EXPLORING PATHWAYS TOWARDS SOCIAL GRADIENTS IN ORAL AND GENERAL HEALTH

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July 2007

ABSTRACT

There are social gradients in general and oral health. Few studies have examined the pathways towards the gradients in oral health and compared them to the pathways suggested for general health gradients. The objectives of this thesis are: (1) to examine and compare the social gradients in selected indicators of oral and general health, (2) to examine the gradients in selected indicators of health-related behaviours, (3) to examine and compare some of the potential pathways towards the gradients in oral and general health. Data were from the Third National Health and Nutrition Examination Survey, pertaining to adults aged 17 years and over in the United States. Oral health indicators were perceived oral health, tooth loss, edentulousness, and four variables indicating periodontal disease. General health indicators were perceived general health, and ischaemic heart disease. Health-related behaviours were smoking, visits to a dentist, frequency of eating fresh fruits and vegetables, and frequency of exercise. Socioeconomic position was measured by years of education and poverty-income ratio. Regression models were conducted to assess education and income gradients in all the health outcomes and all the behaviours, and to examine the effects of certain pathways and factors on health and on the social gradients. These factors included sex, ethnicity, cognitive ability, health-related behaviours and stress (allostatic load). Changes in the social gradients in oral and general health were assessed after adjusting for these factors. There were consistent and similar social gradients in oral and general health (objective 1), consistent social gradients in some but not all health-related behaviours (objective 2), and similar pathways towards the gradients in oral and general health (objective 3). Health behaviours, tooth cleanliness, and stress appeared to be the important pathways affecting the gradients in oral and general health. In conclusion, relative poverty is an important factor that affects the social gradients in oral and general health; similar pathways appear to exist for the oral and general health outcomes explored in this thesis.

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ACKNOWLEDGEMENT

It has been a privilege to do my PhD in the department of epidemiology and public health at University College London. Four years ago, I was motivated by the reputation of this department and the research activities in dental public health, to apply for the PhD program at University College. Having studied in two different universities, in two different countries, I had certain expectations before coming here. It is only fair to say that the education, the guidance and the support I received from my supervisors during the last three years have far exceeded my expectations. There are no words that could describe my gratitude for my supervisors for their help, support and encouragement during the past three years.

I would like to thank my first supervisor, Professor Richard Watt, for his invaluable guidance and advice throughout the evolution of my thesis. I would also like to thank him for his moral support and for giving me the opportunity to broaden my academic and research experience in areas beyond the scope of my thesis. I was motivated by his dedication to his students, and by his talents as a researcher and an educator.

I would also like to thank Dr Georgios Tsakos for his guidance and advice. His insights and critique of the concept, the methods and the interpretation of the data were crucial in this thesis. I would also like to thank him for inviting me to participate in some of his numerous research activities.

I was particularly fortunate to have Professor Aubrey Sheiham as a supervisor. His guidance and advice were the greatest help during the progress of this thesis. His devotion and dedication to his work and to his students are the subjects of admiration and inspiration for me and for everyone around him.

I would also like to thank Professor James Nazroo, Drs. Tarani Chandola, Amanda Sacker and Rachel Cooper for their advice and critique of my thesis.

Chapter 1

General Introduction

Chapter 1

General Introduction

1.1 There are social gradients in morbidity and mortality. Persons at the lower end of the social hierarchy have higher morbidity and mortality rates compared to those at top end (Fuhrer *et al.* 2002; Marmot 2003; Ferrie *et al.* 2003). Even among those who are not poor, the gradient exists. The terms socioeconomic inequalities or disparities in health, generally indicate that poorer people have poor health and everybody else has relatively good health, and reflect the effects of absolute poverty. On the other hand, the term social gradients in morbidity and mortality highlights the fact that not only do those at or below the poverty level have poorer health than the more affluent, but those at the higher levels enjoy better health than those directly below them, and, as we move down the socioeconomic hierarchy, health status gets worse (Adelstein 1980; Kraus *et al.* 1980; Marmot *et al.* 1984; Marmot *et al.* 1991). Although the effects of severe poverty on health may seem obvious through the impact of poor nutrition, crowded and unsanitary housing, and inadequate medical care, an analysis that focuses only on these factors underestimates the potent pervasive effect of socioeconomic position on biological outcomes (Adler *et al.* 1994). The presence of the social gradient in health indicates that the study of the effects of absolute poverty on health is unlikely to explain health differences at the middle and upper levels of the socioeconomic positions on the hierarchy (Adler *et al.* 1994). The significance of assessing the factors affecting the social gradient is that it emphasises the importance of relative status, control over work and living conditions as opposed to absolute poverty and material conditions (Adler *et al.* 1994). The study of the gradients emphasizes that it is not the case that poor people have poor health and everybody else has good health. Therefore, the problem of inequality in health cannot be simply solved by providing access to medical care to everyone or even tackling absolute poverty. Instead, there is a need for better understanding of the socio-environmental determinants of inequality in health. For example, by examining the social gradients in health, the biological, behavioural and psychological mechanisms through which social hierarchy affects health can be identified. One of the possible mechanisms of the social gradients is through psychological mechanisms related to effort-reward imbalances and differing levels of demand and control as we go down each step of the social gradient ladder (Siegrist and Marmot 2004).

The best known study to show the gradient in morbidity and mortality is the Whitehall Study of British Civil Servants. Marmot *et al.* (1984) examined the health of civil servants and demonstrated the clear social gradients in morbidity and mortality. The gradient in mortality ran from the bottom to the top of the social hierarchy (Marmot *et al* 1984). After twenty years, and despite improvements in health, health services, living standards and population awareness of detrimental health behaviours, the Whitehall II study showed a similar gradient in morbidity (Marmot *et al* 1991). Although all the population in the Whitehall study are above the poverty line, there was a gradient in health. Hence, the gradient could not be attributed to absolute poverty, but to relative status, control over decision making, stress and insecurity, among other factors (Marmot *et al.* 1991).

The gradient exists for most, but not all, common diseases and causes of death and for all ages, sex, race and in all industrialised countries (Alder and Strove 1999) and for most health related behaviours (Marmot 1999). For example, in the United States of

America, when the population was categorised according to income, the poorest had the highest mortality rates and people with middle income had mortality rates intermediate between those at the bottom and those at the top (McDonough *et al.* 1997).

Many social conditions were linked to a very broad array of diseases suggesting that socioeconomic and environmental factors affect susceptibility to diseases in general rather than to any specific disease (Cassel 1976; Syme and Berkman 1976; Berkman and Syme 1979). In oral health, Locker (1989) emphasised the theory of general susceptibility and implied that oral diseases are also related to general susceptibility. Therefore, it is reasonable to assume that the patterns and determinants of oral diseases should be similar to those of other chronic diseases because the two main oral diseases, periodontitis and dental caries, are also chronic diseases. Hence, it is hypothesised that the social determinants and the patterns of oral diseases should be similar to those of general chronic diseases. However, there is uncertainty about the similarity and differences between the complex socio-environmental pathways for general and oral health (Sheiham and Nicolau 2005). The assumption is that the same factors which influence general health interact in similar ways to influence oral health, leading to poorer oral and general health in the same sectors of the population. This implies similarities between the determinants of general health and those of oral health.

1.2 Determinants of oral health

Health is the product of a complex interaction between social and environmental factors at the society and individual level, and behavioural, physical and biological factors (Wilkinson 1996). Studies which examined the determinants of oral health have highlighted the importance of socioeconomic factors (Locker 2000; Gilbert *et al* 2003). Other studies of the determinants of oral health linked oral health behaviours, such as tooth brushing, eating habits, smoking and drinking to oral health (Sheiham and Watt 2001). As with poorer health, poorer health-related behaviours cluster mainly in individuals with low socioeconomic position (Blane 1985; Sanders *et al* 2006b). Davis (1980) not only emphasised the impact of social class on oral health and related behaviours but also the importance of demographic factors such as age, sex and race.

Unlike research in the medical literature, there are fewer dental studies which aimed to explain the pathways through which socioeconomic factors influence oral health. Surprisingly, few studies have examined the effects of social deprivation, lack of participation and social isolation on oral health (Locker 2000; Pattussi *et al* 2001; Pattussi 2004). There is also a lack of studies examining how different socioeconomic, behavioural and environmental factors interact with each other and influence oral health (Newton and Bower 2005). Therefore, there is a need to apply the theoretical approaches that have been developed to explain the gradient in general health to research in oral health.

Chapter 2

Literature Review

Chapter 2

Literature Review

2.1 Introduction:

The main focus of this study is to assess whether there is a social gradient in oral health, indicated by periodontal disease, tooth loss and perceived oral health, to explore the similarities and differences in factors affecting the social gradients in oral and general health indicated by ischaemic heart disease and perceived general health, and to examine the potential pathways to the social gradients in oral and general health.

First, a summary of some of the reviews and studies on the social gradients in general health and some of the possible explanations of this phenomenon were reviewed. This was followed by a brief critical overview of the studies addressing the effect of socioeconomic position and ethnicity on oral health. A critique of some reviews that assessed the social gradient in oral health was presented, followed by some specific studies which examined the social gradient in oral health. Some studies were reviewed where the investigators were not primarily concerned about social gradients, but the results indicated the presence of a social gradient in oral health.

A summary of some of the theoretical models, which were developed to examine pathways to the gradients in general and oral health, was presented. This was followed by a proposed model to examine the pathways toward the social gradients in health. Finally, a summary of some of the explanatory pathways towards the social gradients in general and oral health examined in this thesis was presented. The review concluded with a justification for doing this research and highlights of the gaps in the literature.

2.2 Social gradients in health

The study of the effects of socioeconomic position on morbidity and mortality is crucial to understand the determinants of health. While Geoffrey Rose (1992) stated that "the primary determinants of disease are mainly economic and social..", other researchers concentrated on exploring the primary importance of socioeconomic position as determinants of disease. Syme (1996) argued that traditional risk factors for coronary heart disease, namely, smoking, cholesterol and high blood pressure combined account for less than half the occurrence of coronary heart disease. Therefore, it was reasonable to consider that we were missing crucial risk factors with significant power and importance which account for more than half of the occurrence of coronary heart disease. Considering that the data for coronary heart disease are one of the very best available, the results for other diseases are far less impressive (Syme 1996). This phenomenon stimulated those interested in psychosocial determinants to study other risk factors.

As stated earlier, numerous studies have shown that individuals at the bottom of the socioeconomic ladder have higher mortality and morbidity rates than those at the top. Perhaps the most basic reason for differences in health between the rich and the poor is that poorer individuals are more likely to have health damaging exposures and less likely to possess health enhancing resources (Lynch and Kaplan 2000). In other words, the negative health effects on individuals with lower socioeconomic position are the result of absolute poverty. However, studies of the social gradient in health, which exists in all industrialised countries for various diseases and in mortality rates, emphasised the importance of relative poverty and the effects of social hierarchy on health (Wilkinson 1996; Marmot 2003). While the effect of absolute poverty on health is attributed to poor nutrition, low quality water, poor housing and lack of access to other material conditions, the Whitehall study of British civil servants found that differences in health existed between each social position in the hierarchy, even when people were not in absolute poverty (Marmot *et al* 1978; Marmot and Theorell 1988; Marmot 1995; Marmot 1999; Fuhrer *et al.* 2002; Marmot 2003; Ferrie *et al.* 2003) (Figure 2.1).

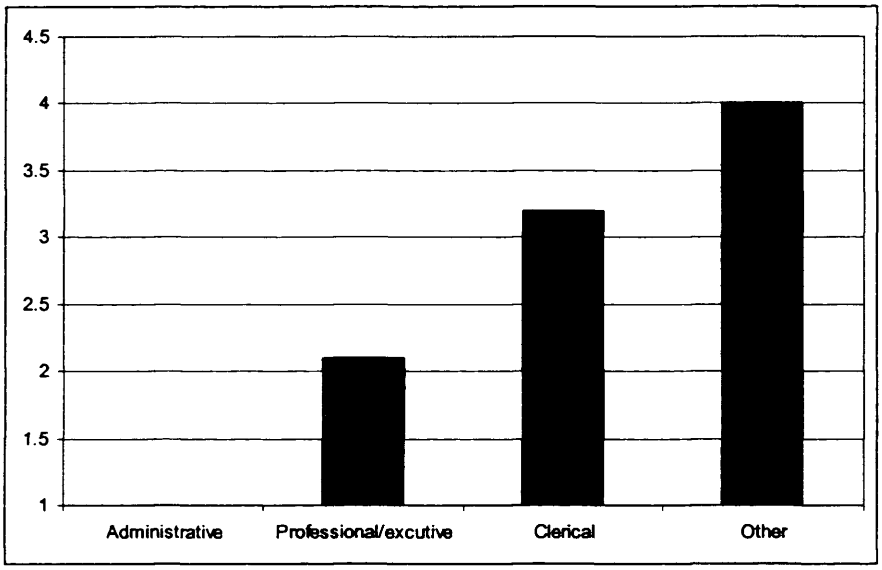


Figure 2.1 Relative risk for death from coronary heart disease according to employment grade in the Whitehall study. (Marmot *et al* 1978)

Civil Service employment grade is correlated with income, hence the lower the grade the less the access to material resources. Nevertheless, most civil servants are above the poverty level below which the obvious causes of material deprivation operate (Marmot 1995). These findings indicate that it is unlikely that this phenomenon is due to material deprivation. The impact of absolute poverty on health cannot explain the social gradients among British civil servants. Moreover, a focus on absolute poverty can limit progress in understanding of determinants of health because it can discourage further explanations (Evans *et al.* 1994).

Further evidence that absolute poverty is not an adequate explanation for the gradients is the fact that in countries where the majority of people live above levels of absolute poverty, there is a gradient in health. For example, a report published by the Ministry of Health and Care Services in Norway demonstrated clear education and income gradients in mortality, morbidity, perceived health and health-related behaviours in Norway (Norwegian Ministry of Health and Care Services 2007) (Figure 2.2).

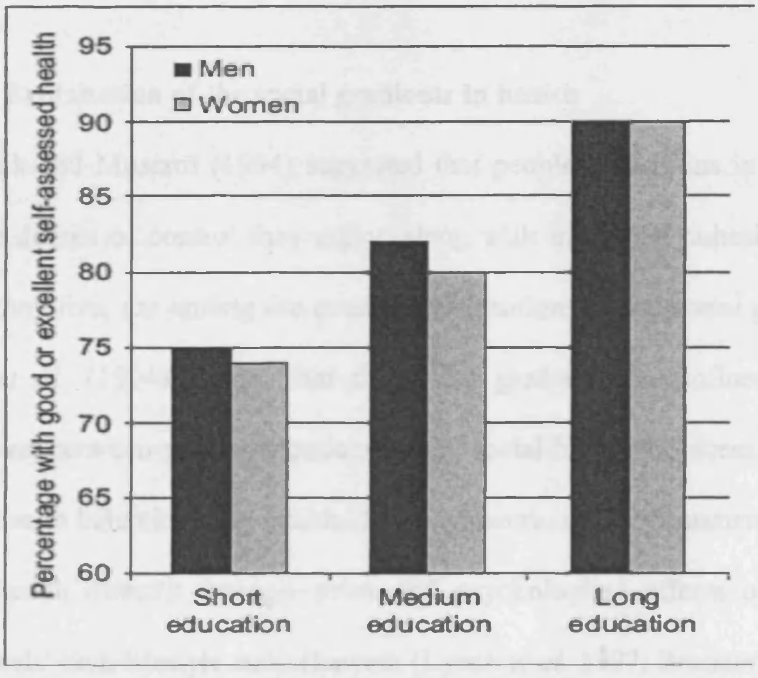


Figure 2.2 Percentage of people who assess their health as good or excellent by education; men and women aged 25-64 (2002). (Norwegian Ministry of Health and Care Services 2007)

An important characteristic of the term "social gradients" which distinguishes it from mere inequality or disparity is that there is not a threshold of absolute deprivation below which people are sicker, but a linear relationship between socioeconomic circumstances and health (Macintyre 1994). The social gradients are consistently found for the majority of indicators in infancy, early childhood and adulthood (Starfield *et al* 2002).

Whenever suitable data were available, researchers have observed the social gradient in health (Marmot 2003). There is a clear relation between social hierarchy and mortality in almost all industrialised countries (Eckersley *et al.* 2001; Kunst and Mackenbach 1994; Shkolnikiov and Cornia 2000). The gradients could be steeper for some diseases and in countries with greater inequality, but they exist for virtually all causes of death (Marmot 2003).

2.2.1 Explanation of the social gradients in health

Frank and Mustard (1994) suggested that people's positions in the social hierarchy and the degree of control they enjoy, along with the social cohesion of the society in which they live, are among the possible explanations of the social gradients. Similarly, Adler *et al.* (1994) argued that the social gradients are influenced by a complex interaction between socioeconomic position, social hierarchy, stress, psychological well-being, health behaviour and health. Socioeconomic and environmental factors can either affect health directly through stress and psychological effects or indirectly through individuals' diet, lifestyle and behaviour (Lynch *et al.* 1997; Brunner 2002).

The meaning of individual social position depends on the society and social environment in which an individual lives. There are two main lines of research on the social environment. First is the effect of income inequality on health. Wilkinson (1996) argued that as income inequality in a society increases, overall health deteriorates and health inequality increases. Higher inequality rates predict worse health. The other line of research is the effect of social capital. The argument is that income inequality could be a marker of social capital which has a direct correlation with health (Putnam 2000).

The association between health and income inequality is attributed to greater inequality in social status, income distribution and social cohesion. Wilkinson emphasised that absolute living standards are important in poorer countries. However, in rich countries, relative deprivation and income inequality have the biggest impact on health through psychological pathways (Wilkinson 2000a). Other studies also emphasised the importance of income inequality, social cohesion and social capital to population health (Kawachi and Kennedy 1997; Wilkinson 1997; Kawachi 2002; Wilkinson 2006).

However, Lynch *et al.* (2003) argued that there is not enough evidence to support the income inequality theory, and that the studies of income inequality did not adjust for other factors such as race/ethnic composition, average state income, individual income and educational attainment. Subramanian and Kawachi (2003) responded by showing evidence which controlled for ethnicity, individual income and educational attainment and still showed the impact of income inequality on morbidity and mortality.

Coburn (2000), in an attempt to explain the socioeconomic inequality in health, argued that neo-liberalism and the decline of welfare state lead to income inequality, low social cohesion and poorer health. Wilkinson's response to this theory was that it limits the effect to historically specific instances while income inequalities seem to be damaging to health whatever their source (Wilkinson 2000b). Although researchers assumed that poorer material conditions account for the social gradient in health, it now appears that a major part of the association between low socioeconomic position and poorer health is related to the experience of low socioeconomic position and subordination itself (Wilkinson 2000). This argument is supported by data on the importance of relative income (Wilkinson 1997) and by the work on the physiological effects of social status among non-human primates where social status of the primates was manipulated while diet and the environment were held constant (Brunner and Marmot 2006; Sapolsky 1998; Shively and Clarkson 1994).

Lynch *et al.* (2000) attributed the effect of income inequality on life expectancy at the population level to neo-materialism; the possession of new technological appliances such as computers, cars, air pollution and safe physical environment. However, they ruled out the mediating rule of psychosocial factors and argued that a focus on these factors ignores material conditions which structure everyday experience and leads to victim blaming (Lynch *et al.* 2000). Their downplaying of the role of psychosocial factors ignores the fact that it is not possible to make such a division between environment and people's psychology (Marmot and Wilkinson 2001). Environment affects how people feel. Living in a damp house with few facilities has obvious effects on people's state of mind. Marmot and Wilkinson (2001) argued that tackling the neo-material determinants alone will not solve the problem of health inequality and social gradients in health because the psychological effects of deprivation involving control over life, insecurity, anxiety, social isolation, socially hazardous environment and depression, remain untouched. Over and above satisfying basic needs, consumption serves social, psychological and symbolic processes (Marmot and Wilkinson 2001).

Wealth is a marker for social status, success and respectability while poverty is stigmatizing. At work, higher income is associated with less subordination, more autonomy, and less job insecurity (Marmot and Wilkinson 2001). Low control over work, low social support, hostility, depression and anxiety are associated with coronary heart disease (Marmot *et al.* 1997; Hemingway and Marmot 1999). There is also evidence of the neuroendocrine pathway through which psychological factors affect health (Brunner and Marmot 2006; McEwen 1998). These findings are also supported by non-human primate studies showing the effects of social status on health in absence of material differences (Brunner and Marmot 1997; Kristenson *et al.* 1998; Sapolsky 1998; Brunner and Marmot 2006).

Income and education levels are factors used as indicators for socioeconomic position (Krieger *et al* 1997; Galobardes *et al* 2006). Marmot (2003) argued that education could be important because people of higher education might have better life chances. There is a close link between social deprivation and children's performance in school. Therefore, education could be a marker for children's social background rather than an indicator of their knowledge. The causal role of education may also be affected by other social conditions affecting adults. If the social conditions of persons with low education were bad, health will suffer more than if there was a less egalitarian distribution of resources and opportunities (Marmot 2003).

Income, on the other hand, is important not because more money in the pocket brings better health, but because money is a marker for social position in most societies (Marmot 2003). Again, emphasising the importance of relative poverty as opposed to absolute poverty, Marmot (2003) gave an example of African American men in US compared to men in Costa Rica. While the latter have lower income, their life expectancy is higher. It is therefore social position, not only money and material conditions, that affects health (Galobardes *et al.* 2006).

Marmot (2003) maintains that the importance of social position lies in two key issues: control and social participation. Firstly, control or power, how much control a person has in the work place or at home, affects health. Jobs with high psychological demands and low control put people at higher risk of cardiovascular diseases. Similarly, low control at home predicts symptoms of depression (Marmot 2003). The lack of social participation appears to have a negative effect on health. At the same time persons who are more socially oriented and have luxurious goods in their households have better health. Marmot argued that "it was not just deprivation that was bad for health, but missing out on the luxuries that defined what it meant to participate fully in what society had to offer" (Marmot 2003).

Brunner (2002) suggested that stress related to social position could affect health through health behaviour, and via psychosocial pathways that affect the neuroendocrine system. Accumulations of stressors exert their effect, the body in response shows biological deviations - allostatic load (MacArthur 1997). Those with a higher allostatic load will have breakdown in functioning and higher risk of disease. On the other hand, work or home related stresses affect individuals' health behaviours (Brunner 2002). Behaviours, such as smoking, show a clear socioeconomic gradient (Jarvis and Wardle 2006) and contribute to the gradients in health in the same manner (Marmot and Wilkinson 2006).

The ability to control disease and death is distributed according to individuals' resources of knowledge, money, power, prestige, and beneficial social connection (Phelan and Link 2005). Others have suggested that intelligence could contribute to the social gradient in health as it affects individual's educational attainment and hence status in the social hierarchy. It also impairs individual's compliance with medical and disease prevention advice and limits benefits from the use of health services (Lubinski and Humphreys 1997; Gottfredson 2004). However, health care services were considered to have a limited effect on health (McKeown and Lowe 1966; Mackenbach *et al.* 1990), a view point challenged by Bunker *et al.* (1994) and Kaplan (2003). There are also other financial, social and psychological barriers to carrying out health related behaviours and to the use of health care even when it is universally available (Marmot and Wilkinson 2006). However, intelligence appears to play a role in individual socioeconomic position and on health that needs to be explored (Gottfredson 2004).

The demonstration of social gradient in health necessitates that we go beyond binary thinking as we are not simply dealing with the problem of absolute poverty. The challenge that the social gradients present is to understand features of social organization which affect health and to work out how to improve the conditions in which people live and work (Marmot 2003). This was illustrated by a recent study that compared health status of older individuals in England and USA and the effect of socioeconomic position on health status (Banks *et al.* 2006). USA residents were much less healthy than their English counterparts. Banks *et al.* (2006) attributed this phenomenon to differences in social environment, health care and social systems (Banks *et al.* 2006).

The examination of the social gradients in health demonstrates what high levels of health are possible in a given society. If it is possible for some people to achieve low levels of morbidity and mortality, then it is possible to achieve similarly low levels of morbidity in all groups. Hence, there is a need to develop preventive policies from a more social and structural view of the determinants of health (Wilkinson 1996).

The universality of the effects of socioeconomic position on health and health-related behaviours, and the persistent social gradients for most chronic diseases, and all countries and age groups, suggest that there might be a generalised susceptibility to disease among certain social levels of the community. In 1937, Frost suggested that the high prevalence of tuberculosis among the poor was not just due to higher risk of exposure, but about their ability to fight disease once exposed, something that changed their non-specific resistance to diseases (Frost 1937). Years later, Cassel (1976), Syme and Berkman (1976) and Berkman and Syme (1979) observed that many social conditions were linked to a very broad array of diseases. They suggested that social factors create a vulnerability or susceptibility to diseases in general, rather than to any specific disease. Locker (1989) also observed the general susceptibility of certain groups of the population to a wide range of chronic disease including oral diseases, namely those who lack social support or close social and emotional ties. Recent advances in the studies of neuroendocrine response found that stressful experiences may alter neuroendocrine-mediated biological pathways and lead to a variety of disorders from cardiovascular disease to cancer and infectious disease (Meanry *et al.* 1998; Sapolsky 1996; McEwen 1998). Bearing in mind this concept of general susceptibility, it is hypothesised that the social causes and the patterns of chronic oral diseases should resemble those of other chronic diseases.

2.3 Social gradients in oral health

There are fewer studies addressing the social gradients and their determinants in oral health compared to those for other chronic diseases. Considering the hypothesis of general susceptibility proposed by Cassel (1976), Syme and Berkman (1976) and Berkman and Syme (1979), it is likely that similar mechanisms cause the social gradients in oral health.

However, most of dental studies that have examined the social determinants of oral health did not attempt to demonstrate the presence of social gradients nor explain the complex interactions of these determinants that affect the gradients in oral health. Numerous dental studies reported that poorer, unemployed and less educated people had poorer oral health status (Ismail *et al.* 1987; Palmqvist *et al.* 1994; Aleksejuniene *et al.* 2002; Green *et al.* 2003; Hobdell *et al.* 2003; Mack *et al.* 2003; Pearce *et al.* 2003; Thomson *et al.* 2004; Paulander *et al.* 2004). Other studies examined differences in oral health status between ethnic groups and found a general trend for persons from ethnic minorities to have poorer oral health. Many of these studies did not examine the effects of socioeconomic position or attempt to explain the causes of the differences between the ethnic groups in oral health (Ismail *et al.* 1988; Marcus *et al.* 1996; Albandar *et al.* 1999, Albandar and Kingman 1999; Jones *et al.* 2000).

With regard to the commonality of causation of oral disease and other major chronic diseases, a limited number of studies suggested that the same social factors affect both oral and other major chronic diseases (Poulton *et al.* 2002; Borrell *et al.* 2004). Another study suggested that there might be biological factors making individuals more susceptible to both diabetes and periodontal disease (Soskolne and Klinger 2001). The majority of the studies which examined the relationship between oral health and general health attempted to prove that dental diseases, such as periodontitis, influence general diseases, such as coronary heart diseases, and tried to find a basis to recommend routine dental treatment for persons with certain chronic conditions (Arbes *et al.* 1999; Hujoel *et al.* 2001; Hujoel *et al.* 2002; Hyman *et al.* 2002; Meurman *et al.* 2004; Chun *et al.* 2005).

This thesis is mainly about the social gradients and their determinants in relation to periodontal disease, tooth loss and perceived oral health, and their similarity with the social gradients in general health. Hence, the review of literature is limited to studies which explicitly addressed the presence of a social gradient in oral disease. Some studies were included that were not specifically looking for social gradients but the results showed the gradients, although the investigators did not attempt to explain the gradient.

2.3.1 The effects of deprivation and socioeconomic position on oral health

Locker (1989) addressed socioeconomic inequality in oral health and acknowledged the presence of social gradients in different aspects of oral health, namely number of missing teeth, periodontal diseases, and number of decayed teeth in UK. Locker (1989) put forward different explanatory theories designed to explain inequality in general health and thought to be applicable to oral health.

Similarly, Chen (1995) reviewed differences in oral health based on population socioeconomic position in industrialised, middle income and low income countries. She reported the presence of social gradients generally in periodontal diseases and tooth loss in different countries. The pattern of dental caries was similar only in industrialised and urban areas in middle income countries. Chen explained the patterns of oral disease by a model which addressed the determinants of oral health at the individual and system level. The review emphasised the importance of oral health-related behaviours.

A review of inequality in oral health status based on British national surveys for children and adults examined the relationship between oral health status and social class (Watt and Sheiham 1999). There were differences in decayed, missing and filled primary and permanent teeth (dmf and DMF scores) in children in different age groups according to families' social class. Although the paper reported a decrease in dental caries in all social classes between 1983 and 1993, during this period the gap in caries experience between social classes had widened for children at age 15 years. There were also differences in children's periodontal disease and trauma with those in lower social classes having a higher prevalence. For adults, there was a social class gradient in the prevalence of edentulousness. However, the difference in the missing teeth for dentate persons was much smaller. The prevalence of periodontal disease was higher among adults in lower social classes (Morris *et al.* 2001), less educated, living in rural areas and men (Figure 2.3).

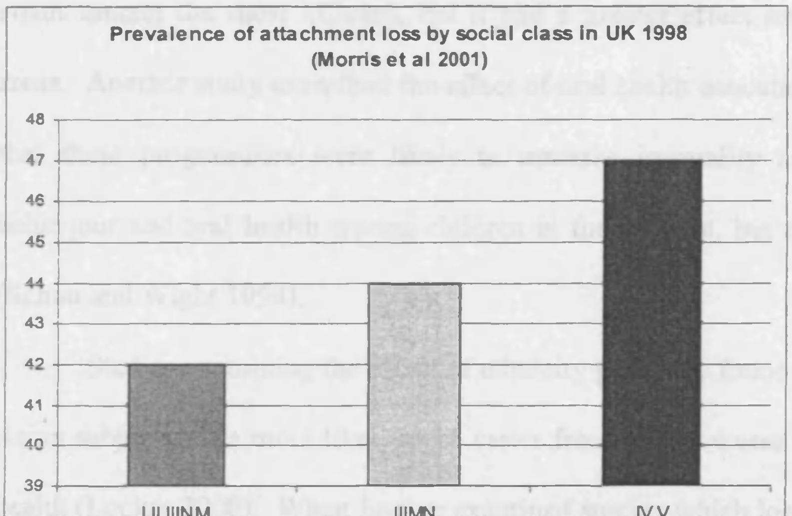


Figure 2.3 **Prevalence of attachment loss by social class in UK. 1998 (Morris *et al* 2001)**

Watt and Sheiham (1999) found differences in caries experience according to ethnic groups and in children's caries experiences between different areas of UK. The prevalence of caries was higher in more deprived areas. In adults there was a great difference in edentulousness between Southern compared to Northern regions of England. The paper highlighted the presence of variation in oral health according to social class and areas of residence (Watt and Sheiham 1999).

In another review, Locker (2000) highlighted the presence of area-based deprivation gradient in oral health. A number of studies which used area-based measures of deprivation to assess correlation with oral health were reviewed. Most of the reviewed studies were based on UK data and used dmf or DMF as outcome measures. There was a consistent association between the score of deprivation and the mean dmf and DMF in most of studies in different areas of UK. One study found a correlation between perceived oral health, oral health behaviour and deprivation score. When Locker reviewed the effect of different interventions on caries experience according to deprivation area, he found that use of dental service by children had no effect on dental status among the most affluent, but it had a greater effect on children from deprived areas. Another study examined the effect of oral health education programme and found that these programmes were likely to increase inequality as they improved health behaviour and oral health among children in the affluent, but not in the deprived areas (Schou and Wight 1994).

Studies examining the effect of ethnicity generally found that Afro-Caribbean and Asian subjects were more likely to be caries free but had worse gingival and periodontal health (Locker 2000). When Locker examined studies which looked at community based risk indicators, he found that children dmf scores were associated with poverty and parents control over their lives. Areas that had high levels of dental caries had a high proportion of low birth weight, lower uptake of vaccination and higher proportion of children in single parents family. In these areas with high dmf scores, babies tended to be bottled-fed, and consumed fruit juice more regularly. Interestingly, children in these areas had poorer school attendance, which was consistent with Marmot's (2003) explanation of the association between education and health. Generally, health behaviour was worse among children in these areas. Locker's review concluded that there was a link between oral health and deprivation. There was also an association between deprivation, general health and health behaviour. The review identified weaknesses in the papers reviewed. For example, areas were categorised into deprivation groups according to their score. This is believed to have masked the actual effect of the deprivation on oral health (Locker 2000). One other weakness of the area-based deprivation measure is that it does not account for other characteristics of the communities such as income inequality or social capital within the community, which were identified as possible causes for inequality in health (Pattussi 2004).

Burt (2005) reviewed studies on the risk factors for oral health. He concluded that while the role of social determinants of health has been well documented in general health, it is still not developed enough in oral health. The available studies indicated that caries is a social disease related to neighbourhood characteristics and financial capabilities, work stress and other social factors. Burt (2005) argued that oral diseases probably have social dimensions similar to that observed in other chronic diseases.

Nuttall (2003) reviewed studies pertaining to inequality in oral health in Britain using the Registrar General's classification of social class and measures of area deprivation. Nuttall (2003) noted the presence of the social gradient, based on measures of deprivation, in caries among 5 and 12 year old children. Higher percentages of the children were caries free among the least deprived. As deprivation increased the percentage of caries free children decreased. The gap in caries levels between the rich and the poor among 5 year-old children in England had widened between 1983 and 1993. Furthermore, there were social class gradients in the prevalence of dental caries among 12 and 15 year old children in England and Scotland and in decayed and missing teeth in the whole population. A social class gradient also existed for complete tooth loss and oral health-related behaviours in the United Kingdom. For example, persons from professional backgrounds were more likely to visit dentists, brush their teeth twice a day and use other cleaning methods (Nuttal 2003).

In a review of the social and psychological factors associated with periodontitis, Sheiham and Nicolau (2005) stated that there was a social gradient in periodontal diseases. Sheiham and Nicolau stated that inequalities in socioeconomic position predict both mortality and morbidity. Rates of morbidity are successively higher at lower grades of the socioeconomic scale. These gradients exist for most common diseases including periodontal diseases. In addition, there are also social gradients in health behaviours similar to those found in morbidity and mortality; "poor people behave badly" (Lynch *et al.* 1997). The increased probability of clustering of risk factors in those in the lower levels of socioeconomic position suggests that environment influences individuals' health risk (Lynch *et al.* 1997). Sheiham and Nicolau (2005) also highlighted different social and psychological factors that affect periodontal health such as work environment, social network, stress, psychology and early life circumstances. These factors are probable explanations of the gradients in oral health.

Other studies also emphasized the effect of stress at and outside work on oral health (Locker 1989; Marcenes and Sheiham 1992; Marcenes and Sheiham 1994; Abegg *et al.* 1999, 2000) and the effect of social cohesion, relative deprivation and social deprivation on oral health (Pattussi *et al.* 2001). Most of the latter factors influence health-related behaviours and thereby, oral health (Pattussi *et al.* 2001; Moyses *et al.* 2006).

2.3.2 Dental Studies explicitly addressing social gradients in oral health

A number of studies found social gradients in a number of indicators of oral health, namely perceived oral health, periodontal disease, dental caries and tooth loss. The following section summarised these studies.

Poulton *et al.* (2002) compared the effect of socioeconomic position and social mobility on some general health indicators such as obesity, systolic blood pressure and cardio-respiratory fitness and oral health, using data from the Dunedin Multidisciplinary Health and Development Study. This study has particular importance as it is one of the few studies which compared social gradients in oral health and general health. A total of 1000 children were assessed at birth, and ages 3, 5, 7, 9, 11, 13, 15 and 26 years. At age 26 they were assessed for body mass index, waist-hip ratio, blood pressure, cardio-respiratory fitness, dental caries, plaque scores, gingival bleeding, periodontal disease, depression, and tobacco and alcohol dependence. There were social gradients in oral health, general health indicators and dependency on alcohol and tobacco. Persons in the lowest socioeconomic groups had poorer general health, poorer oral health, and were more likely to be dependent on alcohol and tobacco than those in the middle socioeconomic group. As people 'ascended' the socioeconomic scale, the proportion with poor oral health, poor general health and substance abuse decreased (Figures 2.4-2.6). Socioeconomic gradients existed at childhood and adulthood and for all the outcomes: oral health, general health and substance abuse. The investigators also examined the effect of social mobility from childhood to age 26 years. Individuals who were persistently in the higher socioeconomic groups had better oral and general health.

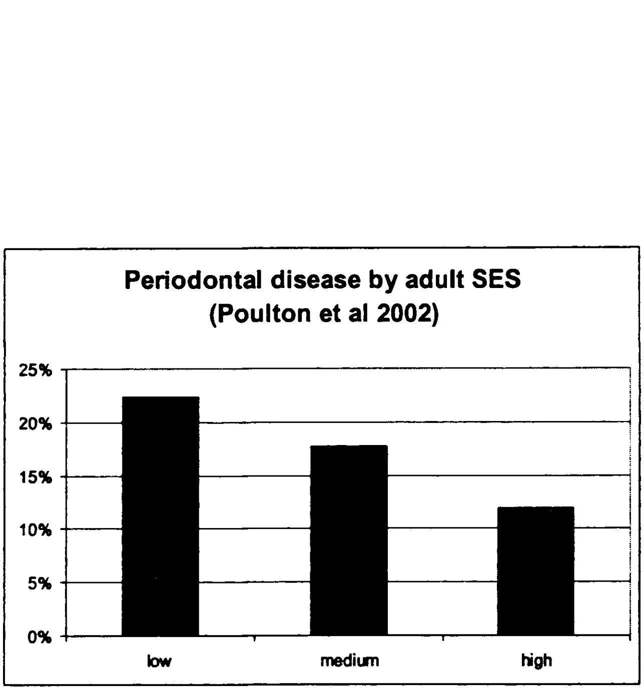


Figure 2.4 Periodontal disease by adults' socioeconomic position (Poulton *et al* 2002)

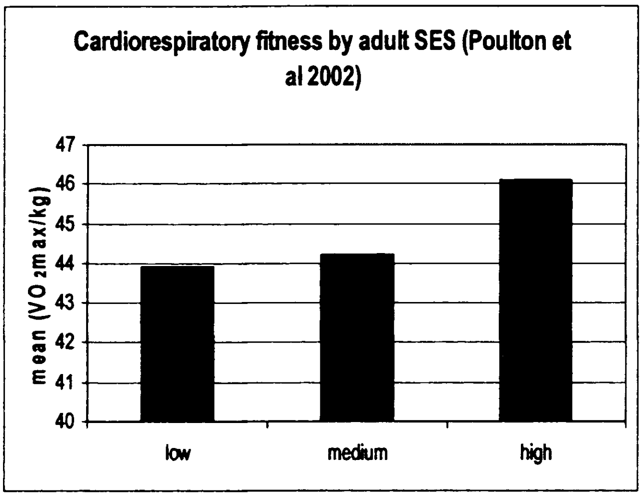


Figure 2.5 Cardio-respiratory fitness by adults' socioeconomic position (Poulton *et al* 2002)

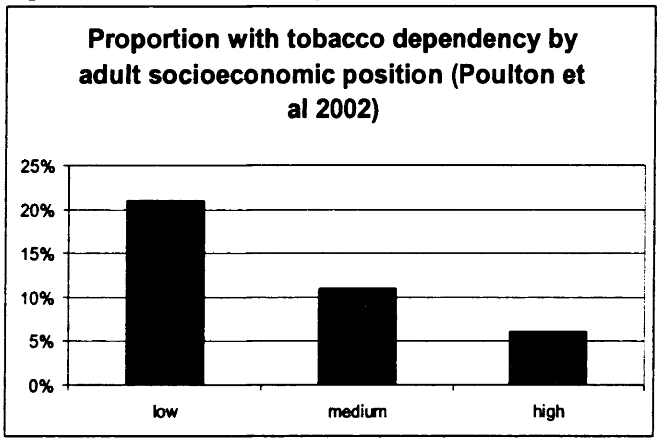


Figure 2.6 Proportion with tobacco dependency by adults' socioeconomic position (Poulton *et al* 2002)

The authors concluded that while other studies of social gradients concentrated on specific diseases such as cardiovascular disease, they found that the gradient is far more ubiquitous and troubling (Poulton *et al.* 2002). Low social class adversely affects many areas of people's health including their physical, mental and oral health. Furthermore, Poulton *et al* (2002) noted that both childhood and adulthood socioeconomic positions were important determinants of the social gradient. For example, both of them were related to poor cardio-respiratory fitness and oral health. Upward mobility was associated with a decrease in waist/hip ratio, while downward mobility was associated poorer fitness and poorer oral health. Depression and substance dependency were strongly linked to adult socioeconomic position. There were two limitations of this study. First, parental occupational status was the only measure of childhood socioeconomic position. Second, adult socioeconomic position at age 26 might not reflect the final socioeconomic destination, and adult achievement later in life might undo earlier childhood influence.

In a study which aimed at assessing changes in social gradients in perceived oral health among Swedish population at two points in time, Stahlnacke *et al.* (2003) sent questionnaires on oral health indicators such as satisfaction with teeth, chewing ability and number of remaining teeth, to a sample of the Swedish population in 1992, and a new questionnaire in 1997, to assess changes in perceived oral health. There were obvious social gradients in the perceived oral health in both 1992 and 1997. Marital status, foreign birth, education and occupation were all related to perceived oral health. Despite the drastic changes in the remuneration of dental care during the study period, changes in perceived oral health were moderate.

In a cross sectional study that aimed at assessing parental social class and children oral health in Spain, Zurriaga *et al.* (2004) gathered clinical dental data from 1433 children aged 6, 12, 15 and 16 years and data on parents' social class. There was a social gradient in dental caries and periodontal disease. The scores of CPITN indicated that periodontal disease and/or calculus were inversely related to parental social class. The social gradients in oral health were steeper in dental caries than in periodontal disease.

Thomson and Mackay (2004) assessed the effect of area-based and household-based socioeconomic position on dental caries among 9-year-old children in New Zealand. Children of lower socioeconomic position had higher dmfs and DMFS scores than those in the higher socioeconomic position groups. The gradient in oral health was clearer and consistent when household-based and area-based measures were combined. After adjusting for ethnicity and exposure to water fluoridation, the gradient was reduced, but not eliminated. One problem with this study was the under-representation of native New Zealanders in the sample. This may have influenced the findings as the native population has higher prevalence of caries than White New Zealanders (Thomson and Mackay 2004).

In a recent study which addressed social gradients in periodontal disease among adolescents, Lopez *et al.* (2006) examined data on 9203 Chilean high school students, using seven marker of periodontal disease including necrotizing ulcerative gingivitis. Father's income, education and owning one car or more were used as indicators of socioeconomic position. The investigators found gradients in all markers of periodontal disease across all measures of socioeconomic position (Lopez *et al.* 2006).

Sanders *et al.* (2006a) examined the effect of perceived social position on reported number of teeth, perceived oral health, Oral Health Impact Profile and chewing ability in a sample of 2,915 Australian adults, aged 43-57 years. They found an approximately linear relationship between perception of social position and oral health. Oral health was poorer at each lower group of socioeconomic position, with the gap being greater between the lowest and second lowest groups of socioeconomic position. Unlike other studies on the subject, the authors concluded that there was a discrete level of income below which oral health deteriorates. However, there were some important limitations of this study. First, the study relied only on measures of perceived oral health and perception of socioeconomic status. Additionally, all measures of oral health were dichotomised and all measures of socioeconomic position were categorised into quintiles. The study did not adjust for some important determinants of oral health, such as use of dental services. It is possible that these aforementioned shortcomings may have influenced the results.

In another study, Sanders *et al.* (2006b) examined the influence of oral health-related behaviours and dental visits on the social gradients in oral health in a group of Australian adults. They found that the gradients attenuated by dental visits but not by oral health-related behaviours. Sanders *et al.* (2006b) concluded that the poor oral health of poorer people was not explained by self-neglect.

Holst (2007) examined the relationship of income with edentulousness and having functioning teeth from 1975 to 2002 in Norway. Tooth loss in absolute terms was more equally distributed in 2002 compared to 1975. However, among the oldest age group the relative differences in tooth loss and edentulousness by family income were steeper in 2002 than in 1975. Holst stated that "elderly people in the highest income groups benefited less from the societal conditions which made it possible to maintain natural teeth". She suggested possible mechanisms for the gradients in tooth loss and argued that the presence of the gradients support the theory for a psychosocial pathway related to relative rather than absolute poverty (Holst 2007).

2.3.3 Studies not specifically addressing social gradients in oral health but reporting them in the results

The following studies did not specifically look for social gradients in oral health. However, since these studies found gradients in oral health they were included in the review.

Drury *et al.* (1999) examined socioeconomic inequalities in oral health using data from the US Third National Health and Nutrition Examination Survey (NHANES III). Variations in the presence of oral disease were measured using an index of socioeconomic position based on income and education and adjusting only for age sex and ethnicity. Although the measures of oral health were crude, the social gradients were clear in all indicators.

In the Florida Dental Care Study, Gilbert *et al.* (2003), examined tooth loss in a population of African and White Americans 45 years old and over, before and after entering the dental care system. There were clear gradients by education level, with persons with highest education having more teeth followed by those immediately below them in terms of education status. There were also gradients in the ability to pay. Ability to pay a $500 dental bill, household income and poverty status were used as indicators of socioeconomic position. African American and persons with lower socioeconomic position were more likely to experience tooth loss and less likely to report that the dentist had discussed alternative treatments. Although African American and persons in the lower socioeconomic group had fewer teeth at baseline, they still lost more teeth after baseline. Despite the presence of clear gradients in oral health, the authors did not make any comments about the observed gradients. The authors identified the length of observation interval as a possible factor that may have influenced the results, and argued that if the interval was extended for a decade the observed socioeconomic differences in tooth loss would be diminished.

In a study aimed at assessing the effects of family income and neighbourhood socioeconomic position on general health and oral health, Borrell *et al.* (2004) found income and education gradients in perceived general health among White Americans (Figure 2.7). For African American, there was clear education gradient in perceived general health and perceived oral health status. However, there was no income gradient in the health of African Americans (Borrell *et al.* 2004).

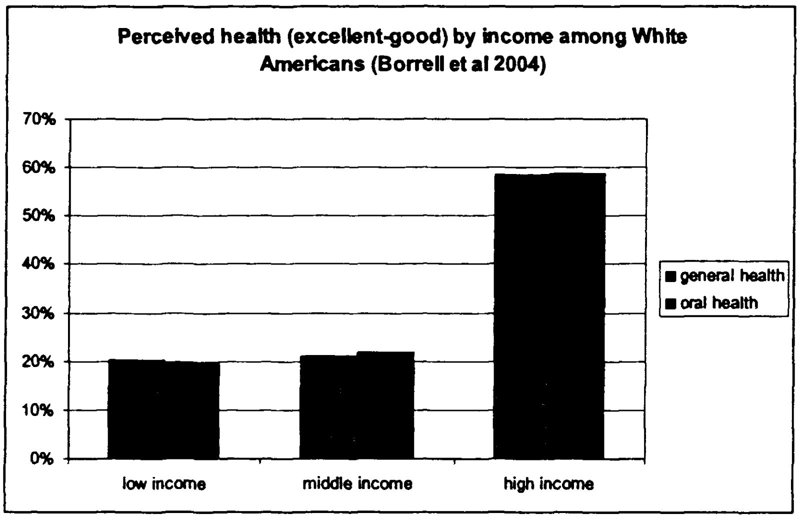


Figure 2.7 Perceived health (excellent-good) by income among White Americans (Borrell *et al* 2004)

There was an education gradient in periodontal disease in a study based on NHANES III (Dye and Selwitz 2005). The percentage of people with periodontal attachment loss was lowest among people with college education, higher among those who completed high school and highest among those who did not complete high school. The authors did not attempt to explain or comment on the educational gradients in attachment loss as this was not among the objectives of the study. Very interestingly, being Mexican American was not associated with poorer periodontal status in any of the indicators. This latter finding is consistent with other findings about Mexican American related to cardiovascular disease, where no social gradient was reported (MMWR 2002).

2.4.1 The use of psychosocial theoretical models to explain the determinants of the gradients in health

In public health, there are numerous theoretical models explaining the pathways between environmental, socioeconomic, behavioural, biological factors and general health (Brunner and Marmot, 2006 Kaplan and Lynch 1999; Kaplan *et al.* 2000; House 2001; Lynch 2000). These models have multilayer pathways through which different environmental, social, economical, behavioural and biological factors may influence health. They run counter to the simple examination of the determinants of health which focuses on one level of the determinants, usually the most proximal ones to the outcomes (Kaplan 2004). For example, the psychosocial models not only focus on the behaviours leading to sickness but also focus on the social, environmental and biological factors that influence the behaviours and hence the disease.

Marmot's Model of Social Determinants of Health (Figure 2.8) shows a psychosocial and biological pathway, through which social environment and economic status are linked to psychological well-being, health behaviour and biological wellbeing, leading to morbidity and mortality as final health outcomes (Brunner and Marmot 2006). Placing health behaviours and psychological well-being as mediating factors between socioeconomic position and working conditions from one side, and health outcomes from the other side, assumes complementary roles for psychology, stress and health behaviours in explaining the social gradients in health. The model also acknowledged the effects of early life circumstances, genes, ethnicity and culture. However, this model has been criticized for not specifically accounting for health services, health policy, social cohesion and income inequality (Newton and Bower 2005). The model also did not emphasise the effects of individual biological differences and personal traits on health.

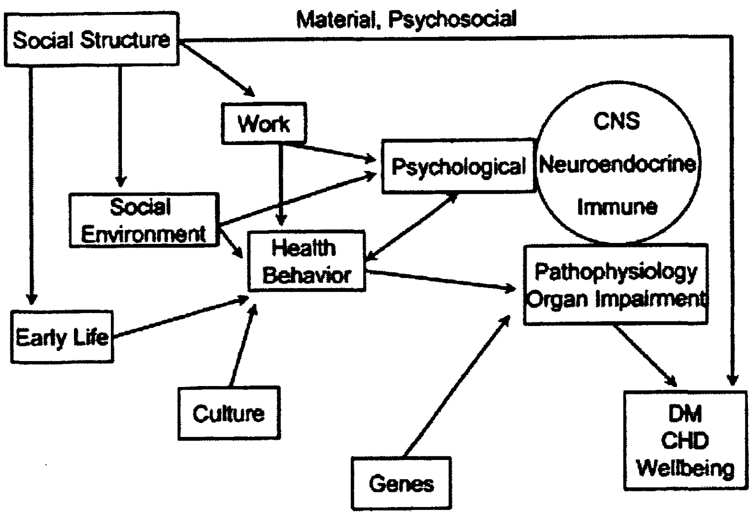


Figure 2.8: Marmot Model for social determinants (Brunner and Marmot 1999)

Other models have been developed to explain the pathways from socioeconomic and environmental factors towards health and disease. Kaplan and Lynch (1999) developed a model for the impact of macroeconomic factors on primordial prevention of cardiovascular disease (Figure 2.9). The model illustrates how global economic policies influence occupational structure, social resources, social structure and the production of food, leading to income inequality, stress and changes in eating habits. The model is ideal for the examination of the socioeconomic determinants of health at the macro level. However, the model does not address individual's variation in relation to health nor the impact of health services on health (Kaplan and Lynch 1999).

Another model was developed to demonstrate a multilevel approach to epidemiology (Kaplan *et al.* 2000). This model acknowledged the effect of social and economic policies at the top of the determinants, this was followed by the effect of education, working condition and health care. The model also emphasised the impact of neighbourhood characteristics, living condition, social capital and social cohesion. This was followed by individuals' characteristics and risk factors, leading to health through pathophysiological pathways. The model also acknowledged the effect of the environment and early life on health (Figure 2.10).

House (2001) developed a model for explaining social inequalities in health and aging (Figure 2.11). According to House's model, social, political and economic policies influence individuals' socioeconomic positions, which in turn influence health either directly or through ability to use health services, health behaviour, stress and social relations. The model also acknowledged the effect of sex and ethnicity on individuals' socioeconomic position and other risk factors. The model addressed the effect of environmental hazards on health. However, this model did not explicitly acknowledge the effect of social cohesion, social capital or early life on health.

Lynch (2000) developed a model for understanding social inequalities in health and aging (Figure 2.12). At the top of the model were the macro-social factors which include political and economic policies, culture and discrimination. These factors were followed by organizational connection and neighbourhood characteristics. The model also recognised the effect of social network, individuals' socioeconomic status, behaviour and human biology. The use of health service was not explicitly addressed, neither was early life.

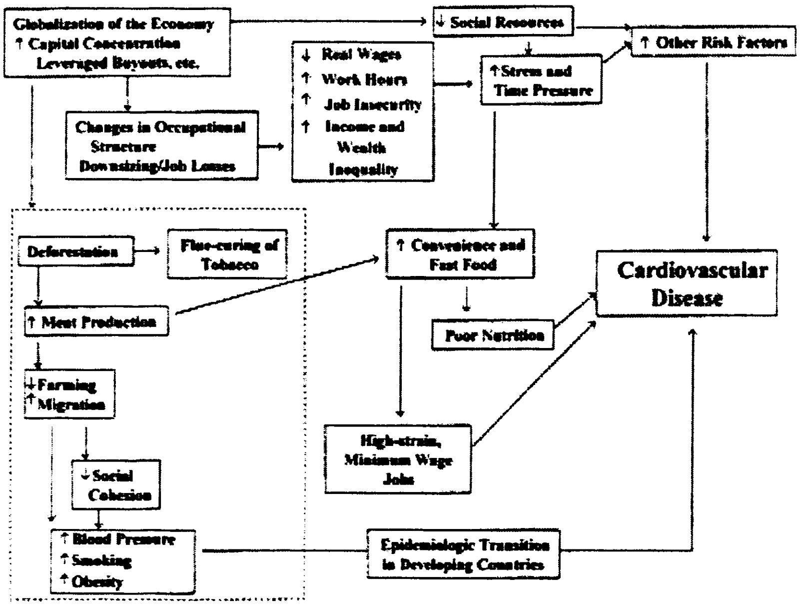


Figure 2.9: Primordial prevention of cardiovascular disease (Kaplan and Lynch 1999)

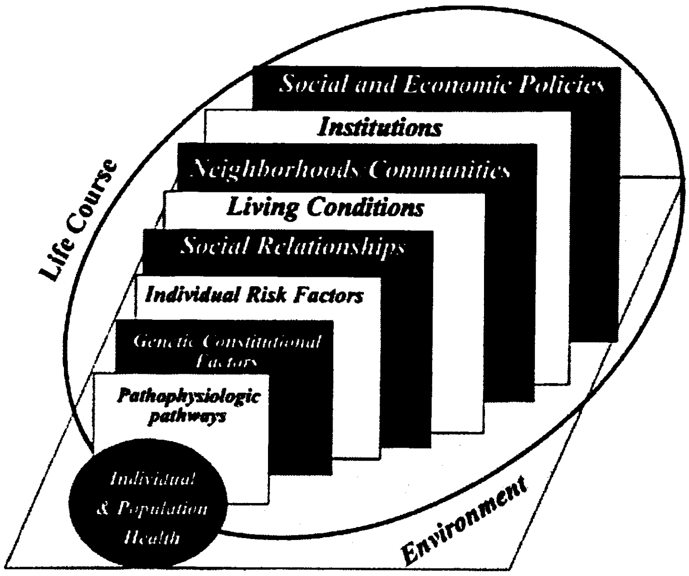


Figure 2.10: Upstream and downstream determinants of population health (Kaplan et al 2000)

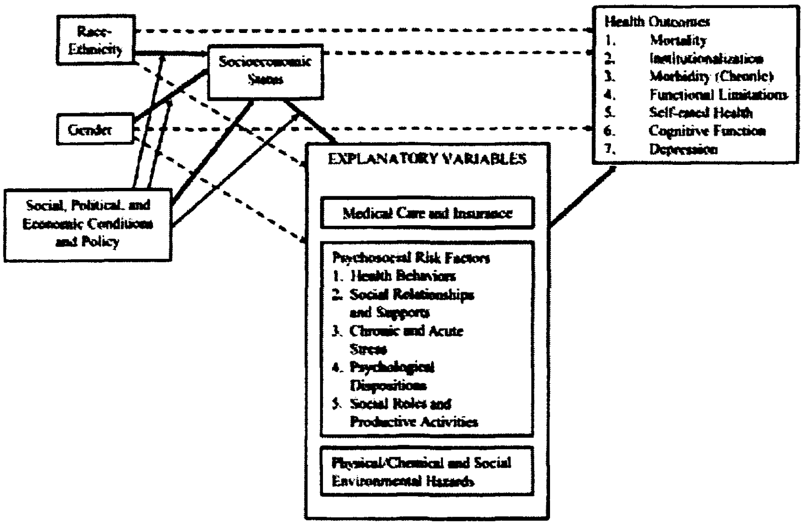


Figure 2.11 Environmental, psychological, and biological pathways linking socioeconomic status to diabetes mellitus (House 2002)

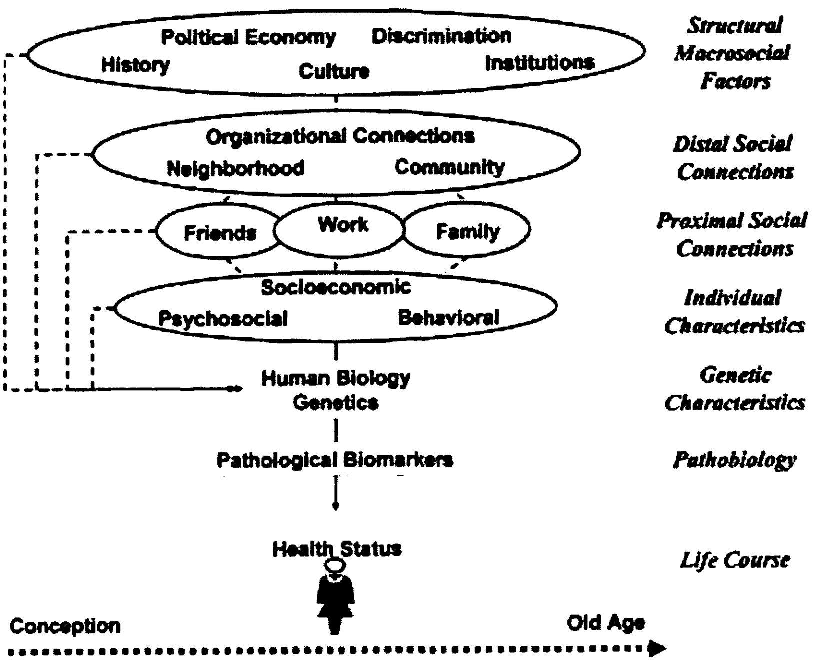


Figure 2.12 A conceptual framework for understanding social inequalities in health and aging (Lynch 2000)

Few dental researchers have used aspects of the abovementioned explanatory models to examine the determinants of oral health. The models that have been used in dental research were not as complex as those used in mainstream epidemiology and excluded a number of health determinants (Hansen *et al.* 1993). Newton and Bower (2005) in reviewing the model suggested by Marmot highlighted the lack of use of theoretical frameworks to examine the determinants of oral health and argued that failure to consider such models have held back developments in oral epidemiology.

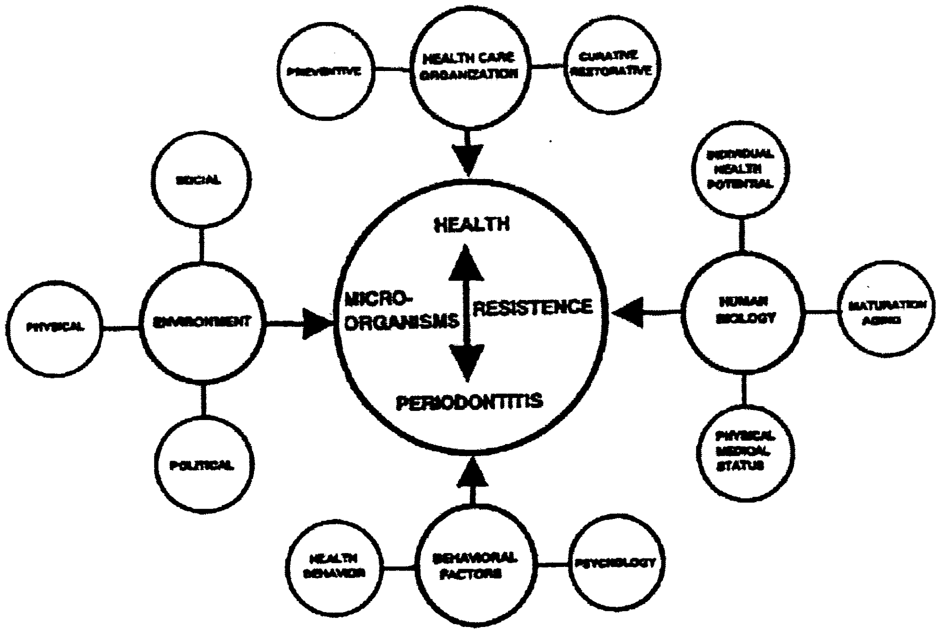


Figure 2.13: The socio-ecologic model for periodontal diseases (Hansen *et al* 1993)

Hansen *et al.* (1993) developed a socio-ecologic model for periodontal disease (Figure 2.13). The model had the advantage of accounting for environmental, social, political, behavioural factors, health services and human biology. The model was based on the assumption that each of the major categories in the model (environmental, health care, behavioural and biological) can affect periodontal health. The model did not account for the interaction between the different groups of determinants. The model also did not address the potential pathways through which environmental and social factors affect periodontal disease.

Holst *et al.* (2001) designed a model modified from the Marmot Model (Brunner and Marmot 2006) to examine the determinants of dental caries (Figure 2.14). The model was designed in a hierarchical fashion starting with political, cultural, health policy and economic conditions. These were followed by social environment, home and school conditions, psychology, health behaviour and material conditions, finally leading to health. The model emphasised possible interactions between the different components of the model and acknowledged the effects of stress on health. However, the model did not explicitly account for biological factors and whether they influenced health related behaviours, nor did it emphasise the use of health services.

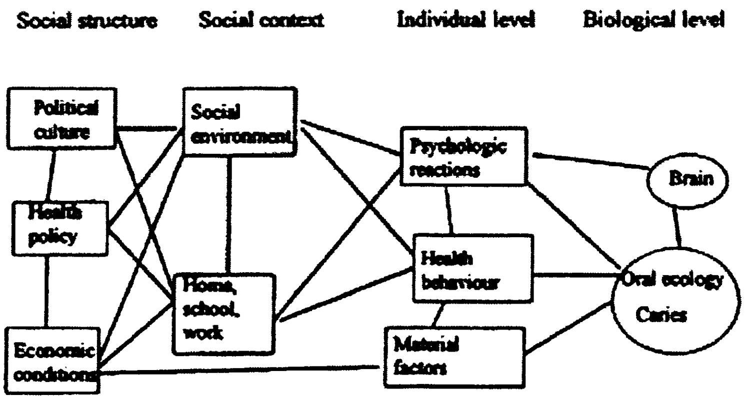


Figure 2.14: An approach to a framework for explaining caries in populations (Holst and Schuller 2001)

Newton and Bower (2005) proposed a model modified from the Chandola Model (Chandola *et al.* 2003) for use in oral health (Figure 2.15). The original model was designed to explore the pathways towards health through education. The modified model had oral health as a final outcome and oral health behaviours as one of the determinants influencing oral health and influenced by other determinants (Newton and Bower 2005). In addition to parental socioeconomic position, psychology, stress, government policies and environment, the model also accounted for cultural influences on health behaviours and education. The model is suitable for analysis of longitudinal data and was designed for structural equation modelling. The layout of the model does not show a hierarchy of the determinants of health. This model did not show whether other biological factors such as sex differences and genetics influence health behaviours, employment opportunities or educational attainment. The model also did not explicitly account for availability and use of health services.

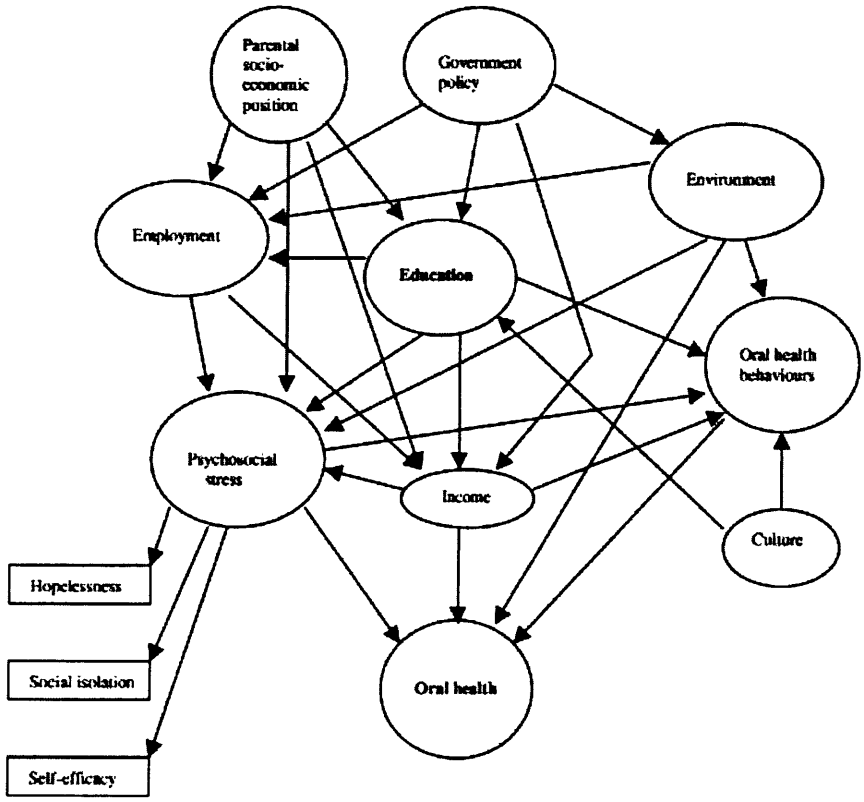


Figure 2.15: The pathways between education and oral health (Newton and Bower 2005)

Watt (2006) developed a model for the determinants of oral health to demonstrate the impact of the broader environment on life style behaviours and health (Figure 2.16). According to the model, oral health behaviours are not only influenced by social networks, social norms, peer pressure and cultural identity, but also by political, environmental and economical policies at the macro level. The impact of health behaviours on health is also affected by individual's characteristics, such as age, sex and genes. The model is ideal for addressing the determinants of health behaviours and their impact on health. However, the model was intended for children's oral health and did clearly show if socioeconomic factors at the individual level would affect other determinants such as employment, income and education.

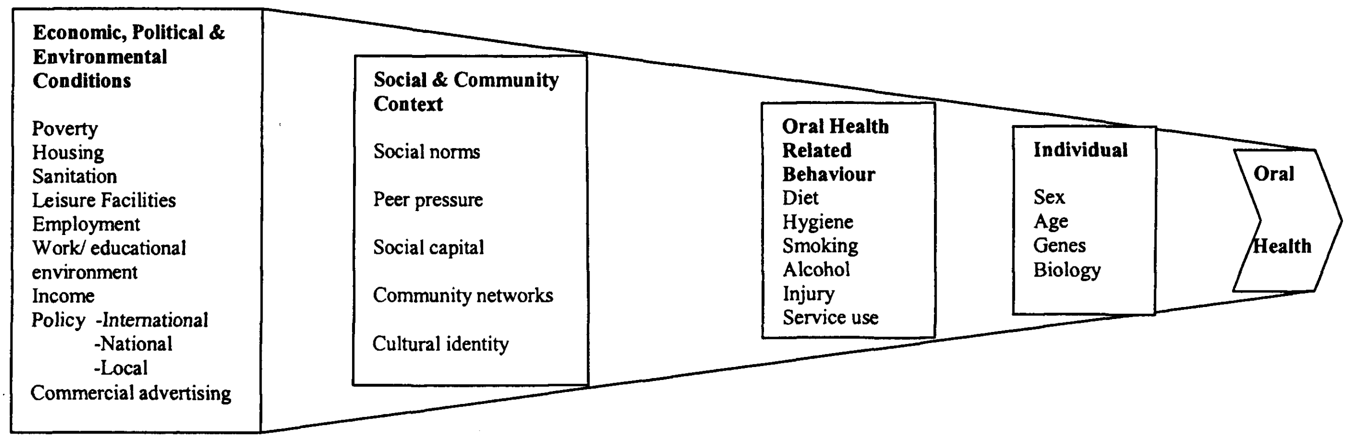


Figure 2.16 Social determinants of oral health (Watt 2006)

Generally, most of the reviewed models did not explicitly address the use of health services. The use of oral health service is an important determinant of oral health (Wamala *et al.* 2006). Hence, health services should be considered in research on the determinants of oral health. Some of these models also did not emphasise the social determinants of health at the macro level, such as social cohesion and social capital. Additionally, some of them did not sufficiently recognise individual's biological characteristics and personal traits.

2.4.2 A proposed theoretical model

The bio-psychosocial model of pathways to oral health

The importance of having a framework to assess the determinants of oral health (Holst *et al* 2001; Newton and Bower 2005) and the lack of use of such models in oral epidemiology provided the incentive for the development of a model to use in the current research. The proposed model attempts to account for potential social, environmental, organizational, behavioural and biological factors that influence health (Figure 2.17). However, due to limitation of availability of data that could be used in this research, only certain parts of the model will be tested.

A bio-psychosocial pathway (Figure 2.17) was modified from the Marmot Model for Social Determinants of Health. The proposed model starts in the outer circle with general socio-environmental factors mostly created or influenced by government policies, corporate groups and society in general. The model next deals with more individual-specific social, economical and environmental factors. Then there are the bio-psychological factors, followed by health behaviours, neuro-endocrine and immune responses, leading to morbidity, organ impairment, disability, handicap and finally leading to mortality.

In the outer circle of the model and to the left there is 'social structure' which includes general policies pertaining to work, education, health and social services. These factors are mainly outside individuals' control and formed by government and society. Following social structure, there are material conditions, then social environment at the country or state level. Material conditions refer to general conditions, facilities and infra structure in the area of residence such as transportation, roads, housing, availability of parks and other recreational facilities. Social environment includes factors such as neighbourhood characteristics, social cohesion, measures of inequality, violence and teenage pregnancy. Both material conditions and social environment are influenced by social structure, namely, policies made by the government that affect living conditions and the environments.

Below these wider general social and environmental factors, come socioeconomic factors which are more specific and directly related to the individual. These factors are influenced by general policies but they are also influenced by individual's characteristics and biological factors. These factors are laid out from left to right in the direction in which they are considered to influence each other. First, there is early life conditions followed by education, then employment and working conditions, followed by financial ability, and finally health service. All of these factors are affected by the more general social conditions, but they also affect each other. For example, education, work, and financial abilities are not independent from early life conditions. Education usually affects work and financial abilities, and so on. Availability and use of health services are affected by government policies and social environment, but are also affected by work and financial ability, especially in countries where universal health coverage is not available. At the same time, factors like education, work and financial ability and use of health services are also influenced by the biological and psychological factors described below.

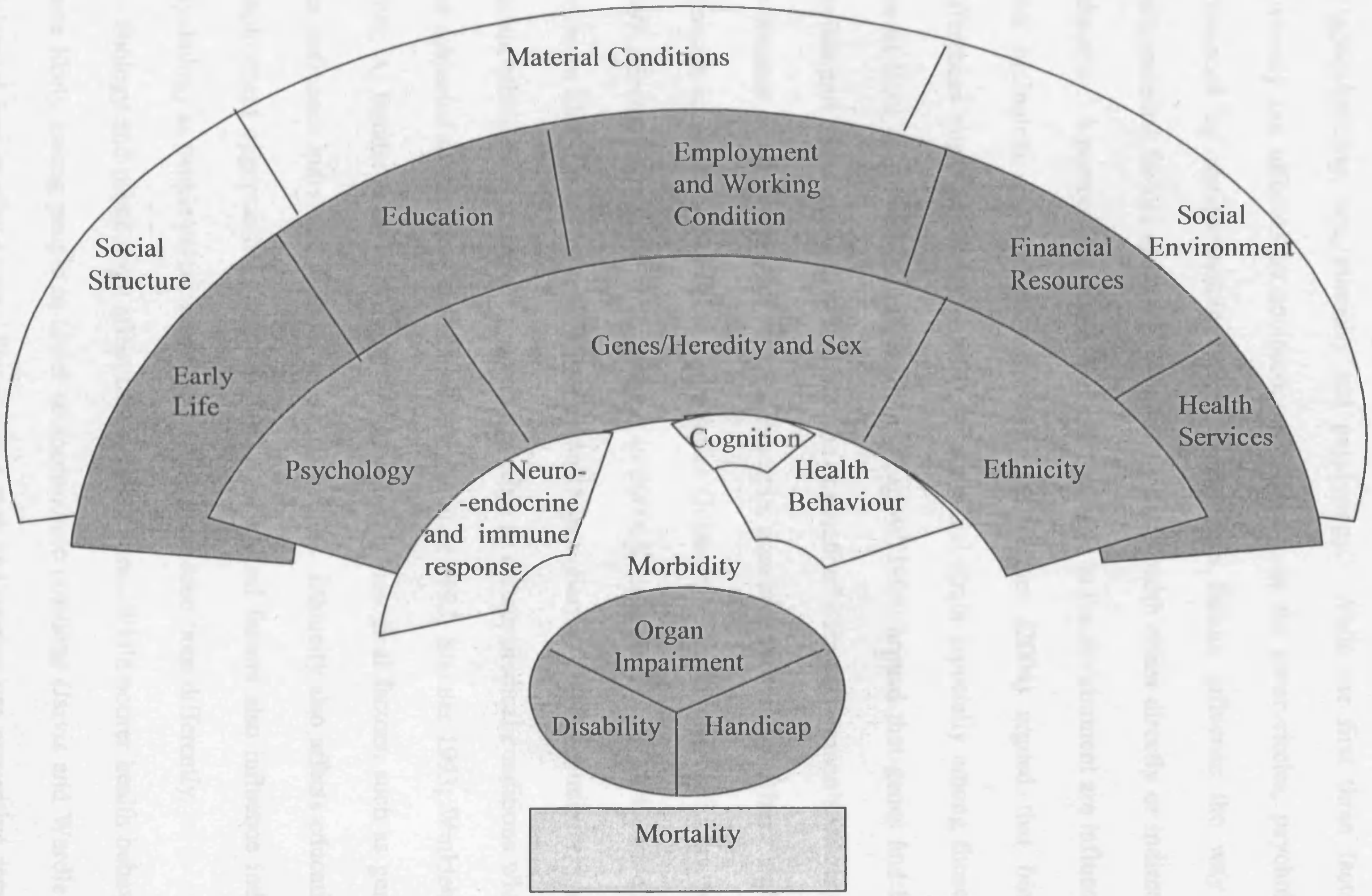


Figure 2.17: Bio-psychosocial pathways to disease

At the next level of the model there are the psychological and biological factors such as genes/heredity, sex, ethnicity and psychology. While the first three factors are obviously not affected by socioeconomic factors, in the outer circles, psychology is influenced by socioeconomic factors. All these factors influence the way socio-environmental factors affect individuals and their health either directly or indirectly via behaviour. A persons' perceptions of and reactions to the environment are influenced by their biological characteristics. Ferrer and Palmer (2004) argued that biological differences might explain variability within social strata especially among those at the lowest level of socioeconomic position. Tarlov (1996) argued that genes and biology explain part of the health differences in the population. Men and women's vulnerabilities to diseases differ (Bartley 2004). For example, men are more likely to have high blood pressure, coronary heart disease and injuries (Johnson 1977; Kennel 1987; Anastos *et al* 1991; Morrongiello *et al* 1998; Smith *et al* 2000; Kruger and Nesse 2004) while women are more likely to suffer from somatic complaints (Bartley 2004). Similarly, people of certain ethnic groups might be more vulnerable to certain medical conditions when they are subjected to the same risk factors (Sorlie *et al* 1993; Stamler 1993; Winkleby *et al* 1998; Al Bandar *et al* 1999). On the other hand, biological factors, such as genes and sex, influence individual's socioeconomic position. Ethnicity also affects education and employment opportunities (Nazroo 2003). Biological factors also influence individual psychology as people perceive socio-environmental conditions differently.

Biology and psychology affect health behaviours. While poorer health behaviour is more likely among people in lower socioeconomic positions (Jarvis and Wardle 2006), biological factors play a role. For example men and women use preventive services to different degrees (Crossner and Unell 1996; Husaini *et al.* 2002). Also violence and bullying among school children is influenced by a child's sex (Baker *et al.* 1992; Moyses *et al.* 2006). People from different ethnic backgrounds use preventive and medical services differently (Powell *et al.* 1987; Dowda *et al.* 2003; Gans *et al.* 2003; Ridlen and Louria 2006). Stress plays an important role in health inequalities, affecting health either directly or indirectly through behaviour (Brunner 2002).

Health and health-related behaviours are also influenced by cognition (Franceschi *et al.* 1983; Schmidt *et al.* 1991; Kalra *et al.* 1993; Elias *et al.* 1997; Madden and Blumenthal 1998; France *et al.* 2000; Gregg *et al.* 2000; Knopman *et al.* 2001; Avlund *et al.* 2004). Health behaviour in turn is influenced by biology, psychological and socioeconomic factors and social environment. Socioeconomic and environmental factors, through psychology, health behaviour and biological factors affect the immune response of the individual and the neuro-endocrine responses (Brunner and Marmot 2006). The interaction between all these factors leads to morbidity, organ impairment and may lead to disability and handicap which is placed in the lower level of bio-psychosocial model (WHO 1980). At the base of the model there is mortality as an end outcome.

There are few models suggesting pathways of the relationship between determinants and oral health. None of them have been empirically tested on a large database. A model based on Marmot model (Brunner and Marmot 2006) that explains the social gradients in health is proposed. This thesis sets out to test some parts of the proposed model (Figure 2.17).

2.5 Summary of selected factors and pathways influencing the gradients in oral and general health

This part includes a review of selected factors and pathways which will be explored in the thesis in relation to oral and general health, and to the social gradients. These factors include; ethnicity and sex, cognitive performance, health-related behaviours, tooth cleanliness and stress indicated by allostatic load.

2.5.1 The effects of ethnicity and sex on health

Several studies have documented differences in morbidity and mortality between ethnic groups in the UK (Rudat 1994; Harding and Maxwell 1997; Nazroo 1997a, b, 2001; Erens *et al.* 2001) and in the US (Rogers 1992; Sorlie *et al.* 1993, 1995; Rogot *et al.* 1993; Krieger *et al.* 1993; Davey Smith *et al.* 1998; Pamuk *et al.* 1998; Williams 2001). The causes of these ethnic differences in health are contested. While some maintain that socioeconomic position plays no, or a minimum role in ethnic differences in health (Wild and McKeigue 1997), others suggested that even if they play a role, the cultural and genetic elements also play a role (Smaje 1996; Diaz *et al.* 2005). Others have considered demographic location to be responsible for these ethnic differences in health (Mensah *et al.* 2005). Whereas others argued that socioeconomic inequalities explain ethnic differences in health (Nazroo 2003; Nazroo and Williams 2006). Experiences of racial harassment and discrimination were also considered as important factors explaining health inequalities between ethnic groups (Kreiger 2000; Williams and Neighbors 2001; Williams *et al.* 2003; Nazroo and Williams 2006).

Studies on oral health differences between ethnic groups suggested that there was a general trend for persons from ethnic minorities to have poorer oral health. Many of these studies did not examine the effects of socioeconomic position on the differences between ethnic groups in oral health (Ismail *et al.* 1988; Marcus *et al.* 1996; Albandar *et al.* 1999, Albandar and Kingman 1999; Jones *et al.* 2000).

There are health differences between men and women (Bartley 2004). Although women have higher prevalence of somatic complaints such as headache and backache (Verbrugge 1985; Verbrugge and Wingard 1987; Popay *et al.* 1993; Feeney *et al.* 1998; Bartley 2004), men have higher prevalence of cardiovascular diseases (Johnson 1977; Kannel 1987; Anastos *et al.* 1991; Smith *et al.* 2000), injuries (Morrongiello *et al.* 1998) and higher mortality rates (Kruger and Nesse 2004). Socioeconomic position affects the health of women and men differently, women's health benefit more than men's from higher socioeconomic circumstances (Kavanagh *et al.* 2006).

Differences in oral health between men and women have been attributed to physiological differences (Covington 1996; McCann and Bonci 2001; Lukacs and Largaespada 2006). Women are higher users of dental services (Zakrzewska 1996; Husaini *et al.* 2002). Additionally, women have better oral health behaviours compared to men which also contribute to the sex differences in oral health (Schuller *et al.* 1998; Sakki *et al.* 1998; Ostberg *et al.* 1999).

The demonstration of the associations between sex and ethnicity on one hand and oral and general health on the other hand, highlights the need to explore the effects of sex and ethnicity on the social gradients in oral and general health.

2.5.2 The effect of cognitive ability on health and on the gradients

A number of researchers have suggested an association between cognitive performance and general health, especially blood pressure and cardiovascular diseases (Franceschi *et al.* 1983; Schmidt *et al.* 1991; Kalra *et al.* 1993; Elias *et al.* 1997; Madden and Blumenthal 1998; France *et al.* 2000; Gregg *et al.* 2000; Knopman *et al.* 2001; Suhr *et al.* 2004; Lawlor *et al.* 2005; Pavlik *et al.* 2005). Studies on animals have found a relationship between dental status and animals memory (Onozuka *et al.* 2000; 20002). Avlund *et al.* (2004) suggested a possible association between oral health and cognitive abilities in humans. Nordenram and Ljunggren (2002) found that cognitive abilities affected dental treatment needs.

The terms ''cognitive ability'' and ''intelligence'' are mostly used interchangeably. Some researchers argued that IQ, as one of the indicators of cognitive ability, accounts for some of the association between socioeconomic position and mortality (Batty and Deary 2004; Gottfredson 2004). Gottfredson (2004) has proposed that intelligence is the ''fundamental cause'' of social inequalities in health, as it lies behind both socioeconomic achievement and health. The mechanism for this is that inadequate health self-care is the principal manner by which intelligence is related to social inequalities in health (Gottfredson and Deary 2004). Others also suggested that intelligence explains the socioeconomic differences in health (Lubinski and Humphreys 1997; Hart *et al.* 2003; Lawlor *et al.* 2006). Singh-Manoux *et al.* (2005) argued that the associations of socioeconomic position and cognitive ability on one hand with health on the other hand, are similar. For example, the pathways linking education and intelligence to health appear to be similar. Social inequalities are linked to educational disadvantage.

As education is closely linked with cognitive ability, a proportion of the relation between education and health is explained by cognitive ability.

The association of cognitive ability with different indicators of health and with socioeconomic position implies that cognitive abilities mediate the social gradients in health, an assumption that this thesis will explore.

2.5.3 Health-related behaviours

Numerous studies have demonstrated the inverse associations between poor health behaviours and general health (Berkman and Breslow 1983; Wilson 1994; US Department of Health and Human Services 1996; Young *et al.* 2005; Jarvis and Wardle 2006; Lantz *et al.* 2006). There is an association between oral health behaviours and oral health (Davis 1980; Locker 1989; Sheiham and Watt 2000).

One feature of adverse health-related behaviours is that they tend to cluster together in the same individuals and they are more prevalent in those at the lower end than those at the top of the social hierarchy (Davis 1980; Blane, 1985; Marmot 1999; Jarvis and Wardle 2006). This implies that socioeconomic circumstances influence health behaviour. Others considered that health behaviour is influenced by a wide array of factors which include culture, ethnicity (Coreil *et al.* 1991; Burt and Eklund 1992; Scribner 1996; Young *et al.* 1998; Ronis *et al.* 1998; Bermudez *et al.* 2000; Dixon *et al.* 2000; Lee *et al.* 2002; Macek *et al.* 2002; Dowda *et al.* 2003; Gans *et al.* 2003; Gilbert *et al.* 2003; Frenn *et al.* 2005; Lara *et al.* 2006; Keiffer *et al.* 2006; Ridlen and Louria 2006), sex (Baker *et al.* 1992; Burt and Eklund 1992; Crossner and Unell 1996; Husaini *et al.* 2002; Johnson 2005), stress and flexibility of work (Brunner 2002; Abegg *et al.* 1999; 2000).

Health behaviours do not eliminate the socioeconomic inequalities in general health (Lantz *et al.* 2006) or in oral health (Sanders *et al.* 2006b). In a recent study on Finnish public employees, Kivimaki *et al.* (2007) examined the effects of health-related behaviour on socioeconomic differences in health and concluded that interventions aimed to reduce risky health behaviours may not completely remove differences in health, although they would reduce these differences (Kivimaki *et al.* 2007).

Considering the effects of health-related behaviours on health and the complex determinants of health-related behaviours, it is reasonable to assume that health related-behaviours mediate the effects of socioeconomic position on health.

2.5.4 The effect of markers of tooth cleanliness on oral health

Cleanliness of teeth plays an essential role in periodontal health (Locker 1989; Haffajee *et al.* 1991; Morris 2001). Teeth cleanliness is also a predictor of tooth loss (Treasure *et al.* 2001; Gilbert *et al.* 1993; Ylostalo *et al.* 2004; Eklund and Burt 1994; Drake *et al.* 1995). Dental calculus is associated with dental plaque and oral hygiene-related behaviours (Pattanaporn and Navia 1998; Timmerman and van der Weijden 2005; Riley *et al.* 2006). As calculus is calcified plaque, it could be considered as a measure of how long dental plaque has remained undisturbed by oral cleaning devices, and therefore it could be used as a surrogate measure of oral hygiene behaviours (Maizels and Sheiham 1987). Higher accumulations of dental calculus are associated with gingivitis and loss of periodontal attachment (Pattanaporn and Navia 1998; Neely *et al.* 2000; Timmerman and van der Weijden 2005; van der Velden *et al.* 2006). Periodontitis and gingivitis were also found to be a predictor of tooth loss (Burt *et al.* 1989; Eklund and Burt 1994; Drake *et al.* 1995; Ong 1998).

Calculus does not cause periodontal disease or tooth loss. Studies have suggested that accumulation of calculus is associated with greater loss of attachment in the individual but not at the sites with calculus (Gilthorpe *et al.* 2000). Also, Netuveli (2002) argued that calculus is a marker of periodontal disease. Hence, it was reasonable to use calculus as a marker of tooth cleanliness, rather than a direct cause of periodontal disease or tooth loss. This thesis assumes that calculus, as a marker of tooth cleanliness, affects the social gradients in clinically measured oral health, namely periodontal disease and tooth loss.

2.5.5 Stress pathways toward the gradients in health

The effect of stress on general health has been extensively addressed (Kaplan 1991; Marmot *et al.* 1997; Seeman *et al.* 1997; McEwen 1998; Hemingway and Marmot 1999; Seeman *et al.* 2001; Szanton *et al.* 2005; Brunner and Marmot 2006). Similarly, a number of oral health studies have demonstrated that stress influences periodontal disease (Monteiro-da-Silva *et al.* 1996; Croucher *et al.* 1997; Alekesejuiene *et al.* 2002; Pistorius *et al.* 2002; Hugoson *et al.* 2002; Vettore *et al.* 2003; Solis *et al.* 2004; Akhter *et al.* 2005; Dolic *et al.* 2005; Newton 2005; Sheiham and Nicolau 2005). Stress affects health either indirectly through influencing health behaviours like smoking or drinking or directly, through increased allostatic load (Brunner 2002).

The body maintains physiological stability through environmental changes. The price of adaptation to external and internal stress may be wear and tear on the organism. People respond to environmental and psychosocial challenges by producing hormonal and neurotransmitters to influence physiological responses throughout the body to cope with the challenge. These responses are referred to as allostasis and allostatic load, meaning maintaining stability through change (Sterling and Eyer 1988). The concept of allostatic load refers to the wear and tear that the body experiences due to repeated cycles of allostasis (McEwen and Stellar 1993; McEwen 1998). This process is influenced by the number of stressful events that an individual experiences and the body's ability to cope efficiently with these events (MacArthur 1997).

Allostatic load induced by stress is considered relevant to coronary heart disease, cancer, infectious diseases and accelerated aging (Brunner 2002). It is therefore reasonable to consider, as others have suggested (Sheiham and Nicolau 2005), that stress affects periodontal diseases as it affects other chronic conditions, and to test the mediating effect of stress, indicated by allostatic load, on the social gradients in oral health.

2.6 Summary of the literature review

There is a social gradient in general morbidity and mortality (Marmot and Wilkinson 2006). Even when the majority of the population lives above absolute poverty level, social gradients still exist (Macintyre 1994). The social gradients in health and longevity exist for most common chronic diseases and causes of death for all ages, sex, race and countries (Adler and Ostrove 1999). While examining inequality between the poor and the more affluent focuses on the material explanation, studying the social gradients additionally highlights the importance of relative poverty, the contribution of work and living circumstances, and the importance of psychosocial factors to health. The universality of social gradients implies that social structure is the main aetiological agent in most chronic diseases (Blane 1984). It also indicates the presence of common risk factors that make certain groups of the population more vulnerable or susceptible to a wide array of chronic diseases (Sheiham and Watt 2000).

Despite the theory of general susceptibility put forward by Cassel (1976), Syme (1976) and Berkman and Syme (1979), few dental studies have been undertaken on the similarities in the social determinants of oral health and general health. A smaller number of studies have addressed the presence of social gradients in oral health (Locker 1989; Watt and Sheiham 1998; Drury *et al.* 1999; Locker 2000; Nuttall 2003; Thomson and Mackay 2004, Holst 2007). These studies showed social class gradients, and deprivation gradients in dental caries, edentulousness, and periodontal diseases in both adults and children. In addition, one study demonstrated the common social gradients in both of oral health indicators and physical health indicators (Poulton 2002).

On the other hand, a number of studies examined the separate effect of socioeconomic factors on oral health, generally showing that poorer people, the unemployed and the less educated have poorer oral health (Mack *et al.* 2003; Pearce *et al.* 2003; Thomson *et al.* 2004; Paulander *et al.* 2004). Other studies were more concerned with the differences between different ethnic groups in regard to oral health status (Marcus *et al.* 1996; Albandar *et al.* 1999; Jones *et al.* 2000). In addition to ignoring the question of social gradient in oral disease and its implications, some of these studies had some methodological errors. For example, some of these studies included mediating variables between socioeconomic position and oral health as confounders, for example the inclusion of smoking as risk factors in a logistic regression analysis containing socioeconomic position confounded the effect of socioeconomic position on periodontitis (Dye and Selwitz 2005). Smoking should be considered as a mediating factor between socioeconomic position and periodontitis rather than a confounder, as it is not independent of socioeconomic position. One of the other limitations of the studies which addressed the relationship of socioeconomic position and ethnicity with oral disease was the inconsistency of the measure of oral health. For example having different definitions of what constitutes a periodontal disease led to conflicting results even when using the same database (Albandar *et al.* 1999; Borrell *et al.* 2002). On the other hand, appropriate accountability for socioeconomic factors might explain a large part of the differences in oral health and related behaviours between ethnic groups (Dykes *et al.* 2002).

While dental studies were more concerned about finding a causal relationship between oral health and general health or to recommend routine periodontal treatment for persons with certain systemic condition (Arbes *et al.* 1999; Chun *et al.* 2005), very few addressed the common determinants of oral and general health. In addition, most of these studies had poor control for confounding factors between oral and general health.

Examining the dichotomous effect of social position on health simplifies the underlying causes of inequality in health and is likely to be limited to materialistic explanations. This materialistic approach to inequality does not explain health differences between individuals at the upper end of the socioeconomic hierarchy and those immediately below them. On the other hand, studying the social gradients and the differences in health between each two successive levels of the social hierarchy, highlights the presence of deeper and more complex pathways to the gradients. These pathways include psychological, stress, social, behavioural, biological, cognitive and materialistic elements.

The present review addressed some of the pathways considered by researchers as mediators to the gradients in general and oral health, and examined some theoretical models toward inequality in health. The pathways and factors addressed in the literature review include sex and ethnicity, cognitive ability, health related behaviours, tooth cleanliness and stress. The study of the social gradients in health necessitates a better understanding of the causes of inequality in health and emphasizes the need for reorienting health policies to address the social determinants of health (Wilkinson 1996; Marmot 2003).

In summary, there is a gap in the literature relating to the social gradients of oral health and the similarities between the social determinants of oral and general health. Firstly, there is an apparent lack of literature explicitly addressing and explaining social gradients in oral health. Secondly, even when the results of a particular study show income or education gradients in oral health, the authors tend to ignore them, and do not try to explain them or comment on their implications (Glibert *et al.* 2003; Borrell *et al.* 2004). There is also a lack of use of theoretical models to explain the interaction between the different determinants of oral health (Newton and Bower 2005). No available studies have explored the potential pathways toward the gradients in oral health and compared them to the similar pathways in general health. Lastly, although many studies examined the correlation between oral health and general health, almost none of them addressed the common social determinants of them which might explain why oral and general chronic diseases occur in the same groups of people.

2.7 Hypothesis and Objectives

2.7.1 Hypothesis

The hypotheses are related to some of the relationships outlined in the bio-psychosocial model (Figure 2.17). The main basis for choosing the particular relationships for testing is that they have not been thoroughly examined before, and most importantly for a study of this nature that requires a large sample, a reliable data set is available to test the hypotheses.

1 Hypothesis One: There are social gradients in oral health, namely periodontal diseases, tooth loss and perceived oral health, and in general health, namely ischaemic heart disease and perceived general health.

2 Hypothesis Two: The social gradients in oral health are similar to those found in general health.

3 Hypothesis Three: There are social gradients in health-related behaviours, such as smoking, dental visits, consumption of fresh fruits and vegetables and physical activities.

4 Hypothesis Four: Certain pathways and factors affect the social gradients in oral and general health, such as sex and ethnicity, cognitive ability, behaviours, tooth cleanliness, and stress.

2.7.2 Objectives

The specific objectives of this research are to:

1. Assess whether there is a social gradient in periodontal diseases, tooth loss and perceived oral health (Hypothesis 1).
2. Examine the social gradients in general health as assessed by ischaemic heart disease and perceived general health (Hypothesis 1).
3. Assess the similarities and differences between the social gradients in oral health indicators (periodontal disease, tooth loss and perceived oral health) and general health (ischaemic heart disease and perceived general health) (Hypothesis 2).
4. Assess the social gradients in health-related behaviours (smoking, visits to dentists, consumption of fresh fruits and vegetables and frequency of physical activities) (Hypothesis 3).
5. Assess the effects of certain factors and pathways on the gradients in general health, namely sex and ethnicity, cognitive ability, health-related behaviours and stress (Hypothesis 4).
6. Assess the effects of certain factors and pathways on the gradients in oral health, namely sex and ethnicity, cognitive ability, health-related behaviours, tooth cleanliness and stress (Hypothesis 4).

The main objective of the study is to examine the relationship between the different determinants of oral health, namely social, economical, behavioural, biological and the gradient in oral health (periodontal health, tooth loss and perceived oral health) and compare them to the determinants of general health (ischaemic heart disease and perceived general health). Periodontal disease was selected as indicator of oral health because it shares some of the determinants with general health (Sheiham and Nicolau 2005) and conforms to the theories put forward about the general susceptibility to disease (Cassel 1976; Syme and Berkman 1976; Berkman and Syme 1979). Ischaemic heart disease was selected because of its sensitivity to socioeconomic inequalities and because it is linked to some of the pathways examined in this thesis (Brunner et al 1997; Knopman *et al* 2001; Ferrie et al 2005; Nazroo and Williams 2006). Tooth loss was selected to indicate tooth mortality as an end outcome of the model. Perceived health is a key indicator of health (Marmot *et al.* 1991; Ferrie *et al.* 2002; Pitiphat *et al.* 2002; Singh-Manoux *et al.* 2006) and enables direct comparison between the gradients in perceived oral and general health.

Chapter 3

Methods

Chapter 3

Methods

3.1 Introduction

The methods used in this research are outlined in this chapter. The method includes selection of database, selection of variables and outline of analysis plan.

The method aimed to select a suitable database and appropriate analysis which would enable testing of the hypotheses and addressing the objectives of the research. A large sample representing a national population was needed to be able to measure the social gradients in oral health and the potential pathways to the gradients. It was impractical to conduct a national survey to collect the needed data as this entails enormous resources and time to conduct. Secondary analysis of a national health survey database was the obvious approach, especially since there is no evidence that such an analysis was carried out using a national survey. The Health Survey for England and the National Diet and Nutrition Survey were considered and ruled out because oral health was not measured adequately, age groups of interest were not included and even for the age groups included only a small sub-sample had a dental examination. The US National Health and Nutrition Examination Survey was considered more appropriate as it included a detailed dental examination especially related to the outcomes of interest, periodontal disease.

The third National Health and Nutrition Examination Survey (NHANES III) was conducted between the years 1988 to 1994 (U.S. Department of Health and Human Services 1997). This survey included detailed information on general health, nutrition, demographic variables, socioeconomic position, use of health services, medical and dental insurance, and health related behaviours of a representative sample of the United States non-institutionalized population with over sampling of ethnic minorities to ensure better representation of these groups. The survey also included detailed data on oral health including periodontal health and calculus, which were assessed by different methods. The oral examination also included details about tooth loss and reasons for tooth loss (disease related or non-disease related). This was appropriate for the purpose of this research as periodontal disease and tooth loss are outcomes of interest. Adequate reliability assessment for oral health examinations was conducted in NHANES III, which implied reliable oral health clinical data. Although a number of dental studies used data derived from this survey, none of them examined the pathways towards the social gradients in oral health or compared them to those in general health. Data are publicly available on the internet and on CD ROM.

3.2 Data Source

NHANES III database

Data was derived from the third National Health and Nutrition Examination Survey (NHANES III) (U.S. Department of Health and Human Services 1997). This survey was selected because it is more comprehensive than the previous two NHANES surveys and more complete than the recent NHANES surveys. Although the general sampling structure of NHANES III was similar to that of NHANES I and II, it did not use an upper age limit. NHANES III also employed a home examination option, thus allowing for the inclusion of the very old, the very young and those unable to attend the mobile examination centre. NHANES III was conducted during the period from 1988 to 1994 in two phases, each of which comprised a national probability sample. The first phase was conducted from 1988 to 1991 at 44 locations. The second phase was conducted from 1991 to 1994 and at 45 different locations. NHANES III covered 39,695 non-institutionalized, non-military Americans; 33,994 were interviewed in their homes and included information on socioeconomic and demographic factors, health behaviour and use of health services. Only 30,818 were examined in the mobile examination centre and an additional 493 were given a special medical examination in their homes. Physicians and dentists performed a standardised medical/ dental examination.

This research focused on results pertaining to the adult population aged 17 years and older. A total of 20,050 individuals completed the interview. However, not everyone who completed the interview had medical/ dental examination.

Periodontal measures were assessed on randomly assigned half-mouths, one upper quadrant and one lower quadrant selected at the beginning of the examination, using the NIDR protocol (Miller *et al.* 1987). Appendix 1 includes a comprehensive description of the oral examination, periodontal and calculus examination, and reliability of the examination.

NHANES III included questions about perceived oral health, perceived general health and a questionnaire for angina pectoris based on the WHO Rose questionnaire (Rose *et al.* 1982). The survey also included comprehensive demographic, socioeconomic, behavioural, and medical variables including years of education, poverty-income ratio, ethnicity, diagnosis of heart attack and diabetes, medical/ dental insurance, dental attendance, smoking, blood pressure, waist hip ratio, body mass index (BMI), frequency of exercise and frequency of eating fattening food. The survey included a number of laboratory findings pertaining to allostatic loads such as triglycerdemia, HDL-cholesterol, plasma glucose, C-reactive protein (CRP) and Fibrinogen. In addition, a sub-sample of the population aged 20 to 59 years completed computerized cognitive tests from the Neurobehavioural Evaluation System (Krieg *et al.* 2001). As NHANES III survey was based on a probability sample design, appropriate sampling weights were used in the analysis. A detailed description of the survey and the analytic guidelines are described in Appendix 1.

3.3 Applying the theoretical model to the research

The bio-psychosocial model is based on the assumption that socioeconomic factors affect health via health behaviours and stress (Figure 2.17). Biological factors influence the effect of socioeconomic factors on health. The model also assumes that socioeconomic factors influence each other in the way they are laid out in the second circle of the model. For example, education influences employment to some extent, which in turn influences financial resources. However, all the components of the model could not be used due to data limitation. The analysis was carried out vertically going from indicators of socioeconomic position in the second level of the model via health behaviours towards health, but also accounted for the effect of the biological factors on health. For example, while it is assumed that persons with lower income have poorer health behaviours (e.g. smoking) and have poorer health (e.g. greater loss of periodontal attachment), the association within different ethnic groups and for both sexes should be considered. Studies have shown that while African American had poorer periodontal health, Mexican American's periodontal health was similar to the rest of the American population (Albandar *et al.* 1999, Albandar and Kingman 1999). Therefore, there is a need to examine the relative effect of ethnicity on oral health in the presence of the socioeconomic factors. Another example is the use of preventive services. The assumption is that people who have medical/ dental insurance are more likely to use preventive medical/ dental services. However, with availability of dental/ medical insurance, there could be differences in utilisation of preventive dental and medical services between the two sexes and between the different ethnic groups (Macek *et al.* 2002).

3.3.1 Parts of the bio-psychosocial models included in the analysis:

Figures 3.1 and 3.2 show sectors of the model to be included in the analysis and the variables included in each sector for oral health and general health, respectively. Due to unavailability of data, sectors in the outer level of the bio-psychosocial model (Figure 2.17) were not included in the analysis. In the second outer level, early life was excluded and socioeconomic variables that fall in the sectors of education, financial ability and health services were included. In the third level, sex and ethnicity were used. In the fourth level, health behaviours, stress and cognition for a sub-sample of the population were used. Finally there were the health outcomes, morbidity and tooth mortality. A summary of all the variables used in the analysis is presented in appendix 2.

3.3.1.1 Socioeconomic factors

Education and income, indicated by poverty-income index, are used to indicate socioeconomic position. Education is a universally acceptable marker of socioeconomic position and allows comparison with other population (Singh-Manoux *et al.* 2006). Higher education provides better life chances and is usually associated with better socioeconomic circumstances (Marmot 2003; Galobardes *et al.* 2006). On the other hand, income is important not only as a marker of materialistic ability, but also as a marker of social position in the society and ability to participate in what the society has to offer beyond the basic needs (Galobardes *et al.* 2006). Higher income is also associated with more control, better rewards and less stress at work (Marmot and Wilkinson 2006). Both of education and income are acceptable measures of social position in the US (Krieger *et al* 1997).

- **Education:**

Education was reported as the number of years of education. The variable was categorised into three groups: less than 12 years, 12 years, and more than 12 years of education. The rational for this categorisation is to reflect (1) not having a high school diploma (less than 12 years), (2) having a high school diploma (12 years), and (3) having post high school education, e.g. community college diploma or a university degree (more than 12 years).

- **Financial ability**

Income indicated by poverty-income ratio was used. The poverty-income ratio was computed as a ratio of two components, the family income and the poverty threshold in the calendar year in which the family was interviewed. As a person's income increased in relation to the poverty threshold, the poverty-income ratio value increased. Poverty threshold values (in dollars) are produced annually by the Census Bureau and are based on calendar years and adjusted for changes caused by inflation between calendar years. Poverty-income ratio allows income data to be analyzed in a comparable manner across the six years of the survey. This variable was used as a continuous variable to indicate financial ability for most of the analysis. However, for part of the analysis poverty-income ratio was categorised into quartiles for better assessment of the gradients or when the analysis was done for population strata. The four groups from lowest to higher income were: less than 1.007, 1.007-1.885, 1.886-3.240 and greater than 3.240.

- **Health services**

-Variables indicating the availability of any medical insurance were aggregated to create one variable indicating any medical insurance.

-Variables indicating the availability of any dental insurance were aggregated to create one variable indicating any dental insurance.

3.3.1.2 Individuals/ biological factors

- Age in years was used as a continuous variable. This variable was also categorised into four groups 17 to 30 years, 31-44 years, 45 to 65 years and 66 years and above for stratification of the sample when prevalence of the conditions were assessed.
- Sex.
- Ethnicity was categorised into four groups in NHANES III, White Americans, African Americans, Hispanic Americans and other ethnicities.

3.3.1.3 Other confounders for health outcomes: this includes certain medical conditions known to affect periodontal disease and ischaemic heart disease, such as reported diagnosis of diabetes, blood pressure and body mass index (BMI). A variable indicating high blood pressure was created from the average systolic and diastolic blood measures. High blood pressure was defined by systolic blood pressure of $\geq$ 130 mm Hg or diastolic of $\geq$ 85 mm Hg.

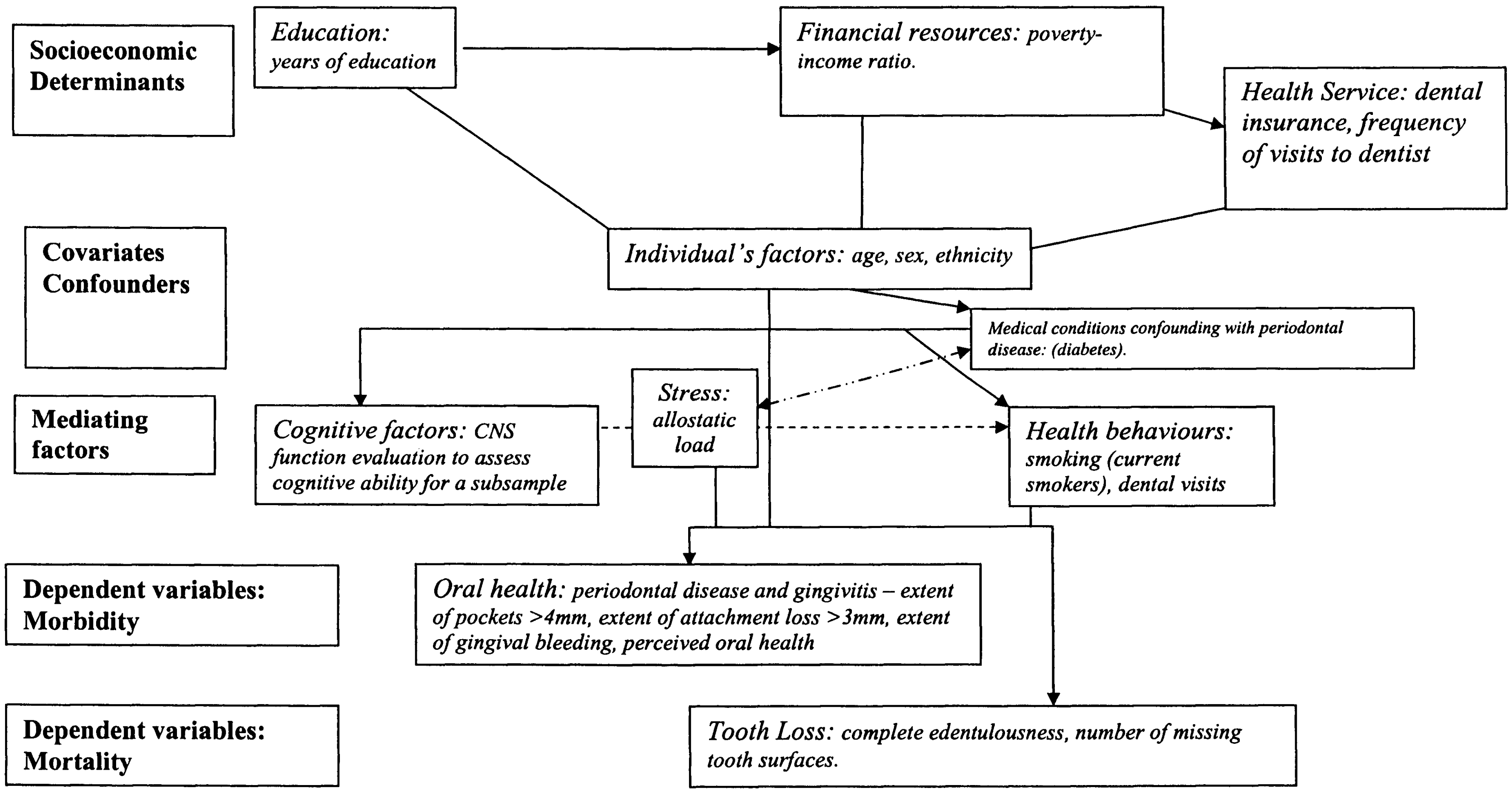


Figure .3.1: A model showing sectors to be examined for oral health outcomes

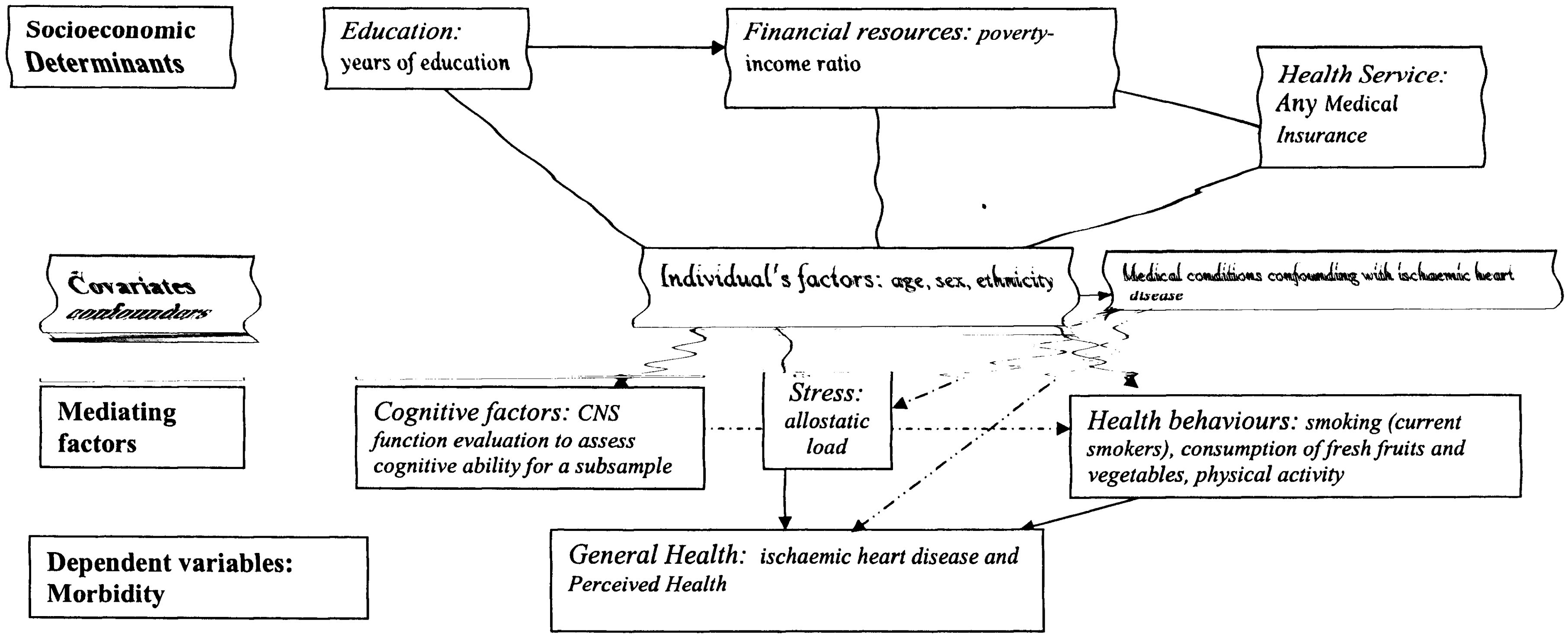


Figure 3.2 A model showing sectors to be examined for general health outcomes

3.3.1.4 Health-related behaviours

-**Smoking**: current smoker (any type of tobacco), frequency of smoking per day (any type of tobacco according to measure of count). Due to the high number of non-respondents to the smoking questions, when the variable "current smoker" was controlled for in a regression models, it was categorised into smoker, non smoker and non-respondent.

-**Frequency of eating fresh fruits and vegetables per day**: answers from question pertaining to eating fresh fruits and vegetables were aggregated (summed) to create this variable.

-**Frequency of physical activity per month**: similarly, answers from questions about frequencies of different physical activities were aggregated (summed).

-**Frequency of visits to dentist/ hygienist**: this variable was categorised to create one variable indicating frequency of dental visits of less than once a year or once a year or more.

-**Tooth cleanliness**: NHANES III did not include data on oral hygiene practices or on dental plaque. However, the database included detailed data on calculus. Considering the association between calculus and tooth cleanliness (see chapter 2 - literature review - 2.5.4), in this analysis calculus was used as a marker of tooth cleanliness rather than a direct cause of periodontal disease or tooth loss. A variable indicating extent of sites with calculus was calculated. That is the ratio of numbers of sites with calculus to all examined sites in the mouth (rationale for this method is similar to that used in periodontal disease; see the section on periodontal diseases under morbidity, bullet 3.3.1.7).

3.3.1.5 Cognition

In NHANES III a sub-sample of the population aged 20 to 59 years completed computerized cognitive tests from the Neurobehavioural Evaluation System (Krieg *et al.* 2001). Three variables were used to indicate cognitive performance; Simple Reaction Time Test, Symbol Digit Substitution Test and Serial Digit Learning Test (Krieg *et al.* 2001). The tests were administered in English or Spanish and were preceded by a practice phase. The Simple Reaction Time Test required subjects to press a button as quickly as possible when a particular shape appeared on a computer screen. The score used is the average response time in milliseconds. In the Symbol Digit Substitution Test a set of 9 symbols matched to the digits 1-9 is presented to the subject. The subject is shown a series of symbols and must match a symbol with its corresponding digit as quickly as possible. This task is intended to measure information processing speed, concentration and motor control. Performance in Symbol Digit Substitution Test was scored as the average time in seconds, needed to correctly match the numbers and symbols on the best 2 out of 4 trials. Finally, the Serial Digit Learning Test is a short-term memory test that requires subjects to reproduce a sequence of 10 numbers presented on the computer screen. The test was stopped when the subject listed the digits in the correct order twice in a row or after 8 trials. Scores were based on the number of errors committed during the trials. The higher scores in the three tests reflect poorer cognitive ability.

3.3.1.6 Stress:

A landmark study investigated allostatic load, as a marker of stress, and defined it by elevations of several risk factors, namely systolic and diastolic blood pressure, waist hip ratio, ratio of total cholesterol to high density lipoprotein (HDL), cholesterol, and HDL cholesterol level plus raised concentrations of glycated haemoglobin, urinary epinephrine (adrenaline), norepinephrine and cortisol, and adrenal androgen, serum dehydroepiandrosterone sulphate (Seeman *et al.* 1997). NHANES III-based studies have included 13 allostatic load markers; increases in blood pressure, glycated haemoglobin, body mass index, triglycerides, cholesterol, C-reactive protein (CRP), Fibrinogen, decreased HDL cholesterol, Albumin, Peak flow, creatinine clearance (Crimmins *et al.* 2003: Allsworth *et al.* 2005). However, in this thesis seven markers were selected to indicate allostatic load as they were considered more relevant to periodontal disease since they were found to be associated with periodontitis (Buhlin *et al.* 2003; Morita *et al.* 2004; Mattila *et al.* 2005; Inoue *et al.* 2005; Dye *et al.* 2005; Loos 2005; Ioannidou *et al.* 2006; Salzberg *et al.* 2006; Czernuk *et al.* 2006; Borges *et al.* 2006). These markers are: central obesity, high blood pressure, hypertriglycerdemia, low high density lipoprotein (HDL) cholesterol, high plasma glucose, CRP and fibrinogen.

Central obesity is considered to exist if a person has a waist circumference >120 cm for males and >88 cm for females. High blood pressure (BP) is BP $\geq$ 130 mm Hg systolic or $\geq$ 85 mm Hg diastolic. Hypertriglycerdemia is triglycerides $\geq$ 150mg/dL. Low HDL cholesterol is HDL cholesterol <40mg/dL for men and <50mg/dL for women. High plasma glucose is glucose $\geq$ 110 gm/dL. CRP was used both as continuous and dichotomous variables ($\geq$10 mg/L). Fibrinogen was also used as continuous and dichotomous variables ($\geq$ 3.25 g/L). These cut-off points were indicated as disease level in other studies (Slade *et al.* 2000; Ford *et al.* 2002, Schwahn *et al.* 2004). In addition, to assess the aggregate effect of the markers of allostatic load, a clustered variable reflecting the seven dichotomous indicators was created. This variable was used as a continuous indicator of allostasis indicating an aggregate of these factors ranging from 0 to 7.

3.3.1.7 Morbidity

- **For oral health: periodontal disease and gingivitis.**

-**Periodontal disease**: other periodontal studies which used NHANES III data categorised severity of periodontal diseases according to pocket depth in a number of teeth but excluded individuals with less than 6 teeth (Albandar *et al.* 1999) or examined a sub-sample of the population (Borrell *et al.* 2002). To account for all individuals who had the examination and account for the number of examined teeth, three variables were created based on the definition used in other NHANES III-based studies (Arbes *et al.* 1999; Slade and Beck 1999; Slade *et al.* 2000). These variables were extent of gingival bleeding, extent of periodontal attachment $\geq$ 3mm and extent of pocket depth $\geq$ 4mm, where the extent is the ratio between sties with the defined condition to all examined sites. It was important to use all of these three variables in the analysis as they reflect the severity of three different markers of periodontal disease; active inflammation (gingivitis), clinical pocket depth and actual pocket depth (loss of attachment).

Additionally, a dichotomous variable indicating periodontitis was also created and defined by the presence of at least one site with loss of attachment $\geq$ 3mm to indicate mild periodontitis (Offenbacher *et al.* 2001) and one site with gingival bleeding. The use of the four periodontal variables, indicating severity and presence of the periodontitis, ensures the results are not coincidental and reduces bias resulting from using a single variable measuring a specific aspect of periodontitis. It is worth noting here that calculus was also used as an extent variable.

-**Perceived oral health** was originally reported in NHANES III in five categories: poor fair, good, very good and excellent. In this analysis perceived oral health was categorised into two groups: poor/fair and good/ very good/ excellent.

Perceived health has a particular importance as it does not only reflect clinically measured health, but psychosocial factors, long standing illness (Singh-Manoux *et al.* 2006), functional ability and number of symptoms (Jylhä *et al.* 1998).

- o **General health**: two variables were used as indicators of general health

-**Perceived general health** was reported and categorised in the same fashion as perceived oral health.

-**Ischaemic heart disease**: this condition is more appropriate to demonstrate social gradients and the stress pathway indicated by allostatic load (Brunner 2002; Marmot and Wilkinson 2006). Individuals were defined as having angina pectoris according to WHO questionnaire (Rose et al. 1982) if they reported they had all of the following symptoms; ever had any chest pain or discomfort, had the pain or discomfort while walking uphill or in a hurry, the pain caused them to stop or slow down, the pain was relieved by standing still, the pain was relieved within 10 minutes, and that the pain was around the sternum, left anterior chest or left arm. Participants who responded that they never walked uphill or in a hurry were considered as having angina if they met the other criteria. In addition, subjects who reported doctor diagnosed heart attack were also included with the angina cases to create a variable for ischaemic heart disease.

3.3.1.8 Mortality: for oral health, tooth loss (tooth death).

- Number of missing tooth surfaces due to disease.
- Complete edentulousness.

3.4 Data Analysis

Due to the sample design of NHANES III, appropriate weighting variables, strata and primary sampling units were used throughout the analysis. The clinical examination was conducted in both the Mobile Examination (MEC) and the Home Examination, therefore the used weight was the final combined MEC and home examination weight. Except for analysis containing variables pertaining to Central Nervous System (cognitive abilities for individuals aged 20-59) where the final CNS weight was used.

Survey command in STATA statistical program was used to analyze the data. Data pertaining to the selected variables was downloaded from the CD ROM (U.S. Department of Health and Human Services 1997) and was converted to STATA file. Some of the variables were categorised to create new variables as described above. Appropriate regression models were used to analyze the relationships between dependent and independent variables.

The review of the literature indicated the presence of social gradients in oral health, general health and related behaviour. Hence, the research assumed the presence of social gradients in oral health, general health and related-behaviours in the study population. Therefore, each indicator of general and oral health was used as the dependent variable in a different regression model. Similarly, each behavioural variable, as described under health-related behaviour (bullet 3.3.1.4), was included in a regression model as a dependent variable. Four variables were used to indicate periodontal disease, namely extent of gingival bleeding, extent of loss of periodontal attachment $\geq$ 3mm, extent of pocket depth $\geq$ 4mm and periodontitis (at least one site with gingival bleeding and one site with loss of attachment $\geq$ 3mm).

For tooth loss, complete edentulousness and number of missing tooth surfaces due to disease were used. Each of perceived oral and general health was used as categorical variables where health is rated poor to fair versus good to excellent. Ischaemic heart disease was used as a dichotomous variable. For health behaviour, four variables were used: frequency of smoking, being a current smoker (when this variable was used as a dependent variable, analysis only was conducted for respondents), frequency of consumption of fresh fruits and vegetables per day and frequency of physical activities per month.

3.4.1 Distribution of health outcomes, health-related behaviour, and overall assessment of the gradients in health

Weighted frequency distributions of all health outcomes and health related behaviours by sex and ethnicity were assessed. To examine the crude picture of education and income gradients in health, the prevalence of the dichotomous health outcomes and the means of the continuous health measures were examined within groups of education and poverty-income index (see bullet 3.3.1.1, socioeconomic factors). As some of the health outcomes, such as periodontitis and ischaemic heart disease, are more common in older individuals, this analysis was stratified according to age groups (see bullet 3.3.1.2, age).

Regression models for each of the health outcomes and the health behaviours were constructed according to the assumption based on the initial bio- psychosocial model (Figure 2.17) and the Figures 3.1 and 3.2. More specific models for each stage of the analysis are presented in Figures 3.3 -3.8. To measure the effects of the different pathways on the social gradients, variables indicating each of these pathways were introduced to the initial regression models to observe change in education and income gradients. This method has the advantage of estimating direct and indirect contributions of explanatory factors (van Oort *et al.* 2005). Other statistical methods such as path analysis, factor analysis and structural equation modelling have the advantage of analysing complex causal pathways in their operating order (Newton and Bower 2005), and taking into account the interaction between the different variables as assumed by the research model. These advanced statistical techniques are more appropriate for analysis of longitudinal data. However, this research is based on a cross sectional study and the establishment of a causal relationship is not possible. Accounting for interaction between the different determinants is beyond the scope of this thesis, though suggested in bio-psychosocial model (Figure 2.17). Hence, the method described above was used in this thesis. The same method was used in other papers, which examined the effect of health behaviour on socioeconomic inequalities in morbidity and mortality (van Oort *et al.* 2005; Kivimaki *et al.* 2007).

3.4.2 Assessing the social gradients in oral and general health

To examine the education and income gradients in oral and general health, appropriate regression models were created for each of the health outcomes variables related to oral and general health. First, binary (unadjusted) relationships of each of the health outcomes were assessed with each of education and income, indicated by poverty-income ratio (used here as a continuous variable with higher value indicating higher income).

In the following steps, adjusted models for each health outcomes were conducted. Perceived oral health (poor/ fair versus good/ very good/ excellent) was analysed using logistic regression model, controlling for dental insurance, age, sex, ethnicity and smoking. For perceived general health (poor/ fair versus good/ very good/ excellent) the same model was used, but dental insurance was replaced by medical insurance. Logistic regression was also used for the dichotomous periodontal variable (at least one site with gingival bleeding and one site loss of attachment $\geq$ 3mm) and ischaemic heart disease (angina pectoris according to the Rose questionnaire or reported diagnosis of heart attack). In the model pertaining to periodontal diseases, the same variables as in perceived oral health model were used and additionally adjusted for reported diagnosis of diabetes. In the ischaemic heart disease models dental insurance was replaced by medical insurance and additionally adjusted for body mass index (BMI) and high blood pressure (systolic $\geq$ 130 Hg mm or diastolic $\geq$ 85 Hg mm).

In the three models for extent of periodontal disease (percentage of sites with gingival bleeding, loss of attachment $\geq$3mm and pocket depth $\geq$4mm to all examined sites), linear regression was used adjusting for the same variables as in the dichotomous periodontal disease model. For edentulousness, logistic regression was used and adjusted for the same variables as the perceived oral health model. Number of missing tooth surfaces is a count of events which is not normally distributed in the population with a variance bigger than the mean. Hence, the most appropriate analysis for this variable is the negative binomial regression. This model controlled for the same variables as the edentulousness model. Figure 3.3 shows the pathways that the analysis explored to assess education and income gradients in oral and general health.

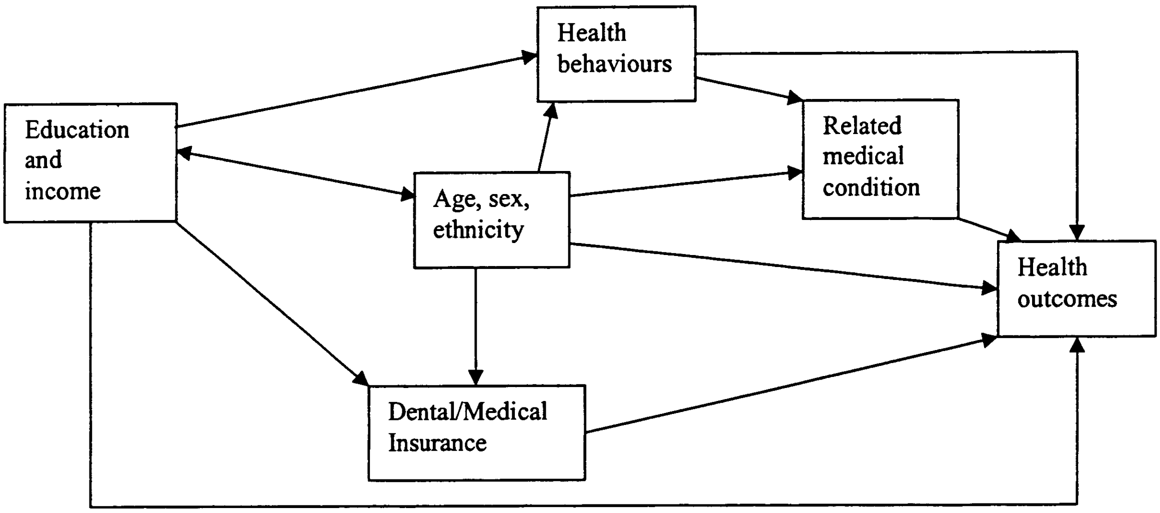


Figure 3.3 A model for examining the social gradients in oral/general health

3.4.3 Assessing the independent effects of race/ethnicity and sex on oral and general health

The bio-psychosocial model assumes that social gradients in general and oral health are influenced by sex and ethnicity. An analysis was conducted to assess the effects of sex and ethnicity on education and income gradients in all oral and general health outcomes used in this thesis. First, the associations between education and income with health outcomes were assessed using appropriate regression models and adjusting for all relevant confounders except ethnicity and sex. Perceived oral health were analysed using logistic regression models controlling for dental insurance, age, and smoking. For perceived general health, the same model was used but dental insurance was replaced by medical insurance.

Logistic regression was also used for the dichotomous periodontal variable and ischaemic heart disease. In the model pertaining to periodontal diseases, the same variables were used as in perceived oral health and additionally adjusted for reported diagnosis of diabetes. In the ischaemic heart disease models, dental insurance was replaced by medical insurance and additionally adjusted for obesity (BMI) and high blood pressure. In the three models for extent of periodontal disease linear regression was used adjusting for the same variables as in the periodontal disease model.

For edentulousness, logistic regression was used and adjusted for the same variables as the perceived oral health model. The model for number of missing tooth surfaces was the negative binomial regression. This model controlled for the same variables as in the edentulousness model. Ethnicity and sex were introduced to all models one at the time then both of them together to examine the changes in education and income gradients in all health outcomes.

To examine the effects of sex and ethnicity on the different health outcomes first unadjusted and adjusted associations were assessed for the whole population. The adjusted models controlled for the same variables as described above. Then, stratifying the sample according to quartiles of income, regression models were conducted for each of the outcomes, to assess whether the effect of ethnicity and sex is uniform across income strata. Similarly, for each level of education, regressions models were conducted in the same fashion (Figure 3.4). These regression models allow for the assessment of the effect of race/ethnicity and sex on oral and general health within stratum of socioeconomic position.

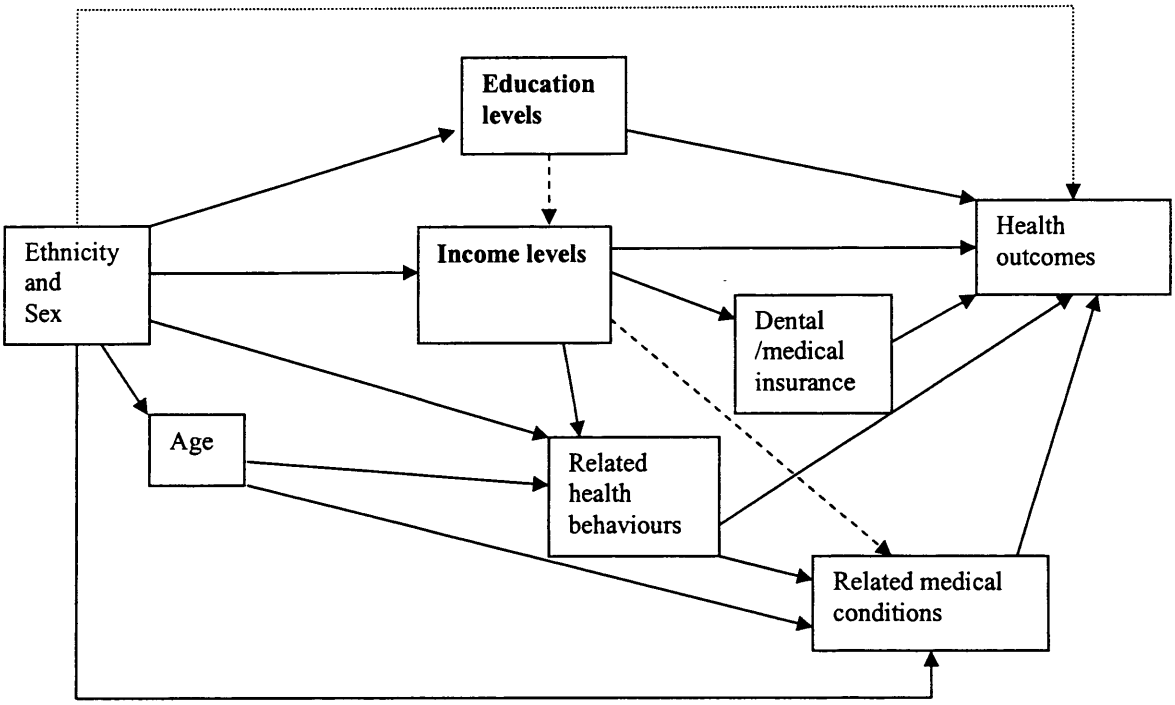


Figure 3.4 **Assessing the independent effect of sex and ethnicity on oral and general health outcomes**

3.4.4 The effect of cognitive performance on the social gradients in oral/general health

This analysis was conducted for periodontal disease, tooth loss and ischaemic heart disease for persons aged 20 to 59 years old. Initial models were conducted for ischaemic heart disease, periodontitis, extent of gingival bleeding, extent of loss of periodontal attachment $\geq$ 3mm, extent of pocket depth $\geq$ 4mm and number of missing tooth surfaces due to disease. Logistic regression was used for the dichotomous periodontal variable and ischaemic heart disease. The model pertaining to periodontal diseases adjusted for education, income, dental insurance, age, sex, ethnicity, smoking and reported diagnosis of diabetes. In the ischaemic heart disease models, dental insurance was replaced by medical insurance and additionally adjusted for obesity (BMI) and high blood pressure. In the three models for extent of periodontal disease (percentage of sites with gingival bleeding, loss of attachment ≥ 3mm, pocket depth ≥ 4mm to all examined sites) linear regression was used adjusting for the same variables as in the periodontal disease model. For number of missing tooth surfaces, the negative binomial regression model was used adjusting for education, income, dental insurance, age, sex, ethnicity and smoking. The scores of cognitive performance tests (Simple Reaction Time Test, Symbol Digit Substitution Test, Serial Digit Learning Test) were introduced to each model to assess the effects of cognitive performance on the social gradients in general and oral health. Additionally, the unadjusted and adjusted association between each of the health outcomes and each of the three tests of cognitive performance were examined (Figure 3.5).

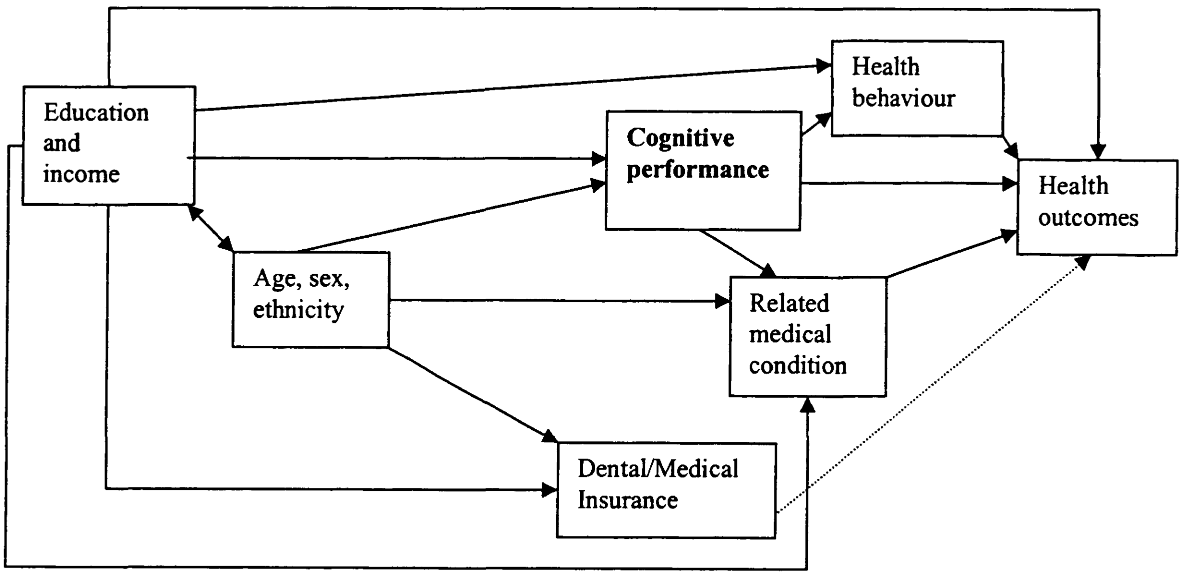


Figure 3.5 **The effect of cognitive performance on the social gradients in oral/general health**

3.4.5 Assessing the gradients in health-related behaviours and their impact on the gradients in oral health and general health

Five indicators of health behaviour were used: (1) being a current smoker, (2) frequency of smoking per day, (3) frequency of eating fresh fruits and vegetables per day, (4) frequency of physical activities per month, and (5) frequency of visits to a dentist (once a year or more and less than once a year). Appropriate regression models were used for each variable. Linear regression was used for frequency of exercises and eating fresh fruits and vegetables, negative binomial regression was used for frequency of smoking per day and logistic regression was used for frequency visits to dentists and being a current smoker. Unadjusted (binary) analysis was conducted to measure the association of each of the behaviours with each of education and income. The adjusted models controlled for education, income, age, sex and ethnicity.

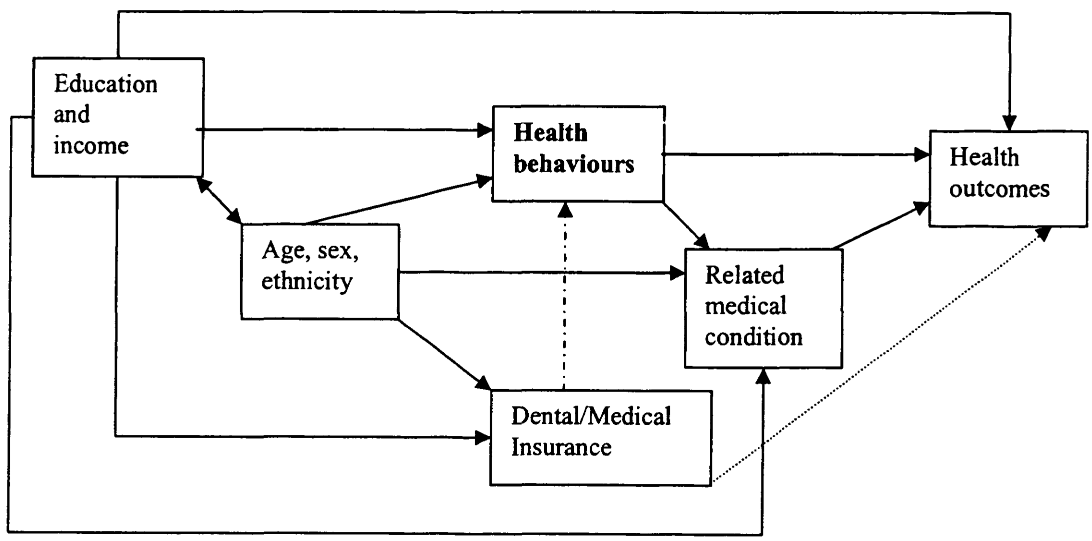


Figure 3.6 Social gradients in health-related behaviour and effect of health behaviours on the gradients in health

To assess the effect of health behaviour on the gradients in oral and general health, relevant health behaviours were added to the models pertaining to each of the health outcomes (as described in bullet 3.4.2) to observe the change in education and income gradients. Health-related behaviours used in the models pertaining to oral health were being a current smoker and frequency of visits to dentists. Health-related behaviours in the general health models were being a current smoker and frequency of physical activities. Other behaviour indicators were excluded either because they did not show an association with health outcomes (frequency of eating fresh fruits and vegetables) or because they had a high percentage of missing values which would affect the analysis (frequency of smoking). Unadjusted associations between each of the included behaviours and each health outcome were also examined (Figure 3.6).

3.4.6 The effect of tooth cleanliness on the social gradients in periodontal health

Extent of calculus was used as an indicator for tooth cleanliness. First, unadjusted and adjusted associations between extent of calculus and socioeconomic position were assessed, using linear regression. Adjusted models controlled for education, income, dental insurance, ethnicity, sex, age, smoking and diabetes.

To assess the impact of adjusting for calculus on the social gradients in periodontal diseases, regression models for tooth loss and each of the periodontal variables were constructed. The model for tooth loss adjusted for education, income, dental insurance, ethnicity, sex, age and smoking. The periodontal disease models additionally adjusted for diabetes. Then the variable for extent of calculus was introduced to these models to observe the change in the gradients before and after adjusting for calculus. Additionally, unadjusted associations between extent of calculus with tooth loss and each of the periodontal measures were measured (Figure 3.7). Logistic regression analysis was used for the dichotomous periodontal variable, linear regression was used for extent of periodontal disease variables and negative binomial regression was used for tooth loss.

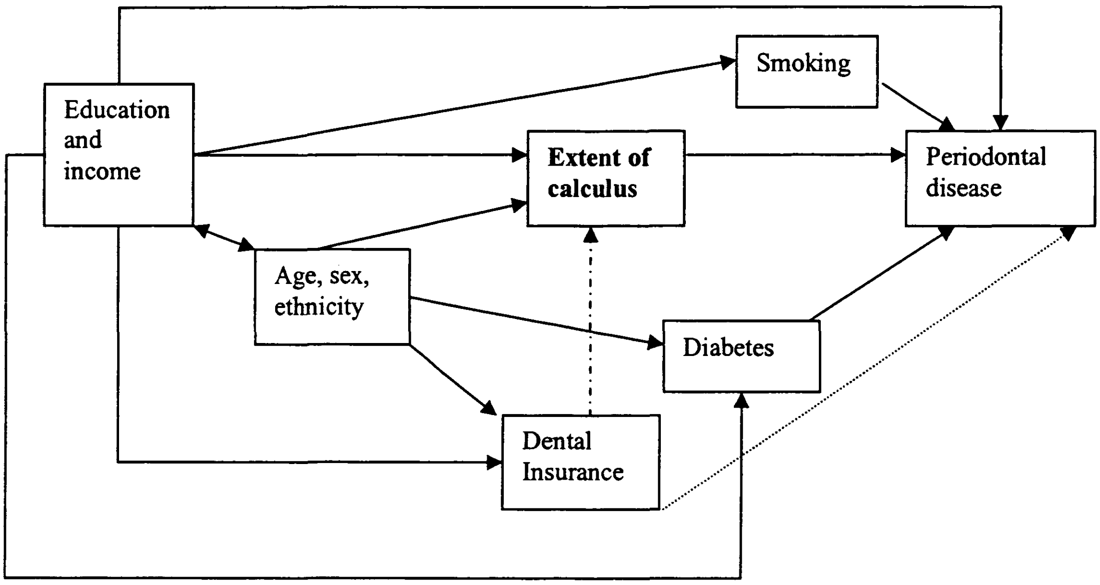


Figure 3.7 **The effect of tooth cleanliness (calculus) on the gradients in periodontal disease.**

3.4.7 A stress pathway linking socioeconomic position to periodontal disease and ischaemic heart disease

This part of the analysis examined the stress pathway, indicated by allostatic load, in two health outcomes, periodontal disease and ischaemic heart disease. Initial linear regression models were constructed for each of the extent of periodontal diseases outcomes and logistic regression for the dichotomous periodontal variable adjusting for income, education, ethnicity, sex, age, smoking, and dental insurance. For ischaemic heart disease, logistic regression was used adjusting for the same variables but replacing dental insurance by medical insurance. Biological indicators of allostasis (central obesity, high blood pressure, hypertriglycerdemia, low HDL-cholesterol, high glucose, CRP and fibrinogen) were then introduced into the models one at a time to assess their effects on the variation in periodontal disease and ischaemic heart disease. Additionally, the aggregated variable indicating clustering of the seven markers was used in separate models to examine its association with the health outcomes. Models adjusting for the aggregate marker of allostasis were compared to those not adjusting for allostasis to assess the effect of allostasis on the social gradients in oral and general health (Figure 3.8). Additional analysis for the dichotomous periodontal disease and ischaemic heart disease were conducted, which only adjusted for allostasis and education and allostasis and income to have a better comparison of the effect of allostasis on social gradients in both health conditions.

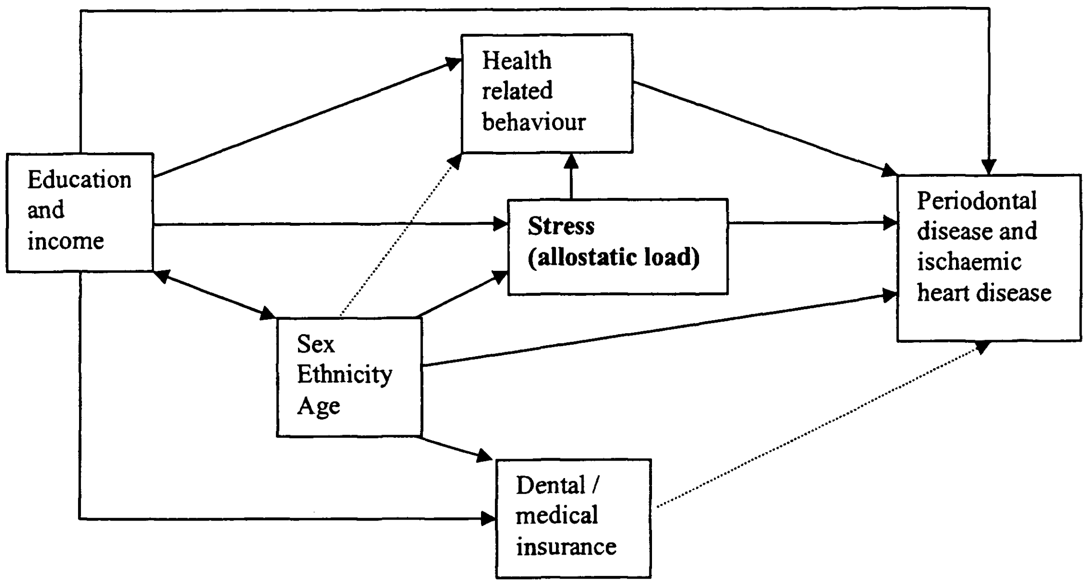


Figure 3.8 A stress pathway linking socioeconomic position to periodontal disease and ischaemic heart disease

3.5 Summary

Data from NHANES III pertaining to individuals aged 17 years and older were used in this thesis to examine the social gradients in oral and general health and explore potential pathways towards the gradients. Indicators of oral health included perceived oral health, periodontitis (at least one site with loss of attachment $\geq$3mm and one site with gingival bleeding), extent of gingival bleeding, extent of loss of attachment $\geq$ 3mm, extent of pocket depths $\geq$ 4mm, loss of tooth surface, and edentulousness. Indicators of general health included perceived general health and ischaemic heart disease based on reported diagnosis and WHO questionnaire for angina pectoris (Rose *et al* 1982). Socioeconomic position was measured by two variables, namely years of education and income. Five indicators of health-related behaviours were selected, namely being current a smoker, frequency of smoking, frequency of eating fresh fruits and vegetables, frequency of physical activities, frequency of visits to dentists. Other factors included in the analysis were sex, ethnicity, age, dental/ medical insurance, calculus, related medical conditions (diabetes, blood pressure, body mass index), markers of allostatic load and cognition tests.

The analysis was conducted using survey commands in STATA statistical software. First, the distributions of the health outcomes by income and education groups were examined. Appropriate regression models for each of the health outcomes and each of the health-related behaviours were conducted to assess the education and income gradients. Additional analyses were conducted to measure the contribution of each of the potential pathways on the gradients. The examined pathways included sex and ethnicity, cognitive ability, health-related behaviours, tooth cleanliness indicated by calculus and stress indicated by markers of allostatic load.

Chapter 4

Distribution of health outcomes, health-related behaviours, and overall assessment of the gradients in oral and general health.

Chapter 4

Distribution of health outcomes, health-related behaviours, and overall assessment of the gradients in oral and general health.

4.1 Introduction

The results of the analysis are presented in Chapters 4-10. Chapter 4 includes a description of the health outcomes, behaviour indicators and socioeconomic position indicators. Thereafter, the prevalence and scores of the health outcomes across education and income groups are presented. The following Chapters (5-10) present the results pertaining to the six models described in the methods section (Chapter 3, Figures 3.3-3.8). Each of the results chapters includes the relevant results, tables, figures and a brief summary highlighting the main findings. The results chapters are followed by a general discussion of all the results, limitations and implications (Chapter 11).

This chapter presents a description of the main variables used in the analysis and an overall description of the distribution of the main health and behavioural variables within different levels of education and income. Analysis showing statistical differences in health by income and education is presented in the following chapters.

4.2 Description of some key variables

Individuals aged 17 years and above were included in the analysis. The total number of persons in this part of the survey was 20,050. However, not all participants had dental examinations (a description of the dental examination is included in Appendix 1). More specifically, only 17,223 individuals had a dental examination, 14,022 had gingival assessments and 13,994 had a periodontal assessment. In the whole population, 46.9% were males, 42.3% were Whites, 27.4% African Americans, 26.5% Hispanic and 3.9% from other ethnic groups. Of those who had a dental assessment 46.9% were males, 40.1% Whites, 28.4% African Americans, 27.5% Hispanic, and 4.1% from other ethnic groups. Age distribution was 26.9% aged 17-30 years, 24.3% aged 31-44 years, 24.0% aged 45-65 years and 24.8% were 66 years and above.

Of the 17,223 persons who had dental examination, 11.4% were completely edentulous and 6.8% were edentulous in one arch. Table 4.1 shows the distribution of all health outcomes, behavioural factors and indicators of socioeconomic position included in the analysis by sex and ethnicity. The general trend was that compared to White Americans, African Americans and Hispanic Americans had poorer health, worse health-related behaviours and lower income and education (Table 4.1). However, there were a few interesting exceptions to that general pattern; 1) A higher percentage of White Americans were completely edentulous and lost more teeth compared to African Americans and Hispanic Americans; 2) Hispanic Americans had lower mean levels of extent of loss of attachment and lower prevalence of ischaemic heart disease compared to White Americans; 3) A higher percentage of African Americans were covered by dental insurance compared to White Americans. Women had better periodontal health and had less calculus but had higher levels of tooth loss and edentulousness compared to men. Although women generally had less income, they visited dentists more frequently than men.

Table 4.1 Distribution of oral health and general health outcomes, behavioural factors and indicators of socioeconomic position by ethnicity and sex in US population aged 17 years and over

	N	Ethnicity (95%CI)				Sex (95%CI)	
		WA	AA	HA	Others	M	F
Mean bleeding extent [1]	14022	8.64 (7.41-9.87)	11.72 (10.12-13.33)	13.66 (11.86-15.46)	10.26 (8.42-12.10)	10.56 (9.33-11.80)	8.35 (7.30-9.39)
Mean extent attachment loss [2]	13994	9.66 (8.76-10.55)	12.13 (11.03-13.24)	7.39 (6.76-8.02)	10.88 (9.30-12.45)	11.77 (10.81-12.73)	8.13 (7.36-8.90)
Mean extent pocket [3]	13994	2.03 (1.53-2.53)	4.85 (4.09-5.61)	2.99 (2.61-3.36)	2.76 (2.07-3.45)	3.05 (2,53-3.58)	1.92 (1.53-2,31)
Number missing tooth surface [4]	17219	28.37 (25.98-30.76)	30.97 (29.25-32.70)	13.45 (12.68-14.23)	25.22 (21.59-28.86)	25.86 (24.01-27.72)	29.24 (27.06-31.41)
Mean extent of calculus [5]	14017	32.37 (29.48-35.27)	50.53 (47.03-54.03)	44.31 (39.67-48.95)	40.61 (35.33-45.90)	40.29 (37.37-43.21)	31.64 (29.26-34.03)
Fresh fruits and vegetables [6]	18156	3.33 (3.25-3.41)	2.82 (2.73-2.90)	3.76 (3.62-3.89)	3.64 (3.38-3.89)	3.13 (3.05-3.20)	3.49 (3.40-3.59)
Physical activity [7]	18148	16.94 (15.67-18.22)	20.34 (18.99-21.69)	14.67 (13.44-15.90)	17.96 (15.56-20.36)	19.38 (18.08-20.67)	15.37 (14.12-16.62)
Number of smoke [8]	4724	19.89 (18.90-20.88)	12.66 (12.21-13.10)	8.48 (7.59-9.37)	12.53 (10.88-14.19)	18.70 (17.64-19.76)	17.34 (16.47-18.21)
Mean income [9]	16373	3.35 (3.21-3.49)	2.04 (1.92-2.16)	1.79 (1.70-1.88)	2.21 (1.91-2.51)	3.16 (3.03-3.28)	2.94 (2.80-3.07)
Periodontal disease (%) [10]	14023	21.50 (19.5-23.8)	26.90 (24.7-29.2)	24.50 (22.3-26.9)	28.30 (24.1-32.8)	26.70 (24.5-29.1)	19.20 (17.2-21.4)
Ischaemic heart disease(%) [11]	17914	7.10 (6.3-8.0)	7.30 (6.5-8.2)	5.90 (5.2-6.5)	6.10 (4.3-8.5)	6..90 (6.1-7.8)	7.10 (6.2-8.0)
Perceived oral health(%) [12]	15804	30.40 (28.2-32.8)	45.00 (43.4-46.7)	54.20 (52.0-56.4)	39.20 (33.3-45.4)	34.60 (32.6-36.7)	33.70 (31.5-36.1)
Perceived general health(%) [13]	18152	13.10 (11.6-14.8)	21.90 (19.9-24.0)	31.00 (28.8-33.2)	21.70 (17.4-26.8)	13.90 (12.6-15.3)	17.40 (15.8-19.1)
Completely edentulous(%) [14]	17223	10.30 (9.1-11.6)	7.50 (6.7-8.5)	2.30 (1.9-2.6)	5.10 (3.3-7.7)	8.60 (7.6-9.6)	9.60 (8.4-11.0)
Smoking(%) [16]	9235	51.50 (48.9-54.1)	68.00 (65.5-70.4)	53.00 (49.9-56.1)	58.40 (51.5-65.0)	34.40 (32.4-36.6)	25.00 (23.4-26.7)
Dental visit(%) [17]	17265	53.70 (51.1-56.4)	33.90 (31.0-36.9)	32.20 (29.0-35.7)	40.20 (34.6-46.0)	44.80 (42.3-47.3)	53.70 (51.1-56.3)
Dental insurance(%) [18]	13821	50.60 (47.0-54.1)	63.20 (57.8-68.4)	42.60 (35.0-50.7)	53.30 (46.6-59.8)	51.90 (48.5-55.2)	51.40 (48.2-54.6)
Medical insurance(%) [19]	15880	95.20 (94.5-95.9)	89.90 (88.0-91.6)	76.40 (73.7-79.0)	94.60 (90.6-97.0)	93.30 (92.2-94.3)	94.20 (93.4-95.0)
Education (%) [20]	18033	22.20 (19.9-24.6)	34.20 (32.6-36.9)	59.80 (56.7-62.9)	39.60 (31.8-47.9)	27.70 (25.4-30.0)	26.10 (24.0-28.3)
Education (%) [21]		34.60 (33.0-36.3)	37.20 (35.1-39.3)	23.60 (21.8-25.5)	24.50 (21.4-27.9)	30.60 (28.9-32.2)	36.30 (34.7-38.0)
Education (%) [22]		43.20 (40.2-46.2)	28.60 (26.0-31.4)	16.60 (14.5-18.9)	35.90 (29.1-43.3)	41.80 (38.9-44.7)	37.60 (35.2-40.1)

[1] Mean of percentage of sites with gingival bleeding to all examined sites .
[2] Mean of percentage of sites with loss of attachment ≥ 3mm to all examined sites
[3] Mean of percentage of sites with pocket depth ≥ 4mm to all examined sites
[4] Mean number of missing tooth surfaces due to disease
[5] Mean of percentage of sites with any calculus to all examined sites
[6] Mean of frequency of eating fresh fruits and vegetables per day
[7] Mean of frequency of physical activity per month
[8] Mean number of any smoke unit per day (only persons who reported smoking are included)
[9] Mean of poverty to income ratio.
[10] Percentage of persons with periodontal disease (at least one site with gingival bleeding and one site with loss of attachment ≥ 3mm)
[11] Percentage of persons with angina pectoris (according to Rose questionnaire) or reported doctor diagnosis of heart attack.
[12] Percentage of persons reporting se perceived oral health poor/fair
[13] Percentage of persons reporting se perceived general health poor/fair
[14] Percentage of persons completely edentulous

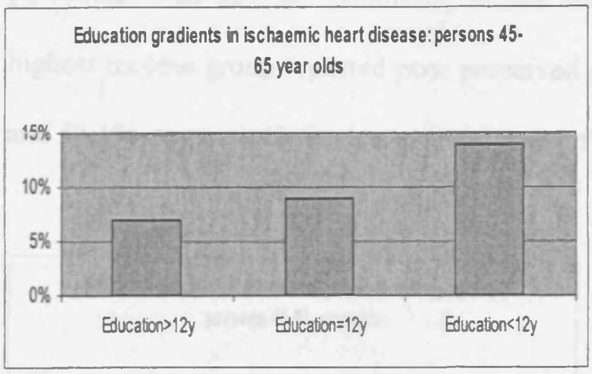
[15] Percentage of persons edentulous in one arch
[16] Percentage of persons currently smoking
[17] Percentage of persons who visited dentist less once a year or more
[18] Percentage of persons who have any dental insurance
[19] Percentage of persons who have any medical insurance
[20] Percentage of persons with education less than 12 years
[21] Percentage of persons with education 12 years
[22] Percentage of persons with education more than 12 years

4.3 Distribution of disease by education and income: Assessing the crude gradients in health

Table 4.2 shows the prevalence of ischaemic heart disease, perceived general health, perceived oral health, periodontitis, edentulousness and the mean extent of gingival bleeding, loss of periodontal attachment, and pocket depth in education and income groups and within age strata.

4.3.1 Social gradients in ischaemic heart disease

There was a consistently higher prevalence of ischaemic heart disease in each lower level of income and education with the exception of the highest and second highest education groups for persons aged 66 years and over (Table 4.2). Education and income gradients in ischaemic heart disease were clearer among participants aged 45 to 65 years. For those aged 45 to 65 years, persons with more than 12 years of education had a prevalence of ischaemic heart disease of 6.5% compared to 8.6% and 13.6% for those in the middle and lowest education groups, respectively. Similarly, for the same age group, persons with the highest income the prevalence of ischaemic heart disease was lower (5.8%) than for those in the second highest income group (8.8%). The prevalence in the second lowest and lowest income groups were 13.5% and 18.1% respectively (Figure 4.1).



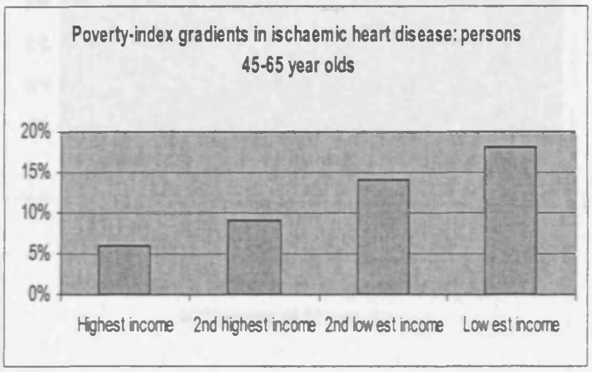


Figure 4.1 Education and income gradients in ischaemic heart disease, persons aged 45 to 65 years

4.3.2 Social gradients in perceived general health

As one descended the education and income gradients more individuals reported poorer perceived general health at each lower level of education and income for all age groups (Table 4.2). Education and income gradients in perceived general health were very clear especially in individuals in the two middle age groups, namely those aged 31-44 and 45-65 years. A clear example of that trend was in the percentages of individuals in the 45-65 years age group reporting poorer general health. At each lower level of education the percentage was half that in the education group directly below them; 9.8% of individuals in the highest education groups reported poor perceived general health, in the second highest education group the percentage was 18.8% and in the lowest education group the percentage was 35.1%. Similarly, in the same age group, 10% of persons with the highest income group reported poor perceived general health compared to 17.8%, 32.7% and 51.1%, respectively in descending levels of income (Figure 4.2).

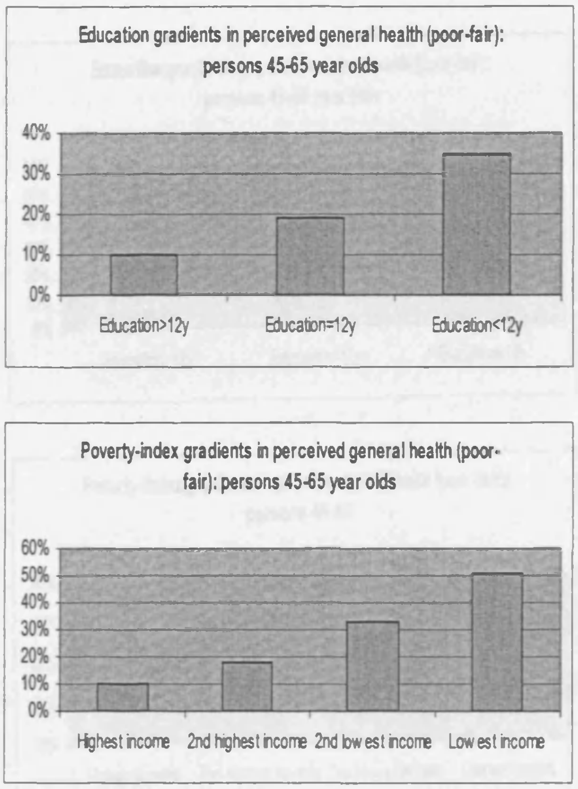


Figure 4.2 Education and income gradients in perceived general health, persons aged 45 to 65 years

4.3.3 Social gradients in perceived oral health

There were consistent education and income gradients in perceived oral health (Table 4.2). At each lower level of education and income, for all age groups, higher percentages of people reported poorer perceived oral health compared to the group directly above them. For persons aged 44 to 65 years, 23.4% of those with highest education reported poorer perceived oral health compared to 41.4% and 55.8% for those in the middle and lowest education groups. Similarly, in the same age group, 27.2% of those in the highest income group reported poorer perceived oral health, the percentages were 39.3%, 52.6% and 65.8% for each lower income group, respectively (Figures 4.3).

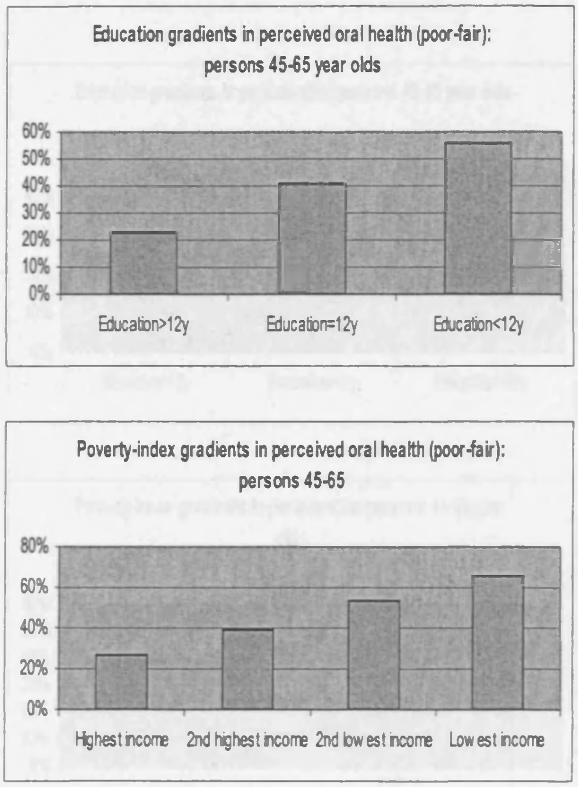
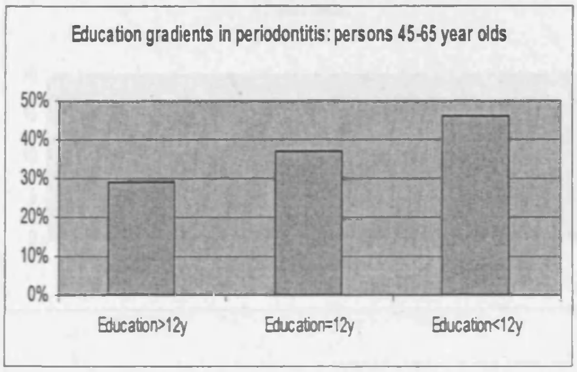


Figure 4.3 Education and income gradients in perceived oral health, persons aged 45 to 65 years

4.3.4 Social gradients in periodontitis (at least one site loss of periodontal attachment >3mm and one site gingival bleeding

The prevalence of periodontitis was higher at each lower level of education and income, and for all age groups (Table 4.2). Education gradients in periodontitis were steeper among individuals in age groups 31 to 44 and 45 to 65 years old. For the age group 45-65 years, 28.9% of individuals in the highest education groups had periodontitis, in the second highest education group the percentage was 37.0% and in the lowest education group the percentage was 46.4%. Similarly, in the same age group, 28.0% of persons in the highest income group had periodontitis compared to 41.4%, 42.4% and 53.4%, respectively in the following income levels (Figure 4.4).



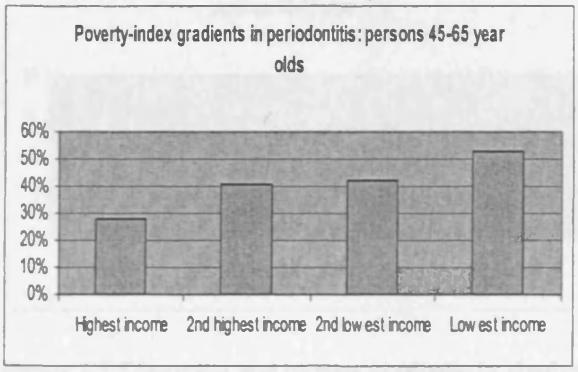


Figure 4.4 Education and income gradients in periodontitis, persons aged 45 to 65 years

4.3.5 Social gradients in the extent of gingival bleeding

There were consistently higher levels of gingival bleeding at each lower level of education and income and for all age groups (Table 4.2). For persons in age group 45-65 years, the extent of gingival bleeding for highest education group was 7.6. It was 10.2 and 15.6, respectively for the middle and lowest education groups. In the same age group, income gradients in gingival bleeding were also clear. The extent of bleeding increased as one went down the income gradient. From highest to lowest income groups, the extent was 8.1, 11.1, 14.0 and 17.3, respectively in the four income groups (Figure 4.5).

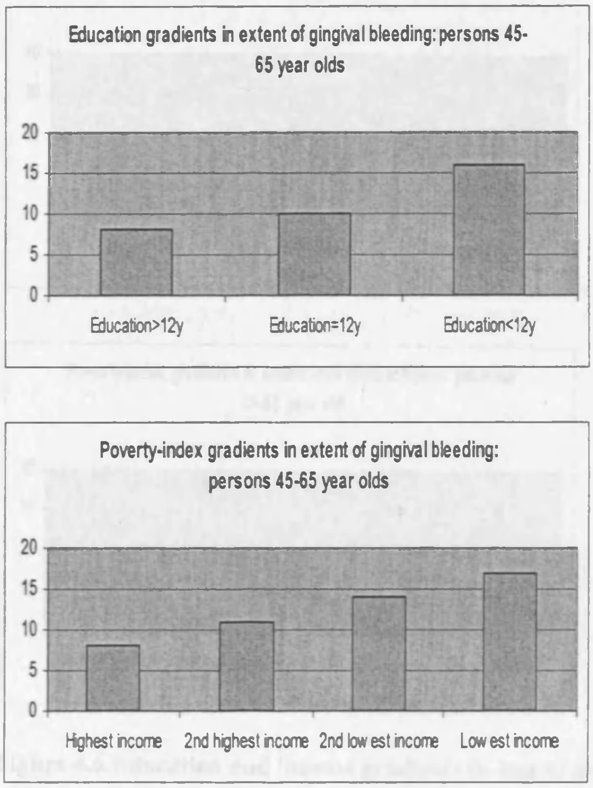


Figure 4.5 Education and income gradients in gingival bleeding, persons aged 45 to 65 years

4.3.6 Social gradients in extent of loss of periodontal attachment

There were consistent education and income gradients in the extent of loss of periodontal attachment (ratio of sites with loss of attachment $\geq$ 3mm to all examined sites) for all age groups. There were higher proportions of sites with loss of attachment at each lower level of education and income (Table 4.2). For persons aged 44 to 65 years, the extent of loss of attachment were 13.5, 20.1 and 29.0 in highest, second and lowest education groups, respectively. In the same age group, the extent of loss of attachment was 14.9, 21.7, 24.5 and 32.3 in the four income groups from highest to lowest, respectively (Figure 4.6).

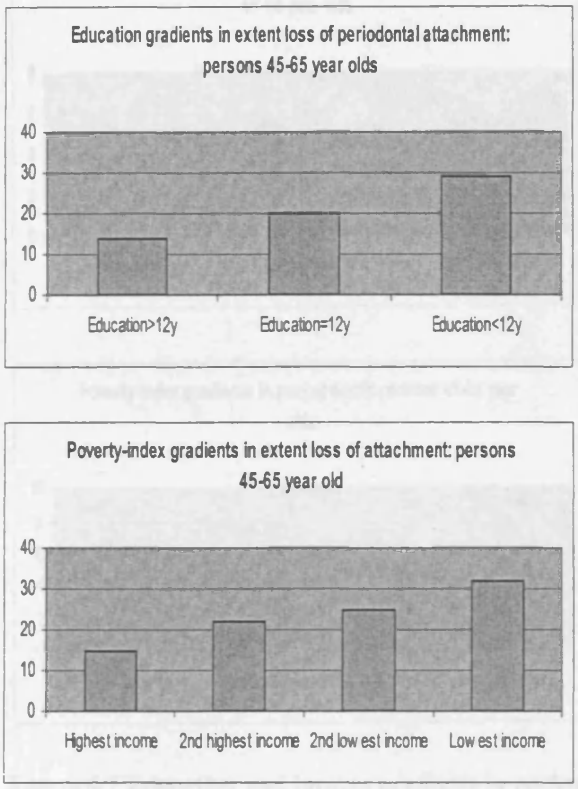


Figure 4.6 Education and income gradients in loss of attachment, persons aged 45 to 65 years

4.3.7 Social gradients in the extent of periodontal pocket depth

There were consistently greater levels of extent of periodontal pocket (ratio of sites with pocket depth $\geq$ 4mm to all examined sites) at each lower level of education and income and for almost all age groups with the exception of the highest age group (66 years and above) (Table 4.2). The gradients were clearer in the two middle age groups; 31 to 44 and 45 to 65 years old. For persons aged 45-65 years, the extent of periodontal pockets in each education group was 2.1 for the highest, 3.9 for the middle and 5.7 for the lowest education groups. In the same age group, income gradients in the extent of periodontal pocket were also clear. The extent of pocket was 2.4, 3.8, 4.9 and 8.5, respectively in the four income groups from the highest to lowest (Figure 4.7).

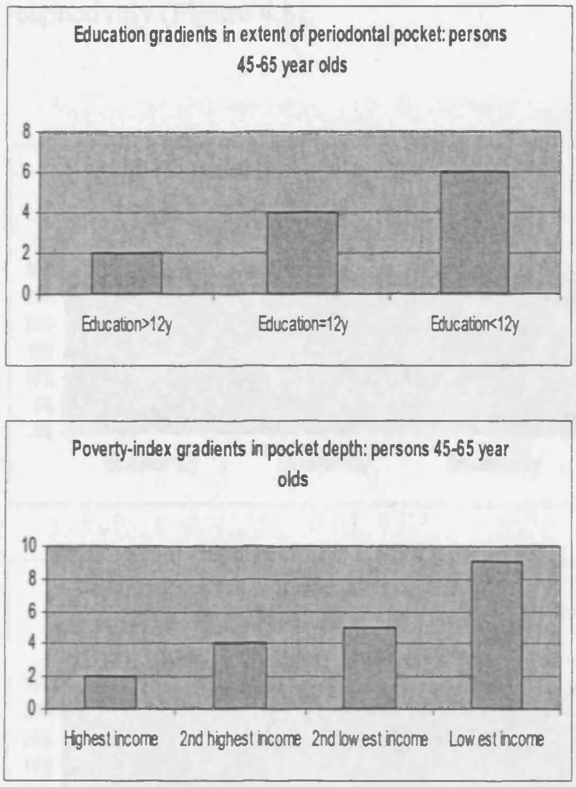


Figure 4.7 Education and income gradients in pocket depth, persons aged 45 to 65 years

4.3.8 Social gradients in edentulousness

There was a consistently higher prevalence of edentulousness in each lower level of income and education with the exception of individuals in the lowest age group (age 17 to 30 years) (Table 4.2). Education and income gradients in edentulousness were clearly demonstrated among participants aged 45 to 65 years old. In this age group, 5.1% of persons with more than 12 years of education were edentulousness compared to prevalence of 14.6% and 27.4% for those in the middle and lowest education groups. Similarly, for the same age group, the prevalence of edentulousness was 7.7% in the highest income group. In the second highest income group, the prevalence was 18.6% and in the second lowest and lowest income group the prevalence was 21.4% and 27.8%, respectively (Figure 4.8).

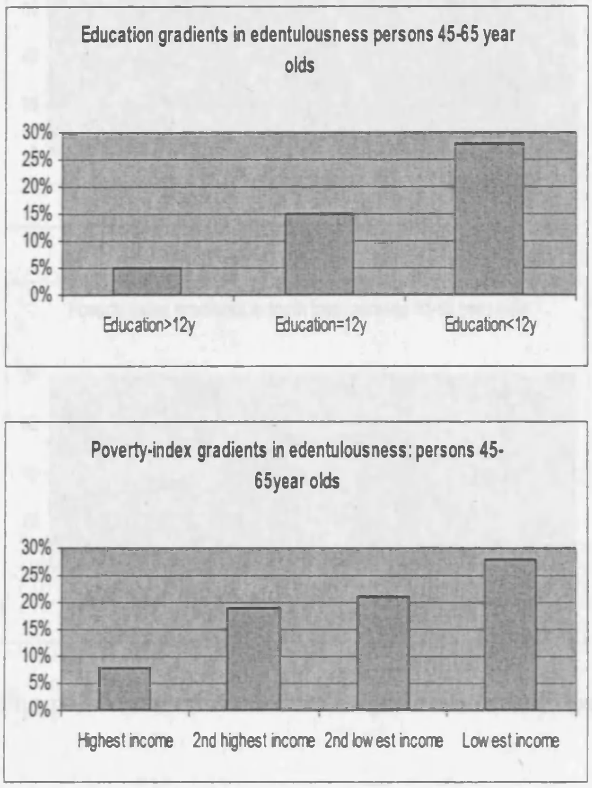
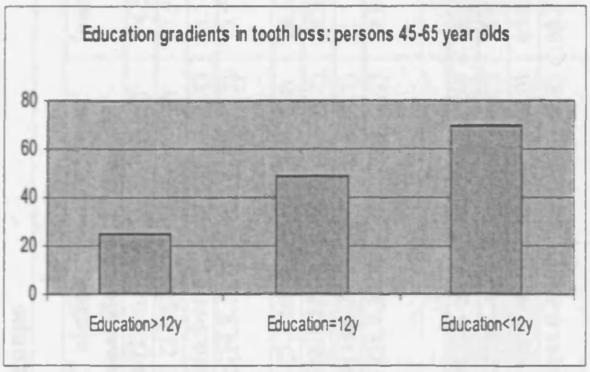


Figure 4.8 Education and income gradients in edentulousness, persons aged 45 to 65 years

4.3.9 Social gradients in number of missing tooth surfaces

There were consistent education and income gradients in tooth loss for all age groups, with the exception of those aged 31 to 44 years in the lowest income group (Table 4.2). For persons aged 44 to 65 years, the mean numbers of missing tooth surfaces were 24.6 in the highest, 48.8 in the middle and 69.7 in the lowest education groups. In the same age group, the mean numbers of missing tooth surfaces were 32.2, 52.1, 60.4 and 68.1 respectively in the four income groups from highest to lowest (Figure 4.9).



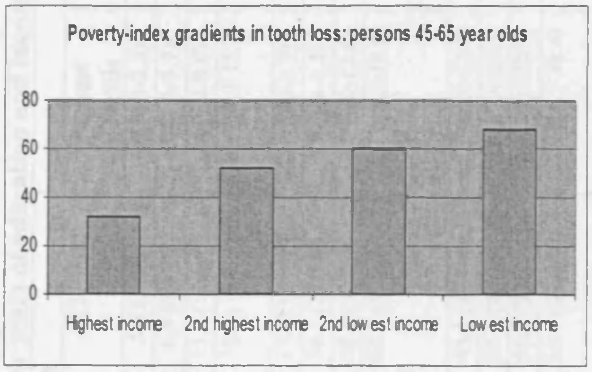


Figure 4.9 Education and income gradients in tooth loss, persons aged 45 to 65 years

Table 4.2 Distribution of general and oral health outcomes, by years of education and income groups

Condition	Age group	Years of education			Income			
		>12 years	12 years	<12 years	highest quartile	2nd highest quartile	2nd lowest quartile	lowest quartile
Ischemic heart disease: prevalence (95%CI)	17-30 years	1.6 (1.0-2.6)	2.5 (1.6-3.8)	5.6 (3.7-8.4)	0.8 (0.3-2.3)	4.0 (2.3-6.9)	3.3 (1.9-5.6)	4.5 (3.2-6.4)
	31-44 years	2.5 (1.7-3.8)	3.4 (2.3-4.9)	8.9 (6.4-12.4)	2.0 (1.1-3.7)	3.7 (2.4-5.4)	6.7 (4.7-9.5)	7.9 (5.4-11.3)
	45-65 years	6.5 (5.1-8.4)	8.6 (6.6-11.1)	13.6 (11.4-16.1)	5.8 (4.2-8.0)	8.8 (6.5-11.9)	13.5 (10.8-16.8)	18.1 (14.3-22.8)
	66+ years	16.8 (13.6-20.6)	14.9 (12.4-17.9)	18.8 (16.3-21.5)	13.3 (11.3-15.7)	17.2 (14.8-19.8)	20.5 (17.7-23.7)	19.7 (15.8-24.3)
Perceived general health poor-fair: prevalence (95%CI)	17-30 years	3.7 (2.5-5.3)	8.0 (6.6-9.6)	17.9 (15.0-21.2)	3.6 (2.3-5.7)	7.6 (5.3-10.9)	10.6 (8.3-13.4)	16.1 (13.0-19.7)
	31-44 years	5.4 (4.0-7.2)	9.4 (7.3-12.0)	30.2 (25.2-35.6)	3.9 (2.8-5.5)	8.6 (6.1-12.0)	14.8 (10.9-19.7)	34.5 (29.0-40.5)
	45-65 years	9.8 (7.5-12.7)	18.8 (16.0-22.0)	35.1 (30.1-40.5)	10.0 (8.0-12.6)	17.8 (13.6-22.9)	32.7 (27.8-38.1)	51.1 (45.7-56.5)
	66+ years	18.5 (13.4-22.1)	24.8 (21.6-28.3)	42.9 (39.8-46.0)	16.3 (13.2-19.9)	30.1 (26.7-33.7)	40.9 (37.9-44.1)	47.9 (42.9-52.8)
Perceived Oral health poor-fair: prevalence (95%CI)	17-30 years	20.0 (16.6-24.0)	29.8 (27.0-32.7)	43.1 (39.2-47.1)	18.2 (14.9-22.0)	25.2 (21.5-29.3)	38.9 (34.2-43.9)	42.5 (37.6-47.5)
	31-44 years	21.2 (18.6-24.1)	37.1 (32.4-42.0)	59.1 (54.2-63.9)	21.2 (17.4-25.5)	34.3 (29.1-40.0)	45.5 (38.6-52.7)	55.8 (49.5-61.9)
	45-65 years	23.4 (20.2-27.0)	41.4 (36.6-46.2)	55.8 (50.5-61.1)	27.2 (24.0-30.8)	39.3 (33.8-45.0)	52.6 (45.2-60.0)	65.8 (59.0-71.9)
	66+ years	36.7 (32.6-41.0)	44.6 (40.7-48.5)	53.7 (49.9-57.5)	33.4 (28.7-38.4)	45.6 (41.6-49.7)	55.3 (49.6-60.8)	63.2 (55.5-70.3)
Periodontal disease: prevalence (95%CI)	17-30 years	7.1 (5.3-9.4)	8.2 (6.4-10.6)	12.6 (9.4-16.7)	5.7 (3.3-9.5)	8.7 (6.7-11.2)	9.5 (7.5-12.0)	14.1 (10.4-18.9)
	31-44 years	17.1 (14.7-19.9)	23.5 (19.5-28.0)	34.7 (28.4-41.7)	15.3 (12.0-19.3)	25.0 (21.6-28.6)	25.9 (20.0-32.7)	37.9 (31.5-44.6)
	45-65 years	28.9 (25.1-33.0)	37.0 (32.4-41.7)	46.4 (41.8-51.1)	28.0 (24.5-31.8)	41.4 (34.9-48.2)	42.4 (35.2-50.0)	53.4 (45.9-60.7)
	66+ years	40.4 (34.6-46.6)	41.1 (34.6-46.6)	49.0 (43.6-54.3)	39.8 (35.3-44.5)	44.3 (36.5-52.4)	45.2 (39.3-51.3)	48.1 (40.7-55.6)
Edentulousness: prevalence (95%CI)	17-30 years	0	0.1 (0.1-0.1)	0.1 (0.1-0.1)	0.1 (0.1-0.1)	0	0.1 (0.1-1.3)	0.4 (0.1-2.1)
	31-44 years	0.8 (0.2-2.7)	2.8 (1.7-4.4)	5.6 (3.6-8.7)	0.9 (0.3-2.2)	2.1 (1.1-4.0)	5.3 (3.1-9.0)	4.0 (2.2-7.3)
	45-65 years	5.1 (3.5-7.5)	14.6 (12.3-17.3)	27.4 (23.4-31.9)	7.7 (5.9-10.2)	18.6 (15.3-22.4)	21.4 (17.9-25.3)	27.8 (22.6-27.8)
	66+ years	16.2 (13.0-20.1)	30.3 (25.5-35.6)	46.0 (42.1-50.0)	15.1 (11.4-19.8)	34.0 (30.1-38.3)	46.1 (42.0-50.2)	47.7 (41.8-53.8)

Table 4.2 (continued) Distribution of general and oral health outcomes by years of education and income groups

Condition	Age group	Years of education			Income			
		>12 years	12 years	<12 years	highest quartile	2nd highest quartile	2nd lowest quartile	lowest quartile
Extent gingival bleeding: mean (95%CI)	17-30 years	6.7 (5.5-8.0)	10.1 (8.5-11.7)	13.3 (11.6-15.0)	6.6 (5.3-7.9)	9.0 (7.9-10.1)	11.5 (9.2-13.9)	12.3 (10.2-14.5)
	31-44 years	5.8 (4.6-6.9)	8.8 (7.1-10.5)	12.1 (9.9-14.3)	5.2 (3.8-6.5)	8.0 (6.5-9.5)	10.6 (8.6-12.7)	14.2 (11.4-16.9)
	45-65 years	7.6 (6.1-9.0)	10.2 (8.8-11.5)	15.6 (13.5-17.6)	8.1 (6.8-9.3)	11.1 (8.5-13.7)	14.0 (10.8-17.2)	17.3 (14.6-20.0)
	66+ years	10.5 (8.8-12.1)	10.8 (8.6-13.0)	15.9 (14.0-17.9)	9.8 (8.2-11.4)	13.4 (10.0-16.8)	14.0 (11.6-16.4)	16.5 (13.1-19.8)
Extent loss of periodontal attachment: mean (95%CI)	17-30 years	0.9 (0.6-1.2)	1.4 (1.0-1.8)	2.2 (1.4-3.0)	0.9 (0.4-1.3)	1.4 (1.0-1.8)	1.5 (1.1-2.0)	2.3 (1.4-3.1)
	31-44 years	4.1 (3.3-4.8)	7.6 (6.5-8.5)	12.8 (10.5-15.2)	4.8 (3.9-5.7)	6.2 (4.7-7.7)	8.9 (6.9-10.8)	12.3 (9.9-14.7)
	45-65 years	13.5 (11.7-15.2)	20.1 (17.9-22.4)	29.0 (25.8-32.2)	14.9 (13.4-16.4)	21.7 (18.5-25.0)	24.5 (20.6-28.5)	32.3 (26.7-37.9)
	66+ years	23.7 (19.3-28.2)	26.7 (22.1-31.3)	35.9 (32.8-39.1)	24.4 (20.0-28.7)	26.8 (23.5-30.2)	35.0 (30.2-39.7)	40.5 (35.5-45.5)
Extent periodontal pocket: mean (95%CI)	17-30 years	0.8 (0.6-1.1)	1.8 (1.3-2.2)	2.4 (1.8-2.9)	0.7 (0.4-1.1)	1.5 (1.1-1.9)	2.1 (1.6-2.7)	2.3 (1.7-2.8)
	31-44 years	1.5 (1.1-1.9)	3.0 (2.2-3.7)	4.8 (3.5-6.1)	1.4 (1.0-1.9)	2.4 (1.8-3.0)	3.7 (2.7-4.6)	5.8 (4.2-7.3)
	45-65 years	2.1 (1.4-2.8)	3.9 (2.9-4.9)	5.7 (4.1-7.4)	2.4 (1.7-3.2)	3.8 (2.6-5.0)	4.9 (3.2-6.6)	8.5 (5.9-11.0)
	66+ years	2.3 (1.5-3.1)	2.1 (1.3-2.9)	4.7 (3.5-5.8)	2.3 (1.5-3.1)	2.6 (1.7-3.5)	3.6 (2.3-4.9)	5.8 (4.1-7.5)
Number of missing tooth surfaces: mean (95%CI)	17-30 years	2.0 (1.3-2.6)	3.9 (3.0-4.9)	5.2 (4.1-6.4)	1.9 (1.2-2.6)	3.4 (2.2-4.6)	4.5 (3.4-5.7)	5.3 (3.9-6.7)
	31-44 years	7.7 (6.1-9.2)	19.0 (16.3-21.7)	29.9 (25.6-34.2)	9.1 (6.5-11.7)	15.5 (12.4-18.6)	24.2 (20.6-27.8)	22.8 (18.4-27.2)
	45-65 years	24.6 (21.5-27.7)	48.8 (45.4-52.3)	69.7 (64.7-74.7)	32.2 (28.9-35.5)	52.1 (47.0-57.2)	60.4 (56.0-64.8)	68.1 (62.7-73.4)
	66+ years	51.3 (46.9-55.7)	72.1 (67.3-76.9)	88.5 (85.2-91.9)	50.5 (45.3-55.7)	75.8 (71.0-80.6)	88.4 (85.5-91.3)	91.8 (86.3-97.3)

4.4 Summary of the results reported in Chapter 4

- African Americans and Hispanic Americans generally experienced poorer general and oral health compared to White Americans.
- Women generally had better oral health and poorer perceived general health compared to men.
- There were clear education and income gradients in all oral and general health outcomes and for almost all age groups.
- Generally, the gradients in oral and general health were steeper for middle-aged individuals than other age groups.
- The distribution of all health outcomes, by education and income, suggests that there are similarities in the social gradients for oral and general health. However, before coming to definitive conclusions on the basis of evidence presented here, further analysis is needed to control for other determinants and confounders. The results of that analysis are presented in Chapter 5.

CHAPTER 5

Assessing education and income gradients in selected oral and general health indicators

CHAPTER 5

Assessing education and income gradients in selected oral and general health indicators

5.1 Introduction

This chapter presents the binary and adjusted association between some general and oral conditions with education and income. The general health indicators are ischaemic heart disease and perceived general health. The oral health indicators are perceived oral health, periodontitis, extent of gingival bleeding, extent of loss of attachment, extent of pocket depth, edentulousness and loss of tooth surfaces.

Odds ratios reflect probability of having the condition, regression coefficients reflect the change in the occurrence of the condition (a negative sign before the figure reflects decrease in the condition), count ratios reflect the ratio of the occurrence of the condition, compared to reference group or baseline.

5.2 Social gradients in oral and general health

5.2.1 Social gradients in ischaemic heart disease

The unadjusted models for ischaemic heart disease showed that persons in the middle and lowest education groups respectively were 1.35 and 2.91 times more likely to have ischaemic heart disease compared to those in the highest education group. Persons at each higher unit of income were 0.83 less likely to have ischaemic heart disease (Table 5.1). In the ischaemic heart disease models adjusting for education, income, sex, ethnicity, age, smoking, medical insurance, diabetes, BMI and blood pressure, the relationship persisted and remained significant except for the middle level of education. Persons in the middle and lowest education groups were 1.00 (CI 0.78-1.26) and 1.43 (CI 1.06-1.91) more likely to have ischaemic heart disease compared to those in the highest education group. With each unit increase in income, individuals were 0.87 (CI 0.82-0.94) less likely to have ischaemic heart disease (Table 5.1). The only other variables that showed significant associations with an increase in the probability of having ischaemic heart disease in the adjusted models were older age, high blood pressure and diabetes.

5.2.2 Social gradients in perceived general health

In the unadjusted models for perceived general health, persons with 12 years and less than 12 years of education were respectively 2.05 and 6.03 times more likely to report poorer general health compared to persons with more than 12 years of education. With each unit increase in income, individuals were 0.67 times less likely to report poorer perceived general health. In the perceived general health models adjusting for education, income, sex, ethnicity, age, smoking and medical insurance, persons in the middle and lowest education groups were respectively 1.45 and 2.57 times more likely to report poorer general health compared to highest education group. For each unit increase in income, individuals were 0.77 (CI 0.73-0.82) times less likely to report poorer perceived general health (Table 5.1). Other factors significantly associated with poorer perceived general health included ethnicity (African Americans, Hispanic Americans), sex (female), and older age.

5.2.3 Social gradients in perceived oral health

In the unadjusted models for perceived oral health, persons with 12 years and less than 12 years of education were respectively 1.99 and 3.4 times more likely to report poorer oral health compared to persons with more than 12 years of education. For each unit increase in income, individuals were 0.78 times less likely to report poorer oral health (Table 5.1). In the adjusted models, which controlled for age, sex, ethnicity, smoking, and dental insurance, the odds ratios attenuated but remained significant at all levels. Persons in the 12 years and less than 12 years of education groups were 1.56 and 2.01 respectively more likely to report poorer perceived oral health compared to the highest education group. In the adjusted models, with each unit increase in income individuals were 0.84 (CI 0.80-0.89) times less likely to report poorer oral health (Table 5.1). Other factors which were significantly associated with poorer perceived oral health included ethnicity: being African American and Hispanic American, older age, and being a current smoker.

Generally, the probability of reporting poorer perceived general health and perceived oral health with lower levels of education and income appeared to be consistent (Figure 5.1).

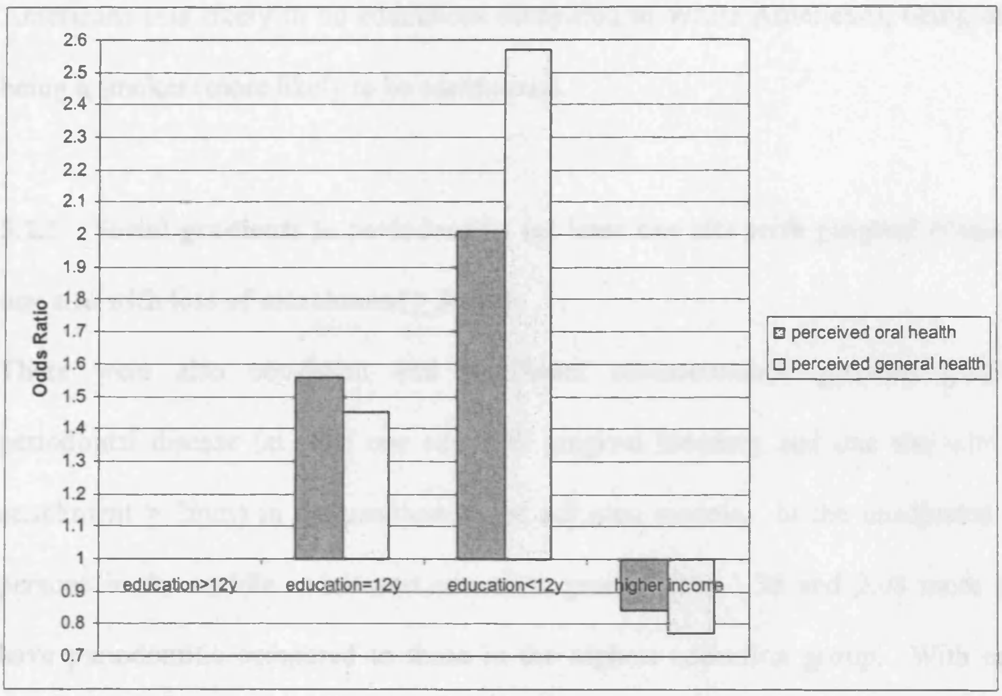


Figure 5.1 **Adjusted odds ratios for having poor-fair perceived General and Oral Health, by education groups and increase in income.**

5.2.4 Social gradients in edentulousness

Being completely edentulous was significantly more likely in persons with less education or who were poorer. The odds ratios were always significant in both of the adjusted and unadjusted models. In the unadjusted models, the middle and lowest education groups had odds ratios of 3.30 and 9.01, respectively, for being edentulous. The association between edentulousness and increase in income had an odds ratio of 0.71. In the adjusted models controlling for education, income, sex, ethnicity, age, smoking and dental insurance, the middle and lowest education groups and the increase of income had odds ratios of 2.40, 3.88 and 0.75, respectively (Table 5.1). Other factors significantly associated with edentulousness included ethnicity (African Americans and Hispanic

Americans less likely to be edentulous compared to White American), being older and being a smoker (more likely to be edentulous).

5.2.5 Social gradients in periodontitis (at least one site with gingival bleeding and one site with loss of attachment ≥ 3mm)

There were also consistent and significant socioeconomic position gradients in periodontal disease (at least one site with gingival bleeding and one site with loss of attachment ≥ 3mm) in the unadjusted and adjusted models. In the unadjusted models, persons in the middle and lowest education groups were 1.38 and 2.08 more likely to have periodontitis compared to those in the highest education group. With each unit increase in income, individuals were 0.90 less likely to have periodontitis (Table 5.1). In models adjusting for education, income, sex, ethnicity, age, smoking, dental insurance and diabetes, the odds ratios for the middle and lowest education groups and income were 1.24, 1.37 and 0.87, respectively (Table 5.1). Other factors significantly associated with higher probability of periodontitis included ethnicity (African Americans and other ethnicities), older age, sex (male) and diabetes.

There were consistent education and income gradients in all the dichotomous oral and general health indicators, namely in ischaemic heart disease, edentulousness and periodontal disease. Similarly, there were consistent socioeconomic position gradients in perceived oral health and perceived general health (Figures 5.1 and 5.2).

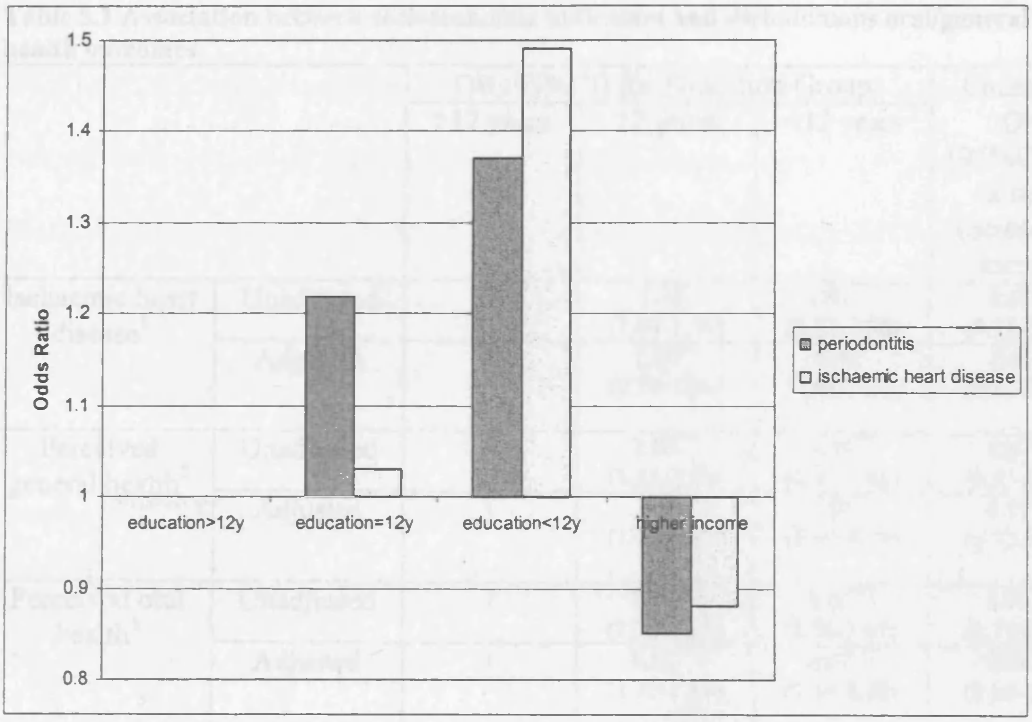


Figure 5.2 Adjusted odds ratios for having periodontal disease and ischaemic heart disease, by education groups and increase in income.

Table 5.1 Association between socioeconomic indicators and dichotomous oral/general health outcomes

		OR (95%CI) for Education Groups			Change in OR (95%CI) for a unit increase of income
		>12 years	12 years	<12 years	
Ischaemic heart disease[1]	Unadjusted	1	1.35* (1.04-1.76)	2.91*** (2.23-3.80)	0.83*** (0.78-0.89)
	Adjusted	1	1.00^{NS} (0.78-1.26)	1.43* (1.06-1.91)	0.87** (0.82-0.94)
Perceived general health[2]	Unadjusted	1	2.05*** (1.65-2.55)	6.03*** (4.87-7.46)	0.67*** (0.63-0.70)
	Adjusted	1	1.45** (1.15-1.83)	2.57*** (2.04-3.23)	0.77*** (0.73-0.82)
Perceived oral health[3]	Unadjusted	1	1.99*** (1.74-2.28)	3.40*** (2.96-3.91)	0.78*** (0.74-0.82)
	Adjusted	1	1.56*** (1.35-1.81)	2.01*** (1.69-2.39)	0.84*** (0.80-0.89)
Edentulousness[4]	Unadjusted	1	3.30*** (2.42-4.50)	9.01*** (6.27-12.94)	0.71*** (0.67-0.75)
	Adjusted	1	2.40*** (1.71-3.36)	3.88*** (2.47-6.10)	0.75*** (0.70-0.80)
Periodontal Disease[5]	Unadjusted	1	1.38*** (1.16-1.64)	2.08*** (1.73-2.50)	0.90*** (0.87-0.93)
	Adjusted	1	1.24* (1.01-1.52)	1.37* (1.07-1.76)	0.87*** (0.84-0.91)

[1] Ischaemic heart disease (angina cases according to Rose questionnaire or reported diagnosis of heart attack), adjusted model controls for education, income, medical insurance, sex, ethnicity, age, smoking (currently smoker), reported diagnosis of diabetes, BMI, and high blood pressure.
[2] Perceived general health poor/fair, adjusted model controls for education, income, medical insurance, sex, ethnicity, age and smoking (currently smoker)
[3] Perceived oral health poor/fair, adjusted model controls for education, income, dental insurance, sex, ethnicity, age and smoking (currently smoker)
[4] Completely edentulous, adjusted model controls for education, income, dental insurance, sex, ethnicity, age and smoking (currently smoker)
[5] Periodontal disease (at least one gingival bleeding site and one site loss of attachment $\geq$ 3mm), adjusted model controls for education, income, medical insurance, sex, ethnicity, age, smoking (currently smoker) and reported diagnosis of diabetes.
*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

5.2.6 Social gradients in the extent of gingival bleeding

The analysis of the association between extent of gingival bleeding, extent of loss of attachment and extent of pocket depth showed significant education and income gradients for these three outcomes in both the unadjusted and adjusted models (Table 5.2).

Extent of gingival bleeding in the unadjusted model was greater by 3.22 and 7.80 for people in the middle and lowest education groups respectively compared to those in the highest education group. For each higher unit of income, the extent of gingival bleeding was smaller by 1.39. In the adjusted models, controlling for education, income, age, sex, ethnicity, dental insurance, diabetes and smoking, the regression coefficient for the middle and lowest education group and income were 2.48, 5.57 and -0.98, respectively (Table 5.2). Other variables in the adjusted models that were significantly associated with higher levels of bleeding extent included lack of dental insurance, sex (male), being a non-smoker, older age and diabetes.

5.2.7 Social gradients in the extent of loss of periodontal attachment

In the unadjusted models for extent of loss of periodontal attachment, the regression coefficients for the middle and lowest education groups and income were 3.36, 10.22 and -0.49, respectively. In the adjusted models, controlling for education, income, age, sex, ethnicity, dental insurance, diabetes and smoking, persons in the middle and lowest education groups had 2.19 and 6.86 greater extent of loss of attachment, respectively. There was a 0.66 decrease in extent of loss of attachment with each higher unit of income (Table 5.2). Other factors significantly associated with an increase in the extent of loss of attachment were ethnicity (African Americans and other ethnicity), older age, diabetes and smoking. On the other hands, additional factors associated with a decrease in the extent of loss of attachment were ethnicity (Hispanic Americans) and sex (female).

5.2.8 Social gradients in the extent of periodontal pocket depth

The extent of periodontal pocket depth for persons in the middle and lowest education groups was greater by 1.29 and 3.07 compared to those in the highest education group. At each higher unit of income there was a 0.51 decrease in the percentage of pocket depth. In the adjusted models, controlling for education, income, age, sex, ethnicity, dental insurance, diabetes and smoking, the regression coefficients for the second and lowest education groups, and income were 0.66, 1.76 and -0.33, respectively (Table 5.2). In addition, ethnicity (African Americans), older age, smoking, sex (male) and diabetes were significantly associated with higher extent of pocket depth.

Overall, education gradients were steeper in loss of attachment and gingival bleeding models compared to pocket depth. Income gradients were steeper in the gingival bleeding models (Table 5.2).

Table 5.2 Association between socioeconomic indicators and extent of periodontal diseases

		Regression Coefficient (95%CI) for Education Groups			Regression Coefficient (95%CI) for income
		>12 years	12 years	<12 years	
Extent of gingival bleeding[1]	Unadjusted	0.00	3.22*** (2.24-4.19)	7.81*** (6.46-9.15)	-1.39*** (-1.70 to-1.08)
	Adjusted	0.00	2.48*** (1.54-3.42)	5.57*** (4.17-6.96)	-0.98*** (-1.26 to-0.70)
Extent of loss of attachment[2]	Unadjusted	0.00	3.36*** (2.37-4.35)	10.23*** (8.55-11.89)	-0.49* (-0.86 to -0.11)
	Adjusted	0.00	2.19*** (1.10-3.27)	6.86*** (5.50-8.22)	-0.66*** (-0.99 to-0.32)
Extent of Pocket depth[3]	Unadjusted	0.00	1.29*** (0.87-1.71)	3.07*** (2.24-3.91)	-0.51*** (-0.66 to -0.36)
	Adjusted	0.00	0.66** (0.27-1.05)	1.76*** (1.05-2.48)	-0.33*** (-0.46 to -0.20)

[1] Percentage of sites with gingival bleeding to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking (currently smoker) and reported diagnosis of diabetes.
[2] Percentage of sites with loss of attachment ≥ 3mm to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking (currently smoker) and reported diagnosis of diabetes.
[3] Percentage of sites with pocket depth ≥ 4mm to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking (currently smoker) and reported diagnosis of diabetes.
*** P<0.001 ** P<0.01 * P<0.05 NS Not significant

5.2.9 Social gradients in the loss of tooth surfaces

The "loss of tooth surface" models showed significant higher count ratios (ratio of missing teeth to baseline) at each lower level of education, and a significant lower count ratio at higher income. In the unadjusted model, the count ratios for the middle and lowest education groups were 2.15 and 3.60 respectively compared to the highest education group. For each higher unit of income, the count ratio was 0.89 (Table 5.3). In the adjusted models, controlling for education, income, age, sex, ethnicity, dental insurance and smoking, the count ratios for the middle and lowest education groups, and income were 1.96, 1.97 and 0.89, respectively (Table 5.3). Ethnicity (African Americans and other ethnicities), older age and smoking were significantly associated with higher count ratios of tooth loss, ethnicity (Hispanic Americans) was associated with a lower level of tooth loss.

Table 5.3 Association between socioeconomic indicators and loss of tooth surfaces

		Count Ratio (95%CI) for Education Groups			Count Ratio (95%CI) for income
		>12 years	12 years	<12 years	
Number of missing tooth surfaces due to disease[1]	Unadjusted	1	2.15*** (1.19-2.42)	3.60*** (3.09-4.20)	0.89*** (0.84-0.89)
	Adjusted	1	1.96*** (1.65-2.33)	1.97*** (1.53-2.55)	0.89*** (0.87-0.91)

[1] Number of missing tooth surfaces due to disease, adjusted model controls for education, income, dental insurance, sex, ethnicity, age and smoking (currently smoker)
*** P<0.001 ** P<0.01 * P<0.05 NS Not significant

5.3 Summary of the results reported in Chapter 5

- This analysis showed consistent education and income gradients in all indicators of oral health.
- Similarly, there were education and income gradients in both indicators of general health.
- Education and income gradients in oral health and general health were similar and consistent.
- The associations between all health outcomes and socioeconomic position were statistically significant almost at all levels, and for all the examined indicators of health in the binary and adjusted analysis, with the exception of the adjusted models for the second highest level of education and ischaemic heart disease.
- The results support the first hypothesis on the presence social gradients in oral and general health.
- The results support the second hypothesis about the similarity of the gradients in oral and general health.
- Having comprehensively established the existence of social gradients in different indicators of oral and general health, the following results chapters address the potential pathways that contribute to the gradients in oral and general health.

CHAPTER 6

Assessing the independent effects of race/ethnicity and sex on oral and general health

CHAPTER 6

Assessing the independent effects of race/ethnicity and sex on oral and general health

6.1 Introduction

This chapter presents results on the associations between sex and ethnicity with the health outcomes, within strata of education and income. The chapter also shows the change in the social gradients in all health outcomes after adjusting for sex and ethnicity.

Odds ratios reflect the probability of having the condition, regression coefficients reflect the change in the occurrence of the condition (a negative sign before the figure reflects decrease in the condition), count ratios reflect the ratio of the occurrence of the condition, compared to reference group or baseline.

6.2 Association of sex and ethnicity with oral and general health outcomes within socioeconomic strata.

Tables 6.1.1 to 6.1.9 show the association of ethnicity and sex with the different health outcomes for the whole population and within income and education strata. For each outcome the unadjusted and adjusted analyses were conducted for the whole population, then for each of the four groups of income levels and the three groups of education levels. For the ethnicity, White Americans were used as a reference group. For the sex, males were the reference group.

6.2.1 Association of ischaemic heart disease with ethnicity and sex

Overall, there was no significant difference in the probability of having ischaemic heart disease between African Americans and White Americans in all the models for the whole population and when stratified according to income and education with one exception, namely the unadjusted model for the lowest level of income in which African Americans were 0.68 times less likely to have ischaemic heart disease compared to White Americans, respectively (Table 6.1.1).

Similarly, there was no significant difference between Hispanic Americans and White Americans in ischaemic heart disease in most of the models. However, as a general trend Hispanic Americans always had lower odds ratios for having ischaemic heart disease. These odds ratios were statistically significant in six of the unadjusted models, the three top income strata and all three education strata with odds ratios of 0.44, 0.53, 0.61, 0.59, 0.54 and 0.62, respectively (Table 6.1.1).

Persons of other ethnicities were not statistically different from White Americans in any of the models pertaining to ischaemic heart disease. There were no statistical differences between men and women in any of the ischaemic heart disease models (Table 6.1.1).

6.2.2 Association of perceived general health with ethnicity and sex

African Americans were more likely to report poorer general health compared to White Americans in the whole population models. The odds ratios were 2.01 and 1.75 in the unadjusted and adjusted models. Generally, African Americans were statistically more likely to report poorer general health across income and education strata. However, in the lowest income stratum there was no significant difference between African Americans and White Americans in perceived general health with odds ratios 1.10 and 1.24 in the unadjusted and adjusted models, respectively (Table 6.1.2).

Hispanic Americans were consistently more likely to report poorer perceived general health compared to White Americans in the whole population and across income and education strata. The odds ratios for the whole populations models were 2.86 and 2.56 in the unadjusted and adjusted models, respectively (Table 6.1.2).

Persons of other ethnicities were statistically more likely to report poorer perceived general health in the whole population model with odds ratios 1.76 and 1.86 in the unadjusted and adjusted models. However, this significance disappeared when the population was stratified according to income and education with one exception, namely the middle education stratum where other ethnicities were statistically more likely to report poorer general health with odds ratios 2.43 and 2.71 in the unadjusted and adjusted models (Table 6.1.2).

The probabilities of women reporting poorer general health were always higher than that for men. However, it was only significant in the whole population models (odds ratio 1.21 in unadjusted and adjusted models), in the lowest level of income (odds ratio 1.22 and 1.44 in unadjusted and adjusted models), and in the lowest education level (odds ratio 1.42 and 1.41 in unadjusted and adjusted models) (Table 6.1.2).

6.2.3 Association of perceived oral health with ethnicity and sex

African Americans were significantly more likely to report poorer perceived oral health compared to White Americans in the whole population model. The odds ratios were 1.84

and 1.66 in the unadjusted and adjusted models. When the population was stratified according to income and education the odds ratio increased in the highest two income groups in the adjusted model and attenuated in the second lowest income group. In the lowest income group there was no statistically significant difference in reported poorer oral health between African Americans and White Americans with odds ratio 1.18 and 1.21 in the unadjusted and adjusted models. Similarly, in the education strata, the probabilities of African Americans reporting poorer oral health in the highest two groups of education were higher than in the whole population model. In the lowest education stratum the probability of reporting poorer oral health slightly attenuated with odds ratios 1.32 and 1.31 in the unadjusted and adjusted model, but remained significant (Table 6.1.3).

As for perceived general health, Hispanic Americans were consistently significantly more likely to report poorer oral health in the whole population models and across strata of socioeconomic position. The odds ratios for Hispanic Americans reporting poorer oral health in the whole population model were 2.47 and 2.06 in the unadjusted and adjusted models (Table 6.1.3).

Persons of other ethnicities were significantly more likely to report poorer oral health in the adjusted whole population model. The odds ratio was 1.41. The significant differences between other ethnicities and White Americans disappeared when the population was stratified according to socioeconomic position (Table 6.1.3).

Women had a lower probability of reporting poorer oral health in the whole population analysis but it was not statistically significant. When the population was stratified according to income and education, women were less likely to report poorer oral health in the highest level of income and the second level of education with odds ratios 0.72, 0.78, 0.78 and 0.77 in the unadjusted and adjusted models, respectively (Table 6.1.3).

6.2.4 Association of periodontal disease with ethnicity and sex

In the whole population analysis, African Americans were significantly more likely to have periodontitis with odds ratios 1.27 and 1.44 in the unadjusted and adjusted models. In the stratified analysis, African Americans maintained significant differences from White Americans in the highest two income levels and in all education levels. In the lowest two income strata there was no statistical difference between African Americans and White Americans (Table 6.1.4).

There was no statistical difference between Hispanic Americans and White Americans in periodontal disease in the whole population model or across socioeconomic position strata (Table 6.1.4).

Individuals of other ethnicities were significantly more likely to have periodontitis in the whole population analysis with odds ratios 1.71 and 2.14 in the unadjusted and adjusted models. The significance of the differences disappeared in the analysis pertaining to the lowest levels of income and education (Table 6.1.4).

Women were consistently and significantly less likely than men to have periodontitis in the whole population and across socioeconomic position. The odds ratios in the whole population analysis were 0.63 and 0.60. The significant difference disappeared only in the adjusted model in the lowest education stratum (Table 6.1.4).

6.2.5 Association of extent of gingival bleeding with ethnicity and sex

African Americans had significantly higher levels of gingival bleeding in the unadjusted model for the whole population but the significance disappeared in the adjusted model with regression coefficient 2.89 and 1.61, respectively. In the income strata there were no differences between African Americans and White Americans in extent of gingival bleeding. However, the significant difference reappeared in the highest level of education stratum with regression coefficients of 2.71 and 2.62 in the unadjusted and adjusted models (Table 6.1.5). Figure 6.1 shows the differences in bleeding extent for African Americans in the whole population and the lowest stratum of income and education.

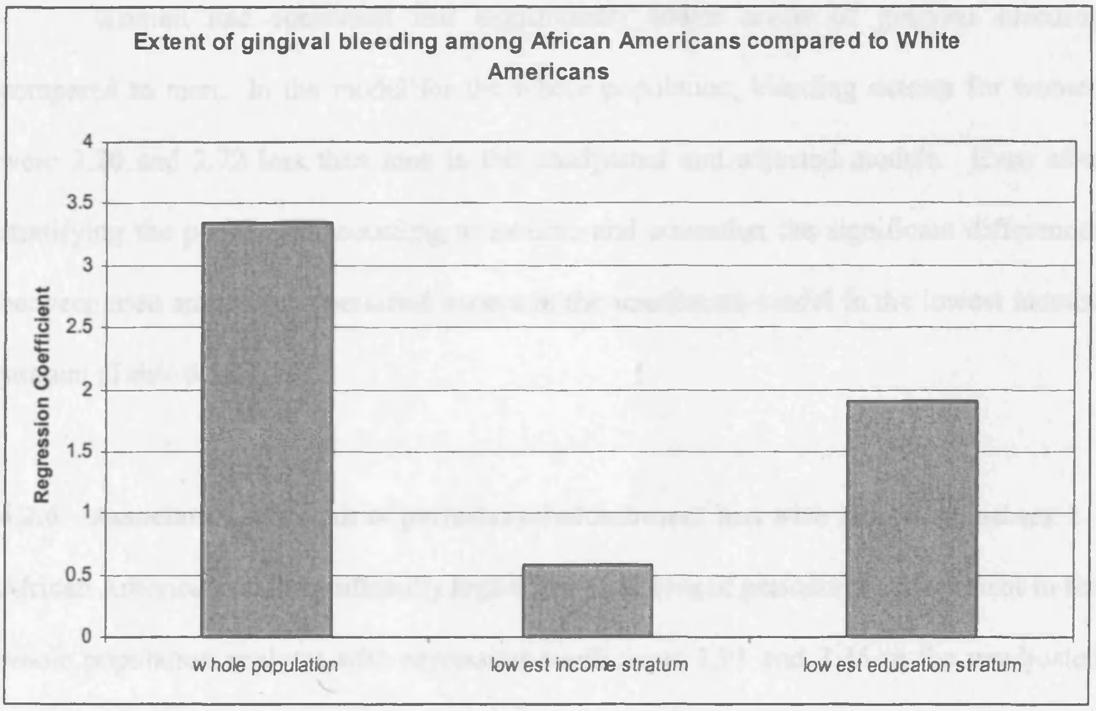


Figure 6.1 Adjusted increases in gingival bleeding among African Americans compared to White Americans in the whole population and the lowest strata of income and education

Hispanic Americans had statistically higher levels of gingival bleeding in the unadjusted model for the whole population with regression coefficient 4.20. However, the difference disappeared in the adjusted model. Across income and education strata, there was no difference in gingival bleeding between Hispanic Americans and White Americans except in the unadjusted model for second highest income stratum and both models of highest education stratum (Table 6.1.5).

Other ethnicities had significantly higher levels of gingival bleeding only in the unadjusted model for the whole population and unadjusted and adjusted models for highest education stratum with regression coefficients 2.79, 4.84, 4.15, respectively (Table 6.1.5).

Women had consistent and significantly lower levels of gingival bleeding compared to men. In the model for the whole population, bleeding extents for women were 2.20 and 2.72 less than men in the unadjusted and adjusted models. Even after stratifying the population according to income and education the significant differences between men and women persisted except in the unadjusted model in the lowest income stratum (Table 6.1.5).

6.2.6 Association of extent of periodontal attachment loss with ethnicity and sex

African Americans had significantly higher levels of loss of periodontal attachment in the whole population analysis with regression coefficients 1.91 and 3.35 in the unadjusted and adjusted models. When the population was stratified according to income and education, the significant differences in loss of periodontal attachment persisted in the adjusted models in the highest three income and highest two education strata. In the lowest levels of income and education there was no difference in loss of periodontal attachment between African Americans and White Americans (Table 6.1.6).

Hispanic Americans had significantly lower levels of loss of periodontal attachment compared to White Americans in the models for the whole population with regression coefficients -2.15 and -1.24 in the unadjusted and adjusted models. In the analysis pertaining to the stratified population according to socioeconomic position, there was no significant difference in loss of periodontal attachment between Hispanic Americans and White Americans in all adjusted models across income and education strata except in the lowest education stratum where Hispanic Americans had less levels of loss of periodontal attachment (-3.09). In all the unadjusted models, Hispanic Americans had significant lower levels of periodontal attachment loss except in the lowest stratum of income (Table 6.1.6).

Persons of other ethnicities had higher level of loss of periodontal attachment in the adjusted models for the whole population, second lowest income stratum, highest and second highest education strata with regression coefficients of 3.82, 6.86, 5.39 and 6.52 respectively (Table 6.1.6).

Women had consistently and significantly lower levels of periodontal attachment loss compared to men in the whole population analysis and across socioeconomic position strata with the exception of the unadjusted model of the second lowest income strata. The regression coefficients in the unadjusted and adjusted whole population analysis were -3.88 and -3.47, respectively (Table 6.1.6).

6.2.7 Association of extent of periodontal pocket depth with ethnicity and sex

African Americans had higher levels of pocket depth compared to White Americans in the whole population analysis with regression coefficients 2.90 and 2.61 in the unadjusted and adjusted models. When the population was stratified according to socioeconomic position, the differences persisted but attenuated and were marginally significant in the adjusted model of the lowest income stratum (Table 6.1.7).

Hispanic Americans only had higher level of pocket depth in the unadjusted model for the whole population with a regression coefficient of 1.01 and in the unadjusted model in the highest education stratum with a regression coefficient of 0.64. In all other models, there were no differences between Hispanic Americans and White Americans in pocket depth (Table 6.1.7).

There was no significant difference in pocket depth between other ethnicities and White Americans in any of the models for the whole population and across socioeconomic position strata (Table 6.1.7).

Women consistently and significantly had lower levels of pocket depths compared to men in the whole population analysis (regression coefficients -1.09 and -0.97 in the unadjusted and adjusted models). This trend persisted when the population was stratified according to income and education with one exception, the adjusted model for highest level of education (Table 6.1.7).

6.2.8 Association of edentulousness with ethnicity and sex

Overall, African Americans were statistically less likely to be edentulous compared to White Americans in most of the models. In the whole population models the odds ratios were 0.65 and 0.60 in the unadjusted and adjusted models, respectively. The significant differences disappeared in the highest income stratum and the highest education stratum. In the lowest income and education strata African Americans were even less likely to be edentulous than they did in the whole population with odds ratios 0.38, 0.41, 0.49 and 0.54 in the unadjusted and adjusted models, respectively (Table 6.1.8).

Hispanic Americans were consistently and significantly less likely to be edentulous in the whole population analysis (odds ratios 0.19 and 0.18 in the unadjusted and adjusted models) and across socioeconomic position strata, with one exception; the adjusted model for the highest education stratum (Table 6.1.8).

Persons of other ethnicities always had lower probabilities of being edentulous. However, the probabilities were not always statistically significant. In the whole population analysis other ethnicities were 0.45 and 0.60 significantly less likely to be edentulous (Table 6.1.8). Overall there were no statistical differences in edentulousness between men and women in the whole population analysis or across socioeconomic position strata (Table 6.1.8).

6.2.9 Association of tooth surface loss with ethnicity and sex

African Americans had significantly higher ratios of tooth loss compared to White Americans in the analysis for the whole population with count ratios of 1.09 and 1.88 in the unadjusted and adjusted models. When the population was stratified according to income and education the significant differences in tooth loss between African Americans and White Americans persisted in the top income and education strata but disappeared in the lowest income and education strata (Table 6.1.9). Figure 6.2 shows the count ratio of tooth loss for African Americans in the whole population, and in the lowest stratum of income and education.

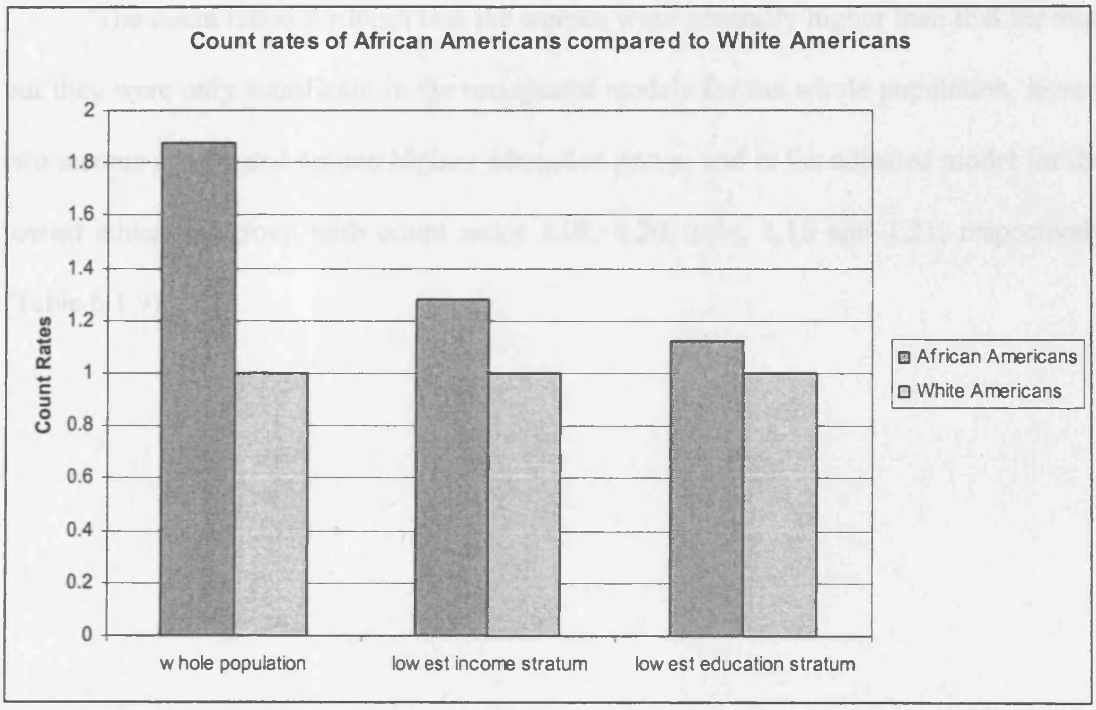


Figure 6.2 Adjusted count ratios of missing tooth surfaces among African Americans compared to White Americans in the whole population and the lowest strata of income and education.

Hispanic Americans had significantly lower ratios of tooth loss compared to White Americans in the models for the whole population with count ratios of 0.48 and 0.76 in the unadjusted and adjusted models. When the population was grouped according to income and education, Hispanic Americans continued to have significant lower ratios of tooth loss with the exception of the adjusted model for the highest income and education strata (Table 6.1.9).

Persons of other ethnicities had higher ratios of tooth loss in the adjusted model for the whole population (1.56). In the adjusted models of the highest two income and highest education strata the significant difference persisted in the same manner.

However, in the lowest education and income strata there was no difference between other ethnicities and White Americans (Table 6.1.9).

The count ratios for tooth loss for women were generally higher than that for men but they were only significant in the unadjusted models for the whole population, lowest two income groups and second highest education group, and in the adjusted model for the lowest education group with count ratios 1.08, 1.20, 1.24, 1.15 and 1.21, respectively (Table 6.1.9).

Table 6.1.1 Associations of ethnicity and sex with ischaemic heart disease

		OR (95%CI) for Ethnicity							OR (95%CI) for Sex		
		White Americans	African Americans		Hispanic Americans		Others		Males	Females	
		Ref	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Ref	Unadjusted	Adjusted
Ischaemic heart disease[2]	Whole population	1	1.03^{NS} (0.83-1.27)	0.94^{NS} (0.76-1.17)	0.87^{NS} (0.71-1.08)	0.90^{NS} (0.69-1.16)	0.89^{NS} (0.55-1.43)	1.04^{NS} (0.68-1.58)	1	0.95^{NS} (0.79-1.14)	1.01^{NS} (0.83-1.22)
	Income 1[1]	1	0.85^{NS} (0.51-1.40)	1.06^{NS} (0.63-1.78)	0.44* (0.20-0.95)	0.57^{NS} (0.25-1.33)	0.08* (0.01-0.59)	0.10* (0.01-0.76)	1	0.79^{NS} (0.49-1.28)	0.94^{NS} (0.56-1.57)
	Income 2	1	0.75^{NS} (0.48-1.16)	0.93^{NS} (0.57-1.50)	0.53* (0.31-0.89)	0.70^{NS} (0.38-1.30)	1.32^{NS} (0.55-3.18)	1.89^{NS} (0.85-4.20)	1	0.97^{NS} (0.67-1.40)	1.11^{NS} (0.77-1.60)
	Income 3	1	0.68* (0.51-0.91)	0.90^{NS} (0.67-1.22)	0.61* (0.41-0.91)	0.93^{NS} (0.59-1.47)	0.60^{NS} (0.26-1.38)	0.89^{NS} (0.37-2.13)	1	0.76* (0.58-0.99)	0.82^{NS} (0.59-1.13)
	Income 4	1	0.83^{NS} (0.52-1.34)	0.76^{NS} (0.48-1.22)	0.72^{NS} (0.44-1.17)	0.86^{NS} (0.47-1.58)	0.44^{NS} (0.15-1.31)	0.51^{NS} (0.18-1.51)	1	1.33^{NS} (0.94-1.89)	1.27^{NS} (0.88-1.83)
	Education1	1	0.95^{NS} (0.60-1.50)	1.18^{NS} (0.72-1.95)	0.59* (0.35-0.99)	0.89^{NS} (0.49-1.62)	0.43^{NS} (0.15-1.21)	0.57^{NS} (0.18-1.69)	1	0.81^{NS} (0.54-1.23)	0.88^{NS} (0.61-1.26)
	Education2	1	0.84^{NS} (0.59-1.20)	1.07^{NS} (0.70-1.65)	0.54** (0.37-0.79)	0.80^{NS} (0.51-1.25)	1.49^{NS} (0.57-3.90)	1.75^{NS} (0.71-4.35)	1	1.01^{NS} (0.71-1.43)	0.97^{NS} (0.67-1.41)
	Education3	1	0.88^{NS} (0.64-1.20)	0.80^{NS} (0.58-1.10)	0.62** (0.46-0.82)	0.80^{NS} (0.55-1.16)	0.71^{NS} (0.31-1.60)	0.92^{NS} (0.39-2.18)	1	1.04^{NS} (0.82-1.32)	1.16^{NS} (0.89-1.52)

[1] Income is categorised into quartiles: 1>3.240, 2 = 1.886-3.240 , 3= 1.007-1.885 and 4 < 1.007. Education 1 >12 years, Education 2=12 years, and Education 3<12 years.

[2] ischaemic heart disease (angina cases according to Rose questionnaire or reported diagnosis of heart attack), in addition to education and income adjusted model controls for medical insurance, sex, ethnicity, age, smoking (currently smoker), reported diagnosis of diabetes, BMI, and high blood pressure.

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

Table 6.1.2 Associations of ethnicity and sex with perceived general health

		OR (95%CI) for Ethnicity							OR (95%CI) for Sex		
		White Americans	African Americans		Hispanic Americans		Others		Males	Females	
		Ref	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Ref	Unadjusted	Adjusted
Perceived general health[2]	Whole population	1	2.01*** (1.72-2.35)	1.75*** (1.51-2.02)	2.86*** (2.37-3.43)	2.56*** (2.06-3.20)	1.76** (1.20-2.59)	1.86** (1.25-2.76)	1	1.21*** (1.10-1.34)	1.21** (1.06-1.39)
	Income 1[1]	1	1.66** (1.24-2.22)	2.09*** (1.52-2.87)	1.65** (1.20-2.27)	2.23*** (1.61-3.09)	1.15^{NS} (0.50-2.64)	1.51^{NS} (0.64-3.58)	1	1.12^{NS} (0.86-1.47)	1.30^{NS} (0.96-1.75)
	Income 2	1	1.41* (1.07-1.85)	1.90*** (1.45-2.48)	1.67** (1.22-2.29)	2.26*** (1.53-3.33)	1.70^{NS} (0.92-3.17)	2.48** (1.39-4.44)	1	1.02^{NS} (0.74-1.40)	1.07^{NS} (0.76-1.51)
	Income 3	1	1.30* (1.05-1.62)	1.93*** (1.47-2.53)	1.70*** (1.29-2.23)	2.64*** (1.79-3.90)	0.85^{NS} (0.48-1.52)	1.31^{NS} (0.70-2.44)	1	1.10^{NS} (0.84-1.44)	1.12^{NS} (0.83-1.52)
	Income 4	1	1.10^{NS} (0.84-1.44)	1.24^{NS} (0.90-1.71)	1.81*** (1.35-2.43)	2.18*** (1.44-3.29)	1.27^{NS} (0.61-2.67)	1.53^{NS} (0.67-3.50)	1	1.22* (1.02-1.46)	1.44** (1.16-1.79)
	Education1	1	1.95*** (1.47-2.58)	2.10*** (1.59-2.78)	1.78** (1.24-2.54)	2.37*** (1.67-3.37)	1.65^{NS} (0.87-3.16)	1.18^{NS} (0.85-3.70)	1	1.19^{NS} (0.87-1.64)	1.18^{NS} (0.82-1.70)
	Education2	1	1.77*** (1.44-2.18)	2.12*** (1.63-2.76)	1.87*** (1.42-2.46)	2.76*** (1.88-4.06)	2.43** (1.32-4.45)	2.71** (1.34-5.50)	1	1.05^{NS} (0.85-1.30)	1.01^{NS} (0.80-1.27)
	Education3	1	1.47*** (1.20-1.79)	1.35** (1.09-1.69)	1.74*** (1.43-2.13)	2.11*** (1.61-2.77)	1.16^{NS} (0.72-1.86)	1.37^{NS} (0.84-2.24)	1	1.42** (1.17-1.73)	1.41** (1.11-1.78)

[1] Income is categorised into quartiles: 1>3.240, 2 = 1.886-3.240 , 3= 1.007-1.885 and 4 < 1.007. Education 1 >12 years, Education 2=12 years, and Education 3<12 years.

[2] Perceived general health poor/fair, in addition to education and income adjusted model controls for medical insurance, sex, ethnicity, age and smoking (currently smoker)

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

Table 6.1.3 Association of ethnicity and sex with perceived oral health

		OR (95%CI) for Ethnicity							OR (95%CI) for Sex		
		White Americans	African Americans		Hispanic Americans		Others		Males	Females	
		Ref	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Ref	Unadjusted	Adjusted
Perceived oral health[2]	Whole population	1	1.84*** (1.61-2.11)	1.66*** (1.43-1.92)	2.47*** (2.01-3.04)	2.06*** (1.72-2.45)	1.35^{NS} (1.00-1.84)	1.41* (1.05-1.90)	1	0.92^{NS} (0.82-1.04)	0.93^{NS} (0.81-1.08)
	Income 1[1]	1	1.77*** (1.45-2.17)	1.94*** (1.59-2.39)	1.76*** (1.43-2.17)	2.05*** (1.57-2.67)	1.18^{NS} (0.61-2.27)	1.39^{NS} (0.73-2.65)	1	0.72*** (0.61-0.86)	0.78* (0.63-0.95)
	Income 2	1	1.60*** (1.25-2.04)	1.87*** (1.40-2.49)	1.48** (1.16-1.76)	1.76*** (1.35-2.29)	1.02^{NS} (0.60-1.76)	1.37^{NS} (0.78-2.38)	1	0.97^{NS} (0.79-1.19)	1.01^{NS} (0.79-1.29)
	Income 3	1	1.25^{NS} (0.91-1.72)	1.44* (1.01-2.05)	1.65** (1.17-2.32)	1.79** (1.26-2.53)	1.28^{NS} (0.65-2.50)	1.60^{NS} (0.76-3.33)	1	1.04^{NS} (0.83-1.29)	1.06^{NS} (0.81-1.37)
	Income 4	1	1.18^{NS} (0.81-1.72)	1.21^{NS} (0.83-1.77)	2.26*** (1.55-3.30)	2.18** (1.43-3.34)	1.30^{NS} (0.66-2.59)	1.31^{NS} (0.66-2.60)	1	1.14^{NS} (0.83-1.57)	1.34^{NS} (0.98-1.85)
	Education1	1	1.86*** (1.44-2.39)	1.91*** (1.47-2.48)	1.56** (1.18-2.06)	1.68*** (1.31-2.15)	1.51^{NS} (0.95-2.41)	1.42^{NS} (0.90-2.24)	1	0.99^{NS} (0.80-1.22)	0.99^{NS} (0.80-1.24)
	Education2	1	1.71*** (1.45-2.02)	1.69*** (1.39-2.07)	1.77*** (1.33-2.36)	2.17*** (1.61-2.92)	1.33^{NS} (0.76-2.31)	1.49^{NS} (0.82-2.72)	1	0.78** (0.65-0.93)	0.77** (0.64-0.92)
	Education3	1	1.32* (1.07-1.64)	1.31* (1.06-1.62)	1.82*** (1.53-2.18)	2.05*** (1.62-2.60)	1.03^{NS} (0.65-1.63)	1.30^{NS} (0.83-2.03)	1	1.06^{NS} (0.80-1.41)	1.16^{NS} (0.82-1.63)

[1] Income is categorised into quartiles: 1>3.240, 2 = 1.886-3.240 , 3= 1.007-1.885 and 4 < 1.007. Education 1 >12 years, Education 2=12 years, and Education 3<12 years.

[2] Perceived oral health poor/fair, in addition to education and income adjusted model controls for dental insurance, sex, ethnicity, age and smoking (currently smoker)

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

Table 6.1.4 Association of ethnicity and sex with periodontal disease

		OR (95%CI) for Ethnicity							OR (95%CI) for Sex		
		White Americans	African Americans		Hispanic Americans		Others		Males	Females	
		Ref	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Ref	Unadjusted	Adjusted
Perio[2]	Whole population	1	1.27*** (1.08-1.50)	1.44*** (1.18-1.75)	1.15^{NS} (0.94-1.40)	1.23^{NS} (0.97-1.57)	1.71*** (1.30-2.23)	2.14*** (1.52-3.02)	1	0.63*** (0.53-0.74)	0.60*** (0.49-0.72)
	Income 1[1]	1	1.24^{NS} (0.90-1.73)	1.54** (1.09-2.17)	0.95^{NS} (0.65-1.39)	1.17^{NS} (0.78-1.74)	2.15** (1.26-3.67)	2.81** (1.54-5.13)	1	0.60*** (0.49-0.73)	0.65** (0.50-0.85)
	Income 2	1	1.07^{NS} (0.83-1.38)	1.45* (1.08-1.93)	0.89^{NS} (0.67-1.17)	1.24^{NS} (0.92-1.66)	1.36^{NS} (0.84-2.19)	1.95* (1.06-3.58)	1	0.63*** (0.50-0.78)	0.60*** (0.47-0.78)
	Income 3	1	1.16^{NS} (0.82-1.64)	1.44^{NS} (0.98-2.10)	1.09^{NS} (0.76-1.56)	1.29^{NS} (0.85-1.96)	1.50^{NS} (0.96-2.35)	2.12** (1.28-3.53)	1	0.68* (0.51-0.91)	0.56** (0.39-0.80)
	Income 4	1	1.13^{NS} (0.68-1.87)	1.28^{NS} (0.72-2.29)	1.02^{NS} (0.63-1.65)	1.00^{NS} (0.51-1.98)	1.35^{NS} (0.69-2.66)	1.72^{NS} (0.67-4.44)	1	0.53*** (0.38-0.74)	0.48** (0.31-0.73)
	Education1	1	1.17^{NS} (0.92-1.50)	1.47** (1.11-1.96)	0.82^{NS} (0.60-1.13)	1.02^{NS} (0.70-1.49)	2.32*** (1.50-3.58)	2.69*** (1.59-4.57)	1	0.51*** (0.40-0.65)	0.51*** (0.38-0.67)
	Education2	1	1.05^{NS} (0.83-1.33)	1.34* (1.02-1.77)	0.80^{NS} (0.62-1.03)	1.11^{NS} (0.83-1.49)	1.44^{NS} (0.84-2.45)	1.82* (1.01-3.30)	1	0.71** (0.55-0.91)	0.65** (0.50-0.83)
	Education3	1	1.34* (1.01-1.80)	1.55* (1.08-2.21)	0.95^{NS} (0.71-1.29)	1.32^{NS} (0.89-1.97)	1.02^{NS} (0.57-1.85)	1.61^{NS} (0.78-3.32)	1	0.71* (0.55-0.93)	0.71^{NS} (0.51-1.01)

[1] Income is categorised into quartiles: 1>3.240, 2 = 1.886-3.240 , 3= 1.007-1.885 and 4 < 1.007. Education 1 >12 years, Education 2=12 years, and Education 3<12 years.

[2] Periodontal disease (at least one gingival bleeding site and one site loss of attachment ≥ 3mm), in addition to education and income adjusted model controls for medical insurance, sex, ethnicity, age, smoking (currently smoker) and reported diagnosis of diabetes.

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

Table 6.1.5 Associations of ethnicity and sex with extent of gingival bleeding

		Regression coefficient (95%CI) for Ethnicity							Regression coefficient (95%CI) for Sex		
		White Americans	African Americans		Hispanic Americans		Others		Males	Females	
		Ref	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Ref	Unadjusted	Adjusted
Extent gingival bleeding[2]	Whole population	0.00	2.89** (1.04/4.74)	1.61^{NS} (-0.13/3.34)	4.20*** (1.98-6.42)	0.87^{NS} (-1.26/3.01)	2.79* (0.44/5.14)	1.49^{NS} (-0.81/3.79)	0.00	-2.20*** (-3.00/-1.40)	-2.72*** (-3.43/-2.00)
	Income 1[1]	0.00	0.62^{NS} (-1.15/2.38)	0.83^{NS} (-0.75/2.40)	1.82^{NS} (-0.27/3.90)	1.52^{NS} (-0.39/3.42)	2.13^{NS} (-1.69/5.95)	2.50^{NS} (-1.26/6.25)	0.00	-2.00** (-3.14/-0.87)	-2.05** (-3.20/-0.90)
	Income 2	0.00	0.82^{NS} (-1.29/2.93)	1.40^{NS} (-0.68/3.48)	2.57* (0.11/5.04)	1.87^{NS} (-0.56 to 4.30)	1.10^{NS} (-2.20/4.41)	1.01^{NS} (-2.20/4.22)	0.00	-2.32** (-3.87/-0.77)	-2.80** (-4.32/-1.28)
	Income 3	0.00	1.87^{NS} (-0.71/4.44)	1.81^{NS} (-0.75/4.37)	1.55^{NS} (-1.65/4.76)	-0.49^{NS} (-4.03 to 3.05)	1.10^{NS} (-3.81/6.00)	0.82^{NS} (-4.11/5.74)	0.00	-3.18*** (-5.24/-1.11)	-3.38** (-5.29/-1.48)
	Income 4	0.00	1.77^{NS} (-1.74/5.28)	0.87^{NS} (-2.95/4.69)	1.46^{NS} (-2.50/5.41)	-1.83^{NS} (-6.19 to 2.52)	2.64^{NS} (-3.82/9.10)	1.76^{NS} (-3.95/7.47)	0.00	-4.72 (-7.80/-1.63)	-5.23** (-8.06/-2.40)
	Education1	0.00	2.71** (1.15/4.27)	2.62** (1.05/4.20)	2.65* (0.22/5.08)	2.34* (0.05-4.64)	4.84*** (2.25/7.43)	4.15** (1.50/6.79)	0.00	-2.00** (-3.09/-0.86)	-2.26*** (-3.23/-1.28)
	Education2	0.00	1.20^{NS} (-1.09/3.49)	0.08^{NS} (-2.25/2.41)	2.09^{NS} (-0.52/4.69)	0.62^{NS} (-1.97/1.95)	-0.86^{NS} (-4.64/2.92)	-2.04 (-6.03/1.95)	0.00	-1.56* (-2.90/-0.23)	-2.57*** (-3.76/-1.39)
	Education3	0.00	2.39^{NS} (-0.30/5.08)	1.32^{NS} (-1.49/4.12)	1.11^{NS} (-1.50/3.71)	-0.78^{NS} (-3.94/2.39)	1.15^{NS} (-3.90/6.21)	-0.27^{NS} (-7.02/4.48)	0.00	-4.01** (-6.53/-1.49)	-4.46** (-7.17/-1.74)

[1] Income is categorised into quartiles: 1>3.240, 2 = 1.886-3.240 , 3= 1.007-1.885 and 4 < 1.007. Education 1 >12 years, Education 2=12 years, and Education 3<12 years.

[2] Percentage of sites with gingival bleeding to all examined sites, in addition to education and income adjusted model controls for dental insurance, sex, ethnicity, age, smoking (currently smoker) and reported diagnosis of diabetes.

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

Table 6.1.6 Associations of ethnicity and sex with extent of loss of periodontal attachment

		Regression coefficient (95%CI) for Ethnicity							Regression coefficient (95%CI) for Sex		
		White Americans	African Americans		Hispanic Americans		Others		Males	Females	
		Ref	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Ref	Unadjusted	Adjusted
Extent loss of attachment[2]	Whole population	0.00	1.91** (0.86/2.96)	3.35*** (2.34/4.37)	-2.15** (-3.68/-0.63)	-1.24* (-2.32/-0.17)	1.87^{NS} (-0.55/4.28)	3.82** (1.37/6.27)	0.00	-3.88*** (-4.92/-2.84)	-3.47*** (-4.29/-2.66)
	Income 1[1]	0.00	1.98^{NS} (-0.14/4.11)	3.57*** (2.02/5.12)	-2.43** (-4.22/-0.63)	-0.19^{NS} (-1.59/1.22)	2.35^{NS} (-2.67/7.37)	3.74^{NS} (-1.56/9.04)	0.00	-5.50*** (-6.70/-4.30)	-4.21*** (-5.23/-3.18)
	Income 2	0.00	1.52^{NS} (-0.14/3.19)	3.95*** (2.19/5.71)	-3.63*** (-5.43/-1.82)	-1.21^{NS} (-2.70/0/27)	0.13^{NS} (-3.45/3.71)	3.53^{NS} (-0.77/7.82)	0.00	-2.86** (-4.62/-1.10)	-2.59** (-4.14/-1.03)
	Income 3	0.00	0.80^{NS} (-1.42/3,02)	3.88*** (1.82/5.93)	-3.00* (-5.54/0.47)	0.11^{NS} (-2.01/2.23)	3.34^{NS} (-3.34/10.03)	6.86* (1.21/12.50)	0.00	-1.39^{NS} (-3.14/0.35)	-3.41* (-5.19/-1.63)
	Income 4	0.00	-0.76^{NS} (-5.69/4.16)	0.58^{NS} (-3.03/4.18)	-4.36^{NS} (-9.29/0.58)	-3.97^{NS} (-8.16/0.21)	0.26^{NS} (-6.95/7.47)	1.92^{NS} (-4.44/8.28)	0.00	-4.47** (-7.11/-1.82)	-3.37** (-5.52/-1.22)
	Education1	0.00	1.48^{NS} (-0.09/3.04)	3.84*** (2.55/5.14)	-2.87*** (-4.18/-1.56)	0.36^{NS} (-0.82/1.53)	4.16* (0.19/8.13)	5.39* (1.35/9.42)	0.00	-3.55*** (-4.79/-2.31)	-2.66*** (-3.59/-1.73)
	Education2	0.00	0.18^{NS} (-1.36/1.72)	3.29*** (1.86/4.72)	-4.78*** (-6.49/-3.08)	-0.36^{NS} (-1.32/1.23)	3.76^{NS} (-2.00/9.52)	6.52* (1.28/11.75)	0.00	-3.78*** (-5.76/-1.79)	-4.29*** (-6.06/-2.52)
	Education3	0.00	0.18^{NS} (-2.17/2.52)	1.90^{NS} (-0.45/4.26)	-8.50*** (-10.89/-6.15)	-3.09* (-5.46/-2.89)	-8.52** (-13.14/-3.89)	-1.91^{NS} (-6.72/2.89)	0.00	-4.70** (-7.44/-1.96)	-4.48*** (-6.59/-2.38)

[1] Income is categorised into quartiles: 1>3.240, 2 = 1.886-3.240 , 3= 1.007-1.885 and 4 < 1.007. Education 1 >12 years, Education 2=12 years, and Education 3<12 years.

[2] Percentage of sites with loss of attachment ≥ 3mm to all examined sites, in addition to education and income adjusted model controls for dental insurance, sex, ethnicity, age, smoking (currently smoker) and reported diagnosis of diabetes.

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

Table 6.1.7 Associations of ethnicity and sex with extent of periodontal pocket depth

		Regression coefficient (95%CI) for Ethnicity							Regression coefficient (95%CI) for Sex		
		White Americans	African Americans		Hispanic Americans		Others		Males	Females	
		Ref	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Ref	Unadjusted	Adjusted
Extent pocket depth[2]	Whole population	0.00	2.90*** (1.98/3.82)	2.61*** (1.74/3.48)	1.01** (0.41/1.62)	0.41^{NS} (-0.25/1.07)	0.73^{NS} (-0.31/1.77)	0.81^{NS} (-0.15/1.78)	0.00	-1.09*** (-1.41/-0.76)	-0.97*** (-1.28/-0.66)
	Income 1[1]	0.00	2.39*** (1.26/3.51)	2.46*** (1.40/3.52	0.41^{NS} (-0.36/1.17)	0.64^{NS} (-0.05/1.32)	0.77^{NS} (-1.02/2.57)	1.16^{NS} (-0.57/2.89)	0.00	-1.20*** (-1.62/-0.79)	-0.91*** (-1.30/-0.52)
	Income 2	0.00	2.09*** (1.31/2.87)	2.45*** (1.63/3.27	0.41^{NS} (-0.36/1.17)	0.67^{NS} (-0.18/1.52)	0.77^{NS} (-1.02/2.57)	-0.41^{NS} (-1.62/0.80)	0.00	-1.02** (-1.67/-0.37)	-0.86** (-1.49/-0.23)
	Income 3	0.00	2.65** (0.97/4.34)	3.03*** (1.41/4.65	0.36^{NS} (-0.85/1.58)	0.50^{NS} (-0.82/1.82)	0.50^{NS} (-2.74/1.74)	0.17^{NS} (-2.40/2.73)	0.00	-1.34** (-2.18/-0.51)	-1.39** (-2.32/-0.46)
	Income 4	0.00	2.21^{NS} (0.40/4.82)	2.45* (0.18/4.72	-0.55^{NS} (-2.59/1.49)	-0.21^{NS} (-2.51/2.09)	3.04^{NS} (-2.12/8.20)	4.19^{NS} (-0.73/9.11)	0.00	-1.53* (-3.04/-0.02)	-1.40* (-2.76/-0.04)
	Education1	0.00	2.36*** (1.63/3.09)	2.39*** (1.64/3.14)	0.44^{NS} (-0.09/0.97)	0.64* (0.12/1.15)	1.12^{NS} (-0.65/2.88)	1.11^{NS} (-0.61/2.82)	0.00	-0.42* (-0.79/-0.05)	-0.32^{NS} (-0.69/0.05)
	Education2	0.00	2.60*** (1.41/3.79)	2.53*** (1.37/3.69)	0.19^{NS} (-0.91/0.53)	0.17^{NS} (-0.47/0.81)	0.78^{NS} (-0.94/2.51)	1.07^{NS} (-0.52/2.65)	0.00	-1.59*** (-2.15/-1.04)	-1.54*** (-2.08/-0.99)
	Education3	0.00	2.88** (1.26/4.49)	2.93** (1.22/4.65)	0.02^{NS} (-1.24/1.29)	0.33^{NS} (-1.14/1.80)	-0.87^{NS} (-2.94/1.21)	0.26^{NS} (-1.97/2.48)	0.00	-1.92** (-2.96/-0.87)	-1.68*** (-2.77/-0.59)

[1] Income is categorised into quartiles: 1>3.240, 2 = 1.886-3.240 , 3= 1.007-1.885 and 4 < 1.007. Education 1 >12 years, Education 2=12 years, and Education 3<12 years.

[2] Percentage of sites with pocket depth $\geq$ 4mm to all examined sites, in addition to education and income adjusted model controls for dental insurance, sex, ethnicity, age, smoking (currently smoker) and reported diagnosis of diabetes.

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

Table 6.1.8 Association of ethnicity and sex with edentulousness

		OR (95%CI) for Ethnicity							OR (95%CI) for Sex		
		White Americans	African Americans		Hispanic Americans		Others		Males	Females	
		Ref	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Ref	Unadjusted	Adjusted
Edentulous[2]	Whole population	1	0.65^{***} (0.54-0.79)	0.60^{***} (0.48-0.77)	0.19^{***} (0.14-0.27)	0.18^{***} (0.13-0.25)	0.45^{*} (0.22-0.90)	0.60^{NS} (0.31-1.19)	1	1.05^{NS} (0.92-1.19)	1.04^{NS} (0.88-1.23)
	Income 1[1]	1	0.86^{NS} (0.49-1.51)	1.18^{NS} (0.66-2.12)	0.23^{*} (0.07-0.75)	0.30^{*} (0.09-0.99)	0.34^{NS} (0.07-1.57)	0.61^{NS} (0.13-2.83)	1	0.90^{NS} (0.60-1.36)	1.10^{NS} (0.77-1.60)
	Income 2	1	0.54^{***} (0.40-0.72)	0.82^{NS} (0.58-1.17)	0.09^{***} (0.06-0.15)	0.15^{***} (0.08-0.25)	0.24^{**} (0.09-0.63)	0.46^{NS} (0.16-1.29)	1	0.93^{NS} (0.72-1.21)	1.05^{NS} (0.80-1.38)
	Income 3	1	0.34^{***} (0.24-0.49)	0.47^{***} (0.33-0.69)	0.13^{***} (0.09-0.20)	0.22^{***} (0.14-0.36)	0.27^{**} (0.11-0.63)	0.54^{NS} (0.21-1.41)	1	1.05^{NS} (0.83-1.34)	0.95^{NS} (0.70-1.28)
	Income 4	1	0.38^{***} (0.26-0.56)	0.41^{**} (0.25-0.68)	0.10^{***} (0.05-0.19)	0.17^{***} (0.09-0.32)	0.58^{NS} (0.22-1.53)	0.78^{NS} (0.36-1.73)	1	1.34^{NS} (0.91-1.99)	1.41^{NS} (0.87-2.27)
	Education1	1	1.05^{NS} (0.57-1.94)	1.61^{NS} (0.81-3.21)	0.09^{**} (0.02-0.41)	0.20^{NS} (0.04-1.01)	0.57^{NS} (0.19-1.74)	0.85^{NS} (0.26-2.76)	1	0.95^{NS} (0.52-1.37)	0.86^{NS} (0.51-1.45)
	Education2	1	0.38^{***} (0.27-0.54)	0.52^{**} (0.34-0.80)	0.11^{***} (0.04-0.29)	0.20^{**} (0.07-0.56)	0.15^{**} (0.04-0.57)	0.20^{**} (0.07-0.61)	1	1.13^{NS} (0.87-1.47)	0.96^{NS} (0.69-1.34)
	Education3	1	0.49^{***} (0.38-0.64)	0.54^{**} (0.39-0.76)	0.09^{***} (0.06-0.14)	0.18^{***} (0.12-0.26)	0.43^{*} (0.19-0.95)	0.78^{NS} (0.36-1.71)	1	1.11^{NS} (0.89-1.39)	1.15^{NS} (0.85-1.57)

[1] Income is categorised into quartiles: 1>3.240, 2 = 1.886-3.240 , 3= 1.007-1.885 and 4 < 1.007. Education 1 >12 years, Education 2=12 years, and Education 3<12 years.

[2] Completely edentulous, in addition to education and income adjusted model controls for dental insurance, sex, ethnicity, age and smoking (currently smoker)

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

Table 6.1.9 Associations of ethnicity and sex with number of missing tooth surfaces

		Count ratio (95%CI) for Ethnicity							Count ratio (95%CI) for Sex		
		White Americans	African Americans		Hispanic Americans		Others		Males	Females	
		Ref	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Ref	Unadjusted	Adjusted
Number of missing tooth surfaces[2]	Whole population	1	1.09* (1.01-1.18)	1.88*** (1.61-2.19)	0.48*** (0.42-0.55)	0.76** (0.63-0.90)	0.84^{NS} (0.68-1.04)	1.56** (1.20-2.02)	1	1.08* (1.01-1.15)	1.06^{NS} (0.97-1.08)
	Income 1[1]	1	1.40*** (1.19-1.65)	2.72*** (2.16-3.43)	0.51*** (0.41-0.64)	0.84^{NS} (0.62-1.14)	0.89^{NS} (0.61-1.30)	1.71* (1.07-2.71)	1	0.94^{NS} (0.82-1.07)	1.03^{NS} (0.89-1.19)
	Income 2	1	0.90^{NS} (0.79-1.02)	1.82*** (1.40-2.35)	0.37*** (0.31-0.45)	0.68* (0.51-0.91)	0.63** (0.47-0.85)	1.58* (1.04-2.40)	1	1.03^{NS} (0.92-1.16)	1.05^{NS} (0.87-1.26)
	Income 3	1	0.81** (0.71-0.94)	1.61*** (1.31-1.98)	0.37*** (0.31-0.42)	0.66** (0.51-0.86)	0.74^{NS} (0.54-1.02)	1.46* (1.10-1.95)	1	1.20** (1.07-1.34)	1.13^{NS} (0.99-1.27)
	Income 4	1	0.75** (0.61-0.92)	1.28^{NS} (0.94-1.74)	0.36*** (0.28-0.47)	0.86^{NS} (0.60-1.24)	0.77^{NS} (0.47-1.24)	1.10 (0.75-1.62)	1	1.24* (1.05-1.45)	1.44* (1.06-1.94)
	Education1	1	1.66*** (1.41-1.97)	3.39*** (2.64-4.35)	0.51*** (0.41-0.64)	1.09^{NS} (0.74-1.59)	1.24^{NS} (0.88-1.73)	2.09** (1.33-3.28)	1	0.95^{NS} (0.79-1.14)	0.96^{NS} (0.81-1.15)
	Education2	1	0.83** (0.75-0.92)	1.36** (1.14-1.63)	0.34*** (0.28-0.41)	0.65*** (0.53-0.80)	0.67* (0.49-0.93)	1.10^{NS} (0.79-1.53)	1	1.15* (1.02-1.29)	1.06^{NS} (0.87-1.28)
	Education3	1	0.82*** (0.74-0.91)	1.12^{NS} (0.93-1.35)	0.31*** (0.27-0.35)	0.64*** (0.51-0.79)	0.67** (0.50-0.89)	1.25^{NS} (0.96-1.62)	1	1.09^{NS} (0.99-1.20)	1.21** (1.05-1.39)

[1] Income is categorised into quartiles: 1>3.240, 2 = 1.886-3.240 , 3= 1.007-1.885 and 4 < 1.007. Education 1 >12 years, Education 2=12 years, and Education 3<12 years.

[2] Number of missing tooth surfaces due to disease, in addition to education and income adjusted model controls for dental insurance, sex, ethnicity, age and smoking (currently smoker)

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

6.3 Effect of ethnicity and sex on the social gradients in oral and general health

Tables 6.2.1 to 6.2.4 show changes in education and income gradients in all oral and general health outcomes after adjusting for sex and ethnicity. Four regression models were constructed for each health outcome. The first model adjusted for relevant confounders but not for sex and ethnicity (see methods in chapter 3). The second model additionally adjusted for sex. The third model additionally adjusted for ethnicity but not for sex. The fourth model adjusted for all confounders including sex and ethnicity. In the text below these four models are referred to as the first, second, third and fourth model in the order described above.

6.3.1 Effect of ethnicity and sex on the social gradients in ischaemic heart disease.

The odds ratios for the middle education group in ischaemic heart disease models were 0.99 in all models and were insignificant. In the lowest education group the odds ratios for ischaemic heart disease were 1.41 in the first and second models and 1.42 in the third and fourth models and were all significant. The probabilities of having ischaemic heart disease as income increased were significant in all four models. They were 0.88, 0.88, 0.87 and 0.87 in the first to fourth models, respectively (Table 6.2.1).

6.3.2 Effect of ethnicity and sex on the social gradients in perceived general health

The probabilities of reporting poorer general health in the middle education group were 1.45, 1.44, 1.47 and 1.45 in the first to fourth models respectively and were all significant. The probabilities of reporting poorer perceived general health in the lowest education group were 2.72, 2.74, 2.55 and 2.57 in the first, second, third and fourth models and were always significant. The probabilities of poorer perceived general health with a unit increase in income were 0.74, 0.74, 0.77 and 0.77 in the first to fourth models and were significant in all models (Table 6.2.1).

6.3.3 Effect of ethnicity and sex on the social gradients in perceived oral health

The odds ratios for the middle education group in perceived oral health models were 1.56 in the first, third and fourth models and 1.57 in the second model and were always significant. In the lowest education group and perceived oral health models, the odds ratios were 2.15, 2.14, 2.01 and 2.01 in the first, second, third and fourth models respectively and were all significant. The probability of reporting poorer oral health as income increased were significant in all four models and were 0.82, 0.82, 0.84 and 0.84 in the first to fourth models, respectively (Table 6.2.2).

6.3.4 Effect of ethnicity and sex on the social gradients in periodontal disease

The probabilities of having periodontal disease in the middle education group were 1.18, 1.22, 1.19 and 1.24 in the first to fourth models respectively, but were significant only in the fourth model, adjusting for both sex and ethnicity. The probabilities of having periodontitis in the lowest education group were 1.41, 1.40, 1.38 and 1.37 in the first, second, third and fourth models, and were always significant. The probabilities of having periodontitis with a unit increase in income were 0.87, 0.86, 0.88 and 0.87 in the first to fourth models, and were significant in all models (Table 6.2.2).

6.3.5 Effect of ethnicity and sex on the social gradients in the extent of gingival bleeding

Persons in the middle education group had a significant increase in the extent of gingival bleeding of 2.29, 2.48, 2.30 and 2.48, in the first, second and fourth models, respectively. The regression coefficients in the lowest education group in the extent of gingival bleeding models were 5.74, 5.66, 5.64 and 5.57 in the first to fourth models respectively, all values were significant. For a higher unit of income, the extent of gingival bleeding was significantly lower by 0.99, 1.04, 0.93 and 0.98 in the first to fourth models, respectively (Table 6.2.3).

6.3.6 Effect of ethnicity and sex on the social gradients in the extent of loss of periodontal attachment

The regression coefficients in the middle education group in the extent of loss of attachment were significantly higher at 1.92, 2.15, 1.95 and 2.19 in the first to fourth models, respectively. Persons in the lowest education group had significantly higher extent of loss of attachment of 6.90, 6.80, 6.94 and 6.86 in the first, second and fourth models, respectively. The regression coefficients for each higher unit of income in the attachment loss models were -0.72, -0.78, -0.59 and -0.66 and were always significant (Table 6.2.3).

6.3.7 Effect of ethnicity and sex on the social gradients in the extent of periodontal pocket

Persons in the middle education group had significantly higher extent of periodontal pockets of 0.62, 0.66, 0.60 and 0.66 in the first, second and fourth models, respectively. The regression coefficients in the lowest education group in the extent of periodontal pockets models were significant at 1.88, 1.78, 1.79 and 1.76 in the first to fourth models, respectively. For each higher unit of income, the extent of periodontal pocket depth was significantly lower by 0.40, 0.41, 0.31 and 0.33 in the first to fourth models, respectively (Table 6.2.3).

6.3.8 Effect of ethnicity and sex on the social gradients in edentulousness

The probabilities of being edentulous in the middle education group were 2.44, 2.43, 2.41 and 2.40, and were significant in all models. In the lowest education group the odds ratios for edentulousness were 3.63, 3.64, 3.88 and 3.88 in the first, second, third and fourth models respectively and were all significant. The probability of being edentulous as income increased were significant in all four models and were 0.77, 0.77, 0.75 and 0.75 in the first to fourth models, respectively (Table 6.2.2).

6.3.9 Effect of ethnicity and sex on the social gradients in the tooth surface loss

For individuals in the middle education group the count ratios of missing tooth surfaces compared to the highest education group were 1.86, 1.85, 1.97 and 1.96 in the first, second, third and fourth models, respectively, and were all significant. The count ratios of tooth loss in the lowest education group were 1.86, 1.86, 1.98 and 1.97 in the first to fourth models, and were all significant. For a unit increase in income, the count ratios of tooth loss were significant at 0.87 in the first and second models and 0.89 in the third and fourth models (Table 6.2.4)

Table 6.2.1 Effect of ethnicity and sex on the association between general health outcomes and socioeconomic position indicators

		OR (95%CI) for Education Groups			Change in OR (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Ischaemic heart disease[1]	1 Unadjusted for ethnicity nor sex	1	0.99 NS (0.79-1.26)	1.41* (1.06-1.88)	0.88** (0.82-0.94)
	2 Unadjusted for ethnicity	1	0.99 NS (0.78-1.89)	1.41* (1.06-1.89)	0.88** (0.82-0.94)
	3 Unadjusted for sex	1	0.99 NS (0.78-1.26)	1.42* (1.06-1.91)	0.87*** (0.82-0.94)
	4 Adjusted for ethnicity and sex	1	0.99 NS (0.78-1.26)	1.42* (1.06-1.91)	0.87** (0.82-0.94)
Perceived general health[2]	1 Unadjusted for ethnicity nor sex	1	1.45** (1.16-1.82)	2.72*** (2.20-3.37)	0.74*** (0.70-0.78)
	2 Unadjusted for ethnicity	1	1.44** (1.15-1.80)	2.74*** (2.21-3.40)	0.74*** (0.70-0.79)
	3 Unadjusted for sex	1	1.47** (1.16-1.85)	2.55*** (2.04-3.20)	0.77*** (0.73-0.81)
	4 Adjusted for ethnicity and sex	1	1.45** (1.15-1.83)	2.57*** (2.04-3.23)	0.77*** (0.73-0.82)

[1] ischaemic heart disease (angina cases according to Rose questionnaire or reported diagnosis of heart attack), first model adjusted for education, income, medical insurance, age, smoking, reported diagnosis of diabetes, BMI, and high blood pressure. In second model sex was added, in third model sex was removed and ethnicity added in fourth model both sex and ethnicity were added.

[2] Perceived general health poor/fair, adjusted model controls for education, income, medical insurance, age and smoking. In second model sex was added, in third model sex was removed and ethnicity added in fourth model both sex and ethnicity were added.

*** P<0.001 ** P<0.01 * P<0.05 NS Not significant

Table 6.2.2 Effect of ethnicity and sex on the association between dichotomous oral health outcomes and socioeconomic position indicators

		OR (95%CI) for Education Groups			Change in OR (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Perceived oral health[1]	1 Unadjusted for ethnicity nor sex	1	1.56*** (1.36-1.79)	2.15*** (1.81-2.54)	0.82*** (0.78-0.87)
	2 Unadjusted for ethnicity	1	1.57*** (1.36-1.80)	2.14*** (1.81-2.53)	0.82*** (0.78-0.87)
	3 Unadjusted for sex	1	1.56*** (1.35-1.80)	2.01*** (1.69-2.39)	0.84*** (0.80-0.89)
	4 Adjusted for ethnicity and sex	1	1.56*** (1.35-1.81)	2.01*** (1.69-2.39)	0.84*** (0.80-0.89)
Edentulous[2]	1 Unadjusted for ethnicity nor sex	1	2.44*** (1.73-3.43)	3.63*** (2.31-5.70)	0.77*** (0.72-0.82)
	2 Unadjusted for ethnicity	1	2.43*** (1.73-3.40)	3.64*** (2.31-5.73)	0.77*** (0.73-0.82)
	3 Unadjusted for sex	1	2.41*** (1.71-3.38)	3.88*** (2.47-6.09)	0.75*** (0.70-0.80)
	4 Adjusted for ethnicity and sex	1	2.40*** (1.71-3.36)	3.88*** (2.47-6.10)	0.75*** (0.70-0.80)
Periodontal disease[3]	1 Unadjusted for ethnicity nor sex	1	1.18NS (0.96-1.44)	1.41** (1.12-1.78)	0.87*** (0.83-0.91)
	2 Unadjusted for ethnicity	1	1.22NS (0.99-1.50)	1.40** (1.10-1.77)	0.86*** (0.82-0.90)
	3 Unadjusted for sex	1	1.19NS (0.97-1.46)	1.38* (1.08-1.76)	0.88*** (0.85-0.93)
	4 Adjusted for ethnicity and sex	1	1.24* (1.01-1.52)	1.37* (1.07-1.76)	0.87*** (0.84-0.91)

[1] Perceived oral health poor/fair, first model adjusted for education, income, dental insurance, age and smoking. In second model sex was added, in third model sex was removed ethnicity added and in fourth model both sex and ethnicity were added.
[2] Completely edentulous, first model adjusted for education, income, dental insurance, age and smoking. In second model sex was added, in third model sex was removed ethnicity added and in fourth model both sex and ethnicity were added.
[3] Periodontal disease (at least one gingival bleeding site and one site loss of attachment $\geq$ 3mm), first model adjusted for education, income, medical insurance, age, smoking and reported diagnosis of diabetes. In second model sex was added, in third model sex was removed and ethnicity added in fourth model both sex and ethnicity were added.
*** P<0.001 ** P<0.01 * P<0.05 NS Not significant

Table 6.2.3 Effect of ethnicity and sex on the association between extent of periodontal disease and socioeconomic position indicators

		Regression coefficient (95%CI) for Education Groups			Regression coefficient (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Extent gingival bleeding[1]	1 Unadjusted for ethnicity nor sex	0.00	2.29*** (1.35-3.24)	5.74*** (4.40-7.08)	-0.99*** (-1.25 to -0.73)
	2 Unadjusted for ethnicity	0.00	2.48*** (1.54-3.42)	5.66*** (4.33-6.98)	-1.04*** (-1.30 to -0.78)
	3 Unadjusted for sex	0.00	2.30*** (1.35-3.24)	5.64*** (4.23-7.05)	-0.93*** (-1.20 to -0.65)
	4 Adjusted for ethnicity and sex	0.00	2.48*** (1.54-3.42)	5.57*** (4.17-6.96)	-0.98*** (-1.26 to -0.70)
Extent loss of attachment[2]	1 Unadjusted for ethnicity nor sex	0.00	1.92** (0.79-3.03)	6.90*** (5.58-8.23)	-0.72*** (-1.03 to -0.41)
	2 Unadjusted for ethnicity	0.00	2.15*** (1.06-3.23)	6.80*** (5.49-8.10)	-0.78*** (-1.09 to -0.47)
	3 Unadjusted for sex	0.00	1.95** (0.83-3.07)	6.94*** (5.57-8.31)	-0.59** (-0.92 to -0.26)
	4 Adjusted for ethnicity and sex	0.00	2.19*** (1.10-3.27)	6.86*** (5.50-8.22)	-0.66*** (-0.99 to-0.32)
Extent pocket depth[3]	1 Unadjusted for ethnicity nor sex	0.00	0.62** (0.23-1.03)	1.88*** (1.19-2.58)	-0.40*** (-0.52 to -0.28)
	2 Unadjusted for ethnicity	0.00	0.66** (0.24-1.08)	1.78*** (1.11-2.46)	-0.41*** (-0.53 to -0.29)
	3 Unadjusted for sex	0.00	0.60** (0.21-0.99)	1.79*** (1.06-2.52)	-0.31*** (-0.44 to -0.19)
	4 Adjusted for ethnicity and sex	0.00	0.66** (0.27-1.05)	1.76*** (1.05-2.48)	-0.33*** (-0.46 to -0.20)

[1] Percentage of sites with gingival bleeding to all examined sites, adjusted model controls for education, income, dental insurance, age, smoking and reported diagnosis of diabetes. In second model sex was added, in third model sex was removed and ethnicity added in fourth model both sex and ethnicity were added.
[2] Percentage of sites with loss of attachment ≥ 3mm to all examined sites, adjusted model controls for education, income, dental insurance, age, smoking and reported diagnosis of diabetes. In second model sex was added, in third model sex was removed and ethnicity added in fourth model both sex and ethnicity were added.
[3] Percentage of sites with pocket depth ≥ 4mm to all examined sites, adjusted model controls for education, income, dental insurance, age, smoking and reported diagnosis of diabetes. In second model sex was added, in third model sex was removed and ethnicity added in fourth model both sex and ethnicity were added.
*** P<0.001 ** P<0.01 * P<0.05 NS Not significant

Table 6.2.4 Effect of ethnicity and sex on the association between tooth loss and socioeconomic position indicators

		Count Ratio (95%CI) for Education Groups			Count Ratio (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Number of missing tooth surfaces[1]	1 Unadjusted for ethnicity nor sex	1	1.86*** (1.59-2.17)	1.86*** (1.48-2.35)	0.87*** (0.85-0.89)
	2 Unadjusted for ethnicity	1	1.85*** (1.58-2.16)	1.86*** (1.48-2.35)	0.87*** (0.85-0.89)
	3 Unadjusted for sex	1	1.97*** (1.65-2.35)	1.98*** (1.53-2.56)	0.89*** (0.87-0.91)
	4 Adjusted for ethnicity and sex	1	1.96*** (1.65-2.33)	1.97*** (1.53-2.55)	0.89*** (0.87-0.91)

[1] Number of missing tooth surfaces due to disease, adjusted model controls for education, income, dental insurance, age and smoking. In second model sex was added, in third model sex was removed and ethnicity added in fourth model both sex and ethnicity were added.

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} Not significant

6.4 Summary of the results reported in Chapter 6

- Africans Americans and Hispanic Americans generally had poorer oral and general health for most indicators of health.
- When the analysis was conducted within strata of income and education, ethnic differences in health disappeared in the lowest strata of socioeconomic position and persisted or increased in the highest strata.
- Women had better periodontal condition, greater number of tooth loss and poorer perceived general health compared to men.
- In the highest strata of income and education women oral and general health was better than that of men.
- Sex and ethnicity had little effect on the social gradients in health.
- The results support, to some extent, the hypothesis about an effect of sex and ethnicity on the social gradients in oral and general health.
- The next chapter of the analysis examines the effect of cognitive ability on the social gradients in ischaemic heart disease, periodontal disease and tooth loss.

CHAPTER 7

The effects of cognitive performance on the social gradients in oral and general health

CHAPTER 7

The effects of cognitive performance on the social gradients in oral and general health

7.1 Introduction

This chapter presents the associations between health outcomes and indictors of cognitive ability and the effect of adjusting for cognitive abilities on the social gradients in health. The analysis was conducted for individuals 20 to 59 years old who participated in the computerized cognitive performance examination in NHANES III. The number of subjects in the analysis ranged from approximately 3140 to 3916, according to the variables included in the regression model. Adjusted and unadjusted models for each outcome were conducted for the same individuals. Higher scores in the cognitive tests indicate decline in cognitive ability (see methods in Chapter 3).

Odds ratios reflect probability of having the condition, regression coefficients reflect the change in the occurrence of the condition (a negative sign before the figure reflects decrease in the condition), count ratios reflect the ratio of the occurrence of the condition, compared to reference group or baseline.

7.2 Associations of cognitive performance with oral and general health

7.2.1 Associations of cognitive performance with ischaemic heart disease

Table 7.1 shows the associations of the three tests of cognitive performance with ischaemic heart disease, periodontal disease and tooth loss. The odds ratios for having ischaemic heart disease for higher score in the Simple Reaction Time Test were significant in both the unadjusted and adjusted models with odds ratios of 1.01. For a higher score of the Symbol Digit Substitution Test, the odds ratio for having ischaemic heart disease was significant at 1.43. In the adjusted model, the odds ratio for having ischaemic heart disease attenuated and lost significance. The probability of having ischaemic heart disease for a higher score in the Serial Digit Learning Test was significant at 1.10, but attenuated to 1.03 and lost significance in the adjusted model (Table 7.1).

7.2.2 Associations of cognitive performance with periodontitis (at least one site with loss of attachment 3mm+ and one site with gingival bleeding)

The odds ratios for having periodontitis for higher scores in the Simple Reaction Time Test were not significant in both the unadjusted and adjusted models. For a higher score in the Symbol Digit Substitution Test there was a significant higher probability of having periodontitis with odds ratio of 1.82. In the adjusted model, the odds ratios attenuated to 1.14 and lost significance. The probability of having periodontitis for a higher score on the Serial Digit Learning Test was significant at 1.06, but lost significance in the adjusted model (Table 7.1).

7.2.3 Associations of cognitive performance with extent of gingival bleeding

Higher scores in the Simple Reaction Time Test were significantly associated with greater bleeding extent, the regression coefficient was 0.04. After adjusting for relevant confounders, the regression coefficient for bleeding extent attenuated to 0.02 and remained statistically significant. For a higher score in the Symbol Digit Substitution Test, there was a significant 2.73 change in the extent of gingival bleeding. After adjusting for relevant confounders the change in the extent of gingival bleeding attenuated to 1.16, but remained significant. The regression coefficients for the Serial Digit Learning Test with gingival bleeding were significant at 0.52 and 0.21 in the unadjusted and adjusted models, respectively (Table 7.1).

7.2.4 Associations of cognitive performance with extent of loss of periodontal attachment

The regression coefficients for the Simple Reaction Time Test with loss of periodontal attachment were insignificant in the unadjusted and adjusted models. For a higher score in the Symbol Digit Substitution Test, there was a significant 6.37 change in the extent of loss of attachment. After adjusting for relevant confounders, the change in loss of attachment attenuated to 1.28 and remained significant. For a higher score in the Serial Digit Learning Test there was a significant 0.62 change in the loss of attachment. After adjusting for relevant confounders the change in loss of attachment attenuated to 0.01 and lost significance (Table 7.1).

7.2.5 Associations of cognitive performance with extent of pocket depth

Higher scores in the Simple Reaction Time Test were not significantly associated with the extent of pocket depth in the both unadjusted and adjusted models. The Symbol Digit Substitution Test was significantly associated with greater pocket extent with a regression coefficient of 1.87. After adjusting for relevant confounders, the change in pocket depth attenuated to 0.48 and lost significance. The regression coefficient for the Serial Digit Learning Test with pocket depth was significant at 0.20, but lost significance in the adjusted model (Table 7.1).

7.2.6 Associations of cognitive performance with loss of tooth surfaces

The count ratio of tooth loss for a higher score in the Simple Reaction Time Test was significant at 1.01, but lost its significance in the adjusted model. Similarly, the count ratio for tooth loss surfaces with higher scores in Symbol Digit Substitution Test score was significant at 2.84, but was attenuated to 1.07 and lost significance in the adjusted model. The count ratios for tooth loss surfaces for higher score in the Serial Digit Learning Test were significant at 1.10 and 1.04 in the unadjusted and adjusted models, respectively (Table 7.1).

Table 7.1 Association between indicators of cognitive performance and health outcomes

		Simple Reaction Time Test[1]	Symbol Digit Substitution Test[2]	Serial Digit Learning Test[3]
OR (95%CI) for ischaemic heart disease[4]	Unadjusted	1.01** (1.01-1.01)	1.43*** (1.28-1.60)	1.10*** (1.05-1.15)
	Adjusted	1.01* (1.01-1.01)	0.97^{NS} (0.82-1.14)	1.03^{NS} (0.98-1.09)
OR (95%CI) for periodontal disease[5]	Unadjusted	1.00^{NS} (0.99-1.01)	1.82*** (1.57-2.09)	1.06*** (1.04-1.09)
	Adjusted	1.00^{NS} (0.99-1.01)	1.14^{NS} (0.99-1.33)	0.99^{NS} (0.96-1.03)
Reg Co (95%CI) for gingival bleeding extent[6]	Unadjusted	0.04*** (0.02-0.05)	2.73*** (1.91-3.54)	0.52*** (0.34-0.69)
	Adjusted	0.02* (0.01-0.04)	1.16* (0.22-2.10)	0.21* (0.02 to 0.40)
Reg Co (95%CI) for extent loss of attachment[7]	Unadjusted	0.01^{NS} (-0.01 to 0.03)	6.37*** (5.09-7.65)	0.62*** (0.47-0.77)
	Adjusted	-0.01^{NS} (-0.02 to 0.01)	1.28* (0.11-2.46)	0.01^{NS} (-0.15 to 0.17)
Reg Co (95%CI) for extent pocket depth[8]	Unadjusted	0.01^{NS} (-0.01 to 0.01)	1.87*** (1.29-2.44)	0.20*** (0.10-0.29)
	Adjusted	-0.01^{NS} (-0.01 to 0.01)	0.48^{NS} (-0.02 to 0.97)	-0.02^{NS} (-0.12 to 0.09)
Count ratio (95%CI) for loss of tooth surfaces[9]	Unadjusted	1.01** (1.01-1.01)	2.84*** (2.31-3.48)	1.10*** (1.07-1.12)
	Adjusted	1.00^{NS} (0.99-1.01)	1.07^{NS} (0.92-1.25)	1.04* (1.01-1.07)

[1] Simple Reaction Time Test Simple Reaction Time Test
[2] Symbol Digit Substitution Test Symbol Digit Substitution Test
[3] Serial Digit Learning Test Serial Digit Learning Test
[4] Odds ratio for ischaemic heart disease (angina cases according to Rose questionnaire or reported diagnosis of heart attack). In addition to the indicator of cognitive performance, adjusted model controls for education, income, medical insurance, sex, ethnicity, age, smoking, BMI, high blood pressure and diabetes.
[5] Odds ratio for periodontal disease (at least one gingival bleeding site and one site loss of attachment $\geq$ 3mm. In addition to the indicator of cognitive performance, adjusted model controls for education, income, medical insurance, sex, ethnicity, age, smoking and diabetes
[6] Regression coefficient for percentage of sites with gingival bleeding to all examined sites. In addition to the indicator of cognitive performance adjusted model controls for education, income, medical insurance, sex, ethnicity, age smoking and diabetes.
[7] Regression coefficient for percentage of sites with loss of attachment $\geq$ 3mm to all examined sites. In addition to the indicator of cognitive performance, adjusted model controls for education, income, medical insurance, sex, ethnicity, age smoking and diabetes
[8] Regression coefficient for percentage of sites with pocket depth $\geq$ 4mm to all examined sites. In addition to the indicator of cognitive performance, adjusted model controls for education, income, medical insurance, sex, ethnicity, age smoking and diabetes
[9] Count ratio for number of missing tooth surfaces due to disease. In addition to the indicator of cognitive performance, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking and the 3 indicators of cognitive performance.
*** $P<0.001$ ** $P<0.01$ * $P<0.05$ ^{NS} not significant

7.3 Effects of cognitive performance on the social gradients in oral and general health.

7.3.1 Effects of cognitive performance on the social gradients in ischaemic heart disease.

The odds ratios for ischaemic heart disease for persons in the middle education group attenuated from 1.28 to 1.20 after adjusting for cognitive performance indicators and were insignificant in both models. For persons in the lowest education group, the odds ratios for having ischaemic heart disease attenuated from 1.95 to 1.84 after adjusting for cognition, both ratios were insignificant. The odds ratios for income with ischaemic heart disease attenuated from 0.87 to 0.88 after adjusting for cognition and were insignificant (Table 7.2.1).

7.3.2 Effects of cognitive performance on the social gradients in periodontitis (at least one site with loss of attachment 3mm+ and one site with gingival bleeding).

The odds ratios for having periodontitis for persons in the middle education group attenuated from 1.16 to 1.14 after adjusting for cognitive indicators and were insignificant in both models. Similarly, the odd ratios for periodontitis for individuals in the lowest education group were not significant in both models at 1.52 and 1.12. For a higher unit of income there was a significantly lower probability of periodontitis with odds ratios of 0.84 in both unadjusted and adjusted models (Table 7.2.1). Figure 7.1 shows the similarity of the effect of cognitive performance indicators on education gradients in periodontitis and ischaemic heart disease.

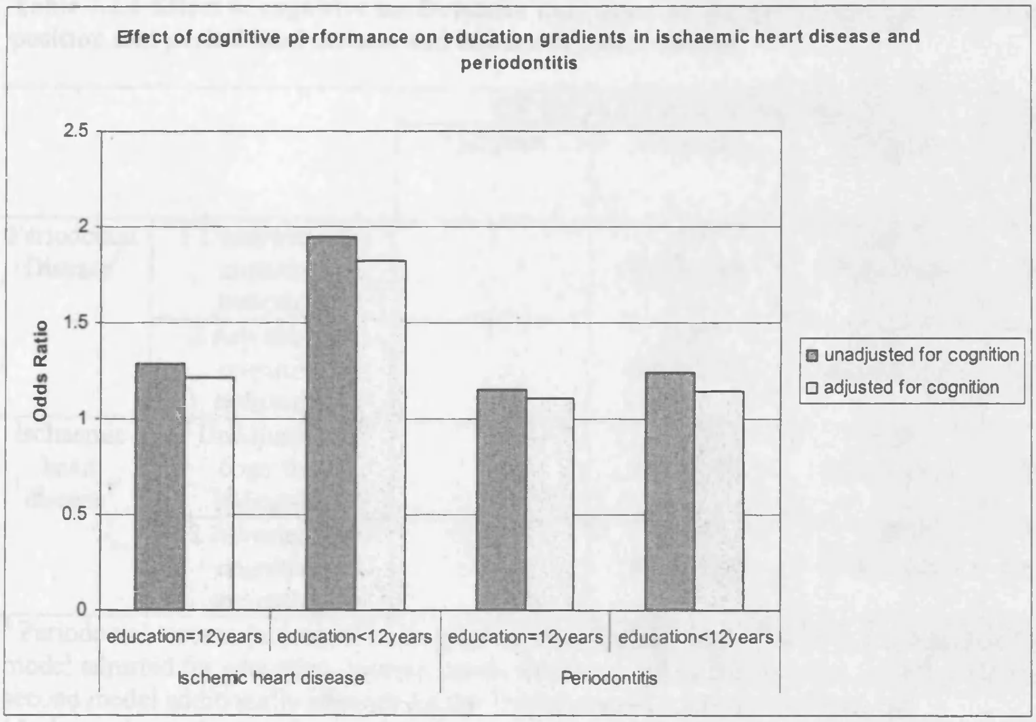


Figure 7.1 Effect of adjusting for cognitive performance indicators on education gradients in periodontitis and ischaemic heart disease

Table 7.2.1 Effect of cognitive performance indicators on the association between socioeconomic position and periodontal disease and ischaemic heart disease.

		OR (95%CI) for Education Groups			Change in OR (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Periodontal Disease[1]	1 Unadjusted for cognitive indicators	1	1.16^{NS} (0.76-1.76)	1.52^{NS} (0.89-2.60)	0.84^{***} (0.74-0.95)
	2 Adjusted for cognitive indicators	1	1.14^{NS} (0.76-1.73)	1.49^{NS} (0.88-2.51)	0.84^{**} (0.74-0.95)
Ischaemic heart disease[2]	1 Unadjusted for cognitive indicators	1	1.28^{NS} (0.75-2.19)	1.95^{NS} (0.95-4.01)	0.87^{NS} (0.69-1.09)
	2 Adjusted for cognitive indicators	1	1.20^{NS} (0.70-2.08)	1.84^{NS} (0.87-3.89)	0.88^{NS} (0.70-1.11)

[1] Periodontal disease (at least one site gingival bleeding and one site loss of attachment ≥ 3mm), first model adjusted for education, income, dental insurance, ethnicity, sex, age, smoking and diabetes. The second model additionally adjusted for the 3 indicators of cognitive performance.

[2] Ischemic heart disease, first model adjusted for education, income, medical insurance, ethnicity, sex, age, diabetes, BMI, high blood pressure and smoking. The second model additionally adjusted for the 3 indicators of cognitive performance.

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} not significant.

7.3.3 Effects of cognitive performance on the social gradients in the extent of periodontal disease variables.

The regression coefficient for gingival bleeding for persons in the middle education group attenuated from 2.76 to 2.16, but maintained significance after adjusting for cognitive performance indicators. For persons in the lowest education group, the regression coefficient for gingival bleeding attenuated from 5.82 to 4.69 after adjusting for cognition. Also the regression coefficient for income and gingival bleeding attenuated from -1.05 to -0.94 after adjusting for cognition and remained significant (Table 7.2.2, Figure 7.2).

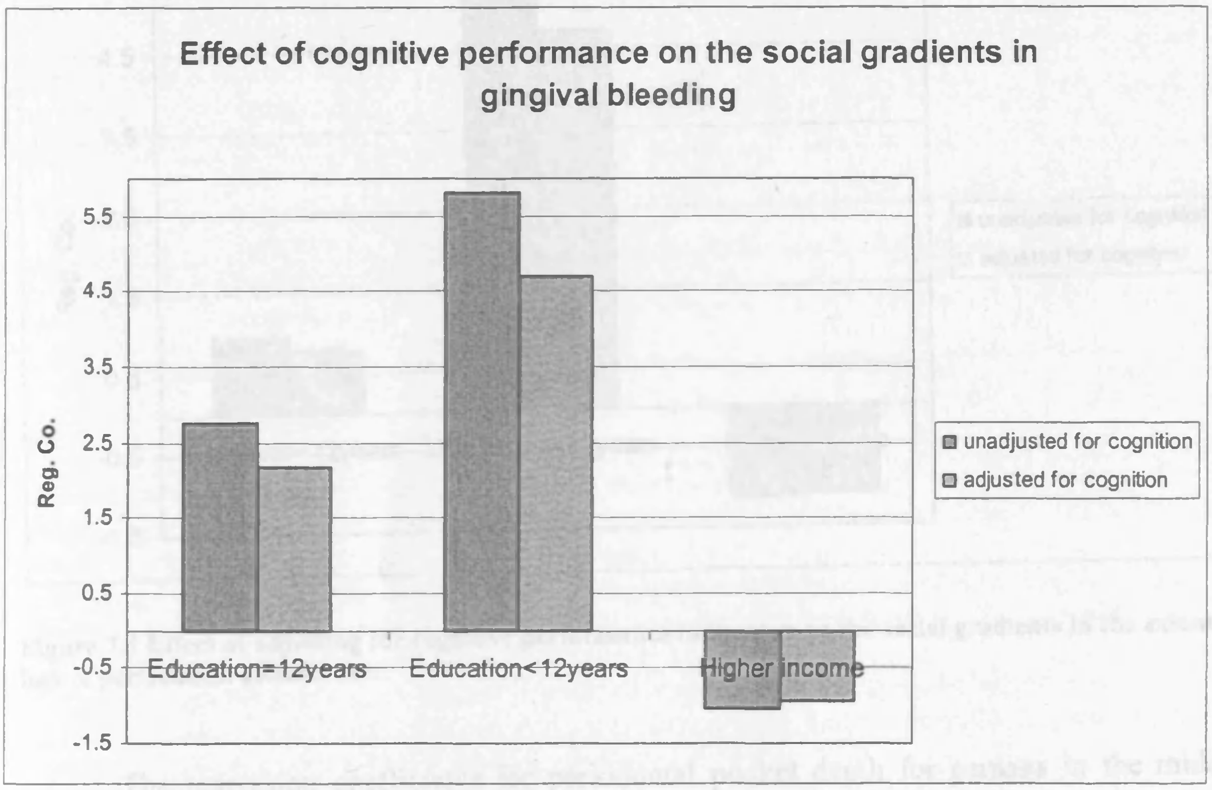


Figure 7.2 Effect of adjusting for cognitive performance indicators on the social gradients in the extent of gingival bleeding.

The regression coefficients for loss of periodontal attachment for persons in the middle education group were insignificant at 0.98 and 0.81 before and after adjusting for cognitive performance indicators, respectively. For individuals in the lowest education group, the regression coefficients for loss of periodontal attachment attenuated from 5.39 to 4.73 after adjusting for cognition and maintained significance. The regression coefficient for income with loss of attachment attenuated from -1.15 to -1.11 after adjusting for cognition and remained significant (Table 7.2.2, Figure 7.3).

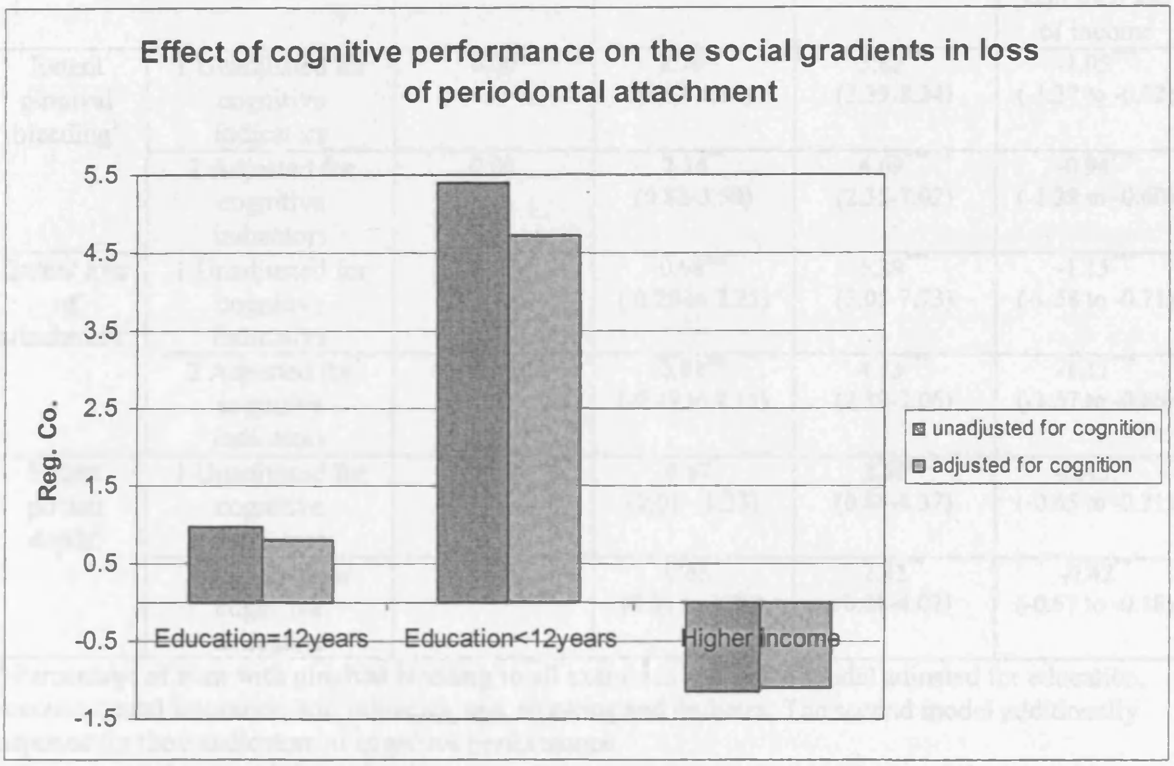


Figure 7.3 Effect of adjusting for cognitive performance indicators on the social gradients in the extent of loss of periodontal attachment.

The regression coefficients for periodontal pocket depth for persons in the middle education group were significant at 0.67 and 0.65 in the unadjusted and adjusted models, respectively. For persons in the lowest education group, the regression coefficient for pocket depth attenuated from 2.60 to 2.42 after adjusting for cognition and remained significant. The regression coefficients for income and periodontal pocket were -0.43 and -0.42 in the unadjusted and adjusted models respectively and were significant (Table 7.2.2).

Table 7.2.2 Effects of cognitive performance indicators on the association between socioeconomic position and extent of periodontal disease.

		Regression coefficient (95%CI) for Education Groups			Regression coefficient (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Extent gingival bleeding[1]	1 Unadjusted for cognitive indicators	0.00	2.76^{***} (1.33-4.18)	5.82^{***} (3.39-8.24)	-1.05^{***} (-1.37 to -0.72)
	2 Adjusted for cognitive indicators	0.00	2.16^{**} (0.82-3.50)	4.69^{***} (2.35-7.02)	-0.94^{***} (-1.29 to -0.60)
Extent loss of attachment[2]	1 Unadjusted for cognitive indicators	0.00	0.98^{NS} (-0.28 to 2.25)	5.39^{***} (3.05-7.73)	-1.15^{***} (-1.58 to -0.71)
	2 Adjusted for cognitive indicators	0.00	0.81^{NS} (-0.49 to 2.11)	4.73^{***} (2.39-7.06)	-1.11^{***} (-1.57 to -0.66)
Extent pocket depth[3]	1 Unadjusted for cognitive indicators	0.00	0.67^{*} (0.01 - 1.33)	2.61^{**} (0.84-4.37)	-0.43^{***} (-0.65 to -0.21)
	2 Adjusted for cognitive indicators	0.00	0.65^{*} (0.01 to 1.29)	2.42^{**} (0.81-4.02)	-0.42^{**} (-0.67 to -0.18)

[1] Percentage of sites with gingival bleeding to all examined sites, first model adjusted for education, income, dental insurance, sex, ethnicity, age, smoking and diabetes. The second model additionally adjusted for the 3 indicators of cognitive performance.
[2] Percentage of sites with loss of attachment ≥ 3mm to all examined sites, first model adjusted for education, income, dental insurance, sex, ethnicity, age, smoking, and diabetes. The second model additionally adjusted for the 3 indicators of cognitive performance.
[3] Percentage of sites with pocket depth ≥ 4mm to all examined sites, first model adjusted for education, income, dental insurance, sex, ethnicity, age, smoking, and diabetes. The second model additionally adjusted for the 3 indicators of cognitive performance.
*** P<0.001 ** P<0.01 * P<0.05 ^{NS} not significant

7.3.4 Effects of cognitive performance on the social gradients in tooth surface loss.

The count ratios for tooth loss surfaces for individuals in the middle education group were significant before and after adjusting for cognition at 2.09 and 1.96. Similarly, the count ratios for tooth loss for individuals in the lowest education group were significant before and after adjusting for cognition at 2.57 and 2.24. For each higher unit in income the count ratios for tooth loss surfaces attenuated from 0.88 to 0.89 after adjusting for cognition and were significant in both models (Table 7.2.3, Figure 7.4).

Table 7.2.3 Effect of cognitive performance indicators on the association between socioeconomic position and tooth loss.

		Count Ratio (95%CI) for Education Groups			Count Ratio (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Number of missing tooth surfaces[1]	1 Unadjusted for cognitive indicators	1	2.09*** (1.54-2.84)	2.57*** (1.72-3.83)	0.88*** (0.83-0.93)
	2 Adjusted for cognitive indicators	1	1.96*** (1.45-2.64)	2.24** (1.42-3.53)	0.89*** (0.84-0.94)

[1] Number of missing tooth surfaces due to disease, first model adjusted for education, income, dental insurance, sex, ethnicity, age and smoking. The second model additionally adjusted for the 3 indicators of cognitive performance.
*** $P<0.001$ ** $P<0.01$ * $P<0.05$ ^{NS} not significant

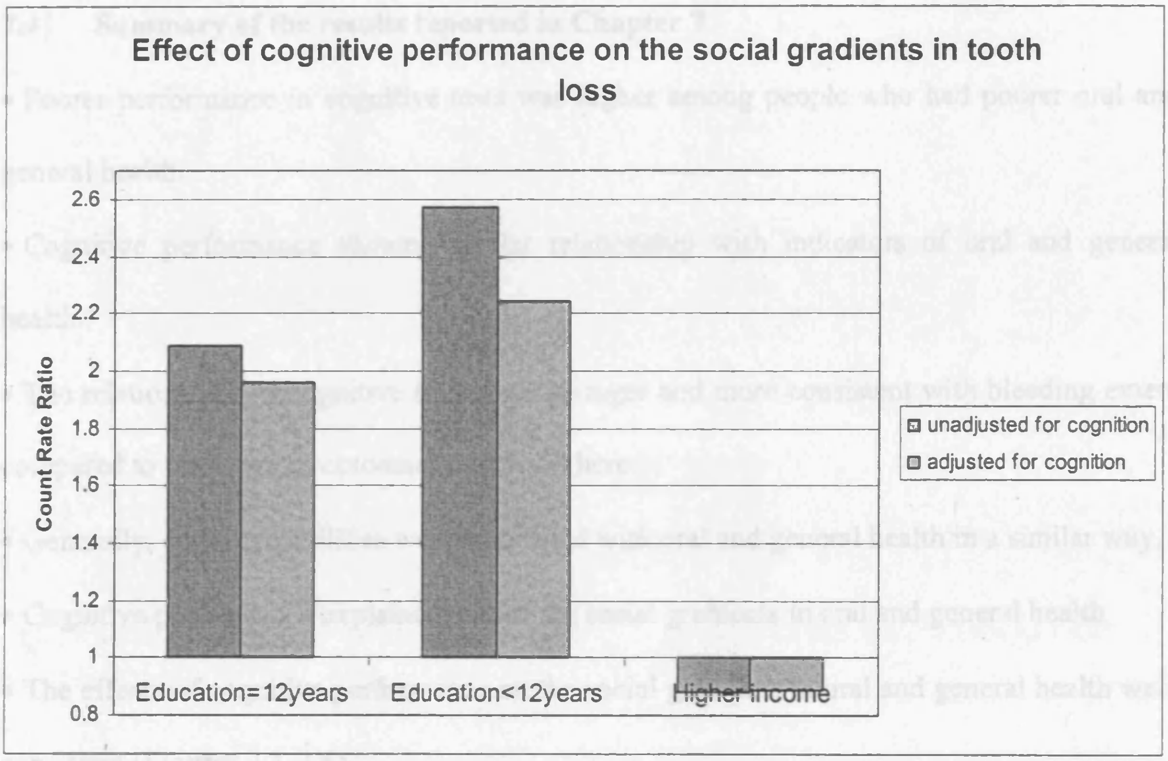


Figure 7.4 Effect of adjusting for cognitive performance indicators on the social gradients in tooth loss.

7.4 Summary of the results reported in Chapter 7

- Poorer performance in cognitive tests was higher among people who had poorer oral and general health.
- Cognitive performance showed similar relationship with indicators of oral and general health.
- The relationships of cognitive tests were stronger and more consistent with bleeding extent compared to other health outcomes examined here.
- Generally, cognitive abilities were associated with oral and general health in a similar way.
- Cognitive performance explained part of the social gradients in oral and general health
- The effects of cognitive performance on the social gradients in oral and general health were consistent (Figures 7.1-7.4).
- The results support the hypothesis that there is a cognitive pathway to the social gradients in oral and general health.
- The next results chapter reports on the role of health related behaviours in the social gradients in oral and general health.

CHAPTER 8

Assessing the social gradients in health-related behaviours and their impact on the social gradients in oral health and general health

CHAPTER 8

Assessing the social gradients in health-related behaviours and their impact on the social gradients in oral health and general health

8.1 Introduction

This chapter presents findings on the associations between some selected health-related behaviours and the indicators of oral and general health. The health-related behaviours presented here are being a current smoker, frequency of smoking per day, frequency of physical activity per month, frequency of eating fresh fruits and vegetables per day and frequency of visits to dentists (once a year or more versus less than once a year) (see method in Chapter 3). The results on the effect of adjusting for health-related behaviours on the social gradients in oral and general health are also presented in this chapter.

Odds ratios reflect probability of having the condition, regression coefficients reflect the change in the occurrence of the condition/ behaviour (a negative sign before the figure reflects decrease in the condition), count ratios reflect the ratio of the occurrence of the condition, compared to reference group or baseline.

8.2 Social gradients in health-related behaviours

Tables 8.1.1 to 8.1.3 display the associations between education and income with the indicators of health-related behaviours. All the adjusted models in Tables 8.1.1 to 8.1.3 controlled for education, income, sex, age, ethnicity, and the respective behaviour.

8.2.1 Social gradients in frequency of physical activity per month

Frequency of physical activity attenuated by 6.21 and 6.04 times a month for those with 12 and less than 12 years of education, respectively, compared to individuals with more than 12 years of education. In the adjusted model, the regression coefficients were -5.35 and -3.99, respectively, for the 12 and less than 12 years compared to the more than 12 years of education group. For a higher unit of income, frequency of physical activity was higher by 0.79 and 0.60 a month, in the unadjusted and adjusted models, respectively (Table 8.1.1). Other factors in the adjusted model significantly associated with frequency of physical activity included being African Americans (more likely to engage in physical activity compared to White Americans), while Hispanic Americans, females and older persons were less likely to engage in physical activity than White Americans, males and younger persons, respectively.

8.2.2 Social gradients in eating fresh fruits and vegetables per day

Frequency of eating fresh fruits and vegetables attenuated by 0.50 and 0.51 in the middle and lowest education groups, respectively, compared to the highest education group. In the adjusted model, regression coefficients for the middle and lowest education groups were -0.50 and -0.66, respectively. The unadjusted and adjusted regression coefficients for income and frequency of eating fresh fruits and vegetables were 0.10 and 0.04 respectively (Table 8.1.1). In the adjusted model, African Americans were significantly less likely to eat fresh fruits and vegetables compared to White Americans, while Hispanic Americans, other ethnicities, females and older individuals were more likely to eat fresh fruits and vegetables frequently.

All education and income differences in physical activity and eating fresh fruits and vegetables frequently were significant. However, this analysis did not clearly demonstrate consistently lower probabilities of these positive behaviours at each lower education level (Table 8.1.1).

Table 8.1.1 Association between socioeconomic position indicators and frequencies of eating fresh fruits per day and vegetables and frequency of taking physical activity per month

		Regression Coefficient (95%CI) for Education Groups			Regression Coefficient (95%CI) for income
		>12 years	12 years	<12 years	
Frequency of physical activity per month[1]	Unadjusted	0.00	-6.21*** (-8.01 to -4.41)	-6.04*** (-8.01 to -4.41)	0.79** (0.27-1.32)
	Adjusted	0.00	-5.35*** (-7.08 to -3.61)	-3.99*** (-6.12 to -1.86)	0.60* (0.04-1.15)
Frequency of eating fresh fruits and vegetables per day[2]	Unadjusted	0.00	-0.50*** (-0.63 to -0.38)	-0.51*** (-0.63 to -0.39)	0.10** (0.07-0.12)
	Adjusted	0.00	-0.50*** (-0.63 to -0.38)	-0.66*** (-0.79 to -0.53)	0.04** (0.02-0.07)

[1] Frequency of eating fresh fruits or vegetables per day, adjusted model controls for education, income, sex, ethnicity, age and ethnicity.
[2] Frequency of physical activity per month, adjusted model controls for education, income, sex, ethnicity, age and ethnicity.
*** P<0.001 ** P<0.01 * P<0.05 NS Not significant

8.2.3 Social gradients in frequency of visits to dentists per year

Table 8.1.2 shows the unadjusted and adjusted association of visits to dentists (once a year or more) and smoking (current smoker) with education and income. Persons in the middle education group were 0.40 times less likely to visit a dentist once a year or more than those in highest education group. After adjusting for age, sex, ethnicity and income, the probability of visits to dentist for this education group attenuated to 0.49. For the lowest education group, the probability of visiting a dentist was 0.19 and 0.33 for the unadjusted and adjusted models. For each higher unit of income the probability of visiting a dentist was higher by 1.53. In the adjusted model the probability was 1.40. The association between visits to dentists with education and income were significant in all unadjusted and adjusted models (Table 8.1.2). Other factors significantly associated with lower frequency of visits to dentists included being African Americans, older age and being a male.

8.2.4 Social gradients in being current smoker

Persons with 12 years of education were 1.96 times more likely to be current smokers compared to those with more than 12 years of education. In the adjusted model, the probability of smoking decreased to 1.79. Persons with less than 12 years of education were 2.06 times more likely to smoke compared to those in the highest education group, in the adjusted model, the probability of smoking increased to 2.19. The odds ratios indicating probabilities of smoking for each unit increase in income, were 0.82 and 0.91 in the unadjusted and adjusted models, respectively. Again, all the aforementioned odds ratios of being a smoker were significant (Table 8.1.2). In the adjusted model, African Americans were significantly more likely to be smokers, while Hispanic Americans and older persons were significantly less likely to be smokers.

Table 8.1.2 Association between socioeconomic position indicators and visits to dentists and currently smoking

		OR (95%CI) for Education Groups			Change in OR (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Frequency visit to dentist[1]	Unadjusted	1	0.40*** (0.34-0.46)	0.19*** (0.16-0.22)	1.53*** (1.45-1.61)
	Adjusted	1	0.49*** (0.43-0.67)	0.33*** (0.28-0.39)	1.40*** (1.34-1.48)
Currently smoking[2]	Unadjusted	1	1.96*** (1.58-2.44)	2.06*** (1.68-2.53)	0.82*** (0.79-0.85)
	Adjusted	1	1.79*** (1.41-2.28)	2.19*** (1.77-2.71)	0.91*** (0.87-0.94)

[1] Visits to dentists once a year or more, adjusted model controls for education, income, sex, ethnicity and age.
[2] Currently smoking, adjusted model controls for education, income, sex, ethnicity and age.
*** P<0.001 ** P<0.01 * P<0.05 NS Not significant

8.2.5 Social gradients in frequency of smoking per day

Persons in the second education group had a count ratio of smoking of 1.21 compared to the highest education group. In the adjusted model, the count ratio was 1.20. For those in the lowest education group, the count ratio of smoking was 1.21 and 1.24 in the unadjusted and adjusted models, respectively, compared to the highest education group. The count ratio of smoking for a unit increase of income was 0.99 and 0.98 for the unadjusted and adjusted models, respectively. All the count ratios for smoking were significant, except for the unadjusted association between income and count of smoking (Table 8.1.3).

Other factors in the adjusted model that were significantly associated with a lower count ratio of smoking were ethnicity (African Americans, Hispanic Americans, other ethnicities), sex (female), and younger age. The change to a higher probability of being current smoker and frequency of smoking observed in some of adjusted models for education and income is a result of the lack of adjusting for negative confounders, such as age.

Table 8.1.3 Association between socioeconomic position indicators and frequency of smoking

		Count ratio (95%CI) for Education Groups			Count ratio (95%CI) for income
		>12 years	12 years	<12 years	
Frequency of smoking per day[1]	Unadjusted	1	1.21*** (1.11-1.32)	1.21*** (1.10-1.35)	0.99NS (0.98-1.02)
	Adjusted	1	1.20*** (1.10-1.32)	1.24*** (1.12-1.37)	0.98* (0.96-0.99)

[1] Number of any smokes per day, adjusted model controls for education, income, sex, age and ethnicity
*** P<0.001 ** P<0.01 * P<0.05 NS Not significant

8.3 Association between selected health outcomes with relevant health-related behaviours.

Eating fresh fruits and vegetables did not show significant associations with any of the health outcomes. Hence this variable was not included in the analysis. Tables 8.2.1 to 8.2.4 show the association between health outcomes and the relevant health behaviours. It is worth noting here that being a current smoker was significantly less likely among older persons. Yet, older people were generally more likely to have poorer health. Therefore, the lack of adjustment for age (a negative confounder) while examining the association between current smoking and different health indicators might lead to misleading associations. Hence, when reporting the association between being a current smoker and different health outcomes, only the adjusted associations were reported.

8.3.1 Associations of perceived general health and ischaemic heart disease with being a current smoker and frequency of physical activity

The adjusted models for perceived general health controlled for education, income, medical insurance, ethnicity, sex, age, smoking and frequency of physical activities. The adjusted models for ischaemic heart disease additionally adjusted for diabetes, BMI and high blood pressure.

Smokers were 1.13 and 1.05 more likely to report poorer perceived general health or have ischaemic heart disease, respectively, but the associations were not significant for both health outcomes. A higher frequency of physical activity was significantly associated with a 0.97 and 0.98 decrease in reporting poorer general health in the unadjusted and adjusted models. Higher frequency of physical activity was significantly associated with lower probability of ischaemic heart disease (0.99) in the unadjusted model. This association disappeared in the adjusted model (Table 8.2.1).

Table 8.2.1 Association between behavioural factors and general health indicators

		OR (95%CI) for Currently smoking	OR (95%CI) for frequency of physical activity
Perceived general health[1]	Unadjusted	0.98^{NS} (0.84-1.14)	0.97*** (0.97-0.98)
	Adjusted	1.13^{NS} (0.94-1.37)	0.98*** (0.98-0.99)
Ischaemic heart disease[2]	Unadjusted	0.71* (0.55-0.93)	0.99** (0.98-0.99)
	Adjusted	1.08^{NS} (0.81-1.43)	1.00^{NS} (0.99-1.01)

[1] Perceived general health poor/fair, adjusted model controls for education, income, medical insurance, ethnicity, sex, age, smoking and frequency of physical activity.
[2] Ischemic heart disease, adjusted model controls for education, income, medical insurance, ethnicity, sex, age, diabetes, BMI, high blood pressure, smoking and frequency of physical activity
*** P<0.001 ** P<0.01 * P<0.05 ^{NS} not significant

8.3.2 Associations of perceived oral health with being a current smoker and frequency of visits to dentists.

Perceived oral health was significantly associated with being a current smoker and frequency of visits to dentists. Smokers were 1.73 times more likely to report poorer oral health, after adjusting for education, income, dental insurance, ethnicity, sex, age, and frequency of visit to dentist. Those visiting a dentist once or more per year had a lower probability of 0.33 for reporting poorer perceived oral health in the unadjusted model. In the adjusted model this probability attenuated to 0.43 (Table 8.2.2).

8.3.3 Associations of periodontitis (one site loss of attachment 3mm+ and one site gingival bleeding) with being a current smoker and frequency of visits to dentists.

Smokers were 1.11 more likely to have periodontitis in the adjusted model, controlling for education, income, dental insurance, ethnicity, sex, age, diabetes and frequency of visit to dentist. However the association was not significant. Additionally, persons who visited the dentist more often were 0.61 and 0.68 times less likely to have periodontitis in the unadjusted and adjusted models, respectively (Table 8.2.2).

Table 8.2.2 Association between behavioural factors and dichotomous oral health indicators

		OR (95%CI) for Currently smoking	OR (95%CI) for visit to dentist ≥ once a year
Perceived oral health[1]	Unadjusted	1.74^{***} (1.40-2.18)	0.33^{***} (0.29-0.38)
	Adjusted	1.73^{***} (1.39-2.17)	0.43^{***} (0.37-0.50)
Edentulousness[2]	Unadjusted	0.81^{*} (0.67-9.8)	0.03^{***} (0.02-0.05)
	Adjusted	1.29^{*} (1.01-1.65)	0.03^{***} (0.02-0.05)
Periodontal Disease[3]	Unadjusted	0.81^{*} (0.67-0.98)	0.61^{***} (0.56-0.83)
	Adjusted	1.11^{NS} (0.86-1.44)	0.68^{***} (0.51-0.73)

[1] Perceived oral health poor/fair, adjusted model controls for education, income, dental insurance, ethnicity, sex, age, smoking and frequency visit to dentist.
[2] Complete edentulousness, adjusted model controls for education, income, dental insurance, ethnicity, sex, age, smoking and frequency visit to dentist
[3] Periodontal disease (at least one site gingival bleeding and one site loss of attachment ≥ 3mm), adjusted model controls for education, income, dental insurance, ethnicity, sex, age, diabetes, smoking and frequency visit to dentist
*** P<0.001 ** P<0.01 * P<0.05 ^{NS} not significant

8.3.4 Associations of extents of gingival bleeding, loss of attachment and pocket depth with being a current smoker and frequency of visits to dentists.

The adjusted models pertaining to extent of periodontal diseases controlled for education, income, dental insurance, ethnicity, sex, age, diabetes, smoking and frequency of visit to dentist. Smokers had a significantly greater level of bleeding extent of 1.51 in the adjusted model. Those with more visits to dentists had significantly lower levels of bleeding extent of 5.24 and 3.33, respectively, in the unadjusted and adjusted models (Table 8.2.3).

Smokers had a significantly higher level of extent of loss of periodontal attachment of 5.06 in the adjusted model. Persons who visited a dentist once a year or more had lower levels of loss of periodontal attachment of 4.35 and 3.09 in the unadjusted and adjusted models, respectively (Table 8.2.3).

Smokers had a significant 1.82 higher level of extent of periodontal pocket depth in the adjusted model. More visits to dentists were associated with significant 2.24 and 1.27

lower levels of extent of periodontal pocket depth in the unadjusted and adjusted models respectively (Table 8.2.3).

8.3.5 Associations of edentulousness with being a current smoker and frequency of visits to dentists.

The adjusted models for edentulousness and loss to tooth surfaces controlled for education, income, dental insurance, ethnicity, sex, age, smoking and frequency of visit to dentist.

Smokers were 1.29 more likely to be edentulous in the adjusted model. Persons who visited a dentist more often were 0.03 less likely to be edentulous in the unadjusted and adjusted models (Table 8.2.2).

8.3.5 Associations of loss of tooth surfaces with being a current smoker and frequency of visits to dentists.

Smokers had a significantly higher count of lost tooth surfaces of 1.35. Persons who visited dentists once a year or more had significantly lower count ratios of 0.37 and 0.51 of missing tooth surface in the unadjusted and adjusted models, respectively (Table 8.2.4).

Table 8.2.3 Association between behavioural factors and extent of periodontal diseases

		Reg. Co (95%CI) for Currently smoking	Reg. Co (95%CI) for visit to dentist ≥ once a year
Bleeding extent[1]	Unadjusted	-0.55^{NS} (-1.43 to -0.34)	-5.24*** (-6.23 to -4.25)
	Adjusted	-1.52** (-2.53 to -0.51)	-3.37*** (-4.36 to -2.38)
Extent loss of attachment[2]	Unadjusted	0.73^{NS} (-1.14 to2.59)	-4.35*** (-5.61 to -3.09)
	Adjusted	4.99*** (3.13-6.85)	-3.12*** (-4.26 to -1.98)
Extent pocket depth[3]	Unadjusted	1.92*** (1.12-2.73)	-2.24*** (-2.73 to -1.75)
	Adjusted	1.81*** (1.01-2.62)	-1.29*** (-1.73 to -0.84)

[1] Percentage of sites with gingival bleeding to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking, frequency visit to dentist and reported diagnosis of diabetes.
[2] Percentage of sites with loss of attachment ≥ 3mm to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking, frequency visit to dentist and reported diagnosis of diabetes.
[3] Percentage of sites with pocket depth ≥ 4mm to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking, frequency visit to dentist and reported diagnosis of diabetes.
*** P<0.001 ** P<0.01 * P<0.05 ^{NS} not significant

Table 8.2.4 Association between behavioural factors and number of missing tooth surfaces

		Count ratio (95%CI) for Currently smoking	Count ratio (95%CI) for visit to dentist ≥ once a year
Number of missing tooth surfaces[1]	Unadjusted	0.86*** (0.80-0.93)	0.37*** (0.34-0.40)
	Adjusted	1.35*** (1.16-1.55)	0.51*** (0.45-0.58)

[1] Number of missing tooth surfaces due to disease, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, frequency visit to dentist and smoking (currently smoker)
*** P<0.001 ** P<0.01 * P<0.05 ^{NS} not significant

8.4 Effects of selected health-related behaviours on the social gradients in oral and general health.

8.4.1 Effects of health-related behaviours on the social gradients in ischaemic heart disease

After adjusting for smoking and frequency of physical activity, the probability of having ischaemic heart disease attenuated from 1.08 to 1.03 for the middle education group and from 1.56 to 1.49 for the lowest education group. The association was not significant for the middle education group and significant in the lowest one in both the unadjusted and adjusted models. The probability of having ischaemic heart as income increased also attenuated after adjusting for behavioural factors from 0.87 to 0.88 and remained significant (Table 8.3.1).

8.4.2 Effects of health-related behaviours on the social gradients in perceived general health.

For perceived general health, after adjusting for smoking and frequency of physical activity the odds ratio for the middle and lowest education groups attenuated from 1.50 to 1.38 and from 2.68 to 2.43, respectively and remained significant. Similarly, the odds ratio for perceived general health as income increased attenuated from 0.77 to 0.78 and remained significant (Table 8.3.1).

8.4.3 Effects of health-related behaviours on the social gradients in perceived oral health.

After adjusting for smoking and visits to dentists the probability of reporting poorer perceived oral health attenuated from 1.71 to 1.44 and from 2.18 to 1.72, and were always significant for the middle and lowest education groups, respectively. Similarly, the odds ratio for poorer perceived oral health as income increased attenuated from 0.84 to 0.88 and remained significant (Table 8.3.1).

8.4.4 Effects of health-related behaviours on the social gradients in periodontitis (one site loss of attachment 3mm+ and one site gingival bleeding).

The odds ratios for periodontal disease for the middle and lowest education groups attenuated from 1.27 to 1.17 and from 1.42 to 1.26 respectively and lost significance after adjusting for smoking and visits to dentist. For a higher unit of income the probability of periodontitis were 0.88 and 0.89 in the unadjusted and adjusted models and were always significant (Table 8.3.1).

8.4.5 Effects of health-related behaviours on the extent of gingival bleeding, loss of attachment and pocket depth.

Extents of gingival bleeding attenuated from 2.22 to 2.05 and from 5.13 to 4.82 and were always significant for the middle and lowest education groups after adjusting for smoking and dental visits. Extent of gingival bleeding attenuated from 0.93 to 0.80 in the unadjusted and adjusted models as income increased (Table 8.3.2).

Similarly, the regression coefficient for extent of loss of periodontal attachment for the middle and lowest education groups changed from 2.97 to 1.77 and from 8.09 to 6.50 but remained significant after adjusting for behaviour. The regression coefficient for loss of periodontal attachment as income increased changed from -0.73 to -0.49 after adjusting for behaviour (Table 8.3.2).

The same relationship was observed in the extent of periodontal pocket depth models with the extent attenuating from 0.92 to 0.51 and from 2.02 to 1.46 for the middle and lowest education groups after adjusting for behaviour and remained significant. Similarly, the lower levels of periodontal pocket extent with increased income changed from -0.36 to -0.26 after adjusting for behaviour (Table 8.3.2).

8.4.6 Effects of health-related behaviours on edentulousness

The probability of being edentulous for the middle and lowest education groups attenuated from 2.56 to 1.77 and 4.21 to 2.50, respectively and remained significant after adjusting for smoking and visits to dentists. For a higher unit of income the odds ratios for being edentulous were 0.75 and 0.88 for the unadjusted and adjusted models, and were always significant (Table 8.3.1).

8.4.7 Effects of health-related behaviours on loss of tooth surfaces.

Count ratio of missing tooth surfaces attenuated from 2.02 to 1.81 and from 2.24 to 1.83 and remained significant for the middle and lowest education groups after adjusting for smoking and visit to dentist. Count ratio of tooth loss with higher income changed from 0.88 to 0.93 after adjusting for behaviour (Table 8.3.3).

Table 8.3.1 Effects of indicators of behaviour on the gradients in the dichotomous oral and general health outcomes

		OR (95%CI) for Education Groups			OR (95%CI) for increase in income
		>12 years	12 years	<12 years	
Ischaemic heart disease[1]	1 Not adjusting for behaviour	1	1.06^{NS} (0.83-1.35)	1.53** (1.14-2.05)	0.88** (0.82-0.94)
	2 Adjusting for behaviour	1	1.01^{NS} (0.79-1.29)	1.45* (1.08-1.93)	0.88*** (0.82-0.94)
Perceived general health[2]	1 Not adjusting for behaviour	1	1.50** (1.20-1.89)	2.68*** (2.15-3.35)	0.77*** (0.73-0.82)
	2 Adjusting for behaviour	1	1.38** (1.10-1.73)	2.43*** (1.95-3.04)	0.78*** (0.74-0.82)
Perceived oral health[3]	1 Not adjusting for behaviour	1	1.71*** (1.47-1.99)	2.18*** (1.82-2.59)	0.84*** (0.79-0.88)
	2 Adjusting for behaviour	1	1.44*** (1.24-1.67)	1.72*** (1.44-2.06)	0.88*** (0.83-0.93)
Edentulous[4]	1 Not adjusting for behaviour	1	2.56*** (1.84-3.58)	4.21*** (2.70-6.56)	0.75*** (0.70-0.81)
	2 Adjusting for behaviour	1	1.77** (1.25-2.50)	2.50*** (1.56-4.01)	0.88*** (0.82-0.94)
Periodontal Disease[5]	1 Not adjusting for behaviour	1	1.29* (1.05-1.59)	1.42** (1.09-1.84)	0.88*** (0.84-0.92)
	2 Adjusting for behaviour	1	1.18^{NS} (0.95-1.47)	1.26^{NS} (0.97-1.62)	0.89*** (0.85-0.94)

[1] Ischemic heart disease, first model adjusted for education, income, medical insurance, ethnicity, sex, age, diabetes, BMI, high blood pressure. The second model adjusted for smoking and frequency of physical activity.
[2] Perceived general health poor/fair, first model adjusted for education, income, medical insurance, ethnicity, sex, age. The second model adjusted for smoking and frequency of physical activity.
[3] Perceived oral health poor/fair, first model adjusted for education, income, dental insurance, ethnicity, sex and age. The second model adjusted for smoking and frequency visit to dentist.
[4] Edentulous, first model adjusted for education, income, dental insurance, ethnicity, sex and age. The second model adjusted for smoking and frequency visit to dentist.
[5] Periodontal disease (at least one site gingival bleeding and one site loss of attachment $\geq$ 3mm), first model adjusted for education, income, dental insurance, ethnicity, sex, age and diabetes. The second model adjusted for smoking and frequency visit to dentist.
*** P<0.001 ** P<0.01 * P<0.05 ^{NS} not significant

Table 8.3.2 Effects of indicators of behaviour on the gradients in the extents of periodontal diseases

		Regression coefficient (95%CI) for Education Groups			Regression coefficient (95%CI) for increase in income
		>12 years	12 years	<12 years	
Extent gingival bleeding[1]	1. Not adjusting for behaviour	0.00	2.25*** (1.38-3.11)	5.18*** (3.81-6.55)	-0.93*** (-1.21 to -0.65)
	2. Adjusting for behaviour	0.00	2.06*** (1.11-3.02)	4.88*** (3.53-6.23)	-0.80*** (-1.07 to -0.52)
Extent loss of attachment[2]	1. Not adjusting for behaviour	0.00	2.99*** (1.91-4.08)	8.09*** (6.68-9.51)	-0.75*** (-1.10 to -0.39)
	2. Adjusting for behaviour	0.00	1.80** (0.71-2.89)	6.53*** (5.15-7.90)	-0.50** (-0.83 to -0.17)
Extent pocket depth[3]	1. Not adjusting for behaviour	0.00	0.95*** (0.55-1.35)	2.09*** (1.34-2.83)	-0.36*** (-0.50 to -0.22)
	2. Adjusting for behaviour	0.00	0.53** (0.14-0.92)	1.53*** (0.82-2.24)	-0.27*** (-0.39 to -0.14)

[1] Percentage of sites with gingival bleeding to all examined sites, first model adjusted for education, income, dental insurance, sex, ethnicity, age and reported diagnosis of diabetes. The second model adjusted for smoking and frequency visit to dentist.

[2] Percentage of sites with loss of attachment ≥ 3mm to all examined sites, first model adjusted for education, income, dental insurance, sex, ethnicity, age and reported diagnosis of diabetes. The second model adjusted for smoking and frequency visit to dentist.

[3] Percentage of sites with pocket depth ≥ 4mm to all examined sites, first model adjusted for education, income, dental insurance, sex, ethnicity, age and reported diagnosis of diabetes. The second model adjusted for smoking and frequency visit to dentist.

*** $P<0.001$ ** $P<0.01$ * $P<0.05$ NS not significant

Table 8.3.3 Effects of indicators of behaviour on the gradients in loss of tooth surfaces

		Count Ratio (95%CI) for Education Groups			Count Ratio (95%CI) for increase in income
		>12 years	12 years	<12 years	
Number of missing tooth surfaces[1]	1. Not adjusting for behaviour	1	2.02*** (1.71-2.39)	2.24*** (1.69-2.97)	0.88*** (0.85-0.91)
	2. Adjusting for behaviour	1	1.81*** (1.55-2.11)	1.83*** (1.45-2.30)	0.93*** (0.90-0.96)

[1] Number of missing tooth surfaces due to disease, first model adjusted for education, income, dental insurance, sex, ethnicity and age. The second model adjusted for smoking and frequency visit to dentist.
*** P<0.001 ** P<0.01 * P<0.05 [NS] not significant

8.5 Summary of the results reported in Chapter 8

- There were clear social gradients in three health-related behaviours, namely being a current smoker, frequency of smoking and frequency of visits to a dentist.
- There were income gradients in frequency of physical activity and frequency of eating fresh fruits and vegetables. However, there was no education gradient for these two behaviours.
- Being a current smoker and frequency of visits to a dentist were associated with oral health outcomes.
- Overall, social gradients in oral and general health attenuated after adjusting for related health behaviours.
- Adjusting for health-related behaviours did affect the significant associations of health outcomes with education and income, except for the association between periodontal disease and education, which was marginally insignificant in the adjusted model.
- The effects of health-related behaviours on the social gradients in oral and general health appeared to be consistent (Figures 8.1 to 8.4).
- The results support the hypothesis about behavioural pathways towards social gradients in oral and general health.
- The next chapter reports the effect of tooth cleanliness, indicated by calculus, on the social gradients in oral health.

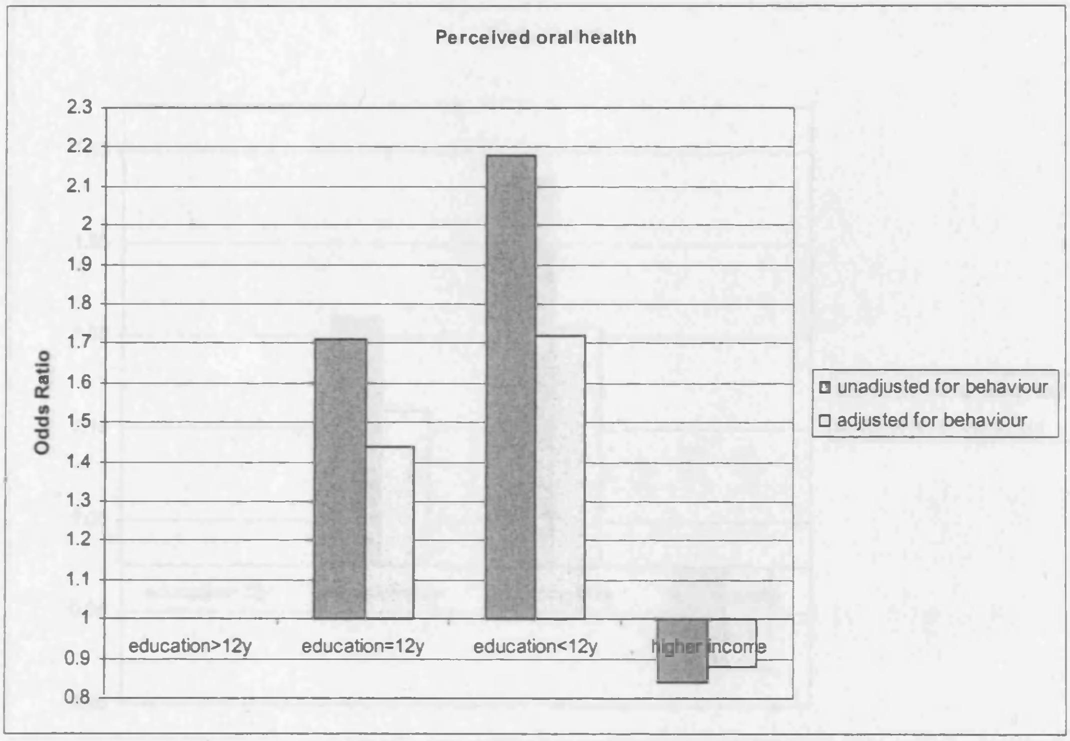


Figure 8.1 Change in the social gradients in perceived oral health, after adjusting for smoking and visits to dentist.

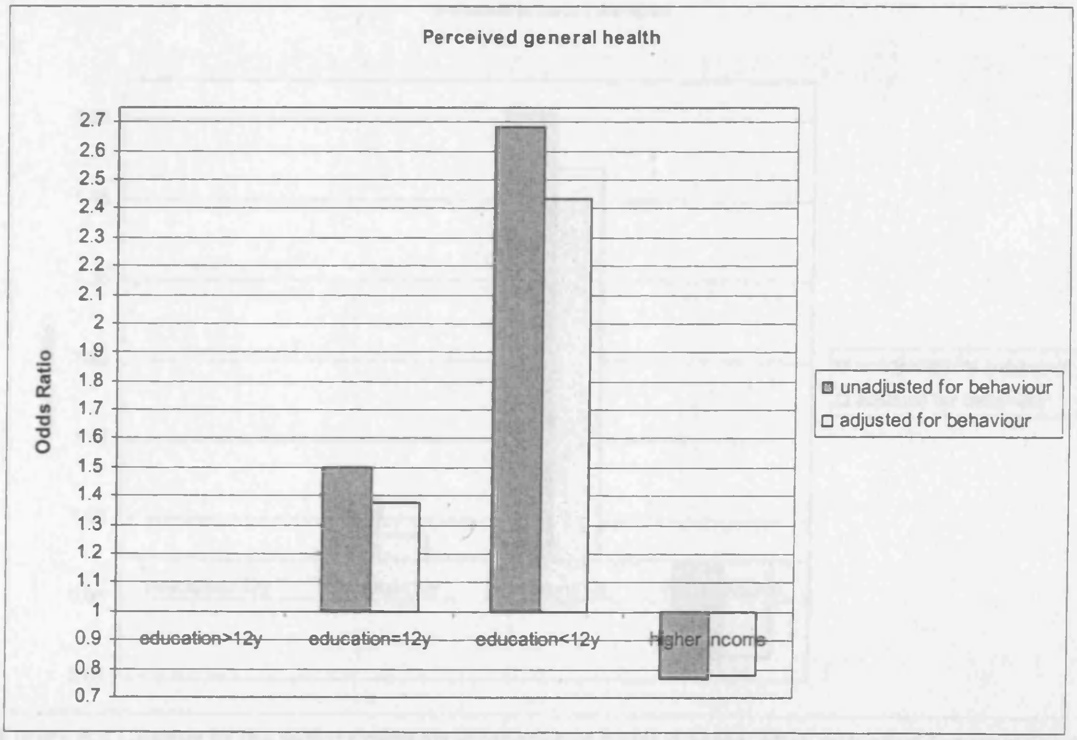


Figure 8.2 Change in the social gradients in perceived general health after, adjusting for smoking and physical activity.

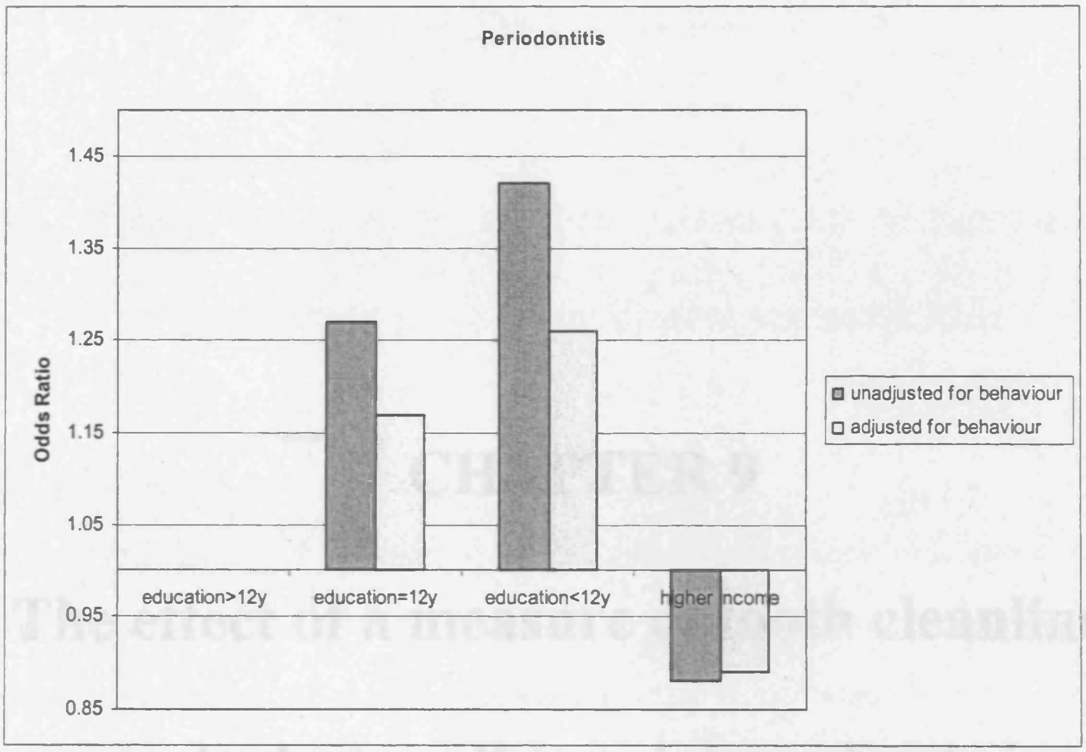


Figure 8.3 Change in the social gradients in periodontal disease, after adjusting for smoking and visits to dentist

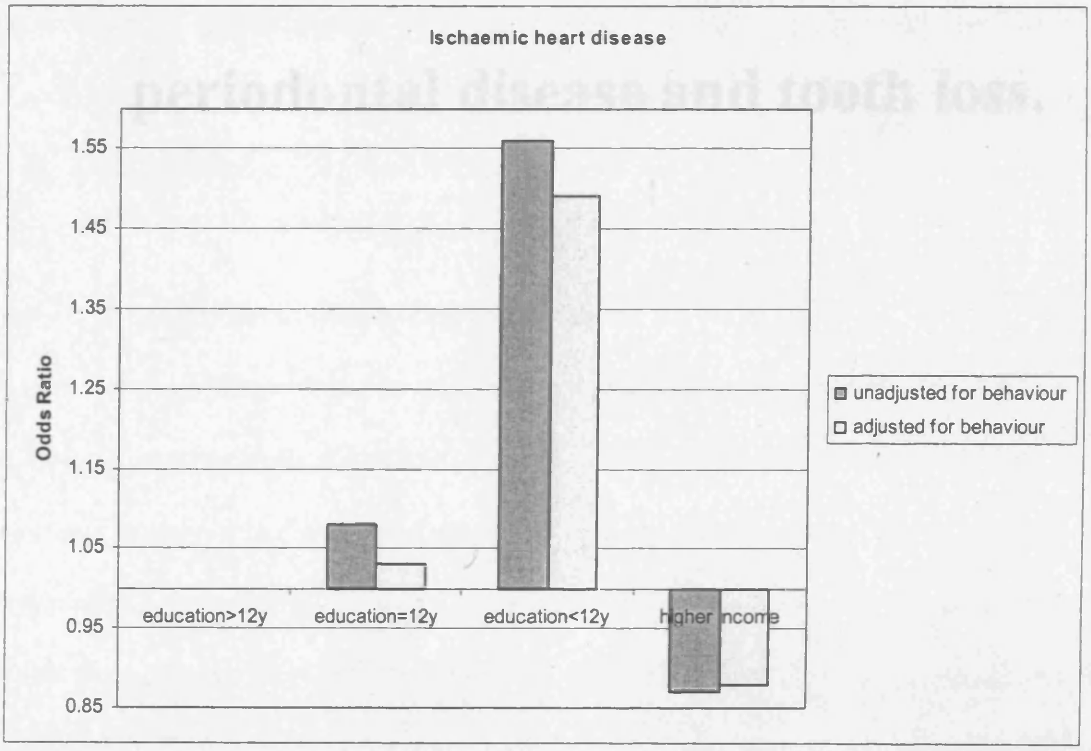


Figure 8.4 Change in the social gradients in ischaemic heart disease, after adjusting for smoking and physical activity

CHAPTER 9

The effect of a measure of tooth cleanliness (calculus) on the social gradients in periodontal disease and tooth loss.

CHAPTER 9

The effect of a measure of tooth cleanliness (calculus) on the social gradients in periodontal disease and tooth loss.

9.1 Introduction

This chapter presents findings on the social gradients in calculus as a marker of tooth cleanliness, examine the association between calculus and oral health indicators and examine the effect of adjusting for calculus on the social gradients in oral health.

Odds ratios reflect probability of having the condition, regression coefficients reflect the change in the occurrence of the condition (a negative sign before the figure reflects decrease in the condition), count ratios reflect the ratio of the occurrence of the condition, compared to reference group or baseline.

9.2 Social gradients in the extent of calculus.

There were very steep education and poverty income ratio gradients in the extent of sites with calculus. Persons with 12 years of education had 10.41 higher percentages of sites with calculus compared to those with more than 12 years of education. Persons with less than 12 years of education had 21.32 higher percentages of sites with calculus compared to those with more than 12 years of education. For each higher unit of income, the extent of calculus was lower by 3.09. After adjusting for dental insurance, ethnicity, sex, age, smoking and diabetes, the gradients in calculus attenuated but remained steep and significant. In the adjusted model, persons with 12 years of education and less than 12 years of education had greater extent of calculus of 6.99 and 12.18 respectively compared to those with more than 12 years of education. Also in the adjusted model, for a higher unit of income the extent of calculus was lower by 1.80 (Table 9.1).

Table 9.1 Association between extent of calculus and indicators of socioeconomic position

		Regression coefficient (95%CI) for Education Groups			Regression coefficient (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Calculus extent[1]	Unadjusted	0.00	10.41*** (8.40-12.41)	21.32*** (18.28-24.36)	-3.09*** (-3.98 to -2.21)
	Adjusted	0.00	6.99*** (5.20-8.79)	12.18*** (10.32-16.22)	-1.80*** (-2.57 to -1.02)

[1] Percentage of sites with calculus (supra/sub-gingival) to all examined sites, adjusted model controls for education, income, dental insurance, ethnicity, sex, age smoking and diabetes.
*** $P<0.001$ ** $P<0.01$ * $P<0.05$ NS not significant

Another model was constructed additionally adjusting for frequency of visits to dentists. The regression coefficients for the middle and lowest education groups and for income remained significant. They were 5.40, 10.77 and -1.15, respectively. Figure 9.1 shows the education and income gradients in extent of calculus.

Other factors that were significantly associated with lower extent of calculus included dental insurance, frequency of visits to dentists and being a female. African Americans, Hispanic Americans, other ethnicities, smoker and older age were associated higher levels of calculus.

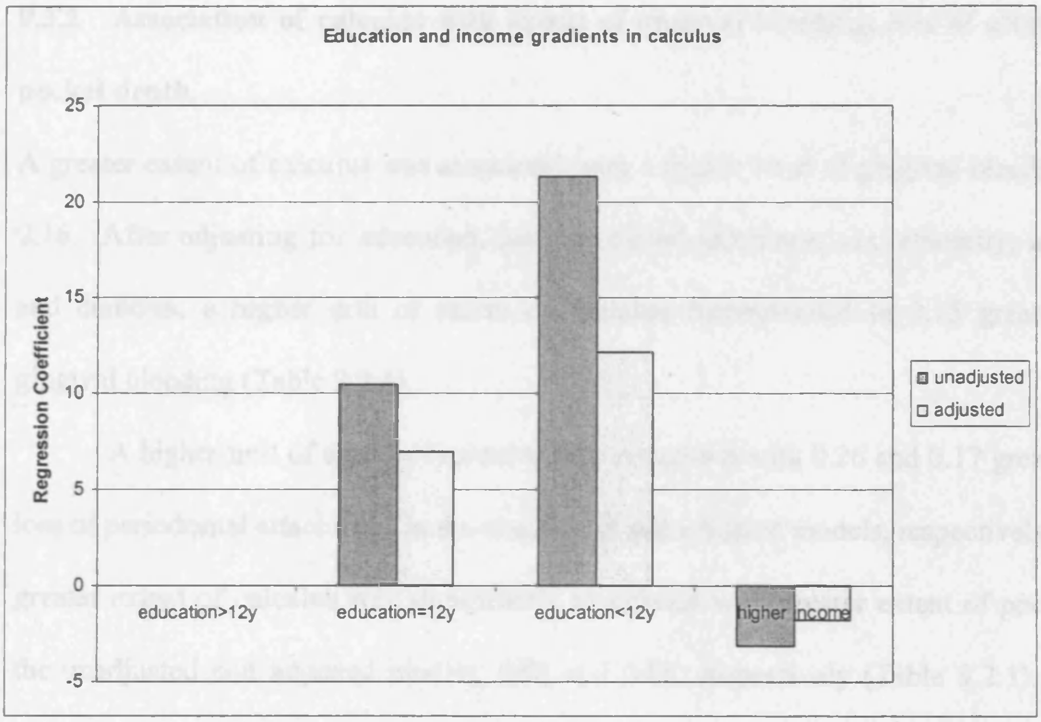


Figure 9.1 Social gradients in extent of calculus

9.3 Associations of calculus with periodontal disease and tooth loss

Calculus used here as a marker of tooth cleanliness, was significantly associated with all indicators of periodontal health and tooth loss in the unadjusted and adjusted models. The results are shown in Tables 9.2.1 and 9.2.2.

9.3.1 Association of calculus with periodontitis (at least one site with loss of attachment 3mm+ and one site with gingival bleeding).

For a higher unit of extent of calculus persons were 1.03 times more likely to have periodontitis. In the adjusted model, the probability for having periodontitis with higher extent of calculus attenuated to 1.02, and remained significant (Table 9.2.1).

9.3.2 Association of calculus with extent of gingival bleeding, loss of attachment and pocket depth.

A greater extent of calculus was associated with a higher level of gingival bleeding extent of 0.16. After adjusting for education, income, dental insurance, sex, ethnicity, age, smoking and diabetes, a higher unit of extent of calculus corresponded to 0.15 greater extent of gingival bleeding (Table 9.2.1).

A higher unit of extent of calculus was associated with 0.26 and 0.17 greater extent of loss of periodontal attachment in the unadjusted and adjusted models, respectively. Similarly, greater extent of calculus was significantly associated with greater extent of pocket depth in the unadjusted and adjusted models, 0.08 and 0.06, respectively (Table 9.2.1). Figure 9.2 shows the adjusted probability of the extent of periodontal disease with a higher unit of the extent of calculus.

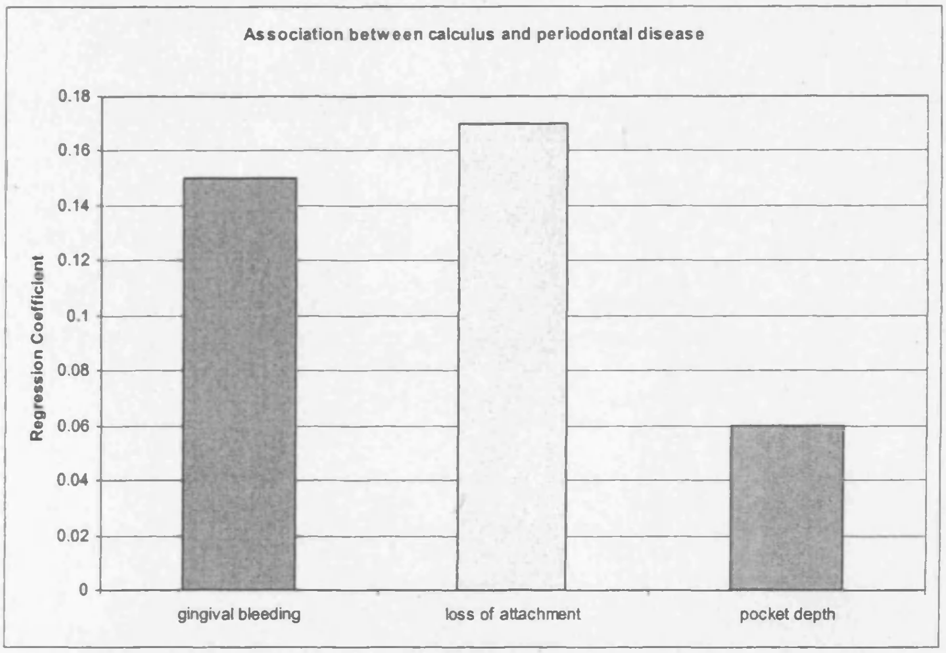


Figure 9.2 Adjusted changes in the extent of periodontal diseases with a unit increase in extent of calculus.

9.3.3 Association of calculus with loss of tooth surfaces

Teeth cleanliness, indicated by calculus, was associated with greater numbers of missing tooth surfaces. For a higher unit of the extent of calculus there was a significant 1.02 count ratio of missing tooth surfaces. After adjusting for education, income, dental insurance, sex, ethnicity, age and smoking the count ratio attenuated to 1.01, and remained significant (Table 9.2.2).

Table 9.2.1 Association between extent of calculus and periodontal disease

		Regression coefficient (95%CI) for extent of Calculus
Extent of gingival bleeding[1]	Unadjusted	0.16*** (0.14-0.18)
	Adjusted	0.15*** (0.12-0.17)
Extent of loss of attachment[2]	Unadjusted	0.26*** (0.23-0.29)
	Adjusted	0.17*** (0.14-0.19)
Extent of pocket depth[3]	Unadjusted	0.08*** (0.06-0.10)
	Adjusted	0.06*** (0.04-0.08)
		OR (95%CI) for extent of Calculus
Periodontal disease[4]	Unadjusted	1.03*** (1.02-1.03)
	Adjusted	1.02*** (1.01-1.02)

[1] Percentage of sites with gingival bleeding to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking, calculus and reported diagnosis of diabetes.

[2] Percentage of sites with loss of attachment ≥ 3mm to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking, calculus and reported diagnosis of diabetes.

[3] Percentage of sites with pocket depth ≥ 4mm to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking, calculus and reported diagnosis of diabetes.

[4] Periodontal disease (at least one site gingival bleeding and one site loss of attachment ≥ 3mm), adjusted model controls for education, income, dental insurance, ethnicity, sex, age, diabetes, smoking and calculus.

*** P<0.001 ** P<0.01 * P<0.05 NS not significant

Table 9.2.2 Association between extent of calculus and tooth loss

		Change in count ratio (95%CI) for a unit increase in extent of Calculus
Number of missing tooth surfaces due to disease[1]	Unadjusted	1.02*** (1.01-1.02)
	Adjusted	1.01*** (1.01-1.01)

[1] Number of missing tooth surfaces due to disease, adjusted model controls for education, income, dental insurance, sex, ethnicity, age and smoking (currently smoker)

*** P<0.001 ** P<0.01 * P<0.05

9.4 Effect of tooth cleanliness (calculus) on the social gradients in oral health.

Calculus as a marker of tooth cleanliness had a large effect on education and income gradients in periodontal diseases and tooth loss. When the models pertaining to indicators of periodontal diseases and tooth loss adjusting for education, income, dental insurance, age, sex, smoking and diabetes were compared to similar models but additionally adjusting for extent of calculus, there were consistent changes in education and income gradients (Tables 9.3.1 and 9.3.2).

9.4.1 Effect of tooth cleanliness (calculus) on periodontitis (at least one site with loss of attachment 3mm+ and one site with gingival bleeding).

The probability of having periodontitis for the middle and lowest education groups attenuated from 1.24 and 1.37 to 1.06 and 1.02 and lost significance in both groups after adjusting for calculus. The odds ratios for having periodontitis as income increased were 0.87 and 0.91 for the models not adjusting and adjusting for calculus respectively and were significant in both models (Table 9.3.1 and Figure 9.3).

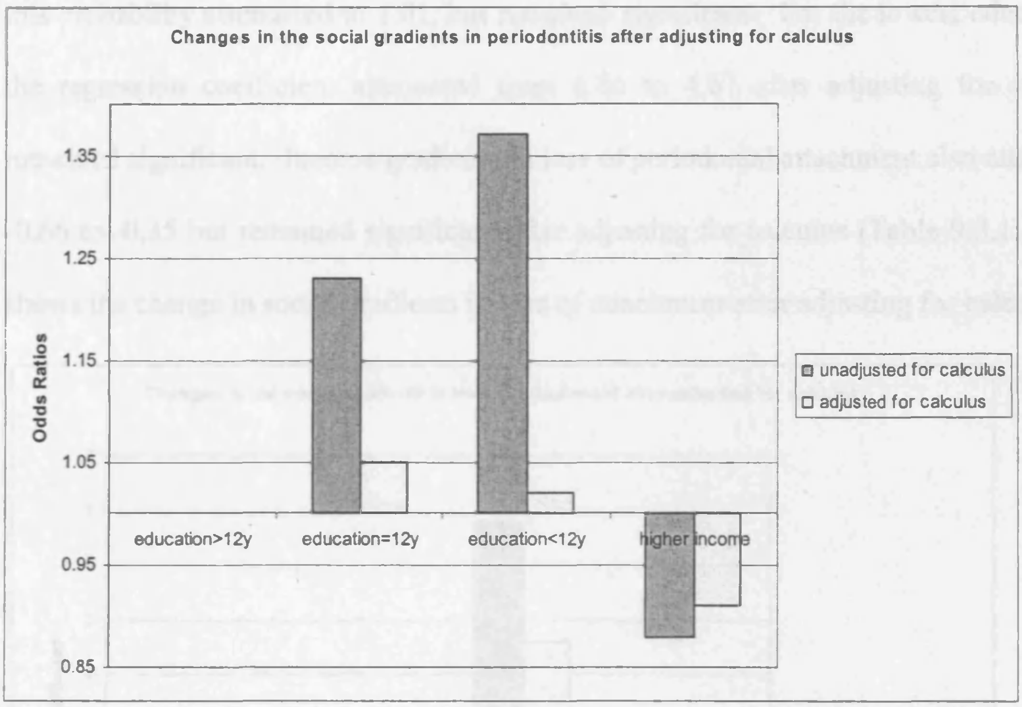


Figure 9.3 Change in the social gradients in periodontitis after adjustment for extent of calculus

9.4.2 Effect of tooth cleanliness (calculus) on the extent of gingival bleeding.

Persons at middle and lowest levels of education had a 2.49 and 5.57 greater extent of gingival bleeding compared to those in the highest education group. After adjusting for calculus, these probabilities attenuated to 1.46 and 3.66 respectively and remained significant. The extent of gingival bleeding as income increased was -0.98, and changed to -0.70 after adjusting for calculus and remained significant (Table 9.3.1).

9.4.3 Effect of tooth cleanliness (calculus) on the extent of loss of periodontal attachment.

Persons in the middle education groups had a 2.19 greater extent of loss of periodontal attachment compared to those in the highest education group. After adjusting for calculus, this probability attenuated to 1.01, but remained significant. For the lowest education group, the regression coefficient attenuated from 6.86 to 4.67 after adjusting for calculus, and remained significant. Income gradients in loss of periodontal attachment also attenuated from -0.66 to -0.35 but remained significant after adjusting for calculus (Table 9.3.1). Figure 9.4 shows the change in social gradients in loss of attachment after adjusting for calculus.

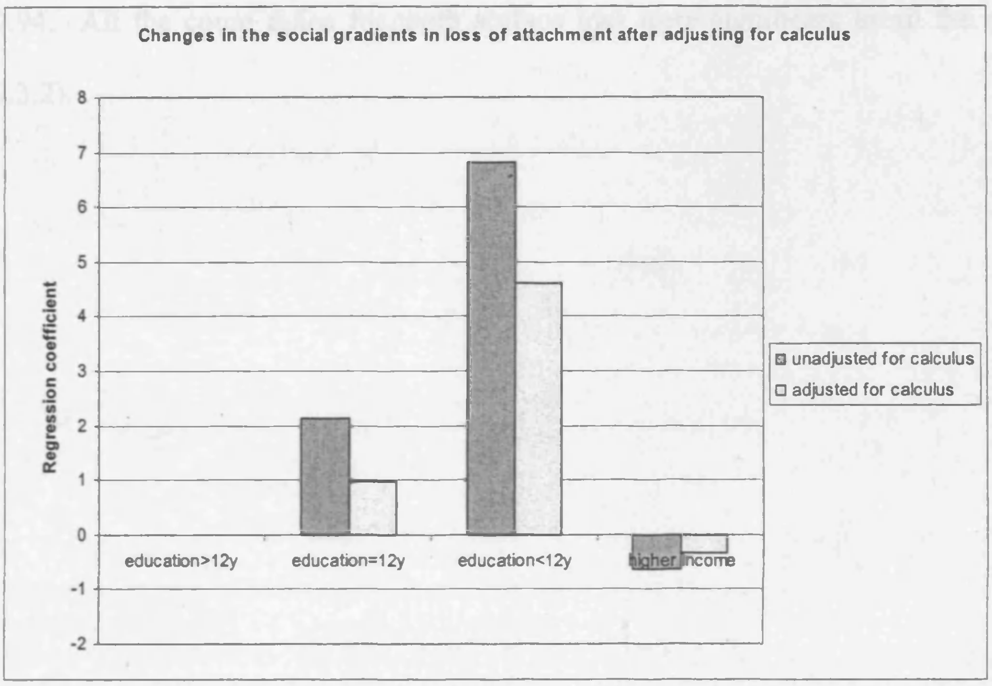


Figure 9.4 Change in the social gradients in loss of periodontal attachment after adjustment for extent of calculus

9.4.4 Effect of tooth cleanliness (calculus) on the extent of pocket depth.

Education gradients for extent of pocket depth attenuated after adjusting for calculus with the regression coefficient for the middle and the lowest education groups changing from 0.66 and 1.76 to 0.24 and 0.97, respectively, and lost statistical significance in the middle education group. Similarly, income gradients in pocket depth attenuated from -0.33 to -0.22 after adjusting for calculus and remained significant (Table 9.3.1).

9.4.5 Effect of tooth cleanliness (calculus) on loss of tooth surfaces.

Adjusting for calculus attenuated education and income gradients in tooth loss. The count ratio of tooth loss in the middle education group compared to highest education group attenuated from 1.89 to 1.74, after adjusting for calculus. For the lowest education group, the count ratio attenuated from 1.97 to 1.70. For income, the count ratio changed from 0.92 to 0.94. All the count ratios for tooth surface loss were significant in all the models (Table 9.3.2).

Table 9.3.1 Effect of calculus on the association between periodontal disease and indicators of socioeconomic position

		Regression coefficient (95%CI) for Education Groups			Regression coefficient (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Extent gingival bleeding[1]	1 Not adjusting for calculus	0.00	2.49^{***} (1.55-3.43)	5.57^{***} (4.17-6.96)	-0.98^{***} (-1.26 to -0.70)
	2 Adjusting for calculus	0.00	1.46^{**} (0.57-2.35)	3.66^{***} (2.35-4.97)	-0.70^{***} (-1.00 to -0.41)
Extent loss of attachment[2]	1 Not adjusting for calculus	0.00	2.19^{***} (1.10-3.29)	6.86^{***} (5.50-8.21)	-0.66^{***} (-0.99 to -0.32)
	2 Adjusting for calculus	0.00	1.01^{*} (0.01 to 2.02)	4.67^{***} (3.28-6.06)	-0.35^{*} (-0.65 to -0.04)
Extent pocket depth[3]	1 Not adjusting for calculus	0.00	0.66^{**} (0.27-1.06)	1.76^{***} (1.05-2.48)	-0.33^{***} (-0.46 to -0.20)
	2 Adjusting for calculus	0.00	0.24^{NS} (-0.17 to 0.64)	0.97^{**} (0.31-1.63)	-0.22^{***} (-0.33 to -0.08)

		OR (95%CI) for Education Groups			OR (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Periodontal disease[4]	1 Not adjusting for calculus	1	1.24^{*} (1.01-1.53)	1.37^{*} (1.07-1.76)	0.87^{***} (0.83-0.91)
	2 Adjusting for calculus	1	1.06^{NS} (0.86-1.30)	1.02^{NS} (0.76-1.35)	0.91^{***} (0.86-0.96)

[1] Percentage of sites with gingival bleeding to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking, and reported diagnosis of diabetes. In second model calculus was added to the model.

[2] Percentage of sites with loss of attachment ≥ 3mm to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking and reported diagnosis of diabetes. In second model calculus was added to the model.

[3] Percentage of sites with pocket depth ≥ 4mm to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking and reported diagnosis of diabetes. In second model calculus was added to the model.

[4] Periodontal disease (at least one site gingival bleeding and one site loss of attachment ≥ 3mm), adjusted model controls for education, income, dental insurance, ethnicity, sex, age, diabetes and smoking. In second model calculus was added to the model.

*** P<0.001 ** P<0.01 * P<0.05 ^{NS} not significant

Table 9.3.2 Effect of calculus on the association between tooth loss and indicators of socioeconomic position

		Count Ratio (95%CI) for Education Groups			Change in count Ratio (95%CI) for unit increase in income
		>12 years	12 years	<12 years	
Number of missing tooth surfaces due to disease[1]	Unadjusted for calculus	1	1.89*** (1.59-2.26)	1.97*** (1.62-2.40)	0.92*** (0.88-0.95)
	Adjusted for calculus	1	1.74*** (1.45-2.08)	1.70*** (1.41-2.04)	0.94** (0.90-0.97)

[1] Number of missing tooth surfaces due to disease unadjusted model controls for education, income, dental insurance, sex, ethnicity, age and smoking (currently smoker), adjusted model additionally controls for calculus extent.

*** P<0.001 ** P<0.01 * P<0.05

9.5 Summary of the results reported in Chapter 9

- There were steep education and income gradients in calculus
- The social gradients in calculus persisted after adjusting for sex, ethnicity, age, dental insurance, frequency of dental visits and smoking.
- Calculus as a marker of tooth cleanliness was significantly associated with all indicators of periodontal diseases and tooth loss.
- In the adjusted models, the association between calculus and oral health attenuated but remained significant.
- Adjusting for the accumulation of calculus explained a greater part of the gradients in periodontal diseases and tooth loss than other health-related behaviours.
- However, after adjusting for calculus, the gradients remained clear for all oral health indicators with the exception of periodontitis and extent of periodontal pockets.
- Calculus as a surrogate marker of oral health behaviour went some way to explain the social gradients in oral disease. This finding supports the fourth hypothesis about a behavioural pathway in the social gradients in oral health.
- The following chapter reports findings on the stress pathway, indicated here by allostatic load, on the gradients in ischaemic heart disease and periodontal disease.

CHAPTER 10

A stress pathway linking socioeconomic position to periodontal disease and ischaemic heart disease

CHAPTER 10

A stress pathway linking socioeconomic position to periodontal disease and ischaemic heart disease

10.1 Introduction

The chapter presents findings on the association of markers of allostatic load, namely C-reactive protein, fibrinogen, plasma glucose, central obesity, hypertriglycerdemia, low HDL cholesterol, high blood pressure and an aggregate variable of these seven markers, with periodontal disease and ischaemic heart disease, and examine the effects of adjusting for allostatic load on the social gradients in these two conditions.

Odds ratios reflect probability of having the condition, regression coefficients reflect the change in the occurrence of the condition (a negative sign before the figure reflects decrease in the condition), count ratios reflect the ratio of the occurrence of the condition, compared to reference group or baseline.

10.2 Associations of indicators of allostatic load with ischaemic heart disease and periodontal disease.

10.2.1 Associations of indicators of allostatic load with ischaemic heart disease.

All seven markers of allostasis, namely C-reactive protein (CRP), fibrinogen, plasma glucose, central obesity, hypertriglycerdemia, low HDL cholesterol, high blood pressure, as well as an aggregated variable of these seven markers, were significantly associated with a greater probability of ischaemic heart disease. In the adjusted model, controlling for education, income, age, sex, ethnicity, medical insurance and smoking, each indicator of allostasis maintained significant associations with ischaemic heart disease but the odds ratios attenuated. The odds ratios for CRP attenuated from 1.32 to 1.21 in the adjusted model. Fibrinogen had the same significant odds ratio of 1.01 in both adjusted and unadjusted models. For central obesity, the odds ratio changed from 1.55 to 1.44. Similarly, the odds ratios for low hypertriglycerdemia, HDL-cholesterol, plasma glucose and high blood pressure attenuated from 1.85, 1.53, 2.13 and 2.45 to 1.67, 1.22, 1.24 and 1.39, respectively. The aggregated allostasis variable had odds ratios of 1.36 and 1.27 in the unadjusted and adjusted models respectively (Table 10.1).

10.2.2 Associations of indicators of allostatic load with periodontal disease (one site with loss of attachment 3mm+ and one site with gingival bleeding).

In the models pertaining to the dichotomous periodontal disease variable, persons who had higher levels of allostasis indicators had higher odds ratios for periodontal disease, but not all of them were significant. C-reactive protein (CRP) was not significantly associated with periodontitis neither in the unadjusted nor in the adjusted models. The odds ratios were 1.11 and 1.03, respectively. Similarly, fibrinogen was not significantly associated with periodontitis in both unadjusted and adjusted models with odds ratios 1.01 and 0.99. Central obesity was significantly associated with periodontitis in the unadjusted and adjusted model with odds ratios of 1.48 and 1.36, respectively. Hypertriglycerdemia had a significant probability in both models of 1.42 and 1.27. Low HDL-cholesterol, plasma glucose and high blood pressure showed significant associations with periodontitis in both the unadjusted and adjusted models with odds ratios 1.50 and 1.46 for low HDL-cholesterol, 2.03 and 1.56 for glucose and 1.84 and 1.44 for blood pressure in the unadjusted and adjusted models, respectively. For a unit increase in the aggregated allostasis variable there was a significant increase in the odds ratio for having periodontitis; 1.22 and 1.15 in the unadjusted and adjusted models, respectively (Table 10.1).

10.2.3 Associations of indicators of allostatic load with extent of gingival bleeding.

There was a significant increase in the extent of gingival bleeding with all markers of allostasis and with the aggregated allostasis variable in the unadjusted models. In the adjusted model CRP maintained its significant association with gingival bleeding and the regression coefficient decreased from 1.73 to 1.34. Fibrinogen had the same regression coefficient of 0.01 in both unadjusted and adjusted models but the association was not significant in the adjusted model. Central obesity maintained its significant association with greater gingival bleeding with regression coefficients of 4.56 and 3.81 in the unadjusted and adjusted models, respectively. Similarly, hypertriglycerdemia, low HDL-cholesterol, plasma glucose and blood pressure maintained their significant association with bleeding extent with regression coefficients attenuating from 2.60, 2.41, 6.31 and 3.83 to 1.76, 2.02, 4.70 and 2.66, respectively. The aggregated allostasis variable maintained significant associations with greater level of gingival bleeding. In the adjusted model the change in the level of gingival bleeding attenuated from 1.67 to 1.37 with a unit increase in allostasis (Table 10.1).

10.2.4 Associations of indicators of allostatic load with extent of loss of periodontal attachment.

A greater extent of loss of periodontal attachment was significantly associated with all markers of allostasis and the aggregated allostatic variable in the unadjusted models. The extent of loss of attachment for those with high CRP decreased from 3.02 in the unadjusted model to 1.05 and lost significance in the adjusted model. Similarly, the extent of extent of loss of periodontal attachment for those with central obesity, hypertriglycerdemia and high blood pressure decreased from 2.75, 2.94 and 7.02 in the unadjusted models to 0.69, 0.01 and 0.41, respectively, and lost significance. Fibrinogen, low HDL cholesterol and glucose maintained their significant relationship with loss of attachment with regression coefficients changing from 0.04, 4.71 and 8.96 to 0.01, 3.23 and to 3.70, respectively. The aggregated allostasis variable had significant effects on extent of loss of attachment in the unadjusted and adjusted models with disease level increasing by 2.56 and 0.93 in both models, respectively, for a unit increase of allostasis (Table 10.1).

10.2.5 Associations of indicators of allostatic load with extent of pocket depth.

Higher level of CRP was significantly associated with greater extent of pocket depth of 0.91 and 0.79 in both unadjusted and adjusted models. Fibrinogen had a significant relationship with periodontal pocket depth in both models with regression coefficients of 0.01 in both models. Central obesity and hypertriglycerdemia were not significantly associated with periodontal pocket extent in unadjusted and adjusted models with regression coefficients changing from 0.75 to 0.80 and 0.36 to 0.07 for both indicators, respectively. Low HDL-cholesterol and high blood pressure were significantly associated with greater extent of periodontal pocket depth in the unadjusted models, but lost significance in the adjusted models with regression coefficient decreasing from 1.11, and 1.12 to 0.73 and 0.79, respectively. Plasma glucose maintained its significant association with pocket depth with regression coefficient attenuating from 1.70 to 1.21 in the adjusted model. The aggregated allostasis variable was significantly associated with greater level of the condition in both unadjusted and adjusted models. For a higher unit of allostasis there were 0.54 and 0.41 greater extents of pocket depth in the unadjusted and adjusted models, respectively (Table 10.1).

Generally the different indicators of allostasis were associated with increased levels of periodontal disease and ischaemic heart disease in most of the models. The aggregated allostasis variable was also significantly associated with all health outcomes in both unadjusted and adjusted models. Figure 10.1 shows the odds ratios for the aggregated allostasis variable with ischaemic heart disease and the dichotomous periodontal variable and indicates similarities of the effects of allostasis on both conditions.

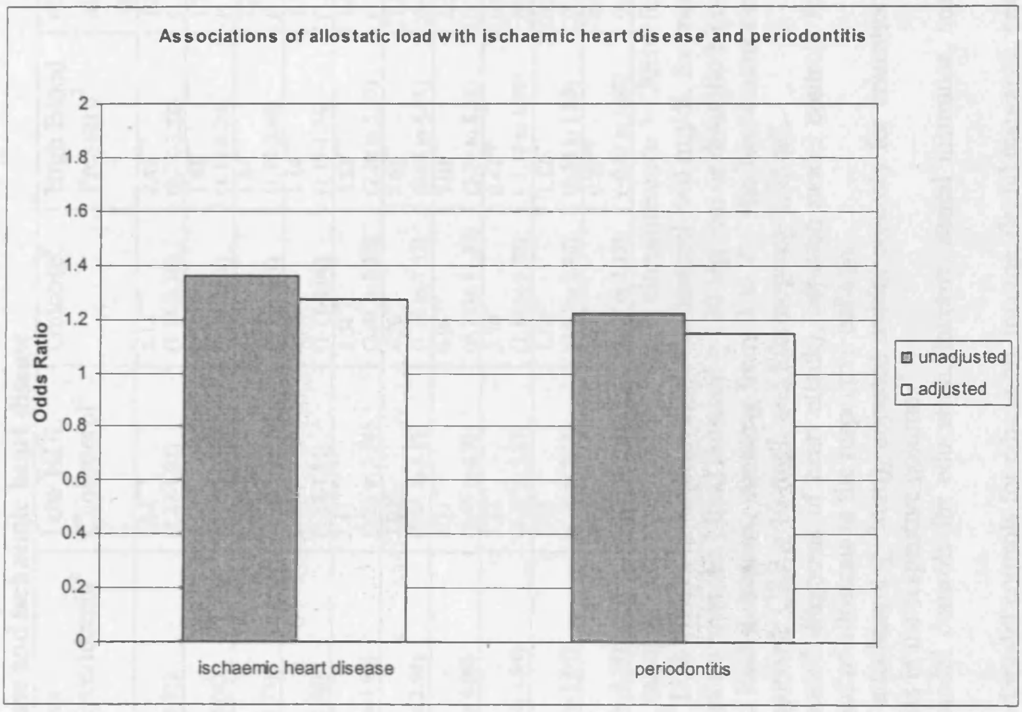


Figure 10.1 Binary and adjusted associations of the clustered allostatic load variable with ischaemic heart disease and periodontal disease

Table 10.1 Association between indicators of allostatic load, periodontal disease and ischaemic heart disease

		CRP[1]	Fibrinogen[2]	Central obesity[3]	Hyper Triglyceridemia[4]	Low HDL Cholesterol[5]	Glucose[6]	High Blood Pressure[7]	Clustered allostatic indicators[8]
Ischaemic heart disease[9] OR (95%CI)	Unadjusted	1.32*** (1.18-1.48)	1.01*** (1.01-1.01)	1.55*** (1.26-1.91)	1.85*** (1.46-2.35)	1.53*** (1.27-1.85)	2.13*** (1.65-2.76)	2.45*** (1.71-3.52)	1.36*** (1.26-1.46)
	Adjusted	1.21** (1.08-1.35)	1.01*** (1.01-1.01)	1.44** (1.14-1.82)	1.67*** (1.33-2.08)	1.53*** (1.26-1.86)	1.57*** (1.25-1.97)	1.62** (1.14-2.29)	1.27*** (1.18-1.36)
Perio[10] OR (95%CI)	Unadjusted	1.11^{NS} (0.97-1.27)	1.01^{NS} (0.99-1.01)	1.48*** (1.24-1.75)	1.42** (1.15-1.75)	1.50*** (1.22-1.84)	2.03*** (1.53-2.67)	1.84*** (1.55-2.18)	1.22*** (1.15-1.29)
	Adjusted	1.03^{NS} (0.89-1.18)	0.99^{NS} (0.99-1.01)	1.36** (1.13-1.65)	1.27* (1.02-1.58)	1.46** (1.18-1.81)	1.56** (1.17-2.08)	1.44*** (1.19-1.74)	1.15*** (1.08-1.23)
Extent gingival bleeding[11] Reg Co (95%CI)	Unadjusted	1.73** (0.65 to 2.80)	0.01* (0.01 to 0.02)	4.56*** (3.32 to 5.80)	2.60*** (1.33 to 3.86)	2.41*** (1.25 to 3.56)	6.31*** (3.44 to 9.18)	3.83*** (2.30 to 5.37)	1.67*** (1.31 to 2.03)
	Adjusted	1.34* (0.32 to 2.36)	0.01^{NS} (-0.01 to 0.02)	3.81*** (2.50-5.12)	1.76** (0.58 to 2.94)	2.02** (0.91 to 3.12)	4.70** (1.88 to 7.52)	2.66** (0.92 to 4.41)	1.37*** (0.99 to 1.75)
Extent loss of attachment[12] Reg Co (95%CI)	Unadjusted	3.02*** (1.43 to 4.60)	0.04*** (0.02 to 0.06)	2.75** (1.19 to 4.30)	2.94** (0.97 to 4.90)	4.71*** (2.49 to 6.93)	8.96*** (6.11 to 11.80)	7.02*** (5.53 to 8.51)	2.56*** (1.98 to 3.13)
	Adjusted	1.05^{NS} (-0.34 to 2.43)	0.01* (0.01 to 0.02)	0.69^{NS} (-1.02 to 2.39)	0.01^{NS} (-1.93 to 1.94)	3.23** (1.23 to 5.23)	3.70** (1.14 to 6.25)	0.41^{NS} (-1.10 to 1.93)	0.93*** (0.36 to 1.49)
Extent pocket depth[13] Reg Co (95%CI)	Unadjusted	0.91** (0.33 to 1.50)	0.01** (0.01 to 0.02)	0.75^{NS} (-0.10 to 1.61)	0.36^{NS} (-0.29 to 1.01)	1.11* (0.10 to 2.12)	1.70** (0.52 to 2.88)	1.12** (0.35 to 1.89)	0.54** (0.22 to 0.85)
	Adjusted	0.79** (0.21 to 1.20)	0.01* (0.01 to 0.01)	0.80^{NS} (-0.12 to 1.73)	0.07^{NS} (-0.60 to 0.74)	0.73^{NS} (-0.21 to 1.67)	1.21* (0.09 to 2.33)	0.79^{NS} (-0.10 to 1.68)	0.41* (0.08 to 0.74)

[1] C-reactive protein: a continuous measure. [2] Plasma Fibrinogen: a continuous variable. [3] Central obesity: waist circumference >120cm for males and >88 cm for females [4] Hypertriglycerdemia: triglycerides ≥ 150mg/dL. [5] Low HDL Cholesterol: HDL Cholesterol <40 mg/dL for men and <50 mg/dL for females. [6] High plasma glucose ≥ 110 gm/dL [7] High blood pressure: systolic blood pressure ≥ 130 Hg mm or diastolic blood pressure ≥ 85 Hg mm. [8] A clustered variable including sum of all the allostatic load indicators, counting from 0 to 7. The two continuous indicators used in the analysis C reactive protein and plasma fibrinogen were categorised: CRP ≥ 10 mg/L and Fibrinogen ≥ 3.25 g/L.

[9] Ischaemic heart disease (angina cases according to Rose questionnaire or reported diagnosis of heart attack), adjusted model controls for education, income, medical insurance, sex, ethnicity, age, smoking and the indicator of allostasis in the respective column.

[10] Periodontal disease (at least one gingival bleeding site and one site loss of attachment ≥ 3mm), adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking and the indicator of allostasis in the respective column.

[11] Percentage of sites with gingival bleeding to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking and the indicator of allostasis in the respective column.

[12] Percentage of sites with loss of attachment ≥ 3mm to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking and the indicator of allostasis in the respective column.

[13] Percentage of sites with pocket depth ≥ 4mm to all examined sites, adjusted model controls for education, income, dental insurance, sex, ethnicity, age, smoking and the indicator of allostasis in the respective column.

*** $P<0.001$ ** $P<0.01$ * $P<0.05$ ^{NS} Not significant

10.3 Effects of allostatic load on the social gradients in ischaemic heart disease and periodontal disease.

Tables 10.2.1 and 10.2.2 show the effect of adjusting for the aggregate allostasis indicator on the social gradients in periodontal diseases and ischaemic heart disease. Generally, the social gradients slightly attenuated for all health outcomes after adjusting for allostasis but maintained its significance whenever significant in the unadjusted model. In both groups of models in this analysis there was adjustment for other relevant confounders (see method in chapter 3 and Tables 10.2.1 and 10.2.2).

10.3.1 Effects of allostatic load on the social gradients in ischaemic heart disease.

Persons with 12 years and less than 12 years of education were 1.07 and 1.18 times more likely to have ischaemic heart disease, respectively. The association was not significant. After adjusting for allostasis, the probability of having ischaemic heart disease attenuated to 0.98 and 1.05 for the second and lowest levels of education and remained insignificant. For each higher unit of income, there were 0.88 significant decreases in the probability of having ischaemic heart disease before and after adjusting for allostasis (Table 10.2.1).

10.3.2 Effects of allostatic load on the social gradients in periodontal disease (one site with loss of attachment 3mm+ and one site with gingival bleeding).

Education and income gradients in the dichotomous periodontal variable were significant at all levels before and after adjusting for allostasis. Persons with 12 years and less than 12 years of education were 1.40 and 1.55 times more likely to have periodontitis, respectively. After adjusting for allostasis, the probability of having the disease decreased to 1.32 and 1.46

for the second and lowest levels of education. For each unit increase in income there were 0.88 decreases in the probability of having periodontitis before and after adjusting for allostasis (Table 10.2.1).

Figures 10.2 and 10.3 show a comparison between the effect of adjusting just for the aggregate allostasis marker on education and income gradients in both of ischaemic heart disease and periodontal disease. Persons in the middle and lowest education groups were significantly 1.29 (95% CI: 0.97, 1.72) and 2.17 (95% CI: 1.66, 2.86) more likely to get ischaemic heart disease. After adjusting just for the aggregate allostasis marker the probabilities dropped to 1.09 (95% CI: 0.81, 1.45) and 1.72 (95% CI: 1.31, 2.26), respectively and remained significant. For a unit increase of income, the probability of ischaemic heart disease was 0.81 (95% CI: 0.75, 0.88) less likely which attenuated to 0.84 (95% CI: 0.78, 0.91) after adjusting just for allostasis and remained significant (Figure 10.2).

Similarly, persons in the middle and lowest education groups were significantly 1.47 (95% CI: 1.23, 1.76) and 2.38 (95% CI: 1.96, 2.89) more likely to have periodontitis. After adjusting just for allostasis, the probabilities of having periodontitis dropped to 1.35 (95% CI: 1.12, 2.64) and 2.11 (95% CI: 1.73, 2.58), respectively, and remained significant. For a unit increase of income, the probability of periodontitis was 0.83 (95% CI: 0.79, 0.87) times less likely which attenuated to 0.84 (95% CI: 0.81, 0.89) after adjusting for allostasis and remained significant (Figure 10.3).

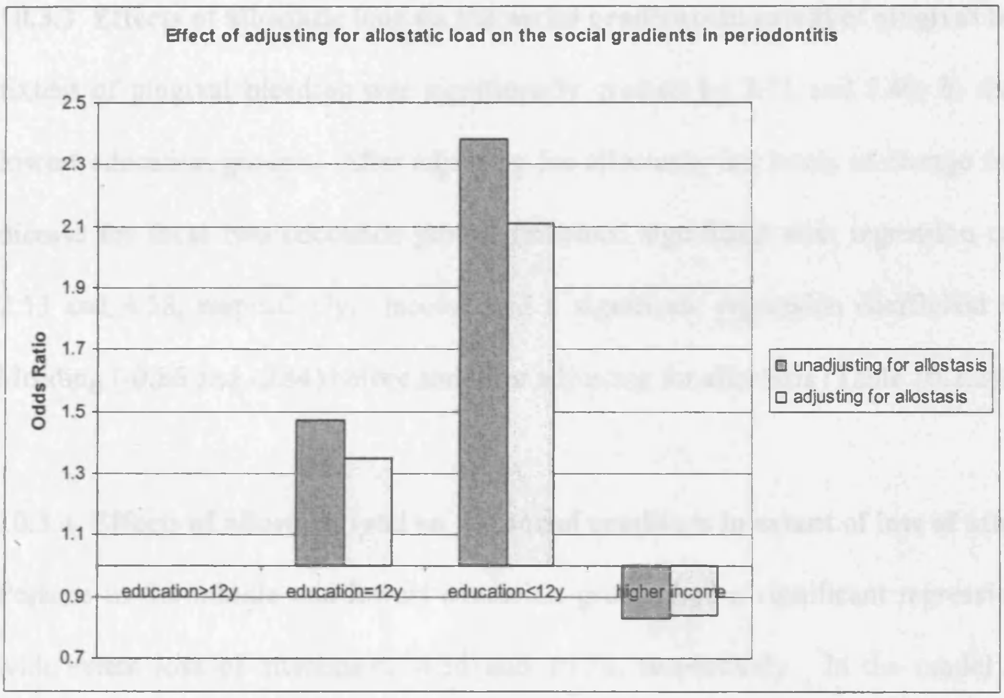


Figure 10.2 Effect of adjusting for allostasis on social gradients in ischaemic heart disease

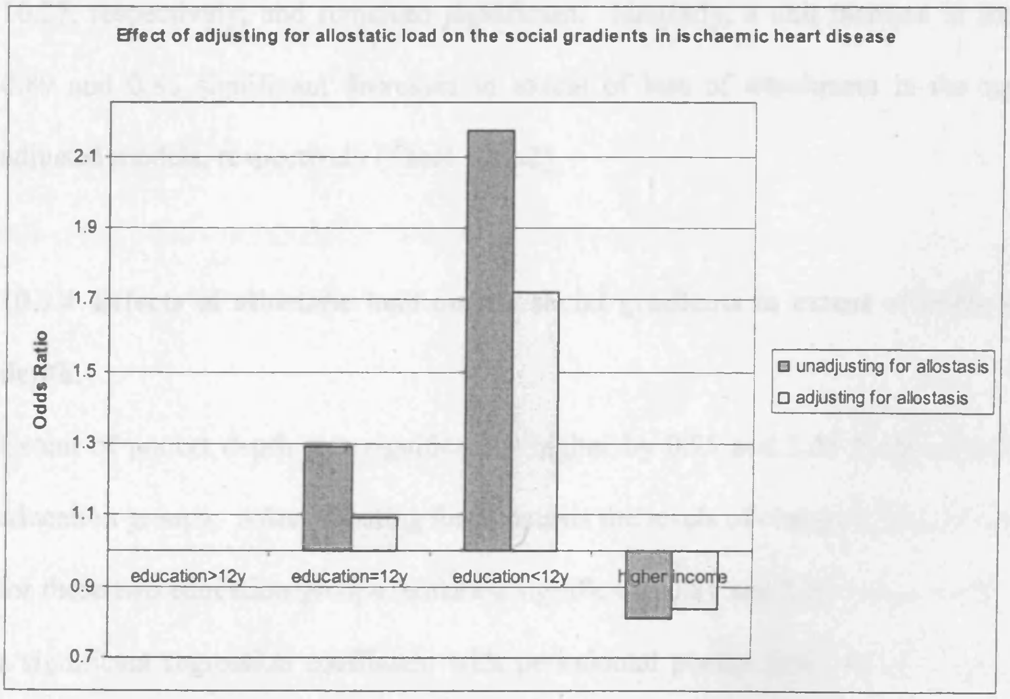


Figure 10.3 Effect of adjusting for allostasis on social gradients in periodontitis

10.3.3 Effects of allostatic load on the social gradients in extent of gingival bleeding.

Extent of gingival bleeding was significantly greater, by 2.71 and 5.40, in the middle and lowest education groups. After adjusting for allostasis, the levels of change in the gingival disease for these two education groups remained significant with regression coefficients of 2.13 and 4.58, respectively. Income had a significant regression coefficient with gingival bleeding (-0.86 and -0.84) before and after adjusting for allostasis (Table 10.2.2).

10.3.4 Effects of allostatic load on the social gradients in extent of loss of attachment.

Persons in the middle and lowest education groups had a significant regression coefficient with extent loss of attachment; 4.36 and 10.58, respectively. In the model adjusting for allostasis, the regression coefficient for these education groups decreased slightly to 4.14 and 10.27, respectively, and remained significant. Similarly, a unit increase in income showed 0.89 and 0.86 significant decreases in extent of loss of attachment in the unadjusted and adjusted models, respectively (Table 10.2.2).

10.3.4 Effects of allostatic load on the social gradients in extent of periodontal pocket depth.

Extent of pocket depth was significantly higher by 0.95 and 2.43 in the middle and lowest education groups. After adjusting for allostasis the levels of change in the periodontal disease for these two education groups remained significant; 0.81 and 2.24, respectively. Income had a significant regression coefficient with periodontal pocket depth of -0.37 and -0.36 before and after adjusting for allostasis (Table 10.2.2).

Generally adjusting for allostasis explained a portion of the education and income gradients in periodontal disease and ischaemic heart disease. Figures 10.4 and 10.5 show the changes in education and income gradients for the extents of gingival bleeding and loss of periodontal attachment after adjusting for allostasis.

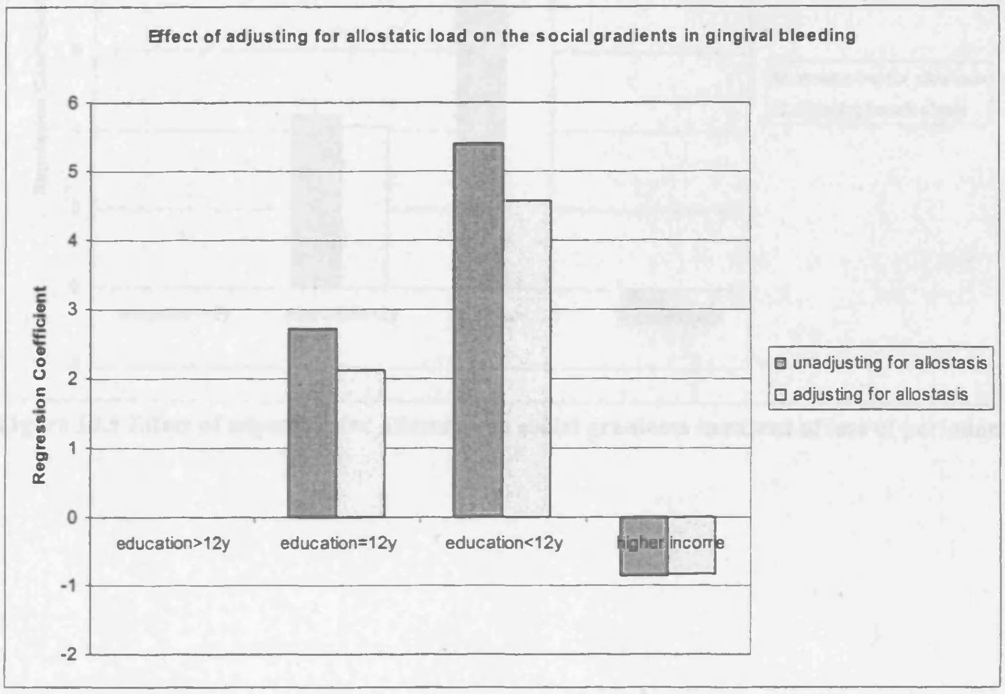


Figure 10.4 Effect of adjusting for allostasis on social gradients in extent of gingival bleeding

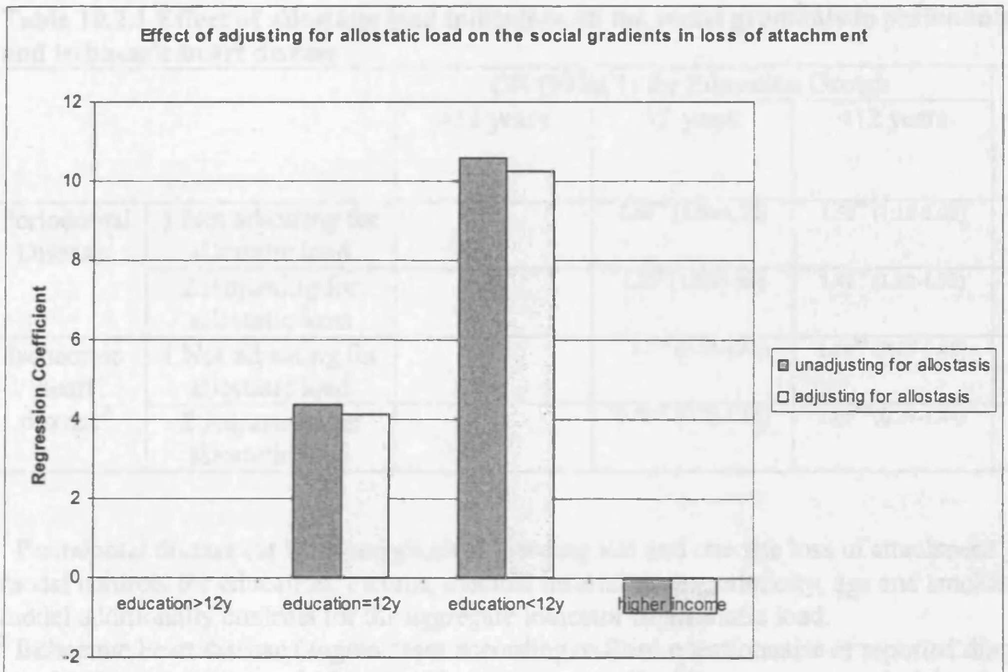


Figure 10.5 Effect of adjusting for allostasis on social gradients in extent of loss of periodontal attachment

Table 10.2.1 Effect of allostatic load indicators on the social gradients in periodontal diseases and ischaemic heart disease

		OR (95%CI) for Education Groups			Change in OR (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Periodontal Disease[1]	1 Not adjusting for allostatic load	1	1.40^{**} (1.14-1.73)	1.55^{**} (1.18-2.05)	0.88^{***} (0.84-0.93)
	2 Adjusting for allostatic load	1	1.32^{*} (1.05-1.66)	1.46^{**} (1.10-1.92)	0.88^{***} (0.84-0.93)
Ischaemic heart disease[2]	1 Not adjusting for allostatic load	1	1.07^{NS} (0.78-1.46)	1.18^{NS} (0.87-1.60)	0.88^{**} (0.81-0.95)
	2 Adjusting for allostatic load	1	0.98^{NS} (0.72-1.35)	1.05^{NS} (0.77-1.44)	0.88^{**} (0.82-0.96)

[1] Periodontal disease (at least one gingival bleeding site and one site loss of attachment $\geq$ 3mm), first model controls for education, income, medical insurance, sex, ethnicity, age and smoking. Second model additionally controls for the aggregate indicator of allostatic load.
[2] Ischaemic heart disease (angina cases according to Rose questionnaire or reported diagnosis of heart attack), first model controls for education, income, medical insurance, sex, ethnicity, age and smoking. Second model additionally controls for the aggregate indicator of allostatic load.
*** $P<0.001$ ** $P<0.01$ * $P<0.05$ ^{NS} Not significant

Table 10.2.2 Effects of allostatic load indicators on the social gradients in extent of periodontal diseases

		Regression coefficient (95%CI) for Education Groups			Regression coefficient (95%CI) for unit increase of income
		>12 years	12 years	<12 years	
Extent gingival bleeding[1]	1 Not adjusting for allostatic load	0.00	2.71*** (1.70-3.73)	5.40*** (3.27-7.51)	-0.86*** (-1.26 to -0.47)
	2 Adjusting for allostatic load	0.00	2.13*** (1.03-3.24)	4.58*** (2.53-6.63)	-0.84*** (-1.24 to -0.44)
Extent loss of attachment[2]	1 Not adjusting for allostatic load	0.00	4.36*** (2.33-6.40)	10.58*** (7.78-13.38)	-0.89*** (-1.46 to -0.32)
	2 Adjusting for allostatic load	0.00	4.14*** (2.07-6.21)	10.27*** (7.45-13.09)	-0.86** (-1.42 to -0.30)
Extent pocket depth[3]	1 Not adjusting for allostatic load	0.00	0.95* (0.15-1.75)	2.43*** (1.18-3.68)	-0.37*** (-0.54 to -0.20)
	2 Adjusting for allostatic load	0.00	0.81* (0.01-1.61)	2.24*** (1.09-3.39)	-0.36*** (-0.54 to -0.19)

[1] Percentage of sites with gingival bleeding to all examined sites, first model controls for education, income, medical insurance, sex, ethnicity, age and smoking. Second model additionally controls for the aggregate indicator of allostatic load.
[2] Percentage of sites with loss of attachment ≥ 3mm to all examined sites, first model controls for education, income, medical insurance, sex, ethnicity, age and smoking. Second model additionally controls for the aggregate indicator of allostatic load.
[3] Percentage of sites with pocket depth ≥ 4mm to all examined sites, first model controls for education, income, medical insurance, sex, ethnicity, age and smoking. Second model additionally controls for the aggregate indicator of allostatic load.
*** P<0.001 ** P<0.01 * P<0.05 NS Not significant

10.4 Summary of the results reported in Chapter 10

- All markers of allostatic load were higher in persons with periodontal disease and ischaemic heart disease.
- The aggregate variable of allostatic load was significantly associated with all health outcomes in the unadjusted and adjusted models.
- Allostatic load had similar associations with oral health and general health.
- Adjustment for allostatic load partially explained the social gradients in periodontal disease and ischaemic heart disease.
- The effects of allostatic load on the social gradients in periodontal disease and ischaemic heart disease were similar.
- The attenuation of education and income gradients in periodontal disease and ischaemic heart disease, after adjusting for allostatic load, supports the hypothesis about a stress pathway affecting the gradients in oral and general health.
- The following chapter is an overall discussion highlighting the main findings, the limitations and the implications of the research conducted in this thesis.

Chapter 11

Discussion

Chapter 11

Discussion

11.1 Overall summary of the findings

The general aims of this thesis were to assess and compare the social gradients in oral health and general health, assess the social gradients in health-related behaviours and examine certain pathways to the gradients in health in a nationally representative sample of the US population. The exploration of potential pathways toward the gradients in oral and general health was guided by the bio-psychosocial model (Figure 2.17).

In relation to the first hypothesis and the first objective, there were consistent gradients in all clinical and subjective indicators of oral health, here represented by periodontal disease, tooth loss and perceived oral health. There were also education and income gradients in general health, indicated by ischaemic heart disease and perceived general health (Hypothesis 1, objective 2). The most interesting finding, one that has not heretofore been reported in a nationally representative sample, is that in the same population, social gradients in oral and general health were generally similar (Hypothesis 2, objective 3).

The results did not fully support hypothesis 3 regarding the presence of social gradients in health-related behaviours. Social gradients in health-related behaviours were only found in "being a current smoker", "frequency of smoking" and "frequency of visits to a dentist". No consistent education gradients were found in "frequency of physical activity" nor in "frequency of eating fresh fruits and vegetables" (Hypothesis 3, objective 4).

The fourth hypothesis was about the effect of certain pathways and factors on the social gradients in oral and general health. The results showed that the gradients in general health attenuated after adjusting for certain factors, namely sex, ethnicity, cognitive ability, health related behaviours and stress indicated by allostasis (Objective 5). Similarly, education and income gradients in oral health attenuated after adjusting sex, ethnicity, cognitive performance, health behaviour, tooth cleanliness and stress indicated by allostasis (Objective 6). Generally, adjusting for these pathways had similar effects on the gradients in oral and general health.

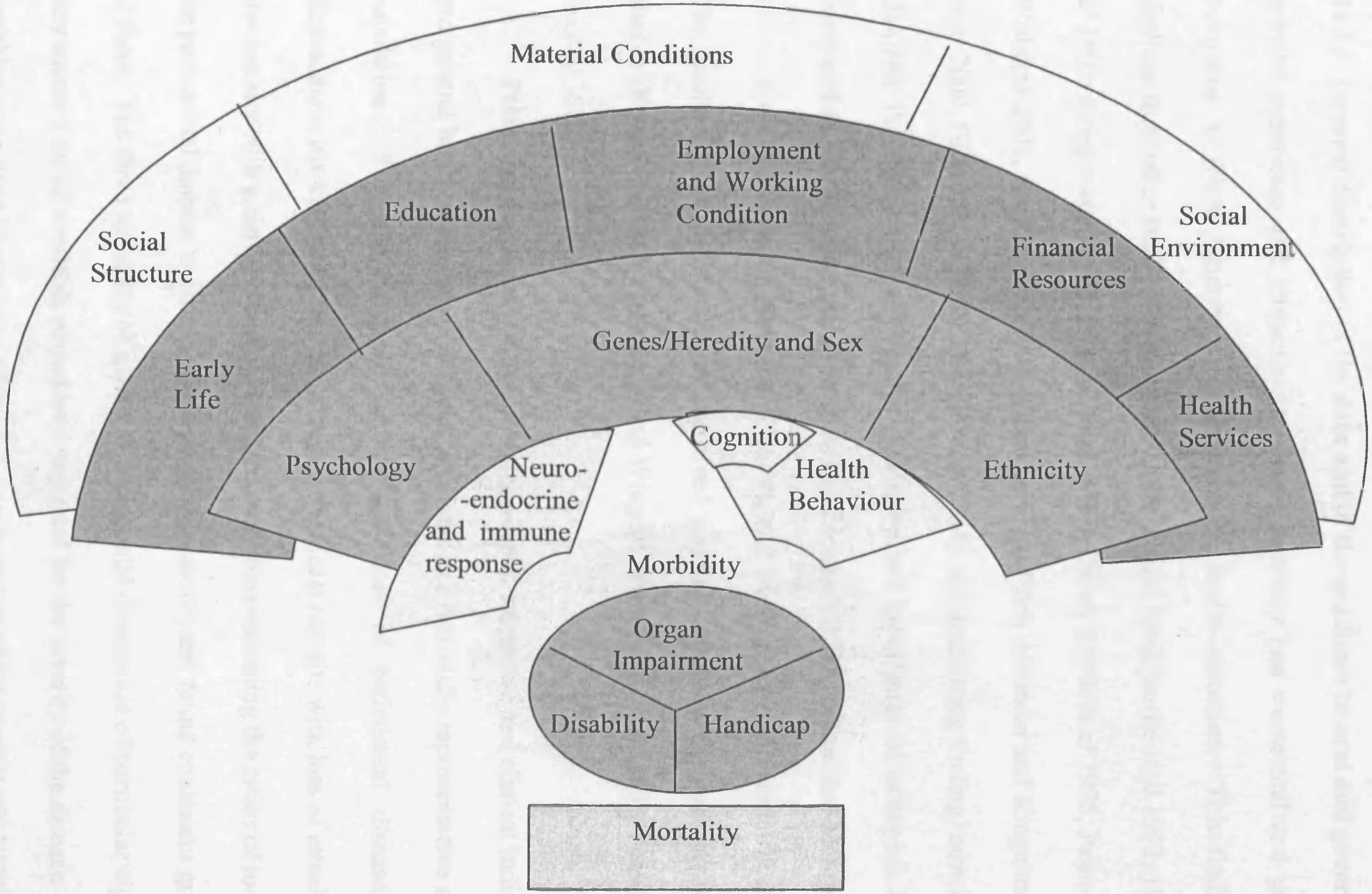


Figure 2.17: Bio-psychosocial pathways to disease

11.1.1 General description of the data and of the gradients in oral and general health

African Americans and Hispanic Americans generally had worse oral and general health compared to White Americans for most of the health outcomes. This findings confirm findings from other studies (Ismail *et al.* 1988; Rogers 1992; Sorlie *et al* 1992; 1995; Rogot *et al* 1993; Krieger *et al* 1993; Marcus *et al.* 1996; Davey Smith *et al* 1998; Pamuk *et al* 1998; Williams 2001; Keiffer *et al* 2006; Albandar *et al.* 1999; Albandar and Kingman 1999; Jones *et al* 2000; Gilbert *et al* 2003; Borrell *et al* 2004). An interesting finding, now known as the Hispanic Paradox, was that Hispanic American had lower rates of ischaemic heart disease compared to White Americans (Markides and Eschbach 2005; Palloni and Morenoff 2001).

Women had better periodontal health, and worse perceived general health than men. The results on sex differences in perceived general health were consistent with previous studies (Verbrugge 1985; Verbrugge and Wingard 1987; Popay *et al* 1993; Feeney *et al* 1998; Bartley 2004).

This thesis has the advantage of using several subjective and clinical indicators of oral and general health to measure the social gradients in a nationally representative sample of US population. The analysis used several indicators of periodontal disease, namely, a dichotomous marker indicating the presence of at least one site with loss of attachment $\geq$3mm and one site with gingival bleeding, and three variables indicating the ratios of tooth sites with the periodontal disease to all examined sites in the mouth and found consistent gradients in all of them. The three variables of extent of periodontal disease are of particular significance as they account for all available periodontal sites and for the severity of the disease. These three variables were used in previous NHANES-based studies (Slade and Beck 1999; Arbes *et al* 1999; Slade *et al* 2000). The use of these four periodontal variables, indicating presence and severity of different markers of periodontal disease, ensures that the results were not coincidental. The analysis also examined the social gradients in loss of tooth surfaces (tooth loss), edentulousness and perceived oral health. General health was assessed by perceived general health and a reliable measure of ischaemic heart disease based on the WHO criteria for diagnosis of angina (Rose *et al* 1982) or diagnosis of heart attack.

There were clear education and income gradients in all health outcomes and for almost all age groups. The distributions of oral and general health outcomes were measured across three groups of education (more than 12 years, 12 years and less than 12 years) and across quartiles of income within age groups. The categorisation of income, as a measure of social status (Marmot 2003), may influence its effect on health, because of minimum differences between individuals with income on the borderline between each two categories. However, there were differences, with very few exceptions, in the distribution of all health outcomes between each successive income groups. These findings confirm previous studies on the social gradients in general health (Marmot *et al* 1991; Brunner *et al* 1997; Ferrie *et al* 2002; Ferrie *et al* 2005; Singh-Manoux *et al* 2006; Marmot and Wilkinson 2006; Banks *et al* 2006) and in oral health (Watt and Sheiham 1998; Zurriaga *et al* 2004; Dye and Selwitz 2005; Lopez *et al* 2006; Sanders *et al* 2006b).

The gradients observed in income and education as markers of social position highlight the importance of relative poverty and relative status as causes for the social gradients in oral and general health (Adler *et al.* 1999). Additionally, the distribution of all health outcomes, by education and income, shows similarities in the social gradients for oral and general health. Others have also suggested the presence of similar social gradients in oral health and general health (Poulton *et al* 2002; Borrel *et al* 2004). This implies commonalities of the social determinants of oral and general health.

Generally, the gradients in oral health reported here were steeper for middle-aged individuals than for other age groups. This is probably because of the nature of the conditions examined here, especially periodontal disease and ischaemic heart disease, which are more common among the middle aged.

The distributions of oral and general health across income and education groups demonstrated the presence of similar social gradients in both oral and general health. This findings support the hypothesis of this thesis on the presence of similar social gradients in oral and general health. Further adjustment for possible explanatory factors confirmed the presence of similar social gradients in oral and general health. The following section discusses this statement.

11.1.2 Social gradients in oral and general health

The probabilities of having poorer perceived oral health, poorer perceived general health, periodontal disease, ischaemic heart disease, tooth loss and edentulousness were higher at each lower level of education and income. The gradients persisted even after adjusting for a number of explanatory variables and confounders. Regression models adjusted for potential confounders and explanatory variables in accordance with the bio-psychosocial model (Figures 2.17 and 3.3).

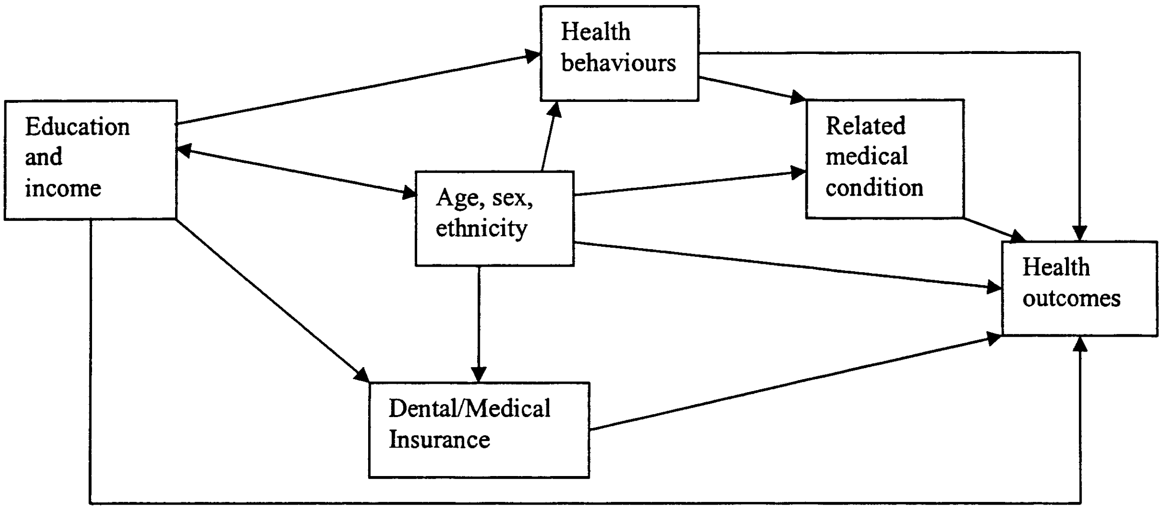


Figure 3.3 **A model for examining the social gradients in oral/general health**

The social gradient observed in perceived oral health was consistent with an earlier study (Stahlnacke *et al.* 2003). The gradients in periodontal diseases were also in accordance with other studies (Zurriaga *et al.* 2004; Dye and Selwitz 2005; Lopez *et al.* 2006; Sanders *et al.* 2006b). The gradients in tooth loss and edentulousness were also consistent with other studies (Ismail *et al.* 1987; Chen 1995; Nuttal 2003; Thomson *et al.* 2004). The social gradient in oral health found here confirms findings from another study (Drury 1999) that examined the NHNAES database, although Drury's study used crude indicators of oral health and did not sufficiently adjust for confounders. This study also has the advantage of examining the similarities between the social gradients in oral and general health in the same population, using both subjective and normative indicators of health, and using different clinical indicators of periodontal disease and tooth loss.

The social gradients in perceived general health reported here were similar to those reported in other studies (Marmot *et al* 1991; Ferrie *et al* 2002; Singh-Manoux *et al* 2006).

Similarly, the gradients in ischaemic heart disease support findings from previous studies (Kraus *et al* 1980; Brunner *et al* 1997; Marmot and Wilkinson 1999; Ferrie *et al* 2005; Banks *et al* 2006).

The similarities of the social gradients in self-assessed and clinically diagnosed oral and general health were consistent with that found in earlier studies (Poulton *et al* 2002; Borrel *et al* 2004). This suggests that there are similarities in determinants of clinically diagnosed and subjective oral health and physical health. However, unlike other studies on the subject, this study has the advantage of examining the gradients in a large national representative sample, for both clinically and subjective health, and using precise and validated clinical measures.

Further support for the existence of social gradients in oral and general health is that education and income gradients were very clear for all health outcomes even when added together in the same model and after adjusting for ethnicity, sex, age, medical/ dental insurance, smoking and diabetes. In the adjusted model for ischaemic heart disease, the increase in odds ratio persisted but lost its significance in the second highest level of education. This is probably because of the excessive adjustment for far more factors in the model for ischaemic heart disease. Some of these factors, such as BMI and high blood pressure, are strong determinants of the ischaemic heart disease.

The regression models for the extent of periodontal disease demonstrated the persistence of education and income gradients, even after adjusting for traditional risk factors such as ethnicity and smoking, which received more attention in earlier studies (Albandar *et al.* 1999; Albandar and Kingman 1999; Borrell *et al.* 2005). In this sense, this study goes a step further in demonstrating the independent relationship between socioeconomic position and periodontal disease, on top of the known associations with ethnicity and smoking. The differences in the extent of periodontal disease at each level of income and education are important given the relatively low baseline value. Using percentage of sites with periodontal disease is also important because it accounts for all the individuals who had a dental examination, thereby better assessing the severity of the disease.

This analysis emphasised the similarities between the social gradients in oral and general health in a US national representative sample. Using globally accepted measures of socioeconomic position such as education (Singh-Manoux *et al.* 2006) to measure the gradients in both clinical and perceived general/oral health implies that the gradients found here are applicable to other populations outside the USA.

The consistent and significant income and education gradients in oral and general health observed in this study indicate that there was no socioeconomic threshold below which health deteriorates more in this population. Others have indicated the presence of a poverty threshold below which oral health deteriorates (Sanders *et al* 2006a). This particular study showed gradients in all used indicators of oral health, but the gap was steeper between the lowest and second lowest socioeconomic groups. The aforementioned study differs from this thesis in relying only on perceived oral health indicators which were always dichotomised to indicate prevalence of poorer oral health (Sanders *et al* 2006a). Similarly, all indicators of socioeconomic position were grouped into quintiles. Although the authors adjusted for some important oral health-related behaviours but they did not adjust for the use of dental services. It is possible that if Sanders *et al* (2006a) had used continuous indicators of oral health, they would have found similar results to that shown in this thesis.

The income gradients in oral and general health, observed in this thesis, are of particular importance, because income, and its distribution in a society, do not only indicate ability to have a better life and better access to health services, but also indicate social status (Marmot 2003), and income inequality in the society (Wilkinson 1996). Both social status and income inequality have a psychosocial impact on the population's health (Wilkinson 1996; Marmot and Wilkinson 2006). The consistently inverse relationship between all health outcomes and all levels of education and income, including the highest levels, implies that relative poverty rather than absolute poverty is the more important causing factor of the gradients. This argument supports the theories put forward about potential pathways affecting the gradients (Adler *et al* 1994; Lubinski and Humphreys 1997; Marmot and Wilkinson 2006; Sheiham and Nicolau 2005), and supports the hypothesis of this thesis. The consistent and similar deterioration of oral health and general health at each lower level as one descended the socioeconomic hierarchy, also supports the Surgeon General contention for considering oral health an integral part of general health (U.S. Department of Health and Human Services 2000).

Examining the binary and adjusted probabilities of oral and general health by income and education established the presence of social gradients in the study population. The remainder of the discussion highlights the importance of certain pathways and factors in the social gradients in oral and general health.

11.1.3 Effects of sex and ethnicity on oral and general health and on the social gradients

This analysis examined the effects of ethnicity and sex on health outcomes in the whole population. For better account for the effects of socioeconomic position on ethnic differences in health, the associations of sex and ethnicity with health were additionally examined across strata of income and education. The changes in education and income gradients after adjusting for sex and ethnicity were examined to assess the potential effects of biological factors, here indicated by sex and ethnicity, on the social gradients in health, as depicted in the bio-psychosocial pathway (Figure 2.17) and model 3.4.

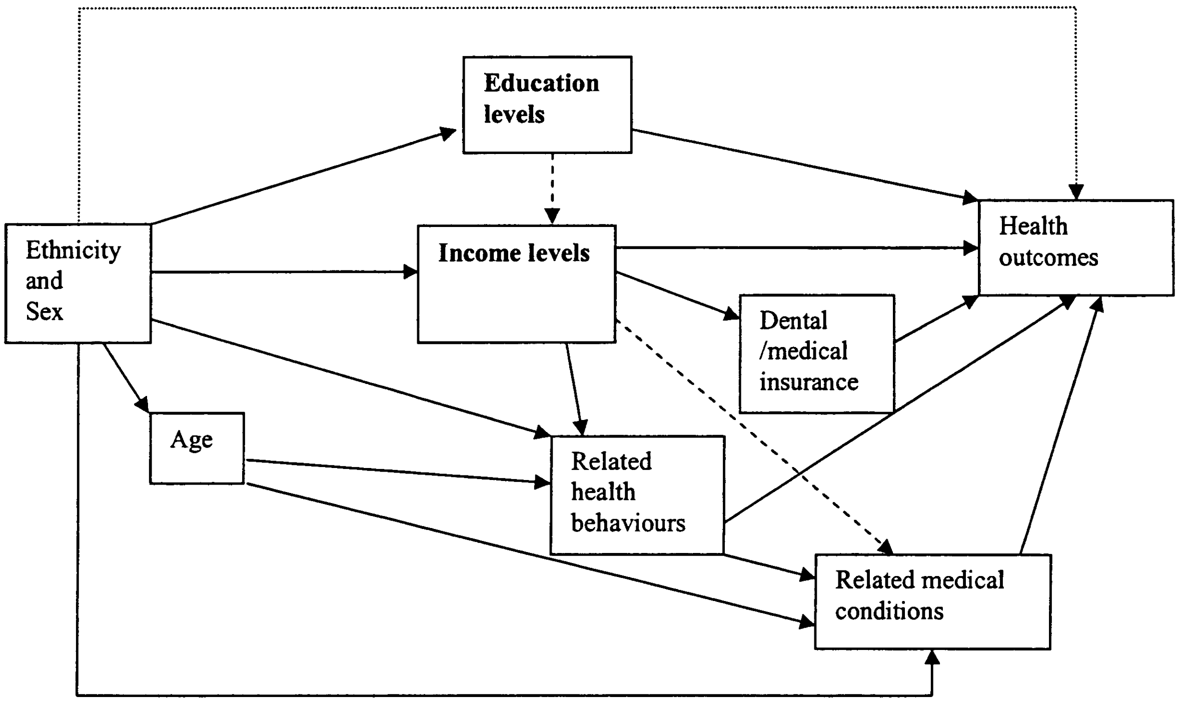


Figure 3.4 **Assessing the independent effect of sex and ethnicity on oral and general health outcomes**

Rates of ischaemic heart disease in the whole population were slightly higher among African Americans compared to White Americans. This slight insignificantly higher probability of the disease disappeared after adjusting for socioeconomic position, as found in a previous study (Nazroo and Williams 2006). The lack of ethnic differences in ischaemic heart disease persisted throughout strata of income and education. On the other hand, ethnic differences were clearly demonstrated in perceived general health. African Americans, Hispanic Americans and other ethnicities were significantly more likely to report poorer perceived general health compared to White Americans. This finding confirms those from several other studies about racial/ethnic differences in morbidity and mortality in the USA (Rogers 1992; Sorlie *et al* 1992; 1995; Rogot *et al* 1993; Krieger *et al* 1993; Davey Smith *et al* 1998; Pamuk *et al* 1998; Williams 2001; Keiffer *et al* 2006). When the population was stratified according to socioeconomic position, the differences in perceived general health between African Americans and Hispanic Americans on one hand and White Americans on the other, increased in the highest levels of income and education but were attenuated in the lowest levels. In the lowest level of income, the statistical difference between African Americans and White Americans in perceived general health completely disappeared, implying that very low income had similar effects on African Americans and White Americans. The fact that there were ethnic differences in perceived general health but not in ischaemic heart disease in the whole population analysis, reflects the multidimensional aspect of perceived general health (Idler and Benyamini 1997).

Generally, the analysis showed that in the whole population African Americans, Hispanic Americans and persons belonging to other ethnicities had poorer oral health for all the indicators, namely, periodontal disease, tooth loss and perceived oral health compared to White Americans. These findings are supported by several USA-based studies which reported racial/ethnic differences in oral health (Ismail *et al.* 1988; Marcus *et al.* 1996; Albandar *et al.* 1999; Albandar and Kingman 1999; Jones *et al* 2000; Gilbert *et al* 2003; Borrell *et al* 2004).

African Americans and Hispanic Americans reported poorer perceived oral health compared to White Americans. For Hispanic Americans, these differences attenuated when the population was stratified according to income and education, indicating that for this particular outcome, socioeconomic position partially explained the differences between Hispanic and White Americans. For African Americans, the differences were even greater in the top levels of income and education but attenuated in the lowest level of education and completely disappeared in the lowest two levels of income.

African Americans and Hispanic Americans had a higher prevalence of periodontitis (one site gingival bleeding and one site attachment loss $\geq$3mm) than White Americans. The differences for Hispanic Americans were not significant in the whole population and attenuated across socioeconomic position strata. For African Americans, the difference in periodontitis was higher in the top income and education strata, but attenuated at the lowest levels and lost its significance.

There were similar differences in gingival bleeding between African Americans and White Americans in the whole population, but these differences completely disappeared when the population was stratified by income and education. Hispanic American had higher levels of gingival bleeding than White Americans, in the unadjusted model for the whole population, as shown by Albandar and Kingman (1999). An interesting finding in the current analysis was that ethnic differences in gingival bleeding completely disappeared when the population was stratified by income and education. This implies that for this particular oral health outcome, which is also a marker of inflammation, socioeconomic position accounted for ethnic differences. Nazroo and Williams (2006) similarly suggested that differences in socioeconomic position explain ethnic differences in health.

Loss of periodontal attachment and pocket depth was higher among African Americans compared to White Americans. These differences by ethnic groups were higher in the top income and education strata, but disappeared in the lowest strata. Hispanic Americans had significantly lower rates of attachment loss in the whole population analysis, but there were no differences across socioeconomic position strata except at the lowest level of education.

African Americans and Hispanic Americans were less likely to be edentulous compared to White Americans. Only at the highest level of income and education did differences between African Americans and White Americans in edentulousness disappear. African Americans had higher rates of missing tooth surfaces than White Americans. The difference was higher among people with higher income and disappeared among the very poor and less educated. Hispanic Americans generally had lower rates of tooth loss regardless of their socioeconomic position. The findings on the differences in tooth loss between ethnic groups may reflect a treatment rather than disease effect (Burt and Eklund 1992). For example, there are different patterns of utilisation and types of treatment prescribed for ethnic groups (Gilbert *et al.* 2003). This difference in treatment prescribed is a possible explanation to the differences, reported here, in tooth loss between African and White Americans in the highest income strata.

The lack of health differences between African Americans and Hispanic Americans compared to White Americans in the lowest socioeconomic strata suggests that very low income has the same health deteriorating effect on the whole population. On the other hand, the existence of ethnic differences in the highest levels of income and education indicates that these differences are influenced by more than income and education. This conclusion is consistent with other studies (Shea *et al* 1991; Coeytaux *et al* 2004; Mensah *et al* 2005). Some researchers have argued that the persistence of differences in health between ethnic groups can be partially attributed to differences in culture and genetics (Smaje 1996; Diaz *et al* 2005). Others have suggested demographic location (Mensah *et al* 2005) and experiences of racial harassment and discrimination (Kreiger 2000; Williams and Neighbors 2001; Williams *et al* 2003; Nazroo and Williams 2006) as important factors explaining health inequalities between ethnic groups. Unfortunately, in NHANES III there are no data on any of these possible contributing factors to health inequalities between ethnic groups to test the abovementioned reasons for ethnic differences in health.

Overall, there were no sex differences in ischaemic heart disease. On the other hand, women reported worse perceived general health. When the analysis was conducted across strata of income and education, the sex differences in perceived general health disappeared in the top income and education strata and existed in the lowest strata. Women are more likely to complain of somatic symptoms such as headache and backache than men (Verbrugge 1985; Verbrugge and Wingard 1987; Popay *et al* 1993; Feeney *et al* 1998; Bartley 2004). However, mortality rates are higher among men than women (Kruger and Nesse 2004), an outcome that could not be tested in this thesis.

There were no sex differences in perceived oral health across socioeconomic position strata except at the highest level of income where women were significantly less likely to report poorer oral health. Women's periodontal and gingival conditions were much better than men's for all the periodontal indicators. Prevalence of periodontitis was lower among women compared to men and remained lower even when the population was stratified according to socioeconomic position strata. Similarly, women had lower levels of gingival bleeding, loss of attachment and pocket depth than men, regardless of the education and income status. These persistent differences in gingival bleeding and periodontal condition between men and women are most probably attributed to sex differences in oral health-related behaviours and oral hygiene. Women have better oral health-related behaviours (Schuller *et al* 1998; Sakki *et al* 1998; Ostberg *et al* 1999), which overcome their so called 'biological vulnerability' (Covington 1996; McCann and Bonci 2001; Lukacs and Largaespada 2006) and their socioeconomic position.

There were no sex differences in the prevalence of edentulousness either in the whole population or across strata of socioeconomic position. On the other hand, women had slightly higher rates of tooth loss than men but the differences were only significant among people in the lowest income and education strata. The sex differences in tooth loss are probably the results of different patterns of utilisation of dental services by women (Petersen and Holst 1995; Zakrzewska 1996; Husaini *et al* 2002).

Generally, women had better health than men in the highest levels of education and income groups. This suggests that women's health benefit more than men's from higher social and economic circumstances. This observation is supported by an earlier study by Kavanagh *et al* (2006) who had a similar conclusion.

The effect of biological factors, indicated by sex and ethnicity, on the social gradients in general and oral health was examined by observing the change in education and income gradients in health after adjusting for sex and ethnicity. Overall, there was a small change in the education and income gradients in general and oral health or no change at all after adjusting for sex and/or ethnicity. The gradients in ischaemic heart disease were not influenced by adjustment for sex and/or ethnicity. The gradients in perceived general health were slightly decreased after adjusting for sex, while the gradients in perceived oral health were slightly decreased after adjusting for ethnicity. These observations are probably due to the high association between sex (female) with poorer perceived general health on one hand and ethnicity (African and Hispanic Americans) with poorer perceived oral health on the other.

The gradients in periodontitis were steeper in the models adjusting for sex. This was mainly due to the negative confounding effect of sex (females) on the social gradients in periodontal diseases. In other words, women were more likely to have better periodontal disease but more likely to have poorer socioeconomic position. One can argue that lower socioeconomic position does not affect women's periodontal health as much as it affects men. On the other hand, adjusting for ethnic groups slightly reduced the gradients in periodontitis, loss of attachment, pocket depth and tooth loss. Again this was mainly a result of the confounding effect of ethnicity on the aforementioned conditions.

This analysis examined the associations of ethnicity and sex with general and oral health for the whole population and across socioeconomic position strata and examined the effect of sex and ethnicity on the social gradients in oral and general health. African Americans and Hispanic Americans generally had worse general and oral health. For the poorest and less educated, these differences disappeared, indicating that very low income has the same detrimental effects in all ethnic groups. Higher levels of income and education were not associated with the expected changes in the health of these ethnic groups, indicating more complex causes for ethnic inequality in health. These causes include culture, genes, experience of discrimination and demographic location among other factors (Smaje 1996; Kreiger 2000; Williams and Neighbors 2001; Williams *et al* 2003; Diaz *et al* 2005; Mensah *et* *al* 2005; Nazroo and Williams 2006). Women's periodontal health was consistently better than men, regardless of socioeconomic position. However, women had poorer perceived general health than men, as suggested by others (Bartley 2003). Generally, women's health benefited more than men's health from better socioeconomic position.

There were changes in the social gradients in most health outcomes after adjusting for sex and ethnicity. These changes indicate that biology, indicated by sex and ethnicity explained a small part of the social gradients in general and oral health.

The bio-psychosocial model (Figure 2.17) postulated a role for biology in the relationship between socioeconomic position and health. Other important biological factors, such as hereditary and genes, are not captured in this data. The findings of the analysis on the associations between sex and ethnicity on one hand and socioeconomic position on the other, and their effects on health, support the theory on the role of biology that was described in the bio-psychosocial model (Figure 2.17). The results imply that women's behaviours moderate the negative effect of poorer socioeconomic position on oral health. On the other hand, it appears that ethnic differences in health cannot only be explained by socioeconomic circumstances.

The following part of the discussion highlights the effect of cognitive performance on health and on the social gradients in health.

11.1.4 Effect of cognitive performance on the social gradients in oral and general health

The association between tests of cognitive performance with oral health, indicated by periodontal disease and tooth loss and general health, indicated by ischaemic heart disease, and the effect of cognitive performance on the social gradients in oral and general health were assessed in this thesis (Figure 3.5). This analysis was conducted for a sub-sample of the population aged 20 to 59 years old who had the digital cognitive test (Simple Reaction Time Test, Symbol Digit Substitution Test and Serial Digit Learning Test) .

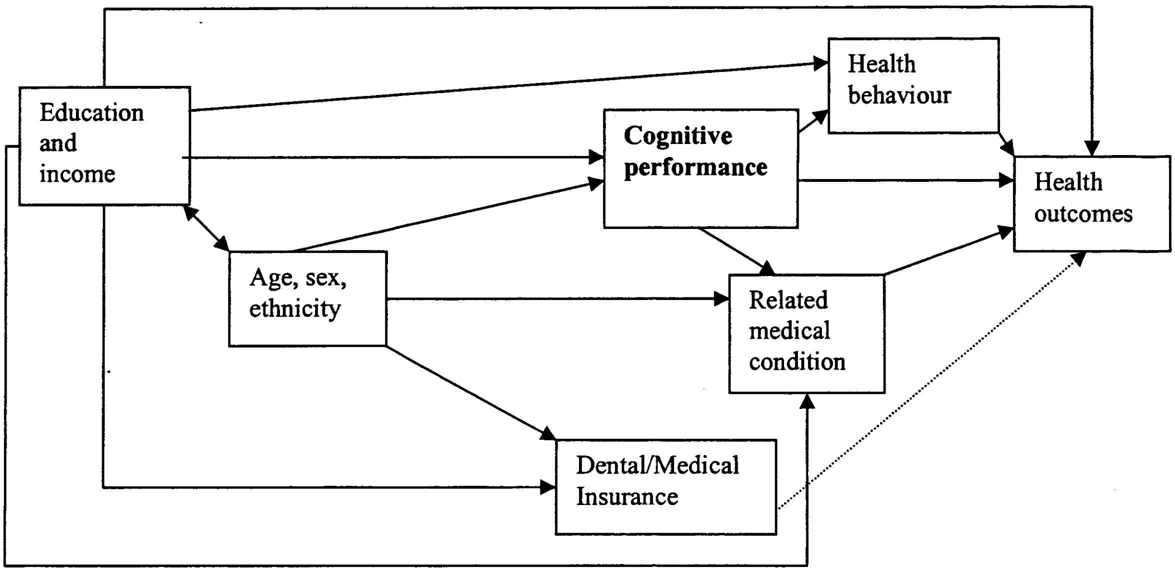


Figure 3.5 **The effect of cognitive performance on the social gradients in oral/general health**

Poorer cognitive performance was associated with ischaemic heart disease. In the adjusted models, which controlled for various confounders, the significant association disappeared except for that with the Simple Reaction Time Test. The association of poor cognitive performance with ischaemic heart disease observed in this analysis is supported by findings from other studies which suggest a relationship between cognitive abilities and general health (Franceschi *et al* 1983; Schmidt *et al* 1991; Kalra *et al* 1993; Elias *et al* 1997; Madden and Blumenthal 1998; France *et al* 2000; Gregg *et al* 2000; Knopman *et al* 2001).

Two studies examined the effect of cognitive ability on tooth loss (Avlund *et al* 2004) and dental treatment needs (Nordenram and Ljunggren 2002). No other known study has examined the association of periodontal disease with cognitive performance. The present analysis showed that most of the indicators of poorer cognitive performance used here were associated with indicators of periodontal diseases, with bleeding extent showing stronger and more consistent associations with all cognitive tests. Similarly, tooth loss was associated with cognitive performance. In the adjusted model only the Serial Digit Learning Test maintained a significant association with tooth loss. This finding supports findings from one study by Avlund *et al* (2004).

The associations between cognitive performance on one hand and oral and general health on the other hand were similar. The nature of the data used in this analysis does not allow conclusions to be drawn on the nature of the association of cognitive performance with oral and general health. Nevertheless, the findings imply a common effect of cognitive ability on both oral and general health and support the theories of general susceptibility to disease (Cassel 1976; Syme and Berkman 1976; Berkman and Syme 1979).

There are no known studies on the effect of cognitive ability on the social gradients in oral health. Some studies examined the effect of intelligence on socioeconomic disparities in health (Lubinski and Humphreys 1997; Hart *et al* 2003; Lawlor *et al* 2006). The bio-psychosocial pathway (Figure 2.17) postulated a mediating effect of cognitive ability on the social gradients in health. This analysis examined for the first time the effect of cognitive performance on the gradients in oral health and compared it to the effect of cognitive performance on general health. Some of the cognitive digital tests, namely the symbol digit substitution test, used in NAHNES III, are recognized as intelligence tests and are part of the Wechsler Adult Intelligence Scale (2004). Adjusting for cognitive performance indicators reduced education and income gradients for periodontitis, extent of gingival bleeding, attachment loss and pocket depth. Similarly, adjusting for indicators of cognition attenuated the gradients in ischaemic heart disease in the same manner. Although the differences between education groups in periodontitis and ischaemic heart disease were not significant, the gradients were clear and were reduced after adjusting for cognitive performance. The lack of significance in education gradients in periodontitis and ischaemic heart disease is probably due the fact that the dichotomous periodontal variable reflects mild form of the disease, the low prevalence of ischaemic heart disease, and to the relatively small number of individuals included in this analysis. Education and income gradients in tooth loss were also attenuated after adjusting for cognitive performance indicators.

Overall, cognitive abilities explained part of the social gradients in oral and general health, a finding which supports the thesis hypothesis about a cognitive pathway linking socioeconomic position to health. Some have argued that intelligence explains the socioeconomic differences in health (Lubinski and Humphreys 1997; Hart *et al* 2003; Gottfredson 2004; Gottfredson and Deary 2004; Lawlor *et al* 2006). The findings of the current analysis showed that cognitive ability contributed to the gradients in oral and general health. Others suggested that intelligence explains all of the socioeconomic difference in health (Gottfredson 2004). The current findings imply that while intelligence has an important effect on the social gradients in health, there are other important factors that contribute to the gradients. The finding also support the argument put forward in the bio-psychosocial model (Figure 2.17) about the mediating effect of cognition on the social gradients in health. The effect of cognition on the social gradients in health could be attributed to a number of factors. These factors include the influence of intelligence on compliance with medical and health promoting advice (Gottfredson and Deary 2004), influence on socioeconomic achievements (Lubiniski and Humphreys 1997; Hart *et al.* 2003), or similarities of the pathways to health between cognition and socioeconomic position (Singh-Manoux *et al.* 2005).

This analysis examined for the first time the effect of cognitive performance on periodontal disease, tooth loss and ischaemic heart disease in the same population and showed associations between cognitive performance indicators and oral and general health. The association between cognitive indicators with oral and general health appeared to be similar. Cognitive performance indicators explained part of the social gradients in oral health and general health and appeared to have the same mediating effect on the gradients in oral and general health.

The following section discusses the effect of health-related behaviours on health and on the social gradients in health.

11.1.5 Effects of health-related behaviours on oral and general health and on the social gradients

This analysis examined the social gradients in health-related behaviours, the association between health-related behaviours and health outcomes and the impact of health behaviours on the social gradients in health (Figure 3.6). Generally, there were income gradients in the five selected health-related behaviours, namely, frequency of physical activity, frequency of eating fresh fruits and vegetables, frequency of visits to dentist, being a current smoker and frequency of smoking. While other studies explicitly indicated the presence of social gradients in health-related behaviour (Davis 1980; Blane 1985; Marmot 1999, Jarvis and Wardle 2006), there was no consistent education gradients throughout all the variables included in this analysis. Only being a smoker and lower frequencies of visits to dentist showed a higher probability at each lower level of education and income. In the adjusted model for frequency of smoking, the lowest education group smoked slightly more often than the middle education group.

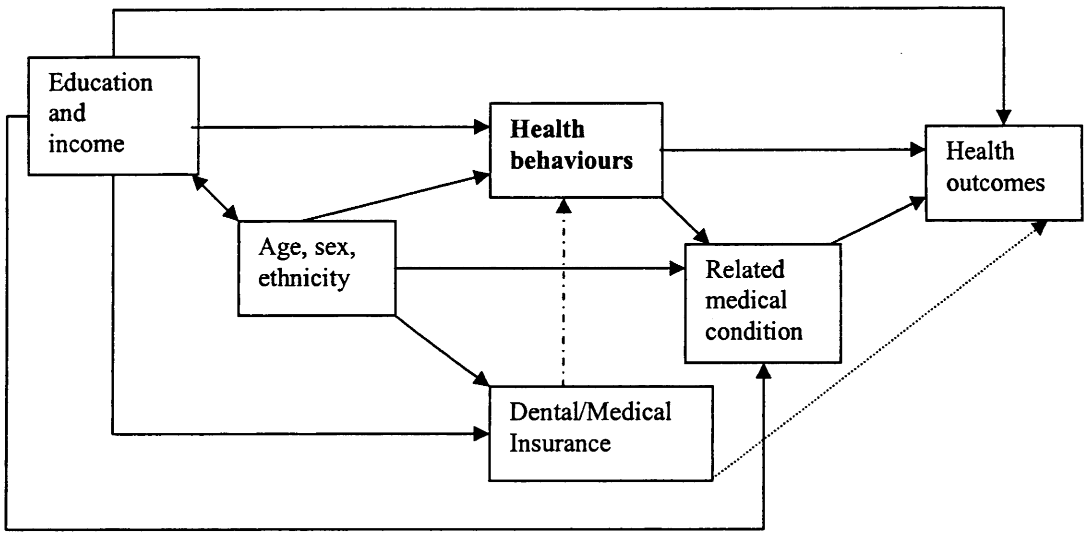


Figure 3.6 Social gradients in health-related behaviour and effect of health behaviours on the gradients in health

Despite the apparent lack of education gradients in some of the health-related behaviours indicators, there were still clear differences in behaviour between the people in the highest education group and those in the middle and lowest education groups. The lack of education gradient in frequency of physical activity may be a statistical artefact through a failure to adjust for other factors not included in the survey, such as social networks and environmental circumstances. There is also the fact that African Americans engaged in physical activities more often than White Americans (Young *et al* 1998), which could have had an impact on this result, particularly, as reported in this thesis, African Americans were generally poorer and less educated than Whites. Most importantly, the two behaviours which were more important in explaining the gradients in oral and general health, namely, current smoking and visit to dentists, showed both education and income gradients similar to that observed in the health outcomes.

Females were more likely to have healthy behaviours compared to males, which was consistent with other studies (Baker *et al.* 1992; Burt and Eklund 1992; Crossner and Unell 1996; Husaini *et al.* 2002; Johnson 2005) except for frequency of physical activity (Fardy *et al* 2000). Most of the health-related behaviours of African Americans and Hispanic Americans were worse than White Americans (Burt and Eklund 1992; Ronis *et al.* 1998; Macek *et al.* 2002; Dowda *et al.* 2003; Gans *et al.* 2003; Gilbert *et al.* 2003; Ridlen and Louria 2006). However, compared to White Americans, African Americans were more active and Hispanic Americans consumed more fresh fruits and vegetables and were less likely to smoke than Whites. This could be attributed to cultural differences related to physical activity and eating habits among these two ethnic groups (Coreil *et al* 1991; Scribner 1996; Young *et al* 1998; Bermudez *et al* 2000; Dixon *et al* 2000; Lee *et al* 2002; Gans *et al* 2003; Frenn *et al* 2005; Lara *et al* 2006; Keiffer et al 2006).

Another observation in the analysis of health-related behaviour was that while younger individuals and African Americans were more likely to be current smokers, those who smoked had a lower frequency of smoking compared to older individuals and White Americans, respectively. The observation about ethnic differences in frequency of smoking was similar to other studies (Fardy *et al* 2000).

Being a current smoker was associated with poorer oral and general health in the adjusted models for all the outcomes, namely ischaemic heart disease, perceived general health, perceived oral health, tooth loss and all periodontal diseases indicators except gingival bleeding. This finding confirms findings from other studies (Berkman and Breslow 1983; Wilson 1994; Jarvis and Wardle 2006; Lantz *et al* 2006). However, in the unadjusted analysis, smoking showed a different relationship with some of the health outcomes from that observed in the adjusted models. This was due to the negative confounding effect of age on this association. In other words, older people were less likely to smoke but more likely to have worse health. Therefore, lack of adjustment for age produced misleading results showing smoking to be associated with better health. The associations between smoking and health outcomes were significant in all the adjusted models except for perceived general health and ischaemic heart disease, which were marginally insignificant. The excessive adjustment in the ischaemic heart disease model, compared to the other models, is a possible explanation for the lack of significant association between smoking and ischaemic heart disease. It is also worth noting that a large section of the study population did not respond to the questions about smoking and were treated in the analysis as non-respondents. This may have influenced the estimation of the actual impact of smoking on health.

Frequency of visits to dentist once a year or more was significantly associated with better oral health in the unadjusted and adjusted models and for all oral health indicators. Generally, the associations between health-related behaviours and oral health were consistent with what has been reported (Davis 1980; Locker 1989; Sheiham and Watt 2000). Interestingly, the NHANES III did not include specific oral health behaviours such as tooth brushing and other oral hygiene practices. Such factors could have explained some of the variation in oral health not explained by the indicators of behaviours used here.

As shown in other studies, physical activity was associated with better general health (US Department of Health and Human Services 1996; Young *et al* 2005; Lantz *et al* 2006). Higher frequency of physical activity showed a marginally significant association with a lower probability of reporting poorer perceived general health in both the unadjusted and adjusted models. However, higher frequency of physical activity was significantly associated with a lower prevalence of ischaemic heart disease only in the unadjusted analysis. This effect disappeared after adjusting for age, sex, ethnicity, education, income, blood pressure, BMI and smoking. Interestingly, frequency of eating fresh fruits and vegetables was not a significant predictor of ischaemic heart disease in this analysis, a finding consistent with other reported studies (Ness and Powles 1997).

The bio-psychosocial pathway (Figure 2.17) suggested that health-related behaviours have a mediating effect on the social gradients in health. Hence, it was essential to measure the impact of health-related behaviours on socioeconomic disparities in oral and general health. Adjusting for the health-related behaviours reduced the education and income gradients for all oral and general health outcomes, namely all indicators of periodontal disease, tooth loss, perceived oral health, perceived general health and ischaemic heart disease. The gradients persisted after adjusting for behaviours and their statistical significance persisted for all of the health outcomes, except for education gradients in periodontitis (at least one site with gingival bleeding and one site with loss of attachment $\geq$ 3mm). In the two models pertaining to periodontitis, the odds ratios for the second and lowest education groups attenuated and lost their significance. In the ischaemic heart disease models, the probability of having the disease was higher at each lower level of education but was only significant in the lowest level in both of the models adjusting and not adjusting for behaviour (being a current smoker and physical activity).

The persistence of the gradients with significant differences for almost all outcomes, after adjusting for health-related behaviours, indicates the crucial importance of the education and income gradients in oral and general health. It also suggests that the health-related behaviours investigated here explained only a small part of the variations in oral and general health. Others have found a similar small effect of health related behaviours on the social gradients in oral health (Sanders *et al* 2006b) and general health (Lantz *et al* 2006). The present analysis reinforces these findings and also has the advantage of using several clinical and subjective indicators of oral and general health in a sample representative of US population.

It could be argued that the lack of statistical control for specific oral health-related behaviours, such as tooth brushing and dental flossing, does not allow conclusions to be drawn about oral health-related behaviours. However, others have shown that health behaviours and access to health services failed to explain the health gradient (Adler *et al* 1993; Adler *et al* 1994; Sanders *et al* 2006b: Jarvis and Wardle 2006).

Wamala *et al* (2006) found that access to dental care explained a large portion of the socioeconomic variation in oral health. This was not found in the present study. An important finding in this research is that the frequency of visits to a dentist did not influence the significance of education and income gradients in oral health. Frequency of visits to a dentist is of particular importance. First, because it indicates healthy behaviour as some visits are often for check-ups and can be considered preventive in nature. Second, frequency of visits to dentists is an indicator of utilisation of health services. Regression models adjusting for more than one variable indicating the use of oral health services (frequency of visits to dentists and dental insurance) still showed significant education and income gradients for almost all oral health outcomes.

Health behaviour is related to socioeconomic position, either directly, such as visits to dentists and eating habits, or indirectly, such as smoking (Jarvis and Wardle 2006). Yet, although reducing risky health behaviours in low-income populations is an important public health strategy, Lantz *et al.* (2006) considered that socioeconomic differences in mortality are due to a wider array of factors and therefore, are likely to persist even with improved health behaviour. Similarly, Watt (2007) argued that a focus on changing oral health behaviour without addressing its social determinants is unlikely to improve oral health. A recent study found similar results in Finnish population and concluded that interventions aimed to reduce health risk behaviour may reduce but not eliminate socioeconomic differences in health (Kivimaki *et al.* 2007). The dual associations observed in this analysis between health-related behaviours with socioeconomic position on one hand and poorer health on the other support the postulates of the bio-psychosocial model (Figure 2.17) about a mediating effect of health behaviours in the social gradients.

The present analysis examined the social gradients in health related behaviours and the effects of these behaviours on the social gradients in health in a nationally representative sample of the American population using numerous clinical and subjective health outcomes. The social gradients in health-related behaviours were not clear for all the indicators of behaviours. However, for those behaviours which were more important for health, such as smoking and frequency of visits to dentists, there were clear education and income gradients. The health-related behaviours examined in this analysis, showed associations with most health outcomes in the expected direction. That is, poorer behaviours were associated with poorer health, except for the association between smoking and gingival bleeding. Adjusting for health-related behaviours attenuated education and income gradients in health. However, socioeconomic position gradients persisted for all health outcomes. The findings support the hypothesis about a health behaviour mediating effect on the social gradients in oral and general health.

The following part of the discussion highlights the importance of calculus as a surrogate indicator of oral hygiene, on oral health and on the gradients.

11.1.6 Effect of a marker of tooth cleanliness (Calculus) on oral health and on the social gradients

This analysis examined education and income gradients in the extent of calculus, the association of calculus as a marker of tooth cleanliness with periodontal diseases and tooth loss, and the effects of adjusting for calculus on the social gradients in oral health. Calculus was used a surrogate measure of tooth cleanliness and oral hygiene (see methods in chapter 3), which mediates the effects of socioeconomic inequality in oral health (Figure 3.7).

Generally, the findings about the determinants of calculus were consistent with previous studies, which found that calculus was associated with older age (Hugoson *et al.* 1995), sex (male) (Beiswanger *et al.* 1989) lower socioeconomic position (Addo Yobo *et al.* 1991; Morris *et al.* 2001), lower education and frequency of tooth cleaning/oral hygiene (Morris *et al.* 2001; Netuveli 2002).

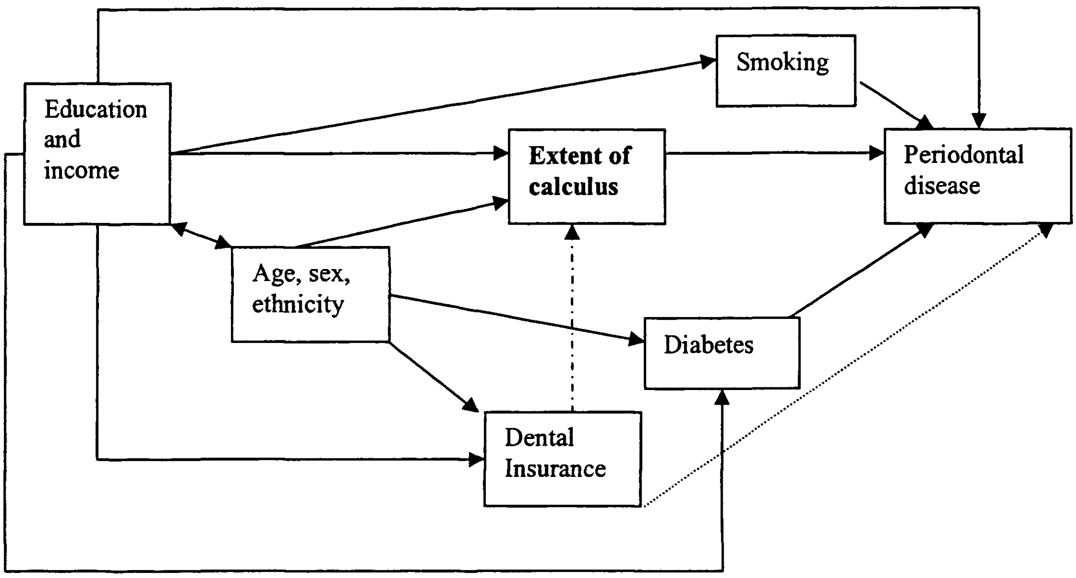


Figure 3.7 The effect of tooth cleanliness (calculus) on the gradients in periodontal disease.

Overall, there were very steep education and income gradients in the extent of the accumulation of calculus which persisted even after adjusting for a number of confounding factors. Other studies have highlighted social inequalities in individuals' levels of calculus (Bourgeois *et al* 1999; Morris 2001; Taani 2002; Green *et al* 2003). However, in this analysis there were large differences in the extent of calculus at each lower level of education and income. Calculus is associated with dental plaque and tooth cleanliness (Pattanaporn and Navia 1998; Timmerman and van der Weijden 2005; Riley *et al* 2006). Hence, these results imply the presence of social gradients in tooth cleanliness. Even when several confounders, including two indicators of use of dental services were adjusted for, the gradients in calculus persisted and remained significant and steep. These gradients in this marker of oral cleaning behaviour (calculus) are similar to that reported about other health behaviours (Davis 1980; Blane, 1985; Marmot 1999). Calculus is mainly a product of two behaviours: personal cleaning and professional cleaning. Therefore, the persistence of the gradients in calculus implies that these two behaviours of personal and professional cleaning of the teeth were consistently less important to individuals as income and education decreased (Brunner 2002; Abegg *et al.* 1999; 2000). The social gradients in calculus as a marker of tooth cleanliness followed the same pattern observed in the social gradients in periodontal health, in smoking and visits to dentists, but the gradients were steeper. This implies that calculus was a very sensitive marker of social inequality compared to other health-related behaviours in this population.

Females had lower levels of calculus, a finding consistent with other oral health-related behaviours in females (Baker *et al.* 1992; Crossner and Unell 1996; Husaini *et al.* 2002). African Americans and Hispanic Americans had more calculus compared to White Americans. Dental insurance, dental attendance and smoking were also important predictors of the levels of calculus. All these factors combined did not significantly reduce the gradients in calculus. Those same factors were important determinants of periodontal disease in this population.

Calculus was significantly associated with increased levels and probabilities of periodontal diseases, a finding consistent with other reports (Pattanaporn and Navia 1998; Timmerman and van der Weijden 2005; Riley *et al* 2006). Even after adjusting for various confounders, the association between calculus and periodontal disease and gingival bleeding remained significant. Some have suggested that the presence of calculus was related to higher levels of periodontal disease in the individual but not at the affected tooth surface (Gilthorpe *et al* 2000) and have postulated that calculus is a marker of oral health but not a cause of disease (Netuveli 2002). Here, it is not argued that calculus causes periodontal diseases or tooth loss, but is a surrogate marker of oral cleanliness.

Calculus was also associated with tooth loss. This finding confirms earlier studies, which showed that tooth cleanliness was associated with tooth loss (Treasure *et al.* 2001; Gilbert *et al.* 1993; Ylostalo *et al.* 2004; Eklund and Burt 1994; Drake *et al.* 1995).

Tooth cleanliness, as indicated by calculus, explained a large portion of the social gradients in periodontal disease and tooth loss. The biggest impact was observed in the model pertaining to periodontitis (one site gingival bleeding and one site loss of attachment $\geq$ 3mm), where education gradients almost disappeared after adjusting for calculus. The gradients remained clear but less steep in the extent of gingival bleeding, loss of periodontal attachment and pocket depth.

The effect of tooth cleanliness on the social gradients in oral health appears to be of vital importance, as other pathways to the gradients in periodontal diseases and tooth loss explored in this thesis did not explain as much of the socioeconomic variations in oral health as did tooth cleanliness. However, considering the presence of consistent and steep education and income gradients in calculus, which persisted even after accounting for visits to dentists and dental insurance, the reason for social inequality in accumulation of calculus and in periodontal diseases cannot be easily explained. Availability of dental services and patterns of attendance explained a small portion of the gradients in tooth cleanliness, but did not abolish them. Sex and ethnicity also explained part of the variation in tooth cleanliness which reflects personal and cultural differences in health-related behaviours between males and females and between ethnic groups (Baker *et al* 1992; Crossner and Unell 1996; Husaini *et al* 2002; Dowda *et al* 2003; Gans *et al* 2003; Ridlen and Louria 2006). Brunner (2002) argued that competition for time allocated for healthy behaviours and work-related stress could influence health deteriorating behaviours. Brunner's suggestion is particularly relevant to oral health because flexibility and control of work and daily activities did influence tooth cleaning behaviours (Abegg *et al.* 1999; 2000). This implies that calculus could be considered a distant marker of different pathways including behaviour and stress.

The results demonstrated the presence of steep gradients in calculus and significant associations between calculus and oral health indicators. The results also showed that calculus, as a marker of oral hygiene behaviour, had a great effect on the social gradients in periodontitis and tooth loss. These findings support the hypothesis about a mediating effect of behaviours on the social gradients in oral health.

The next section of the discussion highlights the effect of stress, indicated by allostatic load, on the social gradients in oral and general health.

11.1.7 A stress pathways towards the social gradients in oral and general health

This analysis examined and tested the significance of the possible stress pathway between periodontal disease, ischaemic heart disease and socioeconomic position (Figure 3.8). Although a stress pathway was suggested as a contributing factor to periodontal disease (Monteiro-da-Silva *et al* 1996; Croucher *et al* 1997; Alekesejuiene *et al* 2002; Pistorius *et al* 2002; Hugoson *et al* 2002; Vettore *et al* 2003; Solis *et al* 2004; Akhter *et al* 2005; Dolic *et al* 2005; Newton 2005; Sheiham and Nicolau 2005), there is no known study that examined the relation between stress, indicated by allostatic load, and oral health

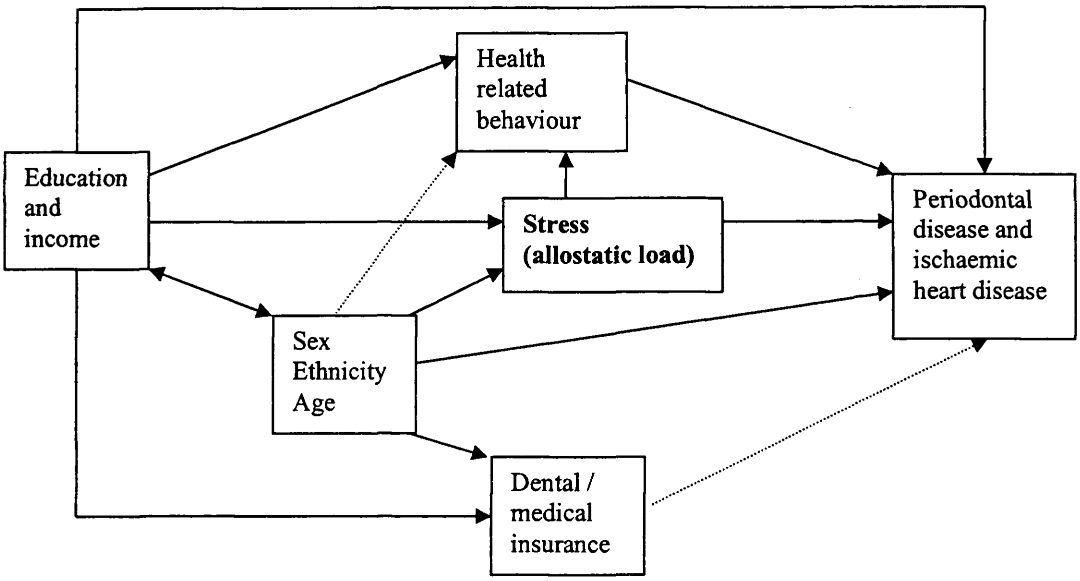


Figure 3.8 A stress pathway linking socioeconomic position to periodontal disease and ischaemic heart disease

Similarly, studies on general health have suggested some stress pathways linking socioeconomic position to general health, especially cardiovascular diseases, using markers of allostasis (Marmot *et al* 1997; Seeman *et al* 1997; McEwen 1998; Hemingway and Marmot 1999; Seeman *et al* 2001; Brunner 2002; Crimmins *et al* 2003; Siegrist and Marmot 2004; Allsworth *et al* 2005; Brunner and Marmot 2006). However, there is no known study which compared the effect of allostasis, as a marker of stress, on oral health and general health in the same population. Some dental studies had examined some of the markers used here as indicators of inflammation or to find a link between oral health and coronary artery disease but not as marker of allostasis and not using a cluster of allostatic markers (Slade *et al* 2000; Buhlin *et al* 2003; Schwahn *et al* 2004; Mattila *et al* 2005). In this analysis seven markers (C-reactive protein, fibrinogen, hypertriglycerdemia, plasma glucose, waist circumference, low

HDL-cholesterol and high blood pressure) were used to indicate allostatic load, measuring their individual and collective effects on periodontal disease and ischaemic heart disease.

Other researchers suggested assessing and examined the effect of clusters of allostasis indicators on health (MacArthur 1997; Seeman *et al* 2001). In this analysis, the effects of clustered allostasis indicators on periodontal disease and ischaemic heart disease were examined.

Generally, all seven markers of allostatic load were higher in persons with periodontal diseases and with ischaemic heart disease. The associations between the markers of allostasis and health outcomes were statistically significant in most of the models but the probability of the diseases attenuated in the adjusted models. The adjusted models controlled for markers of allostasis in addition to other confounders such as age, ethnicity, income, education, dental insurance and smoking. There were variations in the changes in the associations between different markers of allostasis and different health outcome. For example, CRP had odds ratios of 1.32 and 1.21 with gingival bleeding in the unadjusted and adjusted models, while the same marker had odds ratios of 3.02 and 1.05 with loss of attachment in the adjusted and unadjusted model. This is probably because of the direct effect of the marker of allostasis on the respective condition. That is to say, CRP as a marker of inflammation has a stronger association with gingival bleeding than with loss of attachment. It is worth noting here that these markers of allostasis are used to indicate stress. Hence, their occurrence in people with periodontitis and ischaemic heart disease is not coincidental or a result of statistical confounding. Rather, it is because these markers indicate stress, which was shown to be associated with periodontitis and ischaemic heart disease (Brunner 2002; Sheiham and Nicolau 2005).

In addition, an increase in the count of allostatic markers was significantly associated with all indicators of periodontal diseases and ischaemic heart disease. The fact that the count of allostatic markers had similar effects on both periodontal disease and ischaemic heart disease is an important observation. These findings indicate that stress, indicated by allostatic load, affects periodontal disease as it has been shown to affect heart disease (Brunner 2002).

The finding that there were higher levels of the variables, used here as markers of allostatic load, among people with periodontal diseases was suggested in other studies (Buhlin *et al* 2003; Morita *et al* 2004; Mattila *et al* 2005; Inoue *et al* 2005; Dye *et al* 2005; Loos 2005; Ioannidou *et al* 2006; Salzberg *et al* 2006; Czernuk *et al* 2006; Borges *et al* 2006). None of these studies used the range of periodontal disease measures used in the current analysis. Neither did they address these variables as markers of allostatic load nor did they examine their collective effects on periodontal diseases.

The bio-psychosocial pathway (Figure 2.17) suggested a stress pathway explaining the social gradients in oral and general health. Hence, this analysis examined the effect of adjusting for stress indicated by allostasis on education and income gradients in periodontal diseases and ischaemic heart disease in the same population. An effect which no other known study has examined, though deemed important as it demonstrates the commonality of the determinants of oral and general health. Adjusting for allostatic load attenuated education and income gradients for all periodontal disease measures used here and for ischaemic heart disease. The analysis, especially adjusting only for education or income and allostasis, showed similar effects of allostasis on education and income gradients in periodontal disease and ischaemic heart disease.

Stress, indicated by allostatic load explained part of the gradients in periodontitis and ischaemic heart disease. This highlights the likelihood of a possible stress pathway contributing to the social gradients in these two conditions, as suggested by Brunner (2002) and Sheiham and Nicolau (2005). Some important markers of allostatic load such as cortisol, adrenaline, noradrenaline and epinephrine (MacArthur 1997) were not available in NHANES III. It is possible that if these factors were included in the analysis, allostatic load markers would have explained a greater part of the gradients.

Stress is related to relative poverty, social status and income inequality (Wilkinson 1996; Brunner 2003; Marmot and Wilkinson 2006). Hence, the findings of this study on the effect of stress, indicated by allostatic load, on oral and general health and on the gradients highlight the importance of relative poverty rather than absolute poverty in the social gradients in health. The similarities of the effects of allostatic load on the gradients in periodontitis and ischaemic heart disease support the theories about the commonality of pathways to oral and general health (Sheiham and Watt 2000).

This analysis explored the individual and clustered effects of stress, indicated by allostasis, on different indicators of periodontal diseases and compared these effects to that observed in ischaemic heart disease. Higher levels of allostasis were observed in persons with higher levels of periodontitis and ischaemic heart disease. Stress indicated by allostasis explained part of education and income gradients in periodontal disease and appeared to have a similar effect on the gradients in both periodontitis and ischaemic heart disease. The findings of this analysis support the hypothesis of this thesis about a stress pathway in the social gradients in oral and general health.

The following section is a general discussion of all the findings.

11.1.8 General discussion of the results

The existence of social gradients in most common disease in all industrial countries has been well established (Adler and Strove 1999; Marmot and Wilkinson 2006). The occurrence of differences in health status between each two consecutive levels of the social hierarchy, even between those at the top, emphasises the importance of relative status (Marmot 2003). Health inequalities between the poor and the rest of the society reflect the direct effect of material living standards and behavioural factors (Lynch *et al* 1997; Blane *et al* 1998). In contrast, the social gradients reflect psychosocial effect of social comparison (Marmot and Wilkinson 2001), job security, control and power in work place and effort-reward imbalance (Ferrie *et al* 2003; Siegrist and Marmot 2004).

This thesis demonstrated the presence of social gradients in a number of subjective and clinical indicators of oral and general health in a sample representative of the US adult population. The relationship between each of income and education levels with all health outcomes exhibited a dose-response relationship. Even when the analysis was conducted repetitively adjusting for several confounding and mediating factors, the gradients always existed. Education and income were used as marker of socioeconomic position in this thesis. There is a close link between social deprivation and performance in school (Marmot 2003). Hence, education is not only a marker of knowledge and opportunities for better achievement in life, but also a marker of social background and cognitive ability (Galobardes *et al* 2006). Income reflects material ability, access to services, better living conditions, self-esteem and social standing (Marmot 2003; Galobardes *et al* 2006). Krieger *et al* (1997) argued that education and income are acceptable indicators of social position in the US. While income was used as a continuous variable for most of the analysis, education was categorise into three groups which reflect educational achievement; less than high school, high school diploma and post high school education.

The use of both clinical and subjective indicators of health is of particular importance. Clinical measures of health reflect diagnosis of conditions as defined by professionals. On the other hand, perceived health is a multidimensional phenomenon (Idler and Benyamini 1997) which reflects the psychosocial dimension of health, life experiences, functional ability, tiredness, standing illness, and number of symptoms (Jylhä *et al.* 1998; Singh-Manoux *et al.* 2006).

The reported gradients in indicators of social position emphasises the importance of relative rather than absolute poverty and necessitates the exploration of the potential causes of the gradients. The bio-psychosocial model (Figure 2.17) proposed that there is a complex interaction between general policies, material conditions, social environment, early life, individuals' socioeconomic position, use of health services, health behaviours, biological factors, cognitive ability and stress affect morbidity and mortality. The analysis conducted here can only support parts of this argument. The analysis demonstrated that individual's socioeconomic position was associated with health in the form of social gradients. Use of health services, indicated by medical/ dental insurance and frequency of visits to a dentist affected health and the social gradients in health. The use of health services (frequency of dental visits) was shown to be affected by socioeconomic position.

Biology, indicated by sex and ethnicity, was associated with individual's health. The causes of ethnic differences in health are numerous and complicated, one of them is socioeconomic differences between ethnic groups as shown in this thesis. Other causes of ethnic differences, not explored here, include cultural and genetic differences (Samje 1996;

Diaz *et al* 2005), demographic location (Mensah *et al* 2005), racial harassment and discrimination (Nazroo and Williams 2006). There are also sex differences in oral and general health. Women health benefited more from improved socioeconomic position. There are other biological and behavioural factors which influence sex difference in health not explored here (Bartley 2004). Both sex and ethnicity affected the social gradients in oral and general health. The findings support, to some extent, the assumption in the bio-psychosocial model (Figure 2.17) that socioeconomic position affects the health of men and women on one hand and ethnic groups on the other hand, differently.

Poorer cognitive abilities were associated with poorer oral and general health, and influenced the social gradients. Cognitive ability could affect health either because it affects education and socioeconomic achievement (Batty and Deary 2004; Lawlor *et al* 2006), or because it affects compliance with medical advice and health enhancing behaviours (Gottfredson 2004). Cognitive ability could also be a marker of education and affect health in a similar way (Singh-Manoux *et al* 2005; Galobardes *et al* 2006).

Health-related behaviours and tooth cleaning were also shown to be associated with oral and general health and had an impact on the social gradients. Perhaps the biggest attenuation in the social gradients in oral health was observed in the model adjusting for calculus as a marker of oral hygiene. However, health behaviour is influenced by the same causes of the gradients in health, namely stress (Brunner 2002), cognition (Gottfredson 2004), and ethnicity (Lara *et al* 2006). Hence, examining the effect of health behaviour on health should not be separated from its psychosocial, economic, environmental and political determinants (Watt 2007).

Stress played a vital role in the social gradients in health as depicted by the bio-psychosocial model (Figure 2.17). Stress, indicated by allostatic load, was associated with ischaemic heart disease and periodontal disease. Allostatic load explained part of the social gradients. In addition to the direct effect of stress on endocrine and immune system, it also affects health behaviours (Brunner 2002), an association not examined in this thesis.

It could be argued that the relationships between some of the factors examined here in relation to oral and general health are the results of statistical confounding. For example, the relationship between calculus and oral health, or between some markers of allostasis, such as central obesity, and oral health are due to confounding effect. However, such variables were used as markers of other behaviours or conditions believed to be associated with oral and general health. For example, calculus does not cause periodontal disease, but poor oral hygiene does, therefore, calculus as a marker of oral hygiene is associated with periodontal disease. Similarly, there is no evidence for a causal relationship between central obesity and periodontitis, but stress is associated with periodontal disease, hence, central obesity as a marker of stress (allostasis) is associated with periodontal disease.

There appeared to be variations in the effects of the different pathways examined here on the social gradients. Tooth cleanliness appeared to have the greatest impact on the social gradients in oral health. Stress, indicated by allostatic load, had a great impact on ischaemic heart disease and gingival bleeding. This was not surprising considering that the aggregated allostatic marker included a number of inflammatory markers. Frequency of dental visits also had a great impact on the social gradients in oral health. Each of the examined pathways explained part of the gradients. Interestingly, the gradients always existed which indicates the importance of education and income as marker of social position, and indicates the presence of other explanatory factors not explored here.

This thesis addressed certain pathways to the social gradients in health and demonstrated their effects. These pathways also affect each other, as suggested in the bio-psychosocial model (Figure 2.17). The interactions between these pathways were beyond the scope of this thesis. Other studies have examined some of these interactions, for example, the association between stress, sex , ethnicity, intelligence on one hand and health behaviour on the other (Brunner 2002; Husaini *et al* 2002; Lara *et al* 2006; Jarvis and Wardle 2006; Gottfredson 2004).

Syme (1996) stated that all known risk factors for heart disease explain less than half of the variation in this condition and argued that risk factors for other conditions would be even less impressive in explaining the variations in the respective conditions. Syme's hypothesis is applicable to the analysis conducted here. That is to say that there are far more determinants of the health outcomes examined here and of the social gradients, which were not captured in this analysis. However, this analysis went some way in explaining the social gradients in oral and general health. This analysis also demonstrated the commonality of the determinants of oral and general health.

11.2 Limitations of the study

Data for the analysis was from NHANES III, a cross-sectional study. Therefore, conclusions about causal effects cannot be inferred. The limitation of the data also did not allow adjustment for important determinants of health, such as early life socioeconomic position and social mobility (Marmot and Wilkinson 2006). NHANES III did not include information on neighbourhood characteristics, social networks, social capital or social cohesion, all deemed important determinants of health and the gradient (Wilkinson 1996). Other important factors not included in NHANES III, especially in relation to ethnic differences in health, include experiences of racial harassment and discrimination (Kreiger 2000; Williams and Neighbors 2001; Williams *et al* 2003; Nazroo and Williams 2006). The survey also lacked data on specific oral health behaviours such as tooth brushing. Adjusting for such behavioural factors could have changed the steepness of the gradients in oral health. However, other studies found that these oral health-specific behaviours did not the social gradients in oral health (Sanders *et al* 2006b).

Apart from the study design and the lack of some important data, limitations may also be identified in relation to the selection of variables. The dichotomous variable used indicating periodontitis is based on definitions of mild periodontitis (Offenbacher *et al* 2001) and gingival bleeding. However, this variable was not the sole indicator of periodontal disease and was used in combination with three different variables measuring extent of gingival bleeding, pocket depth and loss of attachment, which were used in previous NHANES III-based studies (Arbes *et al* 1999; Slade and Beck 1999; Slade et al 2000). Consequently, those measures should, collectively, go some way in fully covering the different manifestations and levels of periodontal disease.

As mentioned above there were no data on specific oral health behaviours, nor were there data on dental plaque in NHANES III. Therefore, calculus was used as indicator of tooth cleanliness and for the specific behaviour related to tooth cleanliness. This was justified by other studies which suggested that calculus could be used a surrogate measure of oral hygiene behaviours (Maizels and Sheiham 1987).

A diagnosis of angina pectoris based on the WHO questionnaire (Rose *et al* 1982) was used in combination with reported diagnosis of heart attack. Although this is acceptable as a reliable measure of the disease in a survey, it is not as accurate a measure as a diagnosis extracted from medical charts. The digital cognitive tests, which were used in this thesis, were only available for a sub-sample of the population aged 20 to 59 years old. Consequently, a much smaller sample was included in the analysis pertaining to cognitive performance. The three health outcomes examined in relation to cognitive abilities (ischaemic heart disease, periodontitis and tooth loss) are more common in older age groups. The smaller sample and the exclusion of older individuals from the digital cognitive tests probably influenced the strength of the statistical analysis.

NHANES III did not include a number of important indicators of allostatic load such as adrenaline, noradrenaline, epinephrine, cortisol (MacArthur 1997). If such variables were available, they could have explained a greater portion of the gradients in ischaemic heart disease and periodontitis. The cut-off points used for markers of allostatic load used in this thesis were different from those used in previous studies on allostatic load and general health (Seeman *et al 1997*; Seeman *et al* 2001). However, these cut-off points were associated with higher levels of periodontal disease in other studies (Slade *et al* 2000; Schwahn *et al* 2004; Czerniuk *et al* 2006; Borges-Yanez *et al* 2006).

The use of regression models to assess the effect of the different pathways on the social gradients in oral and general health is less powerful and less complex than other advanced statistical methods such as path analysis, factor analysis and structured equation modelling. These methods are more appropriate for establishing causal relationship in longitudinal studies. Some of them account for interactions between the different causal pathways. However, the method used in this thesis has the advantage of accounting for direct and indirect effect of the explanatory factors (van Oort *et al.* 2005). This thesis is based on a cross-sectional survey and does not support conclusions of causal relationships. Additionally, measuring the interactions between the different determinants in the same model was beyond the scope of this thesis. Hence, the selection of regression analysis over the more complex methods appears to be appropriate for this analysis.

11.3 Implications of findings

11.3.1 Policy implications

11.3.1.1 Applicability of the results

This thesis used globally accepted measures of socioeconomic position (Krieger *et al.* 1997; Galobardes *et al.* 2006) to measure the gradients in oral and general health assessed by clinical and subjective measures in a nationally representative sample of the US population. The universality of the measure of socioeconomic position and the use of various indicators of health indicate that the results could be applicable to other populations outside the United States.

11.3.1.2 Integration of oral and general health and common risk factors approach

The results showed that the gradients in periodontal disease and ischaemic heart disease were similar as were the gradients in perceived general health and perceived oral health. In addition to demonstrating similarity of the socioeconomic determinants of oral and general health, markers of allostatic loads, markers of cognitive abilities and smoking had similar effects on oral and general health. These findings support the call for integrating oral health policies with general health policies (U.S. Department of Health and Human Services 2000). Sheiham and Watt (2000) argued that promoting health by controlling risk factors common to a number of diseases may have a major impact on a large number of chronic diseases. Coordinating the work of various specialists to tackle diseases sharing the same risk factors will help deliver the intervention at a lower cost, greater efficiency and effectiveness than disease specific approach. Additionally, a health promotion intervention aimed at tackling heart disease, obesity, diabetes, cancer and oral health is more likely to gain the support of the stakeholders and the community than a disease-specific intervention (Sheiham and Watt 2000). The commonality of the social determinants of oral health and general health and the similar pathways explored in this thesis support the concept of a common risk factor approach.

11.3.1.3 Sex and Ethnicity differences in health

While ethnic differences in oral and general health were not present among the poorest and least educated, there were ethnic differences among those with high levels of income and education. This suggests that ethnic differences in health have other causes in addition to income and education. Health policies aimed at reducing health differences between ethnic groups should consider all these factors.

Women had worse perceived general health than men; a finding supported by other studies (Bartley 2004). On the other hand, women had better periodontal status compared to men which is attributed to better health behaviour (Schuller *et al.* 1998; Sakki *et al.* 1998; Ostberg *et al.* 1999). These two findings should be considered in respective general and oral health policies.

11.3.1.4 Health behaviours and tooth cleanliness

Health-related behaviours explained a small portion of the social gradients in oral and general health. Calculus, as a marker of tooth cleanliness, and oral hygiene had a greater effect on the gradients in oral health than other health behaviours. The persistence of the gradients in oral health after adjusting for dental attendance suggests that the problem of inequality in oral health will not be completely solved by improving access to dental care as others have suggested (Wamala *et al.* 2006). Neither could inequality in health be solved by allocating more resources to oral health programmes aimed at increasing the awareness of oral hygiene behaviours. Indeed health programmes aimed at increasing the population awareness of healthy behaviours increase inequality in oral health rather than reduce it (Schou and Wight 1994; Locker 2000). Although reducing risky health behaviours is an important public health strategy, it should not be the sole intervention. Eliminating or even significantly reducing health inequality requires more radical and comprehensive policy changes which address a wide array of determinants of health.

11.3.1.5 Pathways explaining social gradients in oral and general health

This thesis explored a number of pathways to explain the social gradients in oral health and general health. Each of these pathways explained part of the gradients. Other researchers working on the gradients in health have argued that the determinants of health inequalities are complex (Adler *et al* 1994; Marmot 2003) and hence require more complex and radical policy changes (Wilkinson 1996). Policy makers should look at the bigger picture of the determinants of health and consider the different pathways that affect the gradients in oral and general health. This thesis showed that there are important factors that influence the social gradients in oral and general health, such as health behaviour, stress and oral hygiene. These factors should be addressed by health policy makers.

11.3.2 Directions for Future Research

11.3.2.1 Although this thesis examined various pathways affecting the gradients in oral and general health, further research is needed to replicate or refute the findings of this thesis. There is also a need for research on other explanations for the social gradients in oral and general health, such as early life, social cohesion and social capital, to answer questions not addressed here.

11.3.2.2 There is a need for future research examining the pathways explored here, using longitudinal data to establish causal relationships, and using more complex statistical methods to account for interactions between the different determinants.

11.3.2.3 Considering the limitations of the data used in this thesis, further research using data not available in NHANES III should be conducted. For example, future research should examine the effect of specific oral health behaviours such as tooth brushing and flossing on the gradients in oral health in a nationally representative sample.

11.3.2.4 There is a need for further studies using other markers of allostatic load, not used here, such as cortisol, adrenaline, noradrenaline and epinephrine.

11.3.2.5 Further research on the effect of cognitive ability on oral health among older individuals is also needed.

11.3.2.6 Future research should examine the effects of social cohesion, social capital and early life circumstance pathways on the social gradients in oral health and general health in the same population.

11.3.2.7 Similarities between the gradients in general health and in other indicators of oral health such as dental caries, dental trauma and oral cancer need to be examined in future research.

11.4 Conclusion

11.4.1 There were clear income and education gradients in all health outcomes with individuals experiencing worse oral and general health at each lower level of socioeconomic position. The gradients in oral and general health were consistent.

11.4.2 The gradients in health-related behaviours were clear in three indicators of behaviours, namely being a current smoker, frequency of smoking and frequency of dental visits.

11.4.3 The presence of social gradients in health and related behaviours emphasises the importance of relative income as a cause of the gradients.

11.4.4 Ethnic differences in health are not merely the product of socioeconomic differences but have more complex determinants.

11.4.5 Each of the examined pathways explained part of the gradient. However, none of them fully explained the gradients.

11.4.6 The contributions of each of these pathways to the social gradients in general and oral health demonstrate the complexity of the determinants of health.

11.4.7 The pathways which were explored in both oral health and ischaemic heart disease, namely allostatic load and cognitive ability, had similar effects on both of these chronic conditions, which indicate similar determinants of oral and general health and support the theories about general susceptibility to disease.

11.4.8 This thesis explained parts of the determinants of the social gradients in oral and general health. Further research is needed to examine other causes of the gradients not explored here.

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Appendices

Appendix 1

Description of relevant parts of NHANES III and analytic guidelines

Oral examination in NHANES III (U.S. Department of Health and Human Services 1997) The oral health examination consisted of a visual and tactile oral and dental examination performed on examinees aged 1 year and over by a licensed dentist specially trained in the use of specific epidemiologic indices for oral health. In this research we only include individuals aged 17 and above. Not all persons who completed the interview had dental examination. It should be noted that the diagnostic criteria used are intentionally conservative. When a choice existed between two possible diagnoses, the less severe diagnosis was recorded. Individuals reporting having heart problems and conditions that might require antibiotics before a dental examination were excluded from the examination.

Periodontal examination: For adolescents and adults ages 13 years and over the periodontal measures were done on randomly assigned half-mouths, one upper quadrant and one lower quadrant selected at the beginning of the examination. The buccal and mesial-buccal aspects of each tooth were scored separately for each periodontal measure: gingival bleeding, calculus, gingival recession, and pocket depth. Loss of attachment was derived from two measurements made at each site: (1) the distance from the free gingival margin (FGM) to the cemento-enamel junction (CEJ), and (2) the distance from the FGM to the bottom of the sulcus (pocket depth). When the gingival margin had receded and the CEJ was exposed, the first number was scored as a negative value and was an indication of gingival recession. The loss (level) of attachment variables were calculated by subtracting the recorded distance of the FGM to CEJ from the recorded distance of the FGM to the base of the sulcus.

Tooth loss

The examiner used a mirror and #23 explorer for the DMFS/T index, which is the sum of the number of decayed, missing or filled permanent tooth surfaces/teeth and is, thus, a summary of cumulative caries experience. For teeth scored as missing, posterior teeth receive a count of five missing surfaces and anterior teeth receive a count of four missing surfaces. The occlusal surface is not counted for anterior teeth. A place-holder variable for these surfaces maintains the five-surface pattern (occlusal, lingual, buccal, mesial, distal) to facilitate systematic surface selection by analysts. Third molars are only indicated as present or absent. Only persons with at least one permanent tooth space code indicated were eligible for permanent DMFS/T counts.

Training and Quality Control

The National Institute of Dental Research (NIDR) and the dental consultant provided extensive training of the dental examiners at their time of hire. One examiner was available for the entire six years and performed about half of the examinations. Three more examiners and one back-up examiner performed the rest of the exams. As part of quality control, a separate "gold standard" examiner visited each dental examiner one or two times a year in the MEC for observation and to perform replicate exams of most indices on approximately 30 persons. Each examiner also performed replicate examinations on selected sample persons within the six week examination period available at each location. For all major components of the examination the intra- and inter-examiner measures were in satisfactory ranges.

SAMPLE DESIGN AND ANALYSIS GUIDELINES

Sample Design

The general structure of the NHANES III sample design is the same as that of the previous NHANES. Each of these surveys used a stratified, multi-stage probability design. The major design parameters of the two previous NHANES and the special Hispanic HANES, as well as NHANES III, have been previously summarized (Miller, 1973; McDowell, 1981; NCHS, 1985; NCHS, 1994). The NHANES III sample was designed to be self-weighting within a primary sampling unit (PSU) for subdomains (age, sex, and race-ethnic groups). While the sample was fairly close to self-weighting nationally for each of these subdomain groups, it was not representative of the total population, which includes institutionalized, non-civilian persons that were outside the scope of the survey.

The NHANES III sample represented the total civilian, no institutionalized population, two months of age or over, in the 50 states and the District of Columbia of the United States. The first stage of the design consisted of selecting a sample of 81 PSU's that were mostly individual counties. In a few cases, adjacent counties were combined to keep PSU's above a minimum population size. The PSU's were stratified and selected with probability proportional to size (PPS). Thirteen large counties (strata) were chosen with certainty (probability of one). For operational reasons, these 13 certainty PSU's were divided into 21 survey locations. After the 13 certainty strata were designated, the remaining PSU's in the United States were grouped into 34 strata, and two PSU's were selected per stratum (68 survey locations). The selection was done with PPS and without replacement.

The NHANES III sample therefore consists of 81 PSU's or 89 locations. The 89 locations were randomly divided into two groups, one for each phase. The first group consisted of 44 and the other of 45 locations. One set of PSU's was allocated to the first three-year survey period (1988-91) and the other set to the second three-year period (1991-94). Therefore, unbiased estimates (from the point of view of sample selection) of health and nutrition characteristics can be independently produced for both Phase 1 and Phase 2 as well as for both phases combined.

For most of the sample, the second stage of the design consisted of area segments composed of city or suburban blocks, combinations of blocks, or other area segments in places where block statistics were not produced in the 1980 Census. In the first phase of NHANES III, the area segments were used only for a sample of persons who lived in housing units built before 1980.

For units built in 1980 and later, the second stage consisted of sets of addresses selected from building permits issued in 1980 or later. These are referred to as "new construction segments." In the second phase, 1990 Census data and maps were used to define the area segments. Because the second phase followed within a few years of the 1990 Census, new construction did not account for a significant part of the sample, and the entire sample came from the area segments.

The third stage of sample selection consisted of households and certain types of group quarters, such as dormitories. All households and eligible group quarters in the sample segments were listed, and a subsample was designated for screening to identify potential sample persons. The subsampling rates enabled production of a national, approximately equal-probability sample of households in most of the United States with higher rates for the geographic strata with high Mexican-American populations. Within each geographic stratum, there was a nearly equal-probability sample of households across all 89 stands.

Persons within the sample of households or group quarters were the fourth stage of sample selection. All eligible members within a household were listed, and a subsample of individuals was selected based on sex, age, and race or ethnicity. The definitions of the sex, age, race or ethnic classes, subsampling rates, and designation of potential sample persons within screened households were developed to provide approximately self-weighting samples for each subdomain within geographic strata and at the same time to maximize the average number of sample persons per sample household.

Previous NHANES indicated that this increased the overall participation rate. Although the exact sample sizes were not known until data collection was completed, estimates were made. Below is a summary of the sample sizes for the full six-year NHANES III at each stage of selection:

Number of PSU's	81
Number of stands (survey locations)	89
Number of segments	2,144
Number of households screened	93,653
Number of households with sample persons	19,528
Number of designated sample persons	39,695
Number of interviewed sample persons	33,994
Number of MEC-examined sample persons	30,818
Number of home-examined sample persons	493

Analysis Guidelines

Because of the complex survey design used in NHANES III, traditional methods of statistical analysis based on the assumption of a simple random sample are not applicable. Recent analytic and reporting guidelines that should be used for most NHANES III analyses and publications are contained in Analytic and Reporting Guidelines (U.S. DHHS, 1996). These recommendations differ slightly from those used by analysts for previous NHANES surveys. These suggested guidelines provide a framework to users for producing estimates that conform to the analytic design of the survey. All users are strongly urged to review these analytic and reporting guidelines before beginning any analyses of NHANES III data.

It is important to remember that this set of statistical guidelines is not absolute. When conducting analyses, the analyst needs to use his/her subject matter knowledge (including methodological issues) as well as information about the survey design. The more one deviates from the original analytic categories defined in the sample design, the more important it is to evaluate the results carefully and to interpret the findings cautiously.

In NHANES III, 89 survey locations were randomly divided into two sets or phases, the first consisting of 44 and the other of 45 locations. One set of PSU's was allocated to the first three-year survey period (1988-91) and the other set to the second three-year period (1991-94). Therefore, unbiased national estimates of health and nutrition characteristics can be independently produced for each phase as well as for both phases combined. Computation of national estimates from both phases combined (i.e., total NHANES III) is the preferred option; individual phase estimates may be highly variable. In addition, individual phase estimates are not statistically independent. It is also difficult to evaluate whether differences in individual phase estimates are real or due to methodological differences. That is, differences may be due to changes in sampling methods or data collection methodology over time. At this time, there is no valid statistical test for examining differences between Phase 1 and Phase 2. Therefore, although point estimates can be produced separately for each phase, no test is available to test whether those estimates are significantly different from each other.

NHANES III is based on a complex, multi-stage probability sample design. Several aspects of the NHANES design must be taken into account in data analysis, including the sample weights and the complex survey design. Appropriate sample weights are needed to estimate prevalence, means, medians, and other statistics. Sample weights are used to produce correct population estimates because each sample person does not have the same probability of selection. The sample weights incorporate the differential probabilities of selection and include adjustments for noncoverage and nonresponse. A detailed discussion of nonresponse adjustments and issues related to survey coverage have been published (U.S. DHHS, 1996). With the large oversampling of young children, older persons, black persons, and Mexican-Americans in NHANES III, it is essential that the sample weights be used in all analyses. Otherwise, a misinterpretation of results is highly likely. Other aspects of the design that must be taken into account in data analyses are the strata and PSU pairings from the sample design. These pairings should be used to estimate variances and test for statistical significance. For weighted analyses, analysts can use special computer software packages that use an appropriate method for estimating variances for complex samples such as SUDAAN and WesVarPC.

Although initial exploratory analyses may be performed on unweighted data using standard statistical packages and assuming simple random sampling, final analyses should be done on weighted data using appropriate sample weights. A summary of the weighting methodology and the type of sample weights developed for NHANES III is included in Weighting and Estimation Methodology (U.S. DHHS, 1996).

The purpose of weighting the sample data is to permit analysts to produce estimates of statistics that would have been obtained if the entire sampling frame (the United States) had been surveyed. Sample weights can be considered as measures of the number of persons the particular sample observation represents. Weighting takes into account several features of the survey: the specific probabilities of selection for the individual domains that were oversampled as well as nonresponse and differences between the sample and the total U.S. population. Differences between the sample and the population may arise due to sampling variability, differential undercoverage in the survey among demographic groups, and possibly other types of response errors, such as differential response rates or misclassification errors. Sample weighting in NHANES III was used to:

1. Compensate for differential probabilities of selection among subgroups (i.e., age-sex-race-ethnicity subdomains where persons living in different geographic strata were sampled at different rates);

2. Reduce biases arising from the fact that non-respondents may be different from those who participate;

3. Bring sample data up to the dimensions of the target population totals;

4. Compensate, to the extent possible, for inadequacies in the sampling frame (resulting from omissions of some housing units in the listing of area segments, omissions of persons with no fixed address, etc.); and

5. To reduce variances in the estimation procedure by using auxiliary information that is known with a high degree of accuracy.

In NHANES III, the sample weighting was carried out in three stages. The first stage involved the computation of weights to compensate for unequal probabilities of selection (objective 1, above). The second stage adjusted for nonresponse (objective 2). The third stage used poststratification of the sample weights to Census Bureau estimates of the U.S. population to accomplish the third, fourth, and fifth objectives simultaneously. In NHANES III, several types of sample weights (see the sample weights table that follows) were computed for the interviewed and examined sample and are included in the NHANES III data file. Also, sample weights were computed separately for Phase 1 (1988-91), Phase 2 (1991-94), and total NHANES III (1988-94) to facilitate analysis of items collected only in Phase 1, only in Phase 2, and over six years of the survey. Three sets of pseudo strata and PSU pairings are provided to use with SUDAAN in variance estimation. Since NHANES III is based on a complex, multi-stage sample design, appropriate sample weights should be used in analyses to produce national estimates of prevalence and associated variances while accounting for unequal probability of selection of sample persons. For example, the final interview weight, WTPFQX6, should be used for analysis of the items or questions from the family or household questionnaires, and the final MEC examination weight, WTPFEX6, should be used for analysis of the questionnaires and measurements administered in the MEC. Furthermore, for a combined analysis of measurements from the MEC examinations and associated medical history questions from the household interview, the final MEC examination weight, WTPFEX6, should be used. We recommend using SUDAAN (Shah, 1995) to estimate statistics of interest and the associated variance. However, one can also use other published methods for variance estimation. Application of SUDAAN and alternative methods, such as the average design effect approach, balance repeated replication (BRR) methods, or jackknife methods for variance estimation, are discussed in Weighting and Estimation Methodology (U.S. DHHS, 1996).

Appropriate Uses of the NHANES III Sample Weights

- Final interview weight, WTPFQX6: Use only in conjunction with the sample interviewed at home and with items collected during the household interview.
- Final examination (MEC only) weight, WTPFEX6: Use only in conjunction with the MEC-examined sample and with interview and examination items collected at the MEC.
- Final MEC+home examination weight, WTPFHX6: Use only in conjunction with the MEC+home-examined sample and with items collected at both the MEC and home.
- Final allergy weight, WTPFALG6: Use only in conjunction with the allergy subsample and with items collected as part of the allergy component of the exam.
- Final CNS weight, WTPFCNS6: Use only in conjunction with the CNS subsample and with items collected as part of the CNS component of the exam.
- Final morning examination (MEC only) subsample weight, WTPFSD6: Use only in conjunction with the MEC-examined persons assigned to the morning subsample and only with items collected in the MEC exam.
- Final afternoon/evening examination (MEC only) subsample weight, WTPFMD6: Use only in conjunction with the MEC-examined persons assigned to the afternoon/evening subsample and only with items collected in the MEC exam.
- Final morning examination (MEC+home) subsample weight, WTPFHSD6: Use only in conjunction with the MEC- and home-examined persons assigned to the morning subsample and with items collected during the MEC and home examinations.

- Final afternoon/evening examination (MEC+home) weight, WTPFHMD6: Use only in conjunction with the MEC- and home-examined persons assigned to the afternoon/evening subsample and with items collected during the MEC and home examinations.

Appendix 2

Summary of the variables included in the analysis

1. Health outcome variables

1.1 Ischaemic heart disease: NHNES III included questions pertaining to WHO questionnaire for angina pectoris (Rose et al. 1982). A person is considered to have angina if he/she reported having all of the following symptoms: (1) ever had any chest pain or discomfort, (2) had the pain or discomfort while walking uphill or in a hurry, (3) the pain caused them to stop or slow down, (4) the pain was relieved by standing still, (5) the pain was relieved within 10 minutes, (6) the pain was around the sternum, left anterior chest or left arm. Participants who responded that they never walked uphill or in a hurry were considered as having angina if they met the other criteria. NHNES III also included a question about ever being diagnosed with heart attack. Persons reporting a diagnosis of heart attack or identified as having angina pectoris according to WHO questionnaire were considered to have ischaemic heart disease.

1.2 Perceived general health: NHNAES III included a question about individuals' perception of their general health. Participants were asked to rank their general health as excellent, very good, good, fair or poor. No specific criteria on how to rank perception of health were given. This variable was categorised into two groups: poor or fair versus good, very good or excellent.

1.3 Perceived oral health: Individuals were asked to rank their oral health as poor, fair, good, very good or excellent. No instructions were given on how to rank the oral health.

This variable was categorised into two groups: poor or fair versus good, very good or excellent.

1.4 Periodontitis: A dichotomous variable indicating the presence of periodontitis was created. Individuals having at least one site with loss of periodontal attachment 3mm or greater and at least one site with gingival bleeding were considered to have periodontitis (see appendix 1 for details on periodontal examination).

1.5 Extent of gingival bleeding: A variable indicating extent of gingival bleeding was created, where the extent is the ratio between the sites with gingival bleeding to all examined sites.

1.6 Extent of loss of periodontal attachment 3mm or more: A variable indicating extent of loss of periodontal attachment was created. Extent loss of attachment refers to the ratio between sites with loss of attachment 3mm or more to all examined sites.

1.7 Extent of periodontal pocket 4mm or more: A variable indicating extent of periodontal pocket 4mm or more was created. Extent periodontal pocket is the ratio between sites with pocket 4mm or more to all examined sites.

1.8 Edentulousness: Refers to completely edentulous persons according to the dental examination in NHANES III.

1.9 Tooth loss: This variable indicate the number of missing tooth surfaces due to disease according to the dental examination (see appendix 1 for details on examination for tooth loss).

2. Indicators of socioeconomic position

Two variables were used to indicate socioeconomic position: education and income indicated by poverty-income ratio.

2.1 Education: Participants were asked to report their highest grade of education. This variable was categorised into three groups: less than 12 years, 12 years and more than 12 years of education.

2.2 Poverty-income ratio: NHANES III collected data on family income from all sources per year. Poverty-income ratio was calculated as the ratio between family income and the poverty threshold for each of the years in which the data was collected (1988-1994). This process is believed to account for the inflation during the period in which the survey was conducted. This variable was used as a continuous variable in most of the analysis with higher value for poverty-income ratio indicating higher income. This variable was also categorised into quartiles for part of the analysis (see method in chapter 3).

3. Health related behaviour and tooth cleanliness

3.1 Being a current smoker: participants were asked if they were currently smoking. Due to a great number of missing values in this variable, being a smoker was categorised into three groups: current smoker, non-smoker and non-respondent.

3.2 Frequency of smoking per day: participants were asked how often they smoke per day. Frequency of smoking was created as the count of reported number of smoking of cigarettes, cigars or pipe according to the measuring unit used in the survey.

3.3 Frequency of physical activity per month: participants were asked how often they participated in certain physical activities during the past month. These activities included: jogging, cycling, swimming, aerobic exercise, dancing, callisthenics exercise, and weight lifting. Frequencies of participating in any of these physical activities were aggregated (summed) to create a variable indicated frequency of physical exercise per month.

3.4 Frequency of eating fresh fruits and vegetables per day: participants were asked about the frequency of consuming certain food items per day. Answers pertaining to questions about consuming fresh fruits and vegetables were aggregated (summed) to create a variable indicating frequency of eating fresh fruits and vegetables per day. These food items included: citrus fruits, melons, peaches, nectarine, any other fruit, carrots, broccoli, cauliflower, potatoes, tomatoes, spinach, salad, cabbage, pepper, and any other vegetable.

3.5 Frequency of visits to a dentist during the past year: participants were asked about the number of times they visit a dentist or a hygienist per year. This variable was categorised into two groups: once a year or more versus less than once a year.

3.6 Extent of calculus: As part of the dental examination in NHANES III the presence of calculus on tooth surfaces was examined. A variable was created indicating the extent of calculus, which refers to the ratio between sites with calculus to all examined sites. This variable was used as indicator or tooth cleanliness and as a surrogate indicator of oral hygiene behaviour.

4. Age: this variable refers to age of the participant in year at the time of the survey. Age was used as a continuous variable in most of the analysis.

5 Sex

6. Ethnicity: four groups of ethnicity were reported in NHANES III: White Americans, African Americans, Hispanic Americans, and other ethnicities.

7. Use of health services: questions pertaining to the availability of any medical insurance were aggregated to create a variable indicating availability of medical insurance. Similarly, question pertaining to the availability of any dental insurance were aggregated to create a variable indicating availability of any dental insurance. Frequency of visits to a dentist which is included under health behaviour also indicates use of health services.

8. Cognition: NHNAES III included a computerized cognitive test which was administered to persons aged 20 to 59 years old. Three tests were conducted to measure cognitive ability: Simple Reaction Time Test, Symbol Digit Substitution Test and Serial Digit Learning Test. These three tests are intended to measure memory, information processing speed, concentration. The higher scores in the three tests reflect poorer cognitive ability. These three tests were used in the analysis to indicate cognitive ability. For more details on these tests see method in chapter 3.

9. Stress indicated by allostatic load: NHANES III included data on blood pressure, waist circumference, triglycerides, HDL cholesterol, plasma glucose, C-reactive protein, and fibrinogen. Seven markers of allostatic load were created from these variables to indicate allostatic load as a marker of stress. These markers are: central obesity, high blood pressure, hypertriglycerdemia, low high density lipoprotein (HDL) cholesterol, high plasma glucose, CRP and fibrinogen. Central obesity is considered to exist if a person has a waist circumference >120 cm for males and >88 cm for females. High blood pressure (BP) is BP $\geq$ 130 mm Hg systolic or $\geq$ 85 mm Hg diastolic. Hypertriglycerdemia is triglycerides $\geq$ 150mg/dL. Low HDL cholesterol is HDL cholesterol <40mg/dL for men and <50mg/dL for women. High plasma glucose is glucose $\geq$ 110 gm/dL. CRP was used both as continuous and dichotomous variables ($\geq$10 mg/L). Fibrinogen was also used as continuous and dichotomous variables ($\geq$ 3.25 g/L). Additionally, an aggregate variable including the seven dichotomous indicators was created. This variable was used as a continuous indicator of allostasis indicating an aggregate of these factors ranging from 0 to 7. For more details see method in chapter 3.

10. Diabetes: reported diagnosis of diabetes was included in the analysis for adjustment in regression models pertaining to periodontitis and ischaemic heart disease.

11. Body mass index: during the medical examination, the body mass index of the participant was measured. This variable was used for adjustment in the regression models pertaining to ischaemic heart disease.