people in survival after stroke has been identified (Kissela et al., 2004).

In the United Kingdom, ethnic disparities in cardiovascular disease survival also have been addressed. The South London Stroke Register (SLSR) is a main data source for identifying the ethnic inequalities in cardiovascular disease survival, particularly in stroke survival. The South London Stroke Register (SLSR) is an ongoing population based stroke register recording first stroke in patients of all age groups, covering a multiethnic source population of 271,817 inhabitants (2001) in South London (Wolfe et al., 1993 , Stewart et al., 1999, Sarker et al., 2008). Based on four year South London Stroke Register (SLSR 1995-8) records with 1254 patients, Wolfe et al. (2002) found that although black population had an increased risk of stroke, no significant difference in stroke survival has been identified between black and white population. Wolfe et al. (2005) have done an updated study using the SLSR between January 1995 and December 2002, where 2321 patients with first stroke registered. In their study, black patients showed a clear survival advantage, with five year survival being 57% for black people and 36% for white people. Similar research has been conducted by Sarker et al (2008) using the SLSR between January 1995 and December 2004. After controlling for age, diabetes, stroke severity and stroke unit care, black patients still had a lower risk of death than white patients. Unlike the studies above which have identified significant difference in cardiovascular disease survival among ethnic groups, in the Birmingham Factory Screening Project, Lane et al. (2005) concluded that there was no significant difference in cardiovascular survival between white Europeans and Africa Caribbeans. However, there are few studies concerning cardiovascular disease survival among other ethnic groups, except for the study of Gunarathne et al. (2008b), which found that compared to other ethnic groups, South

Asians had more hyperlipidaemia and poorer survival at 30 days.

The first aim of this chapter is to examine the disparities in CVD survival among different ethnic groups at the English national level using the Hospital Episodes Statistic, which includes all the cardiovascular admissions covering the whole of England. Three year (2003/2004, 2004/2005, 2005/2006) inpatient and outpatient data have been extracted from the Hospital Episode Statistics.

The Hospital Episodes Statistic has a wealth of information about a patient, such as age, sex, ethnic category, clinical information (diagnoses, emergency admission, operations and discharge method, length of stay in hospitals) and geographical information (where the patient was treated and the output area in which they lived). The use of the Hospital Episode Statistics makes several major strengths of this study. Firstly, this study has included all the major ethnic groups in the UK. Previous studies on the ethnic difference in CVD survival in the UK usually focus on the difference in survival between black people and white people (Wolfe et al., 2002, Wolfe et al., 2005, Sarker et al., 2008). Few studies have examined the CVD survival difference among other ethnic groups, e,g, South Asians (Bangladeshi, Pakistani and Indian), who are very important ethnic groups in CVD studies because they usually experience a higher risk of cardiovascular disease morbidity. Secondly, this study has investigated the national difference in CVD survival among ethnic groups. However, the study areas of previous research have been mainly in south London (Wolfe et al., 2002, Wolfe et al., 2005, Sarker et al., 2008) and Birmingham (Lane et al., 2005). In addition, previous studies usually are subject to small sample size or rely on the South London Stroke Register (SLSR). However, the Hospital Episode Statistics have a large number of observations.

However, there is no information in the HES about the patients after being discharged from hospitals. The ONS mortality data have been linked and matched to the hospital episode spells by Gill (2003), which enriched the HES by adding information about death out of hospitals. This data is employed to examine ethnic inequalities in cardiovascular disease survival. Therefore this study has included not only deaths in hospitals but also deaths outside hospitals during the three years. There is one limitation of the data. Although the HES and the ONS mortality data have recorded the deaths, there is no information about the cause of death. Patients with cardiovascular disease were not necessarily dead from cardiovascular disease but from other disease, such as cancer. Given that cardiovascular disease is the leading cause of death in the UK, only the patients that have main diagnosis (first diagnosis) as cardiovascular disease have been extracted, assuming their cardiovascular disease at least contributes to the death (if observed), if they were actually not dead from cardiovascular disease. Furthermore, as cancer is another important cause of deaths in the UK, patients with cancer have been excluded from the analysis.

The second aim of this chapter is to investigate to what extent areal socioeconomic status contributes to ethnic inequalities in cardiovascular disease survival and the impact of geographical scales on socioeconomic status' effect. Lower socioeconomic status, such as poor education, lower income and the type of occupation, as well as living in a disadvantaged area, is an independent determinant of outcomes for many diseases and affects long term survival after critical illness (Ho et al., 2008). There are a few studies that demonstrate the effect of socioeconomic status on CVD survival. For example, significant difference has been found in the adjusted survival curves for 30-day and 1-year stroke mortality between those in the highest and lowest income quintiles (Kapral et al., 2002). The inverse association between neighbourhood socioeconomic status and CVD survival also has been identified. In a population based analysis, Macintyre et al. (2001) examined the effect of socioeconomic deprivation on death from a first myocardial infarction in Scotland. It was reported that people with myocardial infarction who lived in the least deprived areas of Scotland have a greater probability of surviving the first month than people from the most deprived areas. As identified in the previous chapter, areal socioeconomic status measured specifically for different ethnic groups rather than measured for the general population at the same area contributes to the ethnic inequalities in cardiovascular disease incidence. Areal socioeconomic measures extracted specifically for different ethnic groups from the UK 2001 Census at both local authority and Standard Table (ST) ward levels have been used in this study.

The third aim of this chapter is to examine whether geographical distance to treatment sites contributes the ethnic inequalities in cardiovascular disease survival. Given that geographical distance to treatment sites might potentially influence CVD survival (Nicholl et al., 2007) and people from ethnic minorities in lower socioeconomic status might lack accessibility to treatment sites than other population, distance might also contribute to the ethnic inequalities in CVD. Straight line distance, between the population weighted centroid of the output area where the patient lives and the centroid of the postcode area where the treatment site is located, serves as distance to treatment sites in this study. Although there is a potential bias that straight line distance does not accurately reflect the network distance, the correlation between straight line distance and travel time was found to be significantly high (Phibbs and Luft, 1995).

The fourth aim is to examine whether some ethnic groups' relatively low cardiovascular disease survival is because they have developed more serious cardiovascular disease or because they have received less intensive treatment than other ethnic groups. There is no explicit clinical information in the HES that measures cardiovascular disease severity. However, the available information in the HES, such as cardiovascular operation, cardiovascular emergency admission and length of stay in hospitals might serve as severity indicators. This is because patients with more serious cardiovascular disease are more likely to have emergency admissions, cardiovascular operations and long length of stay in hospitals. One point to be addressed is that these CVD severity indicators could also reflect the treatments for cardiovascular disease, since emergency admissions, cardiovascular disease operations and long term of stay in hospitals mean intensive treatment and care, which will enhance their survival to some extent. As a number of studies suggested that diabetes mellitus is associated with increased risk of death from cardiovascular disease, particularly stroke (Sarker et al., 2008, Gunarathne et al., 2008a) and ischaemic heart disease (de Groote et al., 2004). Therefore, diabetes mellitus is also included in the model.

This chapter also examines ethnic inequalities in cardiovascular emergency admissions and operations, and then investigated to what extent areal socioeconomic status measured at different geographical scales contributes to these ethnic inequalities.

7.2 Ethnic Inequalities in CVD Survival

This section presents and discusses how areal socioeconomic status, geographical distance to treatment sites, cardiovascular disease severity/treatment indicators and co-morbidity (diabetes mellitus) contribute to ethnic inequalities in cardiovascular disease survival.

Firstly, Kaplan-Meier curves are created separately for sex, age and ethnic groups, providing insight into the shape of the survival function for each group and giving a general idea of whether or not the groups are proportional.

Controlling only for age and sex, Cox proportional hazards regression is then employed to quantify ethnic inequalities in cardiovascular disease survival. To assess the effect of areal socioeconomic status on the ethnic inequalities in cardiovascular disease survival, a second series of Cox proportional hazards regression models is fitted with areal socioeconomic status specifically measured for each ethnic group at different geographical scales (ST ward level and local authority level). Distance to treatment sites is also fitted into the Cox proportional hazards regression model to determine whether it is significantly and independently associated with the ethnic disparities in cardiovascular disease survival. As an important risk factor of death, cardiovascular disease severity/treatment, measured as heart operation, emergence admission and length of stay in hospital, is also included in the model to investigate whether the higher risk of death for some ethnic groups is because they usually develop more serious cardiovascular disease than other ethnic groups. Lastly, the full models with areal socioeconomic status, accessibility to treatment sites, co-morbidity (diabetes mellitus) and cardiovascular disease severity/treatment indicators are fitted to quantify their effect on the ethnic inequalities in cardiovascular disease survival. The table below briefly shows information about the models.

Aims	Data	Methods	Variables
To examine the relationships between areal socioeconomic status, distance to treatment sites, CVD severity/treatment and ethnic inequalities in CVD survival	• Hospital Episode Statistics • The ONS mortality data • The UK 2001 Census • National Statistics Postcode Directory (NSPD) • Output Area Centroid Coordinates	• Kaplan-Meier Survival Curve • Cox Proportional Hazards Regression	**Age** 16-34 35-44 45-54 55-64 65-74 75-84 **Sex** Male Female **Ethnicity** Indian Pakistani Bangladeshi Other Asian Black Caribbean Black Africa Mixed Chinese White **Areal Socioeconomic Status** Low Qualification Low Social Class Unemployment Living in Overcrowded Accommodation Living in Social Rented Accommodation (ST Ward Level and Local Authority Level) **Distance to Treatment Sites** **CVD Severity Indicators** Length of Stay in Hospital CVD Emergency Admission CVD Operations **Co-morbidity** Diabetes Mellitus

Table 7-1 Introduction to models for ethnic inequalities in CVD survival

In all the Cox proportional hazards regression models, hazard ratio serves as the measure of relative risk, where white group is the reference ethnic group. Compared with white people, a hazard ratio above 1 implies higher risk of death and thus decreased probability of survival, while a hazard ratio less than 1 indicates lower risk of death than white people and an increased probability of survival. Time to death or time of last CVD admission is the dependent variable in the models. If no death is recorded for a given patient, the end of study period served as the censoring date.

7.2.1 Ethnic Inequalities in CVD Survival

The figures below show the Kaplan-Meier survival curves for sex, age and ethnic groups separately. In Figure 7-1, the Kaplan-Meier survival curve shows a clear difference between males and females, where males have better survival. Significant difference is also observed in the Kaplan-Meier survival curve for different age groups in Figure 7-2. As expected, the survival rate decreases as age increases. People under 54 have an almost identically high survival rate. However, the survival rate is much lower in elderly people, particularly for people aged above 85. Given that ethnic minorities, particularly South Asians, are more likely to have cardiovascular disease than white people, reverse findings are observed in the Kaplan-Meier survival curve in Figure 7-3. White people, whose curve (yellow) is under all the other survival curves, are found to have the worst cardiovascular disease survival among all the ethnic groups. All the other ethnic groups have better cardiovascular disease survival, particularly South Asians. There is a modest difference in survival rates between minority ethnic groups; however, the difference between white people and minority ethnic groups in cardiovascular disease survival is substantial.

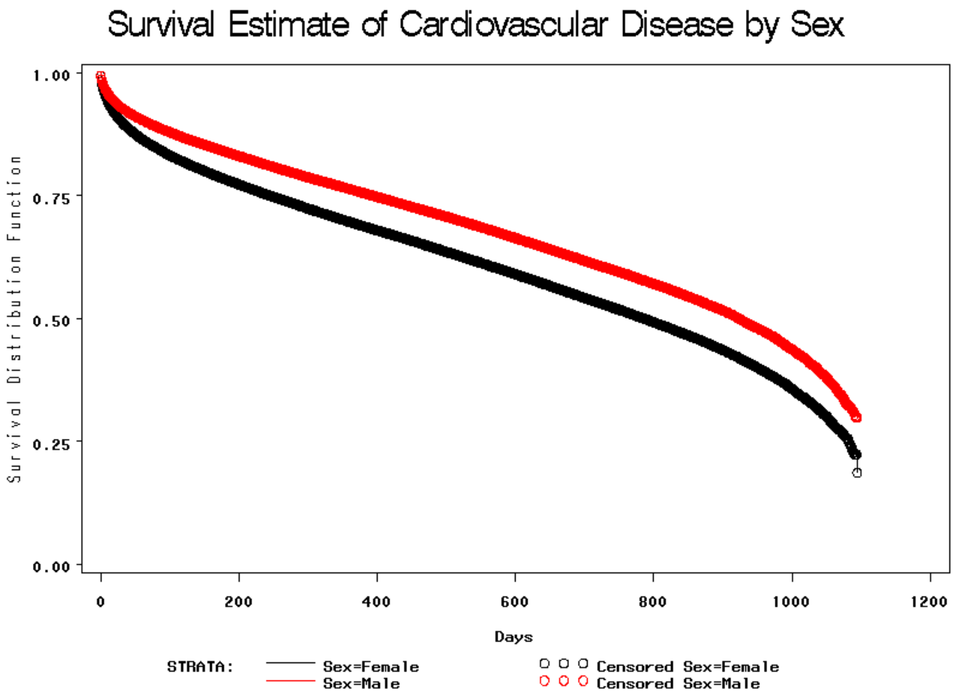

Figure 7-1 Kaplan-Meier survival curves of cardiovascular disease for sex

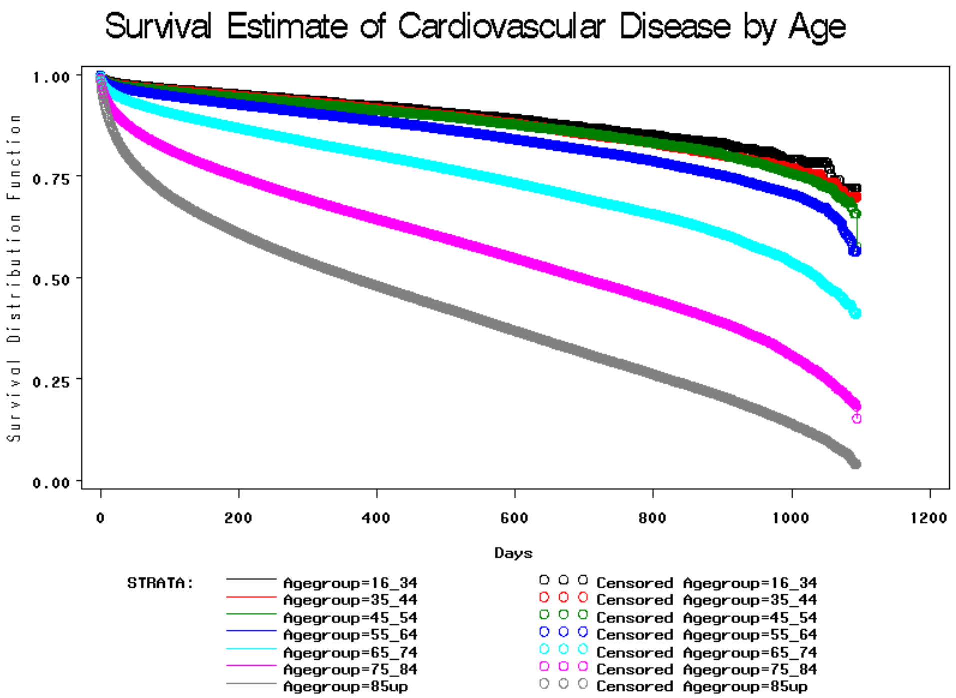

Figure 7-2 Kaplan-Meier survival curves of cardiovascular disease for age groups

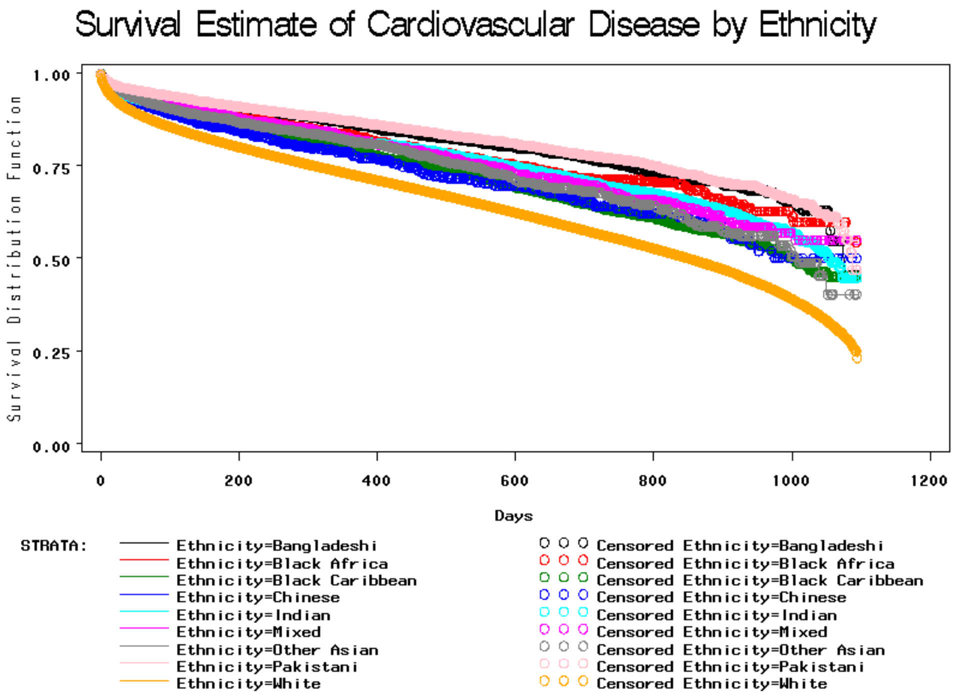

Figure 7-3 Kaplan-Meier survival curves of cardiovascular disease for ethnic groups

The ethnic inequalities in cardiovascular disease survival have been quantified in the Cox proportional hazards regression model controlling for age and sex. As shown in the table below, compared with white people, most minority ethnic groups have lower hazard ratios, implying their better survival from cardiovascular disease. South Asians, particularly Bangladeshi and Pakistani people, who have a significantly higher risk of cardiovascular disease, are found to have lower hazard ratios. The cardiovascular disease survival among Other Asian and Black Africa groups is very close to that of white people. Chinese people, who are much less likely to get cardiovascular disease than any other ethnic group, are also found to have worse survival than most ethnic groups, being similar to white people.

Analysis of Maximum Likelihood Estimates								
		Parameter	*Standard*		*Pr >*	*Hazard*	*95% Hazard Ratio*	
Variable	*DF*	*Estimate*	*Error*	*Chi-Square*	*ChiSq*	*Ratio*	*Confidence Limits*	
Sex								
Male	1	-0.0006619	0.00401	0.0272	0.869	0.999	0.992	1.007
Female						1		
Age								
Age16_34	1	-2.17313	0.03029	5148.7806	<.0001	0.114	0.107	0.121
Age35_44	1	-2.0523	0.02011	10420.0855	<.0001	0.128	0.123	0.134
Age45_54	1	-2.00676	0.01334	22617.2431	<.0001	0.134	0.131	0.138
Age55_64	1	-1.758	0.00873	40510.904	<.0001	0.172	0.169	0.175
Age65_74	1	-1.17553	0.00595	39094.8133	<.0001	0.309	0.305	0.312
Age75_84	1	-0.51021	0.0046	12283.4425	<.0001	0.6	0.595	0.606
Age85up						1		
Ethnicity								
Indian	1	-0.11112	0.01852	36.0206	<.0001	0.895	0.863	0.928
Pakistani	1	-0.29414	0.026	128.0082	<.0001	0.745	0.708	0.784
Bangladeshi	1	-0.21449	0.04766	20.2527	<.0001	0.807	0.735	0.886
Other Asian	1	0.03577	0.04211	0.7217	0.3956	1.036	0.954	1.126
Black Caribbean	1	-0.09008	0.02496	13.0237	0.0003	0.914	0.87	0.96
Black Africa	1	0.07297	0.0492	2.1999	0.138	1.076	0.977	1.185
Chinese	1	0.00279	0.06432	0.0019	0.9655	1.003	0.884	1.138
Mixed	1	-0.15064	0.04751	10.0526	0.0015	0.86	0.784	0.944
White						1		

Model Fit Statistics		
Criterion	*Without Covariates*	*With Covariates*
-2LOGL	6828957.9	6723639.9
Akaike Information Criterion (AIC)	6828957.9	6723669.9
Schwarz's Bayesian Criterion (SBC)	6828957.9	6723827.1

Table 7-2 Ethnic inequalities in CVD survival

7.2.2 Ethnic Inequalities in CVD Survival and SES

Socioeconomic status measures are included in the Cox proportional hazards models to quantify the effect of socioeconomic status measured at different geographical scales on ethnic inequalities in cardiovascular disease survival. The areal socioeconomic measures, including low socioeconomic class, unemployment, low qualifications, living in overcrowded accommodation and living in social rented accommodation, are extracted from the UK 2001 Census in the form of percentages for each ethnic group at both ST ward and local authority levels, serving as independent variables in the Cox proportional hazards models.

As shown in Table 7-3, among the five ST ward level socioeconomic status measures, low socioeconomic class, unemployment and living in overcrowded accommodation, are highly statistically significant ($p < 0.0001$), suggesting that a high level of low socioeconomic class, unemployment and living in overcrowded accommodation is associated with increased risk of death or decreased probabilities of survival from cardiovascular disease. The relationships between areal socioeconomic status measures and the ethnic inequalities in cardiovascular disease survival also have been observed in Table 7-3. After controlling for these socioeconomic status measures, people from all the minority ethnic groups show lower hazard ratios than white people, demonstrating their better survival. However, the socioeconomic status measures have widened the gaps between minority ethnic groups and white people in cardiovascular disease survival.

In addition, the magnitude of the effect of socioeconomic status on cardiovascular disease survival is different for ethnic groups. Compared to the unadjusted hazard ratios in Table 7-2, the hazard ratios of Bangladeshi people drops most, indicating the substantial effect of socioeconomic status on Bangladeshi group. The hazard ratios of Other Asian, Black Africa and Chinese people, which were marginally higher than 1 (white people), are marginally lower than white people after the adjustment for socioeconomic status measures. However, there is little difference between the unadjusted and adjusted hazards ratios for Indian and Mixed groups, suggesting that socioeconomic status measures used here contribute very little to their relative CVD survival.

Analysis of Maximum Likelihood Estimates								
		Parameter	*Standard*		*Pr >*	*Hazard*	*95% Hazard Ratio*	
Variable	*DF*	*Estimate*	*Error*	*Chi-Square*	*ChiSq*	*Ratio*	*Confidence Limits*	
Sex								
Male	1	-0.0006036	0.00444	0.0185	0.8918	0.999	0.991	1.008
Female						1		
Age								
Age16_34	1	-2.18767	0.03058	5117.9731	<.0001	0.112	0.106	0.119
Age35_44	1	-2.06834	0.02027	10413.5864	<.0001	0.126	0.121	0.132
Age45_54	1	-2.02107	0.01345	22582.6432	<.0001	0.133	0.129	0.136
Age55_64	1	-1.7658	0.00879	40370.9036	<.0001	0.171	0.168	0.174
Age65_74	1	-1.18081	0.00598	39020.2535	<.0001	0.307	0.303	0.311
Age75_84	1	-0.51353	0.00462	12343.6531	<.0001	0.598	0.593	0.604
Age85up						1		
Ethnicity								
Indian	1	-0.15653	0.01979	62.5543	<.0001	0.855	0.823	0.889
Pakistani	1	-0.4031	0.02847	200.4192	<.0001	0.668	0.632	0.707
Bangladeshi	1	-0.41203	0.05262	61.3051	<.0001	0.662	0.597	0.734
Other Asian	1	-0.05518	0.04552	1.4695	0.2254	0.946	0.866	1.035
Black Caribbean	1	-0.18218	0.02642	47.5412	<.0001	0.833	0.791	0.878
Black Africa	1	-0.0741	0.05395	1.8869	0.1696	0.929	0.835	1.032
Chinese	1	-0.06034	0.06862	0.7732	0.3792	0.941	0.823	1.077
Mixed	1	-0.20117	0.04941	16.5744	<.0001	0.818	0.742	0.901
White						1		
Socioeconomic Status								
Low Socioeconomic Class (ST ward)	1	0.00286	0.0003009	90.5024	<.0001	1.003	1.002	1.003
Unemployment (ST ward)	1	0.00407	0.0007722	27.8139	<.0001	1.004	1.003	1.006
Overcrowding (ST ward)	1	0.00253	0.0004304	34.5659	<.0001	1.003	1.002	1.003

Model Fit Statistics		
Criterion	*Without Covariates*	*With Covariates*
-2LOGL	6775016.2	6670275.5
Akaike Information Criterion (AIC)	6775016.2	6670311.5
Schwarz's Bayesian Criterion (SBC)	6775016.2	6670500

Table 7-3 Ethnic inequalities in CVD survival and ward level socioeconomic status

Table 7-4 shows the results obtained from the Cox proportional hazards model controlled by local authority level socioeconomic status.

Variable	DF	Parameter Estimate	Standard Error	Chi-Square	Pr > ChiSq	Hazard Ratio	95% Hazard Ratio Confidence Limits	
Sex								
Male	1	0.01131	0.00426	7.05	0.0079	1.011	1.003	1.02
Female						1		
Age								
Age16_34	1	-2.18216	0.03053	5107.6273	<.0001	0.113	0.106	0.12
Age35_44	1	-2.06222	0.02023	10391.7841	<.0001	0.127	0.122	0.132
Age45_54	1	-2.01619	0.01342	22556.5752	<.0001	0.133	0.13	0.137
Age55_64	1	-1.76287	0.00878	40357.0089	<.0001	0.172	0.169	0.175
Age65_74	1	-1.17943	0.00597	39024.2196	<.0001	0.307	0.304	0.311
Age75_84	1	-0.51288	0.00462	12330.8449	<.0001	0.599	0.593	0.604
Age85up						1		
Ethnicity								
Indian	1	-0.1718	0.02027	71.8001	<.0001	0.842	0.809	0.876
Pakistani	1	-0.43265	0.03008	206.9066	<.0001	0.649	0.612	0.688
Bangladeshi	1	-0.50747	0.05542	83.8599	<.0001	0.602	0.54	0.671
Other Asian	1	-0.08669	0.0453	3.6625	0.0557	0.917	0.839	1.002
Black Caribbean	1	-0.18159	0.02653	46.8548	<.0001	0.834	0.792	0.878
Black Africa	1	-0.06414	0.05323	1.4521	0.2282	0.938	0.845	1.041
Chinese	1	-0.0339	0.06545	0.2682	0.6045	0.967	0.85	1.099
Mixed	1	-0.19968	0.04821	17.1582	<.0001	0.819	0.745	0.9
White						1		
Socioeconomic Status								
Low Socioeconomic Class (LA)	1	0.00496	0.0006387	60.2718	<.0001	1.005	1.004	1.006
Low Qualification (LA)	1	0.00189	0.0005182	13.368	0.0003	1.002	1.001	1.003
Overcrowding (LA)	1	0.00483	0.000534	81.9669	<.0001	1.005	1.004	1.006

Analysis of Maximum Likelihood Estimates

Criterion	Without Covariates	With Covariates
-2LOGL	6781659.5	6676766.1
Akaike Information Criterion (AIC)	6781659.5	6676802.1
Schwarz's Bayesian Criterion (SBC)	6781659.5	6676990.6

Model Fit Statistics

Table 7-4 Ethnic inequalities in CVD survival and local authority level socioeconomic status

Of the five local authority level socioeconomic status measures, low socioeconomic class, low qualifications and living in overcrowded accommodation are highly statistically significant ($p < 0.0001$), suggesting that a high level of low socioeconomic class, low qualification and overcrowded accommodation are associated with decreased probabilities of survival from cardiovascular disease. There is no significant difference among the adjusted hazard ratios for ethnic groups in models controlled by ST ward level and local authority level socioeconomic status measures. After controlling for socioeconomic status, all the minority ethnic groups have hazard ratios below 1, indicating all the ethnic minorities have better survival than white people.

In summary, the effect of areal socioeconomic status on CVD survival is relatively stable even if socioeconomic status is measured at different geographical scales. However, given that all the minority ethnic groups have even better CVD survival than white people after controlling for areal socioeconomic status, socioeconomic status measures used here can't explain the observed ethnic inequalities in cardiovascular disease survival at all, but widen the ethnic inequalities.

7.2.3 Ethnic Inequalities in CVD Survival and Distance to Treatment Sites

Distance to treatment sites is a potential factor that affects CVD survival. This section investigates to what extent geographical distance to treatment sites could explain the observed ethnic inequalities in CVD survival. Direct distance to treatment site has been used in the models, having been categorized into five quintiles. Quintile 1 denotes shortest distance to treatment sites and Quintile 5 denotes furthest distance to treatment sites.

Survival rates of CVD for different distance quintiles are modelled in the Kaplan-Meier survival curve shown in Figure 7-4. There is clear difference in survival rates between Quintile 5 and other quintiles. People who live further from treatment sites have higher rate of CVD survival, which is in theory inconsistent with previous studies (Nicholl et al., 2007).

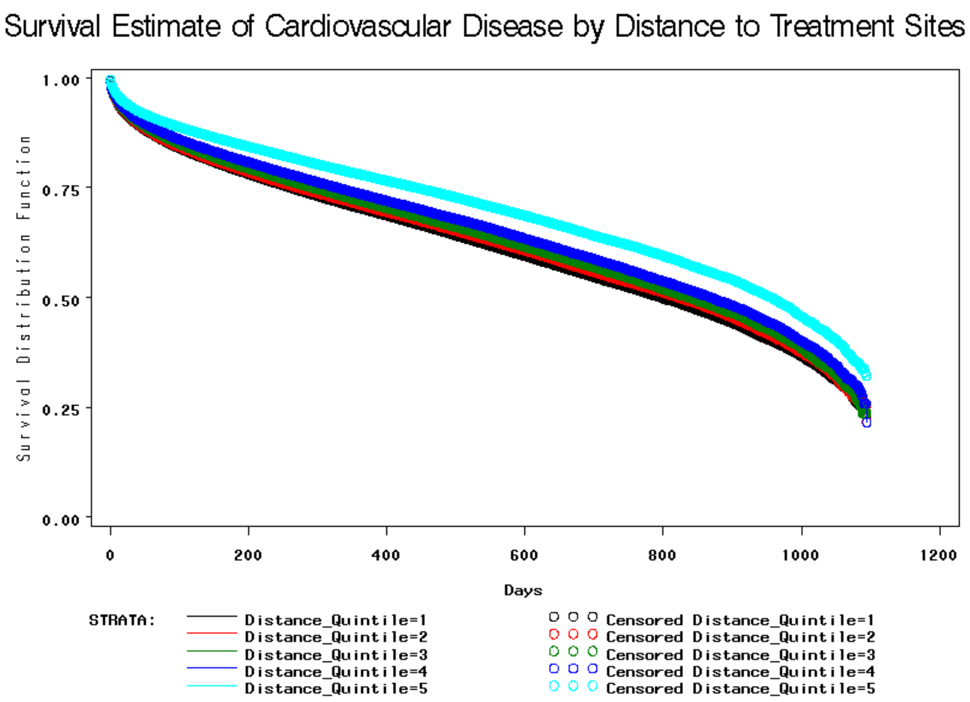

Figure 7-4 Kaplan-Meier survival curve of cardiovascular disease for distance to treatment sites

A similar result is observed in the Cox proportional hazards model controlled by age, sex and ethnicity. Compared with Quintile 5, which is the reference group and has a hazard ratio of 1, all the other quintiles have hazard ratios above 1, indicating shorter distance to treatment sites is associated with worse CVD survival. It might be because people living further from treatment sites have higher socioeconomic status and less serious cardiovascular disease. However, when controlled for areal socioeconomic status measures, CVD severity indicators, including cardiovascular disease operation, cardiovascular emergency admission and length of stay in hospitals, further distance to treatment sites is still associated with better cardiovascular disease survival. Furthermore, compared with the unadjusted hazard ratios of ethnic groups presented in Table 7-2, the hazard ratios adjusted by distance to treatment sites change little, indicating the effect of distance to treatment sites on the ethnic inequalities in CVD survival is little. For these two reasons, distance to treatment sites is not a good predictor of cardiovascular disease survival and will not be included in the later full model.

Analysis of Maximum Likelihood Estimates								
Variable	*DF*	*Parameter Estimate*	*Standard Error*	*Chi-Square*	*Pr > ChiSq*	*Hazard Ratio*	*95% Hazard Ratio Confidence Limits*	
Sex								
Male	1	0.0046	0.00402	1.3125	0.2519	1.005	0.997	1.013
Female						1		
Age								
Age16_34	1	-2.15879	0.03029	5080.0728	<.0001	0.115	0.109	0.123
Age35_44	1	-2.04065	0.02011	10299.4801	<.0001	0.13	0.125	0.135
Age45_54	1	-1.99428	0.01335	22323.0518	<.0001	0.136	0.133	0.14
Age55_64	1	-1.74291	0.00874	39732.612	<.0001	0.175	0.172	0.178
Age65_74	1	-1.16366	0.00595	38199.5394	<.0001	0.312	0.309	0.316
Age75_84	1	-0.50521	0.00461	12033.2431	<.0001	0.603	0.598	0.609
Age85up						1		
Ethnicity								
Indian	1	-0.14686	0.01854	62.7216	<.0001	0.863	0.833	0.895
Pakistani	1	-0.3353	0.02603	165.8976	<.0001	0.715	0.68	0.753
Bangladeshi	1	-0.27383	0.04771	32.947	<.0001	0.76	0.693	0.835
Other Asian	1	0.0021	0.04212	0.0025	0.9602	1.002	0.923	1.088
Black Caribbean	1	-0.14201	0.02502	32.2253	<.0001	0.868	0.826	0.911
Black Africa	1	0.02851	0.04922	0.3354	0.5625	1.029	0.934	1.133
Chinese	1	-0.03101	0.06433	0.2323	0.6298	0.969	0.855	1.1
Mixed	1	-0.17558	0.04752	13.6535	0.0002	0.839	0.764	0.921
White						1		
Distance to Treatment Sites								
Distance_Quintile1 (Shortest)	1	0.19923	0.00611	1063.6293	<.0001	1.22	1.206	1.235
Distance_Quintile2	1	0.16782	0.00615	745.2125	<.0001	1.183	1.169	1.197
Distance_Quintile3	1	0.13927	0.00616	510.6778	<.0001	1.149	1.136	1.163
Distance_Quintile4	1	0.09238	0.00622	220.8095	<.0001	1.097	1.084	1.11
Distance_Quintile5 (Furthest)						1		

Model Fit Statistics		
Criterion	*Without Covariates*	*With Covariates*
-2LOGL	6828957.9	6722341.2
Akaike Information Criterion (AIC)	6828957.9	6722379.2
Schwarz's Bayesian Criterion (SBC)	6828957.9	6722578.3

Table 7-5 Ethnic inequalities in CVD survival and distance to treatment sites

7.2.4 Ethnic Inequalities in CVD Survival and CVD Severity/Treatment

The models above controlled by socioeconomic status and distance to treatment sites can't explain the observed ethnic inequalities in cardiovascular disease survival. This section examines whether some ethnic groups' relatively low cardiovascular disease survival is because they have developed more serious cardiovascular disease or because they have received less intensive treatment. The three CVD severity/treatment indicators are cardiovascular disease operation, cardiovascular emergency admission and length of stay in hospitals.

As shown in Table 7-6, all the three CVD severity/treatment indicators are highly statistically significant, suggesting that CVD patients with more intensive treatment have better survival. Cardiovascular disease operation is the most important positive factor that influences cardiovascular disease survival. The hazard ratio of CVD operation (0.287) is much lower than 1, indicating that cardiovascular operation could significantly enhance short term (three year) CVD survival. Cardiovascular emergency admission with a hazard ratio of 0.983 could also promote CVD survival. However, the hazard ratios of long length of stay in hospitals is very close to 1, suggesting that long length of stay in hospitals doesn't significantly enhance short term CVD survival. It is also surprising that diabetes mellitus has a positive impact on CVD survival.

After controlling for CVD severity/treatment indicators, compared with unadjusted hazard ratios presented in Table 7-2, the hazards ratios of most minority ethnic groups increase towards 1, implying that the disparities in CVD survival among ethnic minorities and white people decrease, the controlled hazard ratios of Indian, Bangladeshi and Chinese people are almost the same as that of white people. However, the relative risk of death for Other Asians is even higher after controlling these severity/treatment indicators. In addition, the controlled CVD survival for Pakistani people is still significantly better than white people.

Analysis of Maximum Likelihood Estimates

Variable	*DF*	*Parameter Estimate*	*Standard Error*	*Chi-Square*	*Pr > ChiSq*	*Hazard Ratio*	*95% Hazard Ratio Confidence Limits*	
Sex								
Male	1	0.07555	0.00402	352.9581	<.0001	1.078	1.07	1.087
Female						1		
Age								
Age16_34	1	-2.12547	0.03044	4875.09	<.0001	0.119	0.112	0.127
Age35_44	1	-1.91716	0.02026	8950.6502	<.0001	0.147	0.141	0.153
Age45_54	1	-1.73925	0.01353	16533.4194	<.0001	0.176	0.171	0.18
Age55_64	1	-1.44223	0.00898	25793.0119	<.0001	0.236	0.232	0.241
Age65_74	1	-0.90916	0.00616	21786.3251	<.0001	0.403	0.398	0.408
Age75_84	1	-0.40029	0.00466	7387.4656	<.0001	0.67	0.664	0.676
Age85up						1		
Ethnicity								
Indian	1	-0.00556	0.01856	0.0896	0.7647	0.994	0.959	1.031
Pakistani	1	-0.20777	0.02606	63.5649	<.0001	0.812	0.772	0.855
Bangladeshi	1	-0.04601	0.04776	0.9282	0.3353	0.955	0.87	1.049
Other Asian	1	0.13998	0.0422	11	0.0009	1.15	1.059	1.249
Black Caribbean	1	-0.11169	0.02503	19.9141	<.0001	0.894	0.852	0.939
Black Africa	1	0.02969	0.04927	0.363	0.5468	1.03	0.935	1.135
Chinese	1	-0.03754	0.06432	0.3406	0.5595	0.963	0.849	1.093
Mixed	1	-0.07961	0.04752	2.8072	0.0938	0.923	0.841	1.014
White						1		
CVD Severity/Treatment								
Diabetes Mellitus	1	-0.0515	0.00501	105.7996	<.0001	0.95	0.941	0.959
CVD Operation	1	-1.24814	0.00671	34640.7587	<.0001	0.287	0.283	0.291
CVD Emergency Admission	1	-0.01714	0.00582	8.6651	0.0032	0.983	0.972	0.994
Length of Stay in Hospitals	1	-0.00121	0.0000354	1170.6681	<.0001	0.999	0.999	0.999

Model Fit Statistics

Criterion	*Without Covariates*	*With Covariates*
-2LOGL	6808620	6656770
Akaike Information Criterion (AIC)	6808620	6656808
Schwarz’s Bayesian Criterion (SBC)	6808620	6657007

Table 7-6 Ethnic inequalities in CVD survival and CVD severity/treatment

7.2.5 Full Model

In the previous sections, it is identified that controlling for socioeconomic status measures widens the ethnic inequalities in CVD survival. However, after controlling for CVD severity/treatment indicators, the disparities between ethnic groups in CVD survival decrease. In this section, both CVD severity/treatment indicators and areal socioeconomic status measures are fitted into the Cox proportional hazards models to investigate how these variables together contribute to the ethnic inequalities in CVD survival. Effect of socioeconomic status measured at both ST ward and local authority level on the ethnic inequalities in CVD survival is examined in two separate models.

In the model controlled by both CVD severity/treatment indicators and ST ward level socioeconomic status measures (Table 7-7), all the four CVD severity/treatment indicators are highly statistically significant ($p < 0.0001$). Socioeconomic status measures are still independently associated with cardiovascular disease survival, but become less important. Only low socioeconomic class and living in overcrowded accommodation are significant in the model. In the model with local authority level socioeconomic status (Table 7-8), the four CVD severity/treatment indicators are also highly statistically significant ($p < 0.0001$). However, low qualification and living in overcrowded accommodation measured at local authority level are significant in the model.

Analysis of Maximum Likelihood Estimates								
		Parameter	*Standard*		*Pr >*	*Hazard*	*95% Hazard Ratio*	
Variable	*DF*	*Estimate*	*Error*	*Chi-Square*	*ChiSq*	*Ratio*	*Confidence Limits*	
Sex								
Male	1	0.07765	0.00407	363.8606	<.0001	1.081	1.072	1.089
Female						1		
Age								
Age16_34	1	-2.13574	0.03073	4831.1152	<.0001	0.118	0.111	0.125
Age35_44	1	-1.92863	0.02043	8912.0684	<.0001	0.145	0.14	0.151
Age45_54	1	-1.74849	0.01363	16448.87	<.0001	0.174	0.169	0.179
Age55_64	1	-1.44672	0.00904	25613.8777	<.0001	0.235	0.231	0.24
Age65_74	1	-0.91183	0.0062	21641.6985	<.0001	0.402	0.397	0.407
Age75_84	1	-0.40143	0.00468	7362.095	<.0001	0.669	0.663	0.676
Age85up						1		
Ethnicity								
Indian	1	-0.07946	0.01971	16.2482	<.0001	0.924	0.889	0.96
Pakistani	1	-0.33146	0.02825	137.6538	<.0001	0.718	0.679	0.759
Bangladeshi	1	-0.29474	0.05235	31.6943	<.0001	0.745	0.672	0.825
Other Asian	1	-0.01281	0.04506	0.0808	0.7762	0.987	0.904	1.078
Black Caribbean	1	-0.19754	0.02616	57.0179	<.0001	0.821	0.78	0.864
Black Africa	1	-0.16712	0.05349	9.7592	0.0018	0.846	0.762	0.94
Chinese	1	-0.14068	0.06717	4.3858	0.0362	0.869	0.762	0.991
Mixed	1	-0.14427	0.04872	8.7677	0.0031	0.866	0.787	0.952
White						1		
CVD Severity/Treatment								
Diabetes	1	-0.05261	0.00503	109.4734	<.0001	0.949	0.939	0.958
CVD Operation	1	-1.24997	0.00675	34292.0304	<.0001	0.287	0.283	0.29
CVD Emergency Admission	1	-0.01806	0.00586	9.5141	0.002	0.982	0.971	0.993
Length of Stay in Hospitals	1	-0.00122	0.0000355	1182.8709	<.0001	0.999	0.999	0.999
Socioeconomic Status								
Low Socioeconomic Class (ST ward)	1	0.0006088	0.0002572	5.602	0.0179	1.001	1	1.001
Overcrowding (ST ward)	1	0.00474	0.0003876	149.5986	<.0001	1.005	1.004	1.006

Model Fit Statistics		
Criterion	*Without Covariates*	*With Covariates*
-2LOGL	6757372.9	6606489.6
Akaike Information Criterion (AIC)	6757372.9	6606531.6
Schwarz's Bayesian Criterion (SBC)	6757372.9	6606751.5

Table 7-7 The effect of CVD severity/treatment and ward level socioeconomic status on ethnic inequalities in CVD survival

Analysis of Maximum Likelihood Estimates								
Variable	*DF*	*Parameter Estimate*	*Standard Error*	*Chi-Square*	*Pr > ChiSq*	*Hazard Ratio*	*95% Hazard Ratio Confidence Limits*	
Sex								
Male	1	0.07611	0.00403	356.0173	<.0001	1.079	1.071	1.088
Female						1		
Age								
Age16_34	1	-2.13374	0.03069	4833.097	<.0001	0.118	0.111	0.126
Age35_44	1	-1.92538	0.02039	8915.9956	<.0001	0.146	0.14	0.152
Age45_54	1	-1.7467	0.01361	16473.8666	<.0001	0.174	0.17	0.179
Age55_64	1	-1.44582	0.00902	25673.794	<.0001	0.236	0.231	0.24
Age65_74	1	-0.91185	0.00619	21720.7805	<.0001	0.402	0.397	0.407
Age75_84	1	-0.4015	0.00467	7380.1043	<.0001	0.669	0.663	0.675
Age85up						1		
Ethnicity								
Indian	1	-0.08963	0.02028	19.5334	<.0001	0.914	0.879	0.951
Pakistani	1	-0.38674	0.03002	165.9212	<.0001	0.679	0.64	0.72
Bangladeshi	1	-0.38451	0.05547	48.0489	<.0001	0.681	0.611	0.759
Other Asian	1	-0.03989	0.04543	0.7712	0.3798	0.961	0.879	1.05
Black Caribbean	1	-0.21376	0.0266	64.5851	<.0001	0.808	0.767	0.851
Black Africa	1	-0.1696	0.05321	10.1591	0.0014	0.844	0.76	0.937
Chinese	1	-0.13449	0.06546	4.2211	0.0399	0.874	0.769	0.994
Mixed	1	-0.16193	0.04819	11.2931	0.0008	0.85	0.774	0.935
White						1		
CVD Severity/Treatment								
Diabetes	1	-0.05222	0.00502	108.0004	<.0001	0.949	0.94	0.959
CVD Operation	1	-1.24986	0.00674	34343.5179	<.0001	0.287	0.283	0.29
CVD Emergency Admission	1	-0.01732	0.00585	8.7675	0.0031	0.983	0.972	0.994
Length of Stay in Hospitals	1	-0.00122	0.0000355	1176.0898	<.0001	0.999	0.999	0.999
Socioeconomic Status								
Low Qualification (LA)	1	0.00237	0.0003302	51.5554	<.0001	1.002	1.002	1.003
Overcrowding (LA)	1	0.00635	0.0005303	143.4343	<.0001	1.006	1.005	1.007

Model Fit Statistics		
Criterion	*Without Covariates*	*With Covariates*
-2LOGL	6761858.7	6610860.9
Akaike Information Criterion (AIC)	6761858.7	6610902.9
Schwarz's Bayesian Criterion (SBC)	6761858.7	6611122.8

Table 7-8 The effect of CVD severity/treatment and local authority level socioeconomic status on ethnic inequalities in CVD survival

The hazard ratios obtained in these two models are compared with the uncontrolled hazard ratios presented in Table 7-2. As shown in Table 7-9, none of the two models has shrunken the ethnic inequalities in CVD survival. After controlling for CVD severity/treatment indicators and areal socioeconomic status measures, the disparities in CVD survival among ethnic groups have widened. All the hazard ratios obtained in these models are below 1, suggesting all the minority ethnic groups have better CVD survival than white people when CVD severity/treatment and areal socioeconomic status are controlled for. However, Indian and Other Asian groups have worse CVD survival than other minority ethnic groups.

	Hazard Ratios Comparison		
Ethnicity	*Uncontrolled*	*Controlled (ST ward)*	*Controlled (Local Authority)*
Indian	0.895	0.924	0.914
Pakistani	0.745	0.718	0.679
Bangladeshi	0.807	0.745	0.681
Other Asian	1.036	0.987	0.961
Black Caribbean	0.914	0.821	0.808
Black Africa	1.076	0.846	0.844
Chinese	1.003	0.869	0.874
Mixed	0.86	0.866	0.85
White	1	1	1

Table 7-9 Hazard ratios comparison

7.3 Ethnicity Inequalities in CVD Severity/Treatment

Cardiovascular operation and cardiovascular emergency admission were found to play a very important role in short term CVD survival. On one hand, they are good indicators of cardiovascular disease severity. On the other hand, these two indicators indicate intensive clinical care and treatment, and also can reflect usage of health service. This section firstly examines ethnic inequalities in cardiovascular disease emergency admission and operations. In addition, in the previous section, after controlling for these indicators, the effect of socioeconomic status on CVD survival becomes weak. However, socioeconomic status might influence CVD survival indirectly by affecting CVD severity/treatment, which is also quantified in this section.

Aims	Data	Methods	Variables
1. To examine ethnic inequalities in CVD emergency admission and CVD operations 2.To investigate the relationships between areal socioeconomic status and ethnic inequalities in CVD emergency admission and CVD operations	• Hospital Episode Statistics • The UK 2001 Census	Multiple Logistic Regression	**Age**: 16-34, 35-44, 45-54, 55-64, 65-74, 75-84 **Sex**: Male, Female **Ethnicity**: Indian, Pakistani, Bangladeshi, Other Asian, Black Caribbean, Black Africa, Mixed, Chinese, White **Areal Socioeconomic Status** Low Qualification Low Social Class Unemployment Living in Overcrowded Accommodation Living in Social Rented Accommodation (measured at both ST ward level and local authority level)

Table 7-10 Introduction to models for ethnicity inequalities in CVD severity/treatment

7.3.1 Ethnic Inequalities in Cardiovascular Emergency Admission and SES

Parameters and odds ratios estimated in logistic regression model for cardiovascular emergency admission controlled for age, sex and ethnicity are presented in Table 7-11. All the minority ethnic groups except for Chinese and Mixed groups have odds ratios higher than 1, indicating they are more likely to have cardiovascular emergency admissions than white people. The relative risk of cardiovascular emergency admission for South Asians and Other Asian people is at least 1.5 times higher than white people, particularly Bangladeshi and Pakistani people. Both Black Africa and

Black Caribbean people have moderately high relative risk of cardiovascular emergency admission. However, Chinese and people from Mixed group are less likely to have cardiovascular emergency admissions than other ethnic groups.

Analysis of Maximum Likelihood Estimates								
		Parameter	*Standard*	*Wald*	*Pr >*	*Odds*	*95% Odds Ratio*	
Variable	*DF*	*Estimate*	*Error*	*Chi-Square*	*ChiSq*	*Ratio*	*Confidence Limits*	
Intercept	1	-2.632	0.00257	1048644.88	<.0001			
Sex								
Male	1	0.4928	0.00267	33958.0454	<.0001	1.637	1.628	1.646
Female						1		
Age								
Age16_34	1	-4.462	0.00866	265459.02	<.0001	0.012	0.011	0.012
Age35_44	1	-3.2738	0.00648	255006.882	<.0001	0.038	0.037	0.038
Age45_54	1	-2.3833	0.00474	252926.671	<.0001	0.092	0.091	0.093
Age55_64	1	-1.5125	0.0038	158779.092	<.0001	0.22	0.219	0.222
Age65_74	1	-0.7974	0.00333	57355.1191	<.0001	0.45	0.448	0.453
Age75_84						1		
Ethnicity								
Indian	1	0.5326	0.00964	3055.0941	<.0001	1.703	1.671	1.736
Pakistani	1	0.9043	0.0122	5507.2672	<.0001	2.47	2.412	2.53
Bangladeshi	1	0.9083	0.021	1877.7422	<.0001	2.48	2.38	2.584
Other Asian	1	0.7588	0.0189	1618.0704	<.0001	2.136	2.058	2.216
Black Caribbean	1	0.1688	0.0133	160.6602	<.0001	1.184	1.153	1.215
Black Africa	1	0.4124	0.0203	412.7134	<.0001	1.51	1.451	1.572
Chinese	1	-0.5002	0.0363	189.6063	<.0001	0.606	0.565	0.651
Mixed	1	-0.0308	0.0235	1.7202	0.1897	0.97	0.926	1.015
White						1		

Model Fit Statistics		
Criterion	*Intercept Only*	*Intercept and Covariates*
-2LOGL	6211655.1	5231256.6
Akaike Information Criterion (AIC)	6211657.1	5231286.6
Schwarz's Bayesian Criterion (SBC)	6211672.6	5231518.4

Deviance and Pearson Goodness-of-Fit Statistics				
Criterion	*Value*	*DF*	*Value/DF*	*Pr > ChiSq*
Deviance	8211.2533	93	88.293	<.0001
Pearson	8063.3011	93	86.7022	<.0001

Table 7-11 Ethnic inequalities in CVD emergency admission

When ward level socioeconomic status measures are fitted into the model, as shown in Table 7-12, all the five ward level socioeconomic status measures, including low socioeconomic class, unemployment, low qualification, livening in overcrowded accommodation and living in social rented accommodation are highly statistically significant ($p< 0.0001$), implying that ward level socioeconomic status is strongly related to cardiovascular emergency admission.

The effect of socioeconomic status on ethnic inequalities in cardiovascular emergency admission also has been observed. After controlling for socioeconomic status, compared to the unadjusted odds ratios in Table 7-11, the odds ratios for most ethnic minorities drop to some extent. However, there are still four ethnic groups having a relatively high risk of cardiovascular emergency admissions, namely Bangladeshi, Pakistani, Indian and Other Asian people. In addition, the effect of socioeconomic status on different ethnic groups is different. The contribution of socioeconomic status to the risk of cardiovascular emergency admission is substantial for Bangladeshi, Pakistani and Black Africa people, and moderate for Other Asian people. However, the relative risk for Pakistani people remains higher, as high as Other Asian people. Given little difference between the unadjusted and adjusted odds ratios for Indian people, socioeconomic status contributes little to their relative risk of cardiovascular emergency admission.

Parameter estimates and odds ratios obtained in the logistic regression model controlled by local authority level socioeconomic status are shown in Table 7-13. All the five local authority level socioeconomic status measures are highly statistically significant ($p< 0.0001$), suggesting that local authority level socioeconomic status is also strongly related to cardiovascular emergency admission. However, compared with the results in Table 7-12, socioeconomic status measured at local authority level makes little difference to the odds ratios, indicating that the effect of socioeconomic status on ethnic inequalities in cardiovascular emergency admission is stable across different geographical scales.

Analysis of Maximum Likelihood Estimates								
		Parameter	*Standard*	*Wald*	*Pr >*	*Odds*	*95% Odds Ratio*	
Variable	*DF*	*Estimate*	*Error*	*Chi-Square*	*ChiSq*	*Ratio*	*Confidence Limits*	
Intercept	1	-3.4461	0.0147	55178.3734	<.0001			
Sex								
Male	1	0.4965	0.00295	28307.5317	<.0001	1.643	1.633	1.653
Female						1		
Age								
Age16_34	1	-4.4777	0.00867	266790.617	<.0001	0.011	0.011	0.012
Age35_44	1	-3.2768	0.00649	255240.342	<.0001	0.038	0.037	0.038
Age45_54	1	-2.3788	0.00474	251694.574	<.0001	0.093	0.092	0.094
Age55_64	1	-1.508	0.0038	157564.702	<.0001	0.221	0.22	0.223
Age65_74	1	-0.7992	0.00333	57477.5423	<.0001	0.45	0.447	0.453
Age75_84						1		
Ethnicity								
Indian	1	0.4728	0.0115	1678.7937	<.0001	1.604	1.569	1.641
Pakistani	1	0.589	0.0159	1370.9644	<.0001	1.802	1.747	1.859
Bangladeshi	1	0.2293	0.0253	82.4593	<.0001	1.258	1.197	1.322
Other Asian	1	0.6085	0.0213	816.1282	<.0001	1.838	1.763	1.916
Black Caribbean	1	-0.1548	0.0142	118.6005	<.0001	0.857	0.833	0.881
Black Africa	1	0.0374	0.0233	2.5844	0.1079	1.038	0.992	1.087
Chinese	1	-0.5018	0.037	183.9588	<.0001	0.605	0.563	0.651
Mixed	1	-0.1953	0.024	66.3883	<.0001	0.823	0.785	0.862
White						1		
Socioeconomic Status								
Low SEC (ST ward)	1	0.00863	0.000315	751.5798	<.0001	1.009	1.008	1.009
Unemployment (ST ward)	1	0.00846	0.000532	252.8697	<.0001	1.008	1.007	1.01
Overcrowding (ST ward)	1	0.0075	0.000326	530.605	<.0001	1.008	1.007	1.008
Low Qualification (ST ward)	1	0.00626	0.000252	616.2432	<.0001	1.006	1.006	1.007
Social Rented (ST ward)	1	0.00338	0.000154	484.1347	<.0001	1.003	1.003	1.004

Model Fit Statistics		
Criterion	*Intercept Only*	*Intercept and Covariates*
-2LOGL	6210662.6	5211583.9
Akaike Information Criterion (AIC)	6210664.6	5211623.9
Schwarz’s Bayesian Criterion (SBC)	6210680	5211933

Deviance and Pearson Goodness-of-Fit Statistics				
Criterion	*Value*	*DF*	*Value/DF*	*Pr > ChiSq*
Deviance	250566.882	1.90E+05	1.3313	<.0001
Pearson	336909.59	1.90E+05	1.79	<.0001

Table 7-12 Ethnic inequalities in CVD emergency admission and ward level SES

Analysis of Maximum Likelihood Estimates								
Variable	*DF*	*Parameter Estimate*	*Standard Error*	*Wald Chi-Square*	*Pr > ChiSq*	*Odds Ratio*	*95% Odds Ratio Confidence Limits*	
Intercept	1	-3.386	0.02	28574.879	<.0001			
Sex								
Male	1	0.4904	0.00326	22619.6423	<.0001	1.633	1.623	1.643
Female						1		
Age								
Age16_34	1	-4.4681	0.00866	266020.619	<.0001	0.011	0.011	0.012
Age35_44	1	-3.2736	0.00648	254831.399	<.0001	0.038	0.037	0.038
Age45_54	1	-2.3818	0.00474	252496.575	<.0001	0.092	0.092	0.093
Age55_64	1	-1.5112	0.0038	158370.185	<.0001	0.221	0.219	0.222
Age65_74	1	-0.7995	0.00333	57586.4111	<.0001	0.45	0.447	0.452
Age75_84						1		
Ethnicity								
Indian	1	0.5488	0.0127	1868.624	<.0001	1.731	1.689	1.775
Pakistani	1	0.6709	0.0182	1360.4477	<.0001	1.956	1.887	2.027
Bangladeshi	1	0.2917	0.0277	111.1858	<.0001	1.339	1.268	1.413
Other Asian	1	0.6904	0.0225	944.2637	<.0001	1.994	1.909	2.084
Black Caribbean	1	-0.1883	0.0148	162.2091	<.0001	0.828	0.805	0.853
Black Africa	1	0.0434	0.0245	3.1461	0.0761	1.044	0.995	1.096
Chinese	1	-0.4281	0.0372	132.3792	<.0001	0.652	0.606	0.701
Mixed	1	-0.2068	0.0243	72.5727	<.0001	0.813	0.775	0.853
White						1		
Socioeconomic Status								
Low SEC (LA)	1	0.00791	0.000439	325.0063	<.0001	1.008	1.007	1.009
Unemployment (LA)	1	0.0112	0.000827	183.3504	<.0001	1.011	1.01	1.013
Overcrowding (LA)	1	0.00416	0.00044	89.474	<.0001	1.004	1.003	1.005
Low Qualification (LA)	1	0.0053	0.000332	255.6875	<.0001	1.005	1.005	1.006
Social Rented (LA)	1	0.00583	0.000244	573.8399	<.0001	1.006	1.005	1.006

Model Fit Statistics		
Criterion	*Intercept Only*	*Intercept and Covariates*
-2LOGL	6211360.7	5223141.7
Akaike Information Criterion (AIC)	6211362.7	5223181.7
Schwarz's Bayesian Criterion (SBC)	6211378.1	5223490.8

Deviance and Pearson Goodness-of-Fit Statistics				
Criterion	*Value*	*DF*	*Value/DF*	*Pr > ChiSq*
Deviance	64782.3242	2.60E+04	2.4965	<.0001
Pearson	86578.4408	2.60E+04	3.3365	<.0001

Table 7-13 Ethnic inequalities in CVD emergency admission and local authority level SES

7.3.2 Ethnic Inequalities in Cardiovascular Operation and SES

Table 7-14 presents the parameters and odds ratios estimated in logistic regression models for cardiovascular operation only controlled for age, sex and ethnicity. The odds ratios of South Asians and Other Asians, particularly Bangladeshi and Pakistani people, are at least two times higher than that of white people, suggesting that South Asian and Other Asian people are much more likely to have cardiovascular operations. Although people from the Mixed group are less likely to have cardiovascular disease, their risk of cardiovascular operation is a little high. The relative risk of cardiovascular operation for Black Africa and Black Caribbean people is very close to that of white people. And Chinese have the lowest risk of cardiovascular operation.

Analysis of Maximum Likelihood Estimates								
		Parameter	*Standard*	*Wald*	*Pr >*	*Odds*	*95% Odds Ratio*	
Variable	*DF*	*Estimate*	*Error*	*Chi-Square*	*ChiSq*	*Ratio*	*Confidence Limits*	
Intercept	1	-4.2039	0.00462	826232.151	<.0001			
Sex								
Male	1	0.8664	0.0037	54824.0943	<.0001	2.378	2.361	2.396
Female						1		
Age								
Age16_34	1	-4.0826	0.0138	87036.872	<.0001	0.017	0.016	0.017
Age35_44	1	-2.4914	0.00891	78235.5052	<.0001	0.083	0.081	0.084
Age45_54	1	-1.2648	0.00615	42310.2447	<.0001	0.282	0.279	0.286
Age55_64	1	-0.3271	0.00523	3912.2464	<.0001	0.721	0.714	0.728
Age65_74	1	0.1138	0.00507	504.5483	<.0001	1.121	1.109	1.132
Age75_84						1		
Ethnicity								
Indian	1	0.8508	0.0103	6830.5209	<.0001	2.341	2.295	2.389
Pakistani	1	1.0428	0.014	5580.2896	<.0001	2.837	2.761	2.916
Bangladeshi	1	1.1028	0.0231	2270.1526	<.0001	3.013	2.879	3.152
Other Asian	1	0.9739	0.0206	2224.4449	<.0001	2.648	2.543	2.758
Black Caribbean	1	-0.1985	0.0199	99.5979	<.0001	0.82	0.789	0.853
Black Africa	1	-0.00481	0.0306	0.0246	0.8753	0.995	0.937	1.057
Chinese	1	-0.4808	0.0452	113.0409	<.0001	0.618	0.566	0.676
Mixed	1	0.2199	0.027	66.1949	<.0001	1.246	1.182	1.314
White						1		

Model Fit Statistics		
Criterion	*Intercept Only*	*Intercept and Covariates*
-2LOGL	3885500.7	3398442.7
Akaike Information Criterion (AIC)	3885502.7	3398472.7
Schwarz's Bayesian Criterion (SBC)	3885518.2	3398704.5

Deviance and Pearson Goodness-of-Fit Statistics				
Criterion	*Value*	*DF*	*Value/DF*	*Pr > ChiSq*
Deviance	3401.8525	93	36.5791	<.0001
Pearson	3489.3778	93	37.5202	<.0001

Table 7-14 Ethnic inequalities in CVD cardiovascular operation

Five ST ward level socioeconomic status measures have been fitted into the model. As shown in Table 7-15, low qualifications, living in overcrowded accommodation and living in social rented accommodation are highly statistically significant ($p< 0.0001$), implying that ST ward level socioeconomic status, particularly the living conditions, are strongly related to cardiovascular operation. After controlling for areal socioeconomic status, the odds ratios of most ethnic groups drop, suggesting socioeconomic inequalities have a contribution to the ethnic inequalities in cardiovascular operation.

The effect of socioeconomic status on Bangladeshi, Pakistani, and Other Asian people's higher risk of cardiovascular operation is obvious. The high risk of cardiovascular operation for Bangladeshi people has largely dropped, indicating low socioeconomic status is a main reason for their very high risk of cardiovascular operation. However, the controlled relative risk of Pakistani, Other Asian people is still significantly high, two times higher than that of white people, indicating that socioeconomic status contributes moderately to their higher risk. The controlled odds ratio of Indian people changes not that much. So socioeconomic status is not an important factor that affects Indian people's higher risk of cardiovascular operation. For people from the Mixed group, their marginally higher risk has been adjusted to a similar level as that of white people by socioeconomic status.

Analysis of Maximum Likelihood Estimates								
Variable	*DF*	*Parameter Estimate*	*Standard Error*	*Wald Chi-Square*	*Pr > ChiSq*	*Odds Ratio*	*95% Odds Ratio Confidence Limits*	
Intercept	1	-4.6607	0.0159	85500.0301	<.0001			
Sex								
Male	1	0.8681	0.0037	55020.617	<.0001	2.382	2.365	2.4
Female						1		
Age								
Age16_34	1	-4.095	0.0138	87470.1868	<.0001	0.017	0.016	0.017
Age35_44	1	-2.4929	0.00891	78314.1564	<.0001	0.083	0.081	0.084
Age45_54	1	-1.2612	0.00615	42062.9391	<.0001	0.283	0.28	0.287
Age55_64	1	-0.3227	0.00523	3805.9684	<.0001	0.724	0.717	0.732
Age65_74	1	0.1145	0.00507	510.4169	<.0001	1.121	1.11	1.132
Age75_84						1		
Ethnicity								
Indian	1	0.7277	0.0127	3289.3335	<.0001	2.07	2.02	2.123
Pakistani	1	0.742	0.0181	1681.9872	<.0001	2.1	2.027	2.176
Bangladeshi	1	0.5038	0.0286	310.2895	<.0001	1.655	1.565	1.75
Other Asian	1	0.7238	0.0238	923.6669	<.0001	2.062	1.968	2.161
Black Caribbean	1	-0.4122	0.0206	400.5575	<.0001	0.662	0.636	0.689
Black Africa	1	-0.4133	0.0337	150.7678	<.0001	0.661	0.619	0.707
Chinese	1	-0.6186	0.046	180.9641	<.0001	0.539	0.492	0.59
Mixed	1	0.0627	0.0275	5.187	0.0228	1.065	1.009	1.124
White						1		
Socioeconomic Status								
Low Qualification (ST ward)	1	0.00479	0.000213	507.2993	<.0001	1.005	1.004	1.005
Overcrowding (ST ward)	1	0.0105	0.000397	701.8208	<.0001	1.011	1.01	1.011
Social Rented (ST ward)	1	0.00164	0.00018	83.4525	<.0001	1.002	1.001	1.002

Model Fit Statistics		
Criterion	*Intercept Only*	*Intercept and Covariates*
-2LOGL	3885220.6	3395610.6
Akaike Information Criterion (AIC)	3885222.6	3395646.6
Schwarz's Bayesian Criterion (SBC)	3885238.1	3395924.8

Deviance and Pearson Goodness-of-Fit Statistics				
Criterion	*Value*	*DF*	*Value/DF*	*Pr > ChiSq*
Deviance	222547.266	1.90E+05	1.1881	<.0001
Pearson	339571.709	1.90E+05	1.8128	<.0001

Table 7-15 Ethnic inequalities in cardiovascular operation and ward level SES

The results of the logistic regression model controlled by local authority level socioeconomic status are shown in Table 7-16. Of the five local authority level socioeconomic status measures, living in overcrowded accommodation and low qualification are highly statistically significant ($p < 0.0001$), suggesting that local authority level socioeconomic status is also strongly related to cardiovascular operation. The effect of living in overcrowded accommodation is relatively stronger than that of low qualification, suggesting living conditions are an important risk factor for cardiovascular operation. The difference between the models fitted by ST ward level socioeconomic status and local authority level socioeconomic status is that the indicator of living in social rented accommodation that was significant at ward level is not significant at local authority level. In addition, the effect of local authority level socioeconomic status on cardiovascular operation seems a little greater than that of ward level socioeconomic status for some ethnic groups, particularly for Other Asians. However, the pattern of the odds ratios for ethnic groups in this model is almost the same as that identified at ward level. Thus, the effect of socioeconomic status on ethnic inequalities in cardiovascular emergency admission is stable across different geographical scales.

Analysis of Maximum Likelihood Estimates								
		Parameter	*Standard*	*Wald*	*Pr >*	*Odds*	*95% Odds Ratio*	
Variable	*DF*	*Estimate*	*Error*	*Chi-Square*	*ChiSq*	*Ratio*	*Confidence Limits*	
Intercept	1	-4.4036	0.0211	43352.6299	<.0001			
Sex								
Male	1	0.8672	0.0037	54916.9496	<.0001	2.38	2.363	2.397
Female						1		
Age								
Age16_34	1	-4.0896	0.0138	87392.0087	<.0001	0.017	0.016	0.017
Age35_44	1	-2.4937	0.00891	78354.5475	<.0001	0.083	0.081	0.084
Age45_54	1	-1.2639	0.00615	42249.0837	<.0001	0.283	0.279	0.286
Age55_64	1	-0.3253	0.00523	3868.498	<.0001	0.722	0.715	0.73
Age65_74	1	0.1145	0.00507	510.6395	<.0001	1.121	1.11	1.133
Age75_84						1		
Ethnicity								
Indian	1	0.6609	0.012	3041.4622	<.0001	1.936	1.891	1.982
Pakistani	1	0.706	0.0178	1579.9065	<.0001	2.026	1.957	2.098
Bangladeshi	1	0.5073	0.0306	275.675	<.0001	1.661	1.564	1.763
Other Asian	1	0.6286	0.0235	715.7407	<.0001	1.875	1.791	1.963
Black Caribbean	1	-0.4013	0.021	366.468	<.0001	0.669	0.643	0.698
Black Africa	1	-0.4911	0.0344	203.4666	<.0001	0.612	0.572	0.655
Chinese	1	-0.7072	0.0459	237.7186	<.0001	0.493	0.451	0.539
Mixed	1	0.0339	0.0277	1.4983	0.2209	1.035	0.98	1.092
White						1		
Socioeconomic Status								
Overcrowding (LA)	1	0.0125	0.000396	992.8326	<.0001	1.013	1.012	1.013
Low Qualification (LA)	1	0.00156	0.000264	34.9099	<.0001	1.002	1.001	1.002

Model Fit Statistics		
Criterion	*Intercept Only*	*Intercept and Covariates*
-2LOGL	3885480.5	3397467.1
Akaike Information Criterion (AIC)	3885482.5	3397501.1
Schwarz's Bayesian Criterion (SBC)	3885497.9	3397763.8

Deviance and Pearson Goodness-of-Fit Statistics				
Criterion	*Value*	*DF*	*Value/DF*	*Pr > ChiSq*
Deviance	54902.4269	2.60E+04	2.1111	<.0001
Pearson	81414.7465	2.60E+04	3.1306	<.0001

Table 7-16 Ethnic inequalities in cardiovascular operation and local authority level SES

7.4 Discussion

In this chapter, a population based study has been conducted to examine ethnic inequalities in cardiovascular disease survival and severity/treatment, and to explore the relationships between socioeconomic status and these ethnic inequalities.

One of the most notable findings in this study is the ethnic inequalities in CVD survival in the UK. Inconsistent evidence on ethnic difference in CVD survival has been reported in both the UK (Wolfe et al., 2005, Lane et al., 2005) and the US (Hartmann et al., 2001, Kissela et al., 2004), as introduced at the beginning of this chapter. Although in the previous chapter we found that South Asians and Other Asians have particularly higher risks for most CVD subtypes and black people have a higher risk of some CVD subtypes than white people, the overall survival of cardiovascular disease for minority ethnic groups is not that poor. In striking contrast, most minority ethnic groups have better CVD survival than white people, particularly South Asia groups. And the CVD survival of other minority ethnic groups is very close to that of white people. In the UK, a number of studies reported that mortality rates of cardiovascular disease were highest for South Asians (Wild and McKeigue, 1997, Bardsley et al., 2000, Aspinall and Jacobson, 2004). Given that South Asians have better CVD survival than most ethnic groups, it seems that the excess mortality from cardiovascular disease for South Asians is mainly because they have excess incidence of cardiovascular disease. Thus the implication of this finding is that white people need to be targeted in cardiovascular disease treatment, although white people have lower risk of getting cardiovascular disease.

Few studies have explored the underlying reasons that cause the ethnic inequalities in CVD survival. This chapter tried to investigate whether areal socioeconomic status, distance to treatment sites and CVD severity/treatment could explain the ethnic inequalities in CVD survival. Lower socioeconomic status, such as poor education, lower income and the type of occupation, as well as living in a disadvantaged area, is an independent determinant of outcomes for many diseases and affect long term survival after critical illness (Ho et al., 2008). There are a few studies that demonstrate the effect of socioeconomic status on CVD survival (Howard et al., 1995, Kapral et al., 2002). The inverse association between areal socioeconomic status and CVD survival also has been identified and noted when information about individual socioeconomic status is not available (Macintyre et al., 2001, Tonne et al., 2005, Chaix et al., 2007). In this study, areal socioeconomic status measured at ST ward level and local authority level has been fitted into the models separately to quantify its effect on ethnic inequalities in CVD survival. The findings of the models are consistent. High levels of low socioeconomic status significantly contribute to worse cardiovascular disease survival, no matter at which geographical scale it is measured. However, after controlling for areal socioeconomic status, the ethnic inequalities in CVD survival are not reduced but in fact become wider. Thus the ethnic inequalities in CVD survival are not due to socioeconomic inequalities across ethnic groups.

The effect of distance to treatment sites on CVD survival as well as ethnic inequalities in CVD survival has also been investigated. Generally, people who need to travel further to treatment sites may experience transportation difficulties and not receive timely treatment and care, which might reduce patient survival. Increased straight-line ambulance journey was found to be associated with increased risk of death (Nicholl et al., 2007). However, in this study, there is inconsistent evidence showing that shorter distance to treatment sites is associated with worse CVD survival. People living further from treatment sites actually have better CVD survival. This might be because people living in suburbs are more likely to be wealthy and with high socioeconomic status, compared with residents in urban centres. However, when controlled for areal socioeconomic status measures and CVD severity/treatment indicators, further distance to treatment sites is still associated with better CVD survival. Another explanation might be that people living further from treatment sites might work in the city centre or town centre, where it is convenient for them to have health care. Thus living further from treatment sites for them is not a disadvantage for CVD survival. In addition, the effect of distance to treatment sites may be greater in cardiovascular emergencies. For example, length of time between the onset of symptoms and treatment for acute myocardial infarction is very critical to survival. However, this study hasn't classified cardiovascular disease based on emergency. Distance to treatment sites also doesn't contribute to ethnic inequalities in CVD survival.

This study also has explored whether the better survival of cardiovascular disease for minority ethnic groups is because they have developed less serious CVD conditions or received more intensive treatment. The results show that having a cardiovascular operation with a hazard ratio of 0.287 could significantly enhance short term (three year) CVD survival. Cardiovascular emergency admission also has a positive impact on CVD survival. It is surprising to find that diabetes mellitus is associated with better CVD survival. However, previous research shows that diabetes mellitus is not a risk factor for all types of cardiovascular disease. For example, Diabetes mellitus was an independent predictor of cardiovascular mortality in ischaemic patients (HR=1.54 [1.13; 2.09]; p=0.006) but not in non-ischaemic patients (HR=0.65 [0.39; 1.07]; p=0.09) (de Groote et al., 2004). After controlling for these CVD treatment/severity indicators and diabetes mellitus, the hazards ratios of most minority ethnic groups, particularly Indian and Bangladeshi people, increase towards 1, implying that the disparities in CVD survival among ethnic minorities and white people have decreased. This reduction of ethnic inequalities in CVD survival suggests that if having received similar level of CVD treatment, most ethnic groups might have similar CVD survival, i.e. compared with minority ethnic groups, white people haven't received treatments as intensive as some minority ethnic groups. There are three hypotheses about why white people receive less intensive CVD treatment. Firstly, white people might develop less serious CVD conditions than minority ethnic groups. Therefore they have less clinical need. However, this might not be true because white people are found to have worse CVD survival than most other ethnic groups. In addition, given that the white population has an older age structure than most minority ethnic groups, as introduced in Chapter Two, some white CVD patients may be too old to have cardiovascular operations, which could significantly enhance survival from CVD. Another hypothesis is that white people might be less likely to use CVD clinical care and treatments, compared with ethnic minorities.

This study has examined the latter two hypotheses by investigating ethnic inequalities in cardiovascular emergency admission and cardiovascular operation. Given that the odds ratio of having cardiovascular operation for age group 65 to 74 (1.121) is higher than 1, where the reference age groups is 75 to 84, the older patients are indeed less likely to have cardiovascular operation. However, the older age structure of white population can't explain their lower usage of CVD clinical care and treatments, particularly CVD operations. After controlling for age, white people are still much less likely to have cardiovascular emergency admissions and cardiovascular operations than South Asians and Other Asians.

Low socioeconomic status is found to be associated with increased risk of cardiovascular emergency admission and operation, because people of low socioeconomic status are less healthy. This indicates that socioeconomic status indirectly contributes to ethnic inequalities in CVD survival by influencing cardiovascular clinical care and treatments. The contribution of socioeconomic status to the higher level of use of cardiovascular emergency admission and operation is substantial for Bangladeshi, Pakistani and Other Asian people, but not Indian people. However, after adjustment for socioeconomic status, the risk of cardiovascular emergency admission and operation for South Asians and Other Asians is still much higher than that of white people. This further confirms that people from South Asia and Other Asian groups are more likely to use CVD clinical care and treatment than white people, which could significantly enhance their survival from cardiovascular disease. However, compared with most minority ethnic groups, white people receive less intensive CVD clinical care and treatment, which worsens their CVD survival.

The ethnic disparities in having cardiovascular emergency admissions and cardiovascular operations could be interpreted from two perspectives. Calling for cardiovascular emergency admission reflects the attitude of CVD patients towards seeking immediate care for cardiovascular disease. South Asians have lower thresholds for action due to their widely perceived increased risk of heart disease (Britton et al., 2004). However, having a cardiovascular operation depends on doctors' perception of cardiovascular disease treatment towards different ethnic groups. The thresholds for intensive treatment for ethnic minorities, particularly South Asians, might also be lower than white people from doctors' perspectives, might be because ethnic minorities are more likely to seek intensive health care and treatment, and doctors are more likely to respond to their search.

It could be argued that white people have less intensive CVD clinical care and treatment because they have less clinical need or less serious CVD conditions. As there is no explicit clinical information about clinical need of CVD treatment in the HES, it is difficult to examine this assumption in this study. However, in the Whitehall II prospective cohort study conducted by Britton et al. (2004), even after adjustment for clinical need (measured based on symptoms of chest pain, recall of diagnosis by doctor, resting electrocardiograms and clinical records), South Asians were still more likely to have cardiac procedures and to take more secondary prevention drugs than white participants. There is also a study reported that South Asians were more likely to seek immediate care (hospital emergency department or general practitioner) for (hypothetical) anginal symptoms than white people (Chaturvedi et al., 1997).

Most of all, white people have worse CVD survival, i.e. higher risk of death, which implies they have more clinical need than ethnic minorities. But they don't receive treatments as intensive as ethnic minorities, as identified from the population study in this chapter, which might be the main cause of ethnic inequalities in CVD survival.

Chapter Eight: Conclusions

8.1 Introduction

In the UK, people from some ethnic groups, particularly South Asian, are at increased risk of cardiovascular disease. However, what causes the ethnic disparities in cardiovascular disease is still not clear and needs investigation. This thesis started by developing a methodology to improve the data quality of ethnicity codes in the Hospital Episode Statistics (HES), and then carried out a population study to examine ethnic inequalities in cardiovascular disease incidence in England at both national and local geographical scales using the HES data. Given that people from minority ethnic groups in the UK on average have low socioeconomic status, which is a major risk factor of cardiovascular disease incidence, this thesis tried to explain the ethnic inequalities in cardiovascular disease incidence from the perspective of socioeconomic status.

Few studies have compared the incidence and outcome of cardiovascular disease from the same population. This thesis explored ethnic inequalities in cardiovascular disease survival and severity/treatment for the same population, with some novel findings that people from minority ethnic groups, who generally have increased risk of cardiovascular disease incidence, have better cardiovascular disease survival than white people. A series of models have been conducted to examine the contribution of areal socioeconomic status measures, distance to treatment sites and cardiovascular disease severity and treatment to the ethnic inequalities in cardiovascular survival. In addition, the relationships between socioeconomic status measures and ethnic inequalities in cardiovascular disease severity and treatment were also investigated in this thesis.

In this conclusion chapter, each of the three thesis objectives outlined in Chapter One is revisited, and the key findings are outlined. Then the limitations of the study and opportunities for further research are discussed, followed by the policy implications of the thesis.

8.2 Revisiting the Thesis Objectives

8.2.1 Ethnicity Code in the Hospital Episode Statistics

The first goal of this study is to examine and explore the potential of the Hospital Episode Statistics for research on ethnic inequalities in health by developing a methodology to improve the data quality of ethnicity code, which is reported in Chapter Four.

In the UK, ethnic inequalities in health are gaining more and more interest from social scientists, epidemiologists and government. However, studies on ethnic inequalities in health in the UK are limited by the availability of relevant data. This is because, firstly, the available routinely collected data that are ethnically coded are limited in the UK. Secondly, surveys that have ethnicity codes are usually restricted to a small number of samples from minority ethnic groups, even in large urban areas, which usually lead to statistically unreliable results.

Hospital Episode Statistics (HES), which is a data warehouse containing details of all the admissions to NHS hospitals in England, have significant potential for studying ethnic disparities in health, due to the large number of events, comprehensive clinical information, full England coverage and fine geographical scale. However, concern over the use of ethnicity data arises because the data quality is not satisfactory. The percentage of Finished Consultant Episodes (FCEs) with invalid ethnicity codes is at a high level.

In Chapter Four, two methods were developed to improve the data quality of ethnicity code in HES, including a record linking method and a coding rate method. Given that more than 12 million episodes are added into HES annually and one person might have more than one episode in HES across many years, the underlying idea of the record linking method is to restore the missing ethnicity codes by linking the admissions with valid ethnicity codes to the historical admissions without valid ethnicity codes based on the same person's unique identifier HESID. If there is a valid ethnicity code within any of a patient's historical admissions, all the other missing ethnicity codes could be replaced by this valid ethnicity code. The potential of this method is that with more and more episodes with valid and accurate ethnicity coding being added into the HES, it is possible to further restore the ethnicity codes in the historical HES data. And by linking the historical admissions in different years, it is also possible to trace individuals' vital medical information and events during the life course.

After restoring ethnicity codes using the record linking method, the percentages of FCEs with valid ethnicity codes increase significantly for recent data years. The most complete ethnicity coding of the general FCEs is achieved in 2004/05, which is about 84 per cent, 7 per cent higher than the old one. However, the overall coding rate of CVD FCEs is better than that of the general FCEs. Nearly 88 per cent of the CVD FCEs are ethnically coded in 2004/05.

As there are remaining 12 per cent CVD FCEs that have invalid ethnicity coding, it might lead to bias when calculating the standardised incidence ratios of cardiovascular disease at local level by simply ignoring these records. Two different coding rate methods, local area-age-sex coding rate method and local area-sex-ethnicity coding rate method, are developed to estimate total number of cardiovascular disease cases for each ethnicity-sex group in a certain geographical region based on the observed number of cases with valid ethnicity codes and the estimated coding rates of different ethnic groups across regions. The local area-age-sex coding rate method assumes that there is no ethnic difference in the coding rates for local area-age-sex groups. And the local area-sex-ethnicity method allows the coding rates to vary across ethnic groups for each local area-sex group. Cataract, which is only related to age and sex, not affected by socioeconomic status and also can represent the whole population (Stocks et al., 2002), is used to calculate the coding rates.

Two criteria were set to select which of the two coding rate methods was going to be used. Firstly, whether the assumption made in the method is sensible and could be supported by available evidence. Secondly, whether the ethnic inequalities in cardiovascular disease obtained from the adjusted data could generally reflect well known knowledge about ethnic disparities in cardiovascular disease. Although the local area-sex-ethnicity coding rate method is superior to the local area-age-sex coding rate method in the assumption, which allows the ethnic difference in the coding rate at small area level, the implementation of this method is not practically feasible. It is greatly affected by the small number problem, which results in unreliable coding rates for minority ethnic groups at local area level. Finally, the local area-age-sex coding rate method is used to adjust the cardiovascular disease data, mainly because firstly, this method is not so affected by the small number problems, secondly the adjusted data could generally reflect well known knowledge about ethnic inequalities in cardiovascular disease, and in addition there is currently available evidence supporting the assumptions of this method.

8.2.2 Ethnic Inequalities in CVD

The second objective of this study is to examine ethnic inequalities in cardiovascular disease in England at both national and local geographical scales, which have been covered in Chapter Five, Chapter Six and Chapter Seven, where Chapter Five and Chapter Six focussed on CVD incidence and Chapter Seven focuses on CVD survival and severity/treatment.

There are substantial studies on ethnic inequalities in cardiovascular disease. However, there are some limitations in previous studies, probably due to the unavailability of relevant data. Firstly, previous studies usually focus on general cardiovascular disease, coronary heart disease and stroke (Nazroo, 1997, Nazroo, 2001, Chaturvedi, 2003, Hsu et al., 1999, Markus et al., 2007); few studies have conducted research on ethnic inequalities in other types of cardiovascular disease, such as hypertensive heart disease, heart failure and rheumatic heart disease. Secondly, most previous research studied CVD conditions among South Asians (Nazroo, 2001, Markus et al., 2007, Bhopal and Sengupta-Wiebe, 2000) or black people (Markus et al., 2007); few studies have brought all the major ethnic groups together, thus the results from different studies about different ethnic groups are not comparable. Thirdly, the study areas of most previous research usually focussed on several major cities, such as London (Aspinall and Jacobson, 2004, Khan et al., 2006, Markus et al., 2007) and Birmingham (Lip et al., 2004, Conway and Lip, 2003, Lane et al., 2005). Little research has been done on geographical relative risk of cardiovascular disease for different ethnic groups in England. Last but not least, as ethnic inequalities in cardiovascular disease are relatively broad topics, which are not limited to incidence and mortality, but also include cardiovascular disease survival, severity and treatment. However, there is little research on ethnic inequalities in cardiovascular disease survival, severity and treatment.

In Chapter Five, ethnic inequalities in different types of cardiovascular disease incidence at both English national and local authority levels were examined, where considerable variations in the standardised incidence ratios of subtypes of cardiovascular disease for different ethnicity-sex groups are observed. The cardiovascular diseases that have been studied in this chapter are general cardiovascular disease, coronary heart disease, stroke, hypertensive heart disease, rheumatic heart disease and heart failure.

In brief, the standardised incidence ratios for white people, particularly white women, are lower or very close to the national average for most cardiovascular diseases. However, white men have about 1.2 times higher standardised incidence ratios of coronary heart disease and heart failure than the general population. As expected, South Asians, particularly the Bangladeshi population, have extremely high standardised incidence ratios for most cardiovascular diseases. Given a large proportion of Other Asians have a South Asian background, it is not surprising to find that the standardised incidence ratios of most cardiovascular diseases for Other Asian are also significantly high. Both Black Caribbean and Black Africa people have lower or similar standardised incidence ratios to the general population in most cardiovascular diseases, particularly Black women, with an exception for stroke and hypertensive heart disease for both Black men and women and heart failure for Black Africa men. Both Chinese people and people of Mixed ethnicity have the lowest standardised incidence ratios for all the cardiovascular diseases, with an exception for rheumatic heart disease among Chinese women, where the standardised incidence ratio is about 1.2 times higher than the national average.

In Chapter Five, the geographical relative risk of cardiovascular disease at local authority level was examined for different ethnicity-sex groups as well. The calculation of standardised incidence ratios for minority ethnic groups at local authority level is greatly affected by the small number problem caused by the small size of population of minority ethnic groups in small areas. Thus two empirical Bayes estimation methods, the Clayton and Kaldor (1987) method and the Marshall (1991) method, are used to reduce the variations of the unstable standardised incidence ratios. The difference between these two methods is that the two methods shrink the local relative risk towards different "average relative risk", i.e. overall mean of local relative risk in the Clayton and Kaldor (1987) method and the national SIRs for that group in the Marshall (1991) method. Large variations of geographical relative risk of cardiovascular disease were observed for different ethnicity-sex groups. When using two different empirical Bayes estimation methods, difference patterns of the geographical relative risk of cardiovascular disease were observed for minority ethnic groups, but not for the white group. However, whichever method is used, in areas with a large size of ethnic minority populations, such as London, the geographical relative risk of cardiovascular disease is relatively stable. Ethnic minorities tend to have a significantly higher risk in local authorities in London.

In Chapter Six, the relative risk of different types of cardiovascular disease for minority ethnic groups to white people was examined in terms of odds ratios at the English national level. The patterns of ethnic inequalities in cardiovascular disease are similar to those identified in Chapter Five, and are not repeated here.

In Chapter Seven, ethnic inequalities in cardiovascular disease survival were examined. Although ethnic minorities, particularly South Asians, are more likely to have cardiovascular disease than white people, increased risk of getting cardiovascular disease for ethnic minorities has not been transferred to increased risk of death from cardiovascular disease. A reverse pattern of ethnic inequalities is observed in both the Kaplan-Meier survival curve and the Cox proportional hazards model in this chapter. White people have a significant disadvantage in cardiovascular disease survival. However, people from most minority ethnic groups have better survival from cardiovascular disease, particularly South Asians.

Chapter Seven also examined ethnic inequalities in cardiovascular disease severity/treatment. Although there is no explicit clinical information available in the HES data to measure cardiovascular disease severity, cardiovascular disease severity could be reflected by cardiovascular disease treatment because patients with more serious cardiovascular disease are more likely to stay in hospital longer, have cardiovascular emergency admission or even undergo a cardiovascular operation. Ethnic inequalities in cardiovascular emergency admissions and cardiovascular operations were studied in this chapter. In terms of cardiovascular emergency admission, people from all the minority ethnic groups except for Chinese and Mixed groups are more likely to have cardiovascular emergency admissions than white people, particularly South Asians and Other Asian people. Chinese people and people of Mixed ethnicity are less likely to have cardiovascular emergency admissions than other ethnic groups. In terms of cardiovascular operation, South Asians and Other Asians are much more likely to have cardiovascular operations than white people after controlling for age and sex. The risk of cardiovascular operation for the Mixed group is moderately higher than white people. However, Black and Chinese people are less likely to have cardiovascular operations.

The findings in this study further confirm the complexity of ethnic inequalities in health. Even in cardiovascular disease, the same ethnic group shows different relative risk to other ethnic groups in different subtypes, and also shows different risk of cardiovascular disease across regions. Nazroo (2003a) suggested that ethnic inequalities in health arise from a number of causes, including migration effects, genetic/biological differences, lifestyle/culture, socioeconomic position, social exclusion and racial harassment, and access to and quality of healthcare. There are a large number of studies which have demonstrated that ethnic minorities, particularly South Asians, who are at a high risk of cardiovascular disease, show high levels of cardiovascular disease classical risk factors, such as hypertension, obesity and smoking (Cappuccio et al., 1997, Ehtisham et al., 2005, Teers, 2001). Ethnic difference also has been found in some novel cardiovascular risk factors, specifically lipoprotein(a) or Lp(a) (Bhatnagar et al., 1995, Anand et al., 1998), C-reactive protein (CRP) (Danesh et al., 2004, Forouhi et al., 2001), fibrinogen (Kain et al., 2001) and homocysteine (Chambers and Kooner, 2001). There are also some studies trying to explain ethnic inequalities in cardiovascular disease from the perspectives of migration effects and gene-environment interactions (Bhatnagar et al., 1995, Khunti and Samani, 2004, Patel et al., 2006) and racial discrimination (Williams et al., 2003, Virdee, 1997, Nazroo, 2003b). However, little is known to what extent these factors contribute to the observed ethnic inequalities in cardiovascular disease. Furthermore, it appears that these explanations of ethnic inequalities in cardiovascular disease are not uniform for ethnic groups. For example, there are important differences between Indians, Pakistanis, and Bangladeshis for many coronary risk factors, such as smoking, blood pressure and concentration of high density lipoprotein cholesterol (Bhopal et al., 1999).

Changes in the ethnic minority population, including aging, lifestyle, increasing cultural assimilation and other factors, need continuous monitoring of ethnic inequalities in cardiovascular disease and other diseases (Johnson et al., 2004). Compared with the evidence of ethnic inequalities in cardiovascular disease identified in the last 10 years, in the Fourth National Survey of Ethnic Minorities (1993 to 1994) (Nazroo, 1997), the Health Survey for England 1999 (Primatesta and Brooks, 2001) and the Health Survey for England 2004 (Mindell and Zaninotto, 2005), the patterns of inequalities in cardiovascular disease identified in this study between the major ethnic groups, namely South Asian, black and white groups, has changed little. However, as new migrant groups arrive into the UK, new ethnic groups have been recognized and added into the ethnicity classification system. Other Asian and Mixed ethnic groups were first included in the ethnicity classification in the UK 2001 Census. In addition, recently, migrants from East Europe countries, i.e. the A8 countries (the Czech Republic; Estonia; Hungary; Latvia; Lithuania; Poland; Slovakia; and Slovenia) to the UK rise rapidly. The health of these new migrants also should be monitored. This study examined the cardiovascular disease conditions of Other Asians and people from Mixed group. However, given that there is no information in the HES for identifying patients from East Europe countries, the cardiovascular disease conditions of East Europeans are unknown. Furthermore, few studies examined the changing pattern of cardiovascular disease in second or even third generations of minority ethnic groups. Given that most Other Asians born in the UK (31 per cent of Other Asians) are second and third generation descendants of Pakistani, Bangladeshi and Indian migrants (Gardener and Connolly, 2005), and that Other Asians have a similarly high risk of most cardiovascular diseases to South Asians, descendants of South Asians might be also at a relatively high risk of cardiovascular disease.

There are very limited data on the mortality of minority ethnic groups in the UK. British death certificates record only country of birth but not ethnicity. However, country of birth is increasingly less relevant as a proxy measure of ethnic origin, because it excludes people from ethnic minority populations born in Britain (Office for National Statistics, 2003). The ONS mortality data have been linked and matched to the hospital episode spells by Gill (2003), which enriched the HES by adding information about death out of hospitals. This data is employed to examine ethnic inequalities in cardiovascular disease survival. In striking contrast to ethnic inequalities in cardiovascular disease incidence, most minority ethnic groups, particularly South Asians, have better cardiovascular disease survival than white people, indicating that the excess mortality from cardiovascular disease for ethnic minorities, particularly South Asians, is mainly because they have excess incidence of cardiovascular disease. The situation that ethnic minorities have a lower burden of disease than white people is termed positive inequalities (Johnson et al., 2004). Positive inequalities are found not only in cardiovascular disease but also in cancer. dos Santos Silva et al (2003) suggested that South Asians had a higher relative survival in breast cancer than non-South Asians even after adjustment for diagnosis, socioeconomic deprivation or disease stage at presentation. The overall rates of cancer appear to be lower among ethnic minorities than white people (Johnson et al., 2004). Therefore the positive inequalities for ethnic minorities in health also require further investigation.

This study adopted the ethnicity classification defined by the Office of National Statistics in the UK 2001 Census, which was based on a combination of categories including ‘race’, skin colour, national and regional origins, and language (Office for National Statistics, 2003). However, the heterogeneity of populations from ethnic groups, which might cause heterogeneity of risk of cardiovascular disease for individuals from the same ethnic groups, must be acknowledged. As discussed in Chapter Five, there is great diversity of ethnic origins within Other Asian and Mixed groups. In particular, Mixed ethnic group were combined from four major groups, Mixed White and Black Caribbean, Mixed White and Black African, Mixed White and Asian and Other Mixed (Bradford, 2006). People from these two groups, particularly Mixed group, don’t share the attributes that define an ethnic group (Gardener and Connolly, 2005, Bradford, 2006). Thus individuals from Other Asian and Mixed group with distinct background may be much less homogeneous in terms of cardiovascular disease risk than that for individuals from other ethnic groups, such as Bangladeshi and Indian. Furthermore, there is heterogeneity between generations within the same ethnic groups in terms of health behaviours and resulting risk factors. Sharma et al (1999) reported that diets of Caribbean-born African Caribbeans in the UK were relatively healthy, however, younger African Caribbeans aged 25–34 years were less likely to follow a traditional diet, but more likely to consume more saturated fat. And a British National Diet and Nutrition Survey showed that diet of Black and Indian children had considerably higher concentrations of selenium than White British children (Bates et al., 2002). This may therefore mean that the risk of cardiovascular disease is different between generations and specialised or more targeted services are required for different generations.

8.2.3 Ethnic Inequalities in CVD and Socioeconomic Status

Given that people from minority ethnic groups in the UK are usually in low socioeconomic status, and that socioeconomic status is a major risk factor of cardiovascular disease, the third aim of this study is to explore the relationships between socioeconomic status and ethnic inequalities in cardiovascular disease. The relationships between areal socioeconomic status and ethnic inequalities in CVD incidence are reported in Chapter Six, and the contribution of areal socioeconomic status to the ethnic inequalities in CVD survival and severity/treatment is reported in Chapter Seven.

In Chapter Six, firstly, a geodemographics dataset, the UK 2001 Census Area Classification, was linked to the HES to examine the variations of risk of cardiovascular disease for ethnic groups between geodemographics groups with different socioeconomic status profiles. There are significant variations of standardised incidence ratios for different ethnicity-sex groups. As expected, the risk of cardiovascular disease for white male population is relatively high in the geodemographics groups of Centre with Industry, Industrial Hinterlands and Manufacturing Towns, but low in the group of London Centres and Prospering Southern England. However, most minority ethnic groups, namely South Asians, Other Asian and Black population, tend to have particularly high standardised incidence ratios in geodemographics groups located in London, such as London Suburbs, London Centre and London Cosmopolitan. This is probably because ethnic minorities in London, particularly Bangladeshi and Pakistani Londoners, have lower socioeconomic status than white Londoners as well as their peers in other parts of the country.

Chapter Six also investigated the effect of areal socioeconomic status measured at different geographical scales on ethnic inequalities in cardiovascular disease, given there is no information about individuals' socioeconomic status in the HES. Areal socioeconomic status measured generally for the whole population, i.e. the English Indices of Deprivation 2004, makes little contribution to the observed ethnic inequalities in cardiovascular disease. However, areal socioeconomic status which is measured specifically for each ethnic community, i.e. areal socioeconomic status extracted from the 2001 Census for each ethnic group, significantly contributes to ethnic inequalities in most cardiovascular diseases studied, but not rheumatic heart disease. Different effects of areal socioeconomic status were observed on different ethnic groups. Generally, the effect of socioeconomic status is substantial on Bangladeshi and Black people for most cardiovascular diseases, but moderate on Pakistani people. However socioeconomic status can't explain the higher relative risk for Indians and Other Asians at all, as well as the low risk of cardiovascular disease for Chinese and Mixed people. Areal socioeconomic status measured at both ST ward level and local authority level has consistent effect on ethnic inequalities in cardiovascular disease.

Chapter Seven examined the contribution of areal socioeconomic status measured at different geographical scales, distance to treatment sites and cardiovascular disease severity/treatment to the ethnic inequalities in cardiovascular disease survival. Although areal socioeconomic status measured specifically for different ethnic groups at different geographical scales has a similar effect on cardiovascular disease survival, areal socioeconomic status can't explain the observed ethnic inequalities in cardiovascular disease survival, but widens the ethnic disparities. Distance to treatment sites can't explain ethnic inequalities in cardiovascular disease survival either. And living further from treatment sites is associated with better cardiovascular disease survival. However, after controlling cardiovascular disease severity/treatment indicators, including cardiovascular disease operation, cardiovascular emergency admission and length of stay in hospitals, inequalities in CVD survival significantly reduced for some ethnic groups, such as Indian and Pakistani groups. Because intensive cardiovascular disease care and treatment, particularly a cardiovascular operation, could significantly enhance short term CVD survival. In the full model controlled by areal socioeconomic status and CVD severity and treatment indicators, the ethnic inequalities in CVD survival can't be explained, but is widened by socioeconomic status. White people still have worse CVD survival than people from most minority ethnic groups.

Chapter Seven also examined the contribution of areal socioeconomic status measured at different geographical scales to the ethnic inequalities in cardiovascular disease severity/treatment in terms of cardiovascular emergency admissions and operations. Low socioeconomic status is significantly associated with the increased risk of cardiovascular emergency admissions and cardiovascular operations for Bangladeshi, Pakistani and Black population, although areal socioeconomic status can't fully explain their high relative risk. However, socioeconomic status contributes little to the increased risk of cardiovascular emergency admissions and operations for Other Asian and Indian people. The contribution of socioeconomic status to the ethnic inequalities in cardiovascular emergency admissions and cardiovascular operations is stable at different geographical scales.

This study conducted a series of models to investigate how socioeconomic status could explain ethnic inequalities in cardiovascular disease incidence, survival, emergency admissions and operations. The patterns of the contribution of socioeconomic status on the relative risk of these situations for ethnic groups are very similar. Generally, low socioeconomic status is a major determinant of the relative risk for Bangladeshi and Black groups. And the effect of socioeconomic status on Pakistanis is also significant. However, socioeconomic status contributes little to the increased relative risk for Indians and Other Asians, as well as the low risk for Chinese and Mixed people. It could be argued that areal socioeconomic status might not be a proper indicator of individuals' socioeconomic status. For example, Indian people on average have a relatively high socioeconomic status (Office for National Statistics, 2005). It is possible that Indian people who have cardiovascular disease are in lower socioeconomic status, which can't be reflected by their areal socioeconomic status. Therefore using areal socioeconomic status measures is subject to the ecological fallacy (Selvin, 1958, Firebaugh, 1978). However, there is evidence that the relationships between areal socioeconomic status and ethnic inequalities in cardiovascular disease found in this study are consistent with the relationships identified using individual socioeconomic status. Nazroo (2001) reported that individual socioeconomic status indicators could largely explain the higher risk of reporting heart disease for Pakistani and Bangladeshi. However, there was little difference between the uncontrolled and controlled risk for Indian people. Similar patterns of the effect of individual socioeconomic status on ethnic groups were also observed in reporting fair or bad general health (Cooper, 2002, Nazroo, 2003b). However, the ecological fallacy might have a great impact on Other Asian and Mixed groups due to the greater heterogeneity of populations from these two groups. Therefore, the effect of socioeconomic status on the relative risk of cardiovascular disease for Other Asian and Mixed groups requires further investigation.

Areal socioeconomic status measured at different geographical scales might have different effect, which is known as the scale effect of the Modifiable Areal Unit Problem (MAUP) (Openshaw, 1984). This study examined the scale effect on the contribution of socioeconomic status to ethnic inequalities in cardiovascular disease incidence, survival, emergency admissions and operations in Chapter Six and Chapter Seven. There are inconsistent findings in previous studies about to what extent the scales of measurement affect the associations between area socioeconomic status and health. Some research reported that areal socioeconomic status measured at a small geographical scale has stronger effect on health (Krieger et al., 2002, Franzini and Spears, 2003, Schuurman et al., 2007). However, some other studies reported that there was little difference in the results when areal socioeconomic status was measured in different scales (Davey Smith et al., 1998, Fiscella and Franks, 2001, Thomas et al., 2006, Lovasi et al., 2008). In this study, the overall effect of areal socioeconomic status on the ethnic inequalities in CVD incidence, survival, emergency admissions and operations is consistent at both ST ward level and local authority level, although the effect of individual areal socioeconomic status measure is not that always consistent. Flowerdew et al (2008) suggested there may be also major differences in the results when the study areas are aggregated in different ways, even if the areas are at the same scale, which is known as the zonation effect or aggregation effect (Openshaw, 1984) of the Modifiable Areal Unit Problem. However, the zonation effect is not modelled in this study.

Controlling for socioeconomic status could explain the relative risk of cardiovascular disease incidence, emergency admissions and operations for some ethnic groups, however, socioeconomic status actually widens the ethnic inequalities in cardiovascular disease survival. But the process of socioeconomic status affecting ethnic inequalities in cardiovascular disease survival might not be that straightforward. Low socioeconomic status is found to be associated with a relatively high risk of cardiovascular disease operations and emergency admissions for ethnic minorities in this study, because people in low socioeconomic status are less healthy and might have more serious cardiovascular disease situations. Cardiovascular disease operations and emergency admissions could significantly enhance survival from cardiovascular disease. Thus ethnic minorities, particularly South Asians and Other Asians, who are much more likely to have cardiovascular disease operations and emergency admissions, have better cardiovascular disease survival. This is not to suggest that most ethnic minorities have better CVD survival directly because they are in low socioeconomic status. Low socioeconomic status is an important determinant of cardiovascular disease operations and emergency admissions for ethnic minorities. The positive effect of these intensive cardiovascular clinical care and treatments seems to be greater than the negative effect of low socioeconomic status on cardiovascular disease severity and survival. For this reason, most minority ethnic groups have better CVD survival. However, low socioeconomic status is not the main determinant for ethnic minorities' high level of use of intensive cardiovascular clinical care and treatments. After controlling for socioeconomic status, South Asians and Other Asians are still more likely to have cardiovascular disease operations and emergency admissions. This could be interpreted as ethnic minorities are more likely to seek intensive health care and treatment due to their widely perceived increased risk of cardiovascular disease (Britton et al., 2004), and doctors are more likely to respond to their needs.

8.3 Limitations of the Study

While this study further examined ethnic inequalities in CVD in the UK, inevitably, there are some limitations of this study. These limitations are mainly due to the data used in this study

Firstly, the data quality of ethnicity coding in Hospital Episode Statistics data is not satisfactory. The percentage of Finished Consultant Episodes (FCEs) with invalid ethnicity codes is at a high level. Two methods, i.e. the record linkage method and the coding rate method, were developed in Chapter Three to improve the data quality and reduce the uncertainties caused by the missing ethnicity codes. However, it is acknowledged that there are limitations of these two methods. For the record linkage method, as restoring the missing ethnicity codes is based on historical admissions with valid ethnicity code of individual patients, sicker patients, who have more admissions, are more likely to have at least one valid ethnicity code than less sick patients. Thus ethnicity of sicker patients might be more likely to be identified than less sick patients, which might introduce bias. However, it seems reasonable to assume that this will be true of all ethnic groups and therefore there will be no bias when making comparisons between ethnic groups. For the coding rate method, the method used in this study assumes that there is no ethnic difference in the probability of missing ethnicity code within the same local area-age-sex group. This method does not allow ethnic difference in the coding rate at small area level. However, this method is finally used in this study mainly because that the method that tries to model the ethnic difference in the coding rate at small area level, i.e. the local area-sex-ethnicity coding rate method, is greatly affected by the small number problem, which makes the estimated coding rates for minority ethnic groups very unreliable.

Secondly, the limitation of conducting this study at ecological level must be acknowledged. Given that there is no information about individual socioeconomic status in the HES data, areal socioeconomic status measures are used in this study. Although ecological studies have been continuously and widely used in health studies (Firebaugh, 1978, McLoone and Boddy, 1994, Stewart and Kuulasmaa, 1994, Diez-Roux et al., 2000, Whitley et al., 1999, Geronimus, 2006), making an inference about an individual based on aggregate data can introduce bias, known as the ecological fallacy. However, as individual socioeconomic status measures are often not available for analysis, ecological analysis will continue to be used in health studies, with careful interpretation of results (Geronimus, 2006).

Thirdly, unhealthy behaviours, such as smoking, physical inactivity and eating less fruits and vegetables, are not controlled in this study due to data unavailability. These are very important risk factors of cardiovascular disease. Some research has found that people from certain minority ethnic groups are more likely to engage in unhealthy behaviours. For example, South Asians in the UK were found to participate far less in recreational physical activity than Europeans, which would increase their obesity, systolic blood pressure, and blood glucose (Hayes et al., 2002). In addition, smoking is much more common among Bangladeshi and Pakistani men in Britain than white men, particularly Bangladeshi men (Health Education Authority, 2000, Department of Health, 1999). These risk factors might contribute to the ethnic disparities in cardiovascular disease, although they may be highly correlated with socioeconomic status which is controlled for.

Fourthly, as mentioned in Chapter Seven about ethnic inequalities in CVD survival, there is no cause of death in the HES data. In addition, there is no information about patients after they have been discharged from hospitals in the HES data. The ONS mortality data have been linked and matched to the hospital episode spells by Gill (2003), which enriched the HES by adding information about death out of hospitals. This data was employed to examine ethnic inequalities in cardiovascular disease survival. An assumption made in this chapter was that the patients with first diagnosis of CVD who died in the hospitals or after discharge from hospital died as a result of CVD. However, this assumption will introduce some uncertainties, i.e. the deaths may not be from CVD, but from other disease or accidents, although cardiovascular disease is the biggest cause of death in the UK. In order to reduce the uncertainties, only the patients whose main diagnosis (first diagnosis) was CVD were selected in the study. In addition, considering cancer is also an important cause of death in the UK, patients with cancer were also excluded from the analysis. Even so, it is still acknowledged that there is uncertainty in the cause of death. However, CVD should at least contribute to the deaths. Furthermore, it seems that there is no non-CVD cause of death to be concentrated in a particular ethnic group, therefore, there might be little bias when comparing CVD survival between ethnic groups. It is also acknowledged that there is no data about cardiovascular disease deaths for patients who don't have any CVD admissions ever in the HES, which is more likely to occur in cardiovascular emergencies. However, compared with the number of recorded CVD deaths, this number is believed to be small. Therefore, CVD deaths before admitting to hospitals seems introduce little bias.

8.4 Opportunities for Further Research

While this study has explored several aspects of ethnic inequalities in CVD, a number of opportunities for further research also arise, which are discussed briefly in this section.

Firstly, cardiovascular disease conditions of White Irish people and Eastern European immigrants, which have not been studied here, need investigation. White people as a whole were studied in this research as a reference group. However, there is ethnic diversity within the white group. White Irish group, which represents around 1.2 per cent of the total UK population, similar to that of Pakistani group, has a different background from the White British group, in terms of age distribution, socioeconomic status, age-standardised rates of reporting not good health and limiting long term illness (Office for National Statistics, 2005). In addition, the recent rise in migration to the UK from East Europe countries, i.e. the A8 countries (the Czech Republic; Estonia; Hungary; Latvia; Lithuania; Poland; Slovakia; and Slovenia), also requires attention to their health. Compared with the White British group and other ethnic groups, people from these two groups may have different relative risk of cardiovascular disease, and the effect of socioeconomic status on their cardiovascular disease may be different from that on other ethnic groups, which needs further research.

Secondly, it is found in this study that areal socioeconomic status measures contribute little to Indian people's increased risk of cardiovascular disease. Areal socioeconomic status also can't explain Chinese people's lower risk of cardiovascular disease. These findings raised two opportunities for further research to examine the relationships between socioeconomic status and cardiovascular disease among Indian and Chinese people. The first one is to further confirm whether socioeconomic status *per se* contributes to their increased or lower cardiovascular disease risk when individual socioeconomic status measures are available, because areal socioeconomic status is subject to the ecological fallacy. The second one is to investigate the role of other risk factors rather than socioeconomic status factors, such as physical inactivity, smoking, dietary and culture-related characteristics, in their cardiovascular disease risk, to investigate whether these risk factors are the underlying reason for their increased or lower risk of cardiovascular disease.

Thirdly, people from minority ethnic groups, particularly South Asians, are found to have better CVD survival than the white population. The disparities in CVD survival between ethnic groups still exist after controlling for socioeconomic status and CVD severity. Further research is needed to identify the underlying reasons for this finding, which is opposite to the pattern in CVD incidence. Given that the ethnic inequalities in CVD survival identified in this study are based on 3 years data, advantage in CVD survival might be because their cardiovascular operations promote short term survival, particularly for South Asians, whose relative risk of CVD operations is much higher. Thus the first direction is to examine ethnic inequalities in long term CVD survival when relevant data are available, to investigate whether the advantages in CVD survival still exist for people from minority ethnic groups. The second direction is to investigate the role of family care outside hospitals and to investigate to what extent family care contributes to ethnic inequalities in CVD survival. This is because in culture of minority ethnic groups, particularly South Asians, family members are more likely to live together, thus patients are more likely to receive more family care. However, this is not the case for white people, which might worsen their CVD survival.

8.5 Policy Implications of the Thesis

A number of findings identified throughout this study would be of use to support policy making.

Firstly, in order to monitor and promote health of people from minority ethnic groups, ethnicity information should be widely collected in high quality in health data and surveys, particularly national collected data. This is because ethnicity data is fundamental to understand ethnic inequalities in health that support health policy. However, currently, there are limited health data, particularly mortality data, with ethnicity information available in the UK. Furthermore, the data quality of ethnicity coding in these data is not satisfactory, such as the HES used in this study, which have largely limited research on ethnic inequalities in health.

In addition, only collecting ethnicity information in health data is not enough, it is helpful to collect ethnicity information in other health-related data, such as health service related data, socioeconomic status data and life style data, at individual level and small geographical scales. Most often, health data need to be linked to these data to understand the underlying relationships. However, given that few health-related data contain ethnicity information, it is difficult to add extra information to current health data with ethnicity information.

Secondly, health policies and health campaigns for cardiovascular disease among ethnic groups should acknowledge the national and geographical variations of risk of cardiovascular disease for ethnic groups. South Asians in the UK are at a high risk of cardiovascular disease. There are a number of health campaigns that target the South Asian community to promote their awareness of cardiovascular disease and reduce their modifiable cardiovascular disease risk factors, such as NHS Asian tobacco campaign. However, in this study, it is found that different ethnicity-sex groups have different risk of different types of cardiovascular disease at both national and geographical level. For example, South Asian men have significantly high standardised incidence ratios of most cardiovascular diseases, particularly Bangladeshi men. However, Indian women standardised incidence ratios are not that high in stroke and coronary heart disease. Black people have a higher risk of stroke and hypertensive heart disease, but a lower risk of coronary heart disease. Thus health policy and health campaign for a certain cardiovascular disease should be customized to focus the ethnic groups at a higher risk of that cardiovascular disease rather than always focusing on South Asians. Furthermore, even within South Asians, Indian, Pakistani and Bangladeshi also have different risk for different types of cardiovascular disease, which should also be considered in health policies and health campaigns.

Thirdly, health policies and health campaigns which aim to reduce ethnic inequalities in cardiovascular disease should focus on deprived areas, particularly socioeconomic deprived areas in London. It is found that in this study, areal socioeconomic status measures are significantly associated with cardiovascular disease and contribute to ethnic inequalities in cardiovascular disease as well. After controlling for areal socioeconomic status, the relative risk of some ethnic groups is largely reduced. So health policies and health campaigns need to have geographically defined priority. One point needs to address is how to identify deprived areas. In this study, it is found that English Indices of Multiple Deprivation contributes little to ethnic inequalities in cardiovascular disease, because the deprivation indices are measured based on the general population and not able to reflect the actual deprivation of minority ethnic groups. However, areal socioeconomic status measures specifically extracted from the 2001 Census for each ethnic group could explain ethnic inequalities in cardiovascular disease to some extent. Thus when identifying deprived areas, it is better to conceptually divide neighbourhoods into different ethnic group communities and measure the deprivation for each ethnic group community, as people from minority ethnic groups living in wealthy neighbourhoods may experience high deprivation. However, the geographical scale at which deprivation is measured seems not to matter, because in this study, socioeconomic status measured at both ST ward level and local authority has consistent effects ethnic inequalities in cardiovascular disease.

Last but not least, white people need to be targeted in cardiovascular disease treatment in health policy and by doctors. White people have lower risk of getting cardiovascular disease. However, in striking contrast, most minority ethnic groups have better cardiovascular disease survival than the white population. One of the main reasons is that compared with minority ethnic groups, white people are less likely to have intensive cardiovascular disease clinical care and treatments, even after controlling for age, gender and socioeconomic status, perhaps because they are perceived to have lower risk of cardiovascular disease than ethnic minorities by both themselves and doctors. However, given that cardiovascular disease treatment, particularly cardiovascular operation, could significantly enhance survival, white people need to be cared for and treated as intensively as other ethnic groups.

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