Developmental Pathways to Childhood Literacy and Numeracy: The Role of Early Health

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Abstract

Aims

The primary aim of this research was to investigate possible developmental pathways to childhood literacy and numeracy achievement and thus to contribute to the development of more effective prevention and early intervention strategies. More specifically, I aimed to enhance our understanding of (1) how birth characteristics interact with familial and social contextual factors to exert their impact on literacy and numeracy achievement in primary school children in grade three; (2) the early health factors that influence literacy and numeracy achievement; and (3) the extent to which early health may help explain the social gradient in academic achievement.

Methods

This research used longitudinal de-identified population-based data linked across the Western Australian Government Departments of Education and Training, Health, and Disability Services. These datasets contained academic achievement data for children as well as demographic and health information for both children (including birth details) and their parents. The study population comprised all children that were born in Western Australia from 1988 to 1997 and who subsequently participated in the Western Australian Literacy and Numeracy Assessment between 2000 and 2005. Data were analysed using multivariate and multilevel regression models (both linear and non-linear), taking into account the hierarchical structure of the data and a range of potential confounders.

Main Findings

- Appropriate growth of a baby in the uterus was associated with better numeracy and literacy scores. However, in children born to single mothers and to mothers residing in educationally deprived areas, there was a weaker association between some of the birth characteristics (percentage of optimal birth weight and Apgar score at 5 minutes) and numeracy and literacy, suggesting that improvements in these birth characteristics would only confer marginal benefits for academic achievement.

- Frequent and longer cumulative hospital admissions were associated with a greater risk of not reaching the minimum standards in literacy and numeracy. Aboriginal children with either very short or very long admissions achieved better mean academic outcomes than Aboriginal children with medium-long stays. For instance, a single hospital admission of at least seven consecutive days decreased the mean academic performance of Aboriginal children, both before and after school entry. In contrast, among non-Aboriginal children, a similar decrease in the mean performance was observed for hospital admissions occurring only after school entry (after the age of 6).
- Children who were hospitalised for non-infectious respiratory diseases, infections (both respiratory and non-respiratory) and for external causes (mainly injuries and poisoning) were at a greater risk of not reaching the benchmark standards compared to those who had no record of hospitalisation at all. Aboriginal children were least likely to reach the benchmark standards if they had frequent admissions (at least 4) for both respiratory and non-respiratory infections, while non-Aboriginal children were at the highest risk for failing the benchmark if they were frequently (at least 4) admitted for non-respiratory infections.
- All children who had contact with mental health services before school entry continued to have contact between ages 6 to 8. Children were least likely to attain the benchmark standards if they had a secondary diagnosis for mental health problems (most frequently related to developmental disorders of speech and language) in addition to a primary diagnosis for physical health problems. In contrast, Aboriginal children who had a primary diagnosis of mental health problems (most frequently a combination of stress, anxiety, depression or worry) were more likely to have better educational outcomes than those who had no mental health contact at all.
- The social gradient in numeracy attainment was partially mediated by maternal characteristics (teenage motherhood and, to a lesser extent, single marital status, with parental mental health having a slight additional effect). However, none of the child factors (including birth characteristics, mental and physical health) had any significant mediating effect on numeracy attainment.

Conclusions

This research is the first Australian study to investigate developmental pathways to numeracy and literacy skills through the examination of early health factors including birth characteristics, using longitudinal, population-based linked health and education data. These studies suggest that, contrary to initiatives which predominantly focus on improving teaching at school, the focus should be on ensuring that all children have the best possible start to life. This will set children on a positive developmental pathway and maximise their chances of succeeding academically. This research also identified a range of risk and protective factors for academic achievement of primary school children. An adequate understanding of how these factors relate to academic achievement is essential for the development of evidence-based prevention, secondary and tertiary intervention strategies, thus enabling an integrated health and education approach.

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Chapter One

Introduction

This thesis consists of a series of six related papers which investigate antecedent risk factors and pathways to poor academic achievement in primary school children in Western Australia.

The world is currently moving away from a manufacturing-based and towards a knowledge-based economy. As a result, societies are becoming increasingly dependent on an educated workforce and need all their members to be literate and proficient in basic numerical skills. Hence, the ability to develop successfully these skills has become crucial for the future of children. Educational competence is a key component of healthy development because school performance not only affects how individuals develop but also the extent to which they can later participate in society culturally, socially and economically.

Although most children will learn such skills with little difficulty, some children may never even reach the basic levels of literacy and numeracy. Indigenous children and those from a disadvantaged background are least likely to succeed in reaching these levels. Because not one but multiple factors influence the development of literacy and numeracy skills, there is no single solution to redress current disparities in children's achievement. At the same time, remedies for these problems are highly complex and pose a great challenge to society. Recently, the research and policy focus has shifted from trying to improve educational outcomes alone to addressing the improvement of educational performance of children while simultaneously reducing educational disparities, particularly those associated with socioeconomic inequality.

The overall objective of the research described in this thesis is for its outcomes to be used to inform the development of evidence-based policies for improving the academic achievement of disadvantaged children. Approaches to primary prevention of underachievement are currently not available and targeted strategies are limited. Consequently, minimising this underachievement is central to the government's goal of ensuring that all children achieve the basic skills.

Research Aim

The primary aim of the research described in this thesis was to investigate antecedent pathways to childhood literacy and numeracy achievement in grade 3 (at age approximately 8 years), using linked de-identified population-based data from the Western Australian Government Departments of Education and Training, Health, and Disability Services. The overall goal is to contribute to the evidence base for developing effective prevention and early intervention strategies.

Specific Objectives

- To investigate how child characteristics at birth interact with familial and social contextual factors to exert their impact on academic achievement;
- To identify early physical, mental health and social characteristics of children that influence academic achievement; and
- To investigate potential mediators between socioeconomic status and academic achievement.

Outline of the Thesis

Chapter 2 outlines the background literature, starting with a description of theories and models of human development, followed by a review of the current literature on academic achievement and its determining factors that are particularly relevant to this research. Chapter 3 describes the overall methodology of this work and the datasets used. Chapters 4 to 9 are presented as research papers (two of which have already been published).

The first study (Chapter 4) investigates the association between child characteristics at birth, maternal factors, school and neighbourhood socioeconomic status and numeracy achievement. The paper also investigates how interactions between birth characteristics, school and maternal and neighbourhood factors influence numeracy outcomes. This work has been published in the American Journal of Epidemiology (Appendix A).

The second study (Chapter 5) reports on the association and interactions between birth characteristics, maternal factors and socioeconomic status in their impact on literacy achievement. This work has been published in the Journal of Epidemiology and Community Health (Appendix A). The key results from the two published articles were summarised in a briefing paper for the Government Departments (Appendix B).

The third study (Chapter 6) examines the relationships between the timing, frequency and length of hospital admissions in early and mid childhood and the subsequent risk of below benchmark performance in literacy and numeracy. This work is currently being prepared for submission to a peer-reviewed international journal.

The fourth study (Chapter 7) investigates the relationship between specific diagnoses for common but preventable diseases and the risk of not reaching literacy and numeracy benchmark standards. These diagnoses include admissions for respiratory non-infectious diseases, respiratory and non-respiratory infections, and for external causes. This chapter was inspired by the findings described in Chapter 6, which showed that children with more frequent and longer hospital admissions were at an elevated risk of falling below numeracy and literacy benchmarks. This work is currently being prepared for submission to a peer-reviewed international journal.

The fifth study (Chapter 8) investigates the effect of child contact with mental health services (before and after school entry) on subsequent academic achievement. This work is currently being prepared for submission to a peer-reviewed international journal.

The last study (Chapter 9) reports the testing of the validity of hypothesised biological embedding of socioeconomic inequalities in academic achievement. Specifically, potential mediators that link socioeconomic status with numeracy achievement were investigated, using the major risk factors identified in the previous studies. This work is currently being prepared for submission to a peer-reviewed international journal.

Finally, the overall conclusions of the findings of this research, their policy and research implications and recommendations are presented and discussed in Chapter 10.

Chapter Two

Literature review

Here a brief overview of the theories and models of human development and population health relevant to the research described in this thesis is introduced. Current literature on academic achievement is then discussed, in particular in relation to students both within Australia and globally, followed by an examination of individual, family, school and neighbourhood characteristics associated with academic achievement. An outline of factors associated with Aboriginal educational disadvantage is then presented.

THEORETICAL APPROACHES TO THE STUDY OF HUMAN DEVELOPMENT

The concept of developmental health

There is increased recognition that many of the chronic conditions and illnesses that have emerged over the past few decades have complex developmental trajectories and involve many antecedent factors. To enable effective prevention of these complex conditions it is necessary to understand better how different social, economic, psychological and biological factors influence human behaviour and development, and the key mechanisms that underlie these processes. In 1999, Keating and Hertzman described a new holistic approach to the study of human development which they termed “developmental health” (Keating & Hertzman, 1999). Developmental health does not simply refer to physical health, but rather it encompasses a range of developmental outcomes including physical and mental health and wellbeing. In contrast to the discipline-centred approaches of the past, developmental health acknowledges that human development is embedded in a wider contextual environment. This approach aims to improve the understanding of complex human behaviour and the causal pathways leading to differential developmental outcomes through the integration of research from distinct disciplines, including human biology, psychology, medicine, sociology, education, epidemiology and child development (Jessor, 1993).

Interaction processes in human development

Human development can be described as a complex interaction between biological, psychological and social factors from conception onwards (Keating & Hertzman, 1999; Shonkoff & Phillips, 2000). This ongoing interaction is complex because biological factors influence individuals' wellbeing, which together with social factors can modify brain processes and ultimately change the expression of the genetic makeup of individuals (Curtis & Cicchetti, 2003). Such interaction, while ongoing throughout individuals' lifetime, is especially influential within the first few years of life, as during this time the brain experiences its fastest transformation and the majority of all future brain functions are established (Shonkoff & Phillips, 2000, Keating & Hertzman, 1999).

Influence of the environment on the developing child

Brain development begins *in utero*. During this period, a developing fetus is especially vulnerable to adverse environmental exposures, including maternal poor health, inadequate nutrition or stress during pregnancy, as well as maternal risk-taking behaviours such as smoking, alcohol consumption and illicit drug use (Schempf, 2007; Bailey & Sokol, 2008). Such exposures disrupt the fetus' neurocognitive development and can lead to permanent disorders, such as restricted fetal growth, birth defects, developmental disorders or intellectual disability (Schempf, 2007; Bailey & Sokol, 2008; Figueras, Meler, *et al*., 2008*)*.

Immediately after birth, an infant's brain begins a phase of fast growth in which synapses between neurons are rapidly created to enable transmission of information in the brain (Hertzman, 2000). During this period, infants' brains are more "plastic" compared to older children's brains but need appropriate stimulation from the environment to acquire new abilities (Hertzman, in Keating & Hertzman (Eds.), 1999). This period of over production of synapses is later replaced by a phase of "neural sculpting", in which less used synapses are eliminated and those more frequently used are retained and reinforced, resulting in a more efficient brain (Nelson, 2000). A unique characteristic of the developing brain is thus its “plasticity”, which is the ability to change as a result of a new experience. If the experience does not occur during the critical stages of development, it is possible that some new capabilities may be lost. A lack of physical and emotional stimulation during the critical stages of brain development may compromise a child’s neurodevelopment through adverse neural sculpting (Keating & Hertzman, 1999). Examples may include the development of speech, vision or emotion, all of which crucially depend on early experiences (Nelson, 2000). While the majority of capabilities develop during critical stages of development, some skills and a limited version of other capabilities still develop throughout sensitive period of development. During the earliest stages of development, children are therefore highly vulnerable to exposure to detrimental factors which are likely to have long-term consequences for individuals throughout their lives (Wadsworth, 1999; Shonkoff & Phillips, 2000).

RESEARCH MODELS OF HUMAN DEVELOPMENT

Latent, cumulative and pathway model

Given the complexity of human development and the ongoing interactions between biological, psychological and social factors, it is highly likely that there may be multiple pathways linking early experiences with human development over the life course. Hertzman and Power (2003) proposed a three-fold model to explain how different experiences can have *latent*, *cumulative* or *pathway* effects on individual trajectories.

A latent effect occurs when a single experience manifests itself in developmental outcomes at a later stage, independently of any intervening circumstances. According to the latent model, there are critical periods of development in which children need to be appropriately stimulated to develop neural pathways (Keating & Herztman, 1999). A lack of appropriate stimulation during this critical period may permanently compromise the developmental capacity of the child (Lewis & Maurer, 2005; Hertzman, 2000; Shonkoff & Phillips, 2000).

The most compelling evidence of the latent effect comes from experimental animal studies which showed that “exposing pregnant animals to uncontrollable stress produces direct and long-term effects on behavioural and neuromotor development and physiology in the offspring” (O’Connor, 2003, p.682). Human studies are dependent on “natural” experiments, which make proving latency relationships more difficult. Some studies that focussed on the absence of a normal caretaking environment showed that individuals can recover from earlier adversities (Rutter, Colvert, *et.al.*, 2007; Van Ijzendoorn & Juffer, 2006). However, a far more dramatic example of the latent effect on development comes from a study of the long-term deprivation of nurturing. A unique study of a girl called "Genie", who was deprived of human nurturing for 11 years during her early childhood until the age of 13, suggested that it may not be possible to fully develop language and many other social behaviour skills after the critical period of early development has passed (Curtis,1977). After being deprived of any interaction with other individuals during her entire childhood, Genie was only able to make animal-like sounds and lacked an understanding of how to socially interact with others. With special individual coaching, Genie was able to acquire language by using the right-hemisphere of her brain similarly to someone learning a foreign language, but she was unable to hold a longer conversation or form sentences on her own. This study demonstrates that while individuals are able to recover from their adverse experiences, they may not recover fully and there may be a ceiling effect for extreme experiences. This demonstrates the importance of early childhood interactions for later development.

The second model proposes that advantages and disadvantages often accumulate over time and that they may act in combination (Hertzman & Power, 2003). The cumulative model is supported by evidence of the dose-response relationship in which longer exposure to adverse experiences is associated with poorer developmental outcomes. In their research, Power, Manor and Matthews (1999) showed that a longer time spent in the lowest socioeconomic group was increasingly associated with higher odds of poor self-reported health at the age of 33. This suggests that the accumulation of exposure to poor socioeconomic conditions may be more detrimental for later health outcomes than the timing of that experience alone.

However, Hertzman and Power (2003) argued that not only longer exposures to a single factor may affect developmental outcomes, but also multiple factors can accumulate over time or even interact in their effects on developmental outcomes. This is supported by evidence from another study of the same British birth cohort, which looked at multiple factors at different stages of life contributing to a higher risk of chronic illness and disability at the age of 33 (Power, Li, & Manor, 2000). The interactive effect has been demonstrated in the Rutter, Quinton and Hill (1990) study of children brought up in institutions who were less likely to have adverse psychosocial health if they had supportive partners later in their life. Therefore, the cumulative duration of a single factor, a combination of different factors and interactions of early-life with later-life factors can all influence health and developmental outcomes.

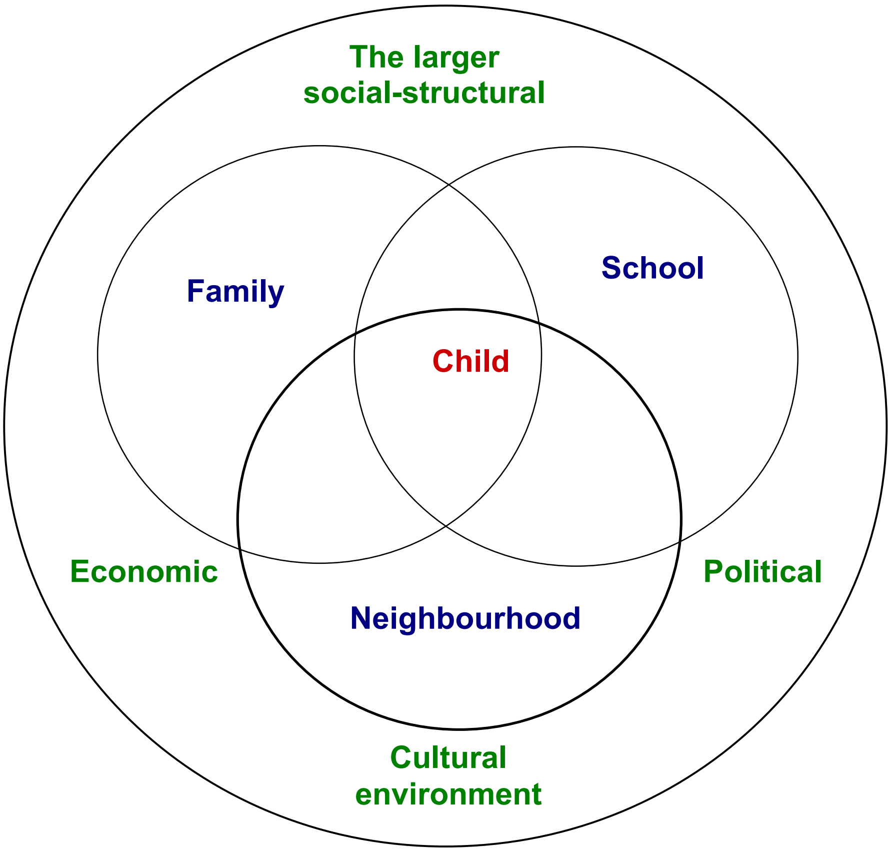
Finally, the pathway model indirectly connects early experiences with subsequent developmental outcomes. It states that early life experiences can also set a child on a distinct socioeconomic pathway, either increasing or decreasing the risk of subsequent exposures, which then influences a child's health and developmental outcomes later in life (Hertzman & Power, 2003). There is evidence that parents with poorer education and socioeconomic status provide less stability and security as well as less stimulation to their children (Hertzman & Power, 2003). Such deprivation may result in lower school readiness and behavioural problems in school, which can lead to dropping out of school and subsequent mental and physical health problems (Hertzman, 2002). The pathway model describes a dependent sequence of events which form an individual's trajectory across the life course.

The evidence supporting this three-fold (latent, cumulative and pathways) model emphasises early life events in studying individual trajectories of developmental outcomes. Hertzman and Power (2003) argued that using a longitudinal perspective is a prerequisite in pathway analyses and that without the consideration of early experiences on subsequent developmental outcomes it is unlikely that researchers will be able to fully understand processes leading to differential developmental outcomes.

Bioecological model

At the heart of the integrative approach of developmental health lies the bioecological model of human development. Developmental psychologist Urie Bronfenbrenner proposed a bioecological model to explain how individuals may both affect their proximal and distant environments and be influenced by them (Figure 1). The bioecological model has been extended from the originally articulated Bronfenbrenner's ecological model (1979) by allowing for interactions with other factors, such as genes, resources, ecological niches, and time.

Figure 1: Bioecological influences shaping child development.



Adapted from: Jessor, R. Successful adolescent development among youth in high risk settings. American Psychologist 1993;48(2):117-126.

In this model, Bronfenbrenner and Morris (in Damon & Lerner (Eds.), 1998) described human development as ongoing reciprocal interactions between *process*, *person*, *environment* and *time*. Processes refer to proximal reciprocal interactions between the child and its immediate environment, which depend on the characteristics of the child, family, friends, teachers and other individuals. These characteristics can include individual skills, experiences and abilities needed for the proximal interactions to take place and to be maintained, and individual temperament that can influence those proximal interactions.

The environment consists of four nested settings: the *microsystem*, the *mesosystem*, the *exosystem*, and the *macrosystem*. The microsystem refers to the immediate environment in which the child actively interacts and includes any immediate relationships with the child, such as the child's immediate family, the school and neighbourhood, and stability within the microsystem. The more stable, encouraging and nurturing these relationships and places are, the better the child will be able to grow.

The mesosystem connects the different parts of a child's microsystem, such as their parents with the child's teachers or school. The exosystem includes additional people and places which interact with some parts of the child's microsystem but not necessarily with the child, such as parental place of work, their friends or the larger neighbourhood. The macrosystem is the largest and most remote environment. It incorporates the culture and the wider society, including the economic, legal and political systems, and the values and beliefs of that society. These represent the various ecological niches that profoundly influence how families conduct their daily activities.

The final dimension of this model is *time*, which can have either a proximal or distal effect on a child's development. Bronfenbrenner and Morris refer to the proximal effect of time either as the *microtime*, which is an ongoing or one-off occurrence of proximal processes, or as the *mesotime*, which is the periodical occurrence of these processes over longer periods, usually several days (in Damon & Lerner (Eds.), 1998). These authors refer to the distal effect of time as the *macrotime*, which is the lifetime experience of the individual in the wider society and which incorporates an interaction with proximal processes (Bronfenbrenner & Morris, in Damon & Lerner (Eds.), 1998, p.995).

Bronfenbrenner's bioecological model differs from other models in three distinct ways. The first is that the environment is not limited to a single environment but involves a number of interacting levels that have both proximal and distal effects on human development. The second is that individuals are not simply shaped by their environments but also actively influence those environments. These influences are thus 'bi-directional' and occur within and between levels. Finally, the interaction between the child and environment includes not only all possible relationships between children, family and neighbourhoods but also between other available resources and characteristics, including individuals' temperament, experience and capacity, and these interactions can change over time.

Family and community resource framework

In an attempt to extend the earlier version of Bronfenbrenner's ecological model, developmental psychologist Jeanne Brooks-Gunn (1995) proposed a family and community resource model to emphasise the importance of family and community resources in child developmental outcomes. This resource framework draws on recent theories in economics (Becker, 1963), sociology (Coleman, 1988; Haveman & Wolfe, 1994), developmental and disciplinary psychology, and was developed in collaboration with Greg Duncan, Kristine Moore, and Brett Brown, prominent economists and sociologists. The key family resources include income, time, human and psychological capital (Brooks-Gunn, 1995). Human capital includes parental education and occupation, while psychological capital may consist of parenting behaviour, parental mental health or parental beliefs. Community resources that are accessible to children may include child care, schools, peer groups and community services (Brooks-Gunn, 1995). While this resource model specifies in detail the psychological and social processes within the family and community that may be studied, its use is predominantly limited to researchers using survey data, as the type of variables required are not routinely collected in administrative data.

Socioeconomic gradient in developmental outcomes

Increased recognition of the importance of contextual influences on the developmental outcomes of individuals has inspired a significant amount of research into the socioeconomic environments in which people live and how they influence health and developmental outcomes later in life (Hertzman & Power, 2003). Extensive research has demonstrated that a higher socioeconomic position is associated with improved developmental outcomes in individuals and that in societies with large social and economic differences the overall level of health and wellbeing of the population is lower than in more egalitarian societies (Hertzman, 2002). This observation has been termed the "socioeconomic gradient" (Hertzman, 2002) to reflect that the "change in outcomes is gradual and occurs across the full range of socioeconomic levels" (Brownell, Roos, *et. al*., 2006, p.5).

This gradient has been found for most health and developmental outcomes across the individual life course, including infant mortality, birthweight, mental health, educational and behavioural outcomes, cardiovascular disease, obesity and premature mortality (Keating & Hertzman, 1999; Hertzman, 2002; Caldas & Banston III, 1997; Sirin, 2005). Moreover, the gradient has been observed between high-income and low-income countries as well as within countries (Marmot & Friel, 2008). The importance of social and economic circumstances for individual developmental outcomes has been further confirmed by the emergence of the gradient effect in all new diseases, such as heart disease, cancer and dementia (Hertzman, 2002). As the gradient “cannot be explained away by reverse causation”, Hertzman argued that this effect represents a “causal” relationship (2002, p.2). This realisation is of particular concern to countries with high socioeconomic inequalities, such as the United States and Australia.

Biological embedding of socioeconomic disadvantage

The significant evidence demonstrating the link between socioeconomic status and health, on the one hand, and the link between socioeconomic status and educational outcomes, on the other, points to the possibility that early adverse experiences may be linked with low educational attainment *via* poor health. Hertzman (in Keating & Hertzman (Eds.), 1999) called this process “biological embedding”. Based on evidence from non-human primate and human biology, Hertzman theorised that early experiences in an “unstimulating, emotionally and physically unsupportive environment will affect the sculpting and neurochemistry of the central nervous system in adverse ways, leading to cognitive and socio-emotional delays” (in Keating & Hertzman (Eds.), 1999, p.31). Hertzman further theorised that these delays will disrupt children’s educational and social progress, leading to a “more acute and chronic stress” and, eventually, affect their long-term health and wellbeing (p.31). This hypothesised biological embedding of the social gradient in education has never been tested, despite the fact that evidence of biological embedding would provide valuable information for policies aiming to reduce socioeconomic inequalities in educational attainment. This is particularly pertinent to Australia, where the rates of emergence of certain complex diseases and socioeconomic inequalities have been increasing and educational inequalities persisting despite Australia’s increasing wealth (Stanley, Richardson, & Prior, 2005).

SUMMARY

Human development is a complex process influenced by biological factors as well as the environment in which children grow up. An individual’s potential begins to be shaped *in utero* and most of his/her future capabilities are determined within the first few years after birth, when the child’s brain develops at its fastest rate and adverse experiences can leave long-term and sometimes irreversible effects on the child’s development. The early life experiences to which children are exposed can affect their subsequent development either directly through the accumulation of exposures, or indirectly *via* a specific socioeconomic pathway.

Children's development and their future potential can be influenced by a number of factors, but one of the most influential is their socioeconomic background. The socioeconomic status of both the community in which they live and their family shapes the early life experiences of children. Sometimes such experiences very early in life may modify the development of neural pathways, which can then have long-lasting impact on their health and wellbeing. This hypothesis, which has become known as "biological embedding", has never been tested, despite its potential importance for intervention policies. Little is therefore known about whether socioeconomic position does indeed influence children's developmental outcomes *via* a biological mechanism.

There is no doubt that focusing on the interaction between factors at many levels of the environment and the integration of different fields is the appropriate approach to study developmental health outcomes. Both the bioecological and the resource frameworks provide appropriate models for investigating how different environments, experiences and resources lead to different outcomes in developmental health.9\

EDUCATIONAL ACHIEVEMENT

Global rates of educational achievement

Educational achievement can be simply defined as the highest level of education attained by an individual. However, other definitions are also possible, depending on the specific purpose of reporting. Attainment may thus correspond to the highest degree obtained, a high school completion, retention rates, repeated grades, overall performance at school, attainment of a specific grade, the highest skills attained, benchmark performance or a rank order. Such diversity in measurements and definitions complicates comparisons of educational outcomes across different countries or jurisdictions.

Irrespective of how achievement is measured, international comparative statistics demonstrate that developing countries have the lowest rates of educational achievement (UNDP, 2008). The United Nations survey has showed that in most of those countries less than 50% of all adults, defined as individuals aged over the age of 14 years, could read and write, with Mali having the worst outcomes with only 23% of adults being literate, compared with the global average of 82%. However, developing countries are unlikely to have enough available resources to spend on children's elementary education and some children may not be able to attend even primary school if their families depend on their labour for survival.

These very low rates of population literacy are in stark contrast to those of developed countries with high literacy rates of most of their adult population (UNDP, 2009). To achieve these high rates of literacy, developed nations spend a significant proportion of their resources on school education, and attendance at primary and secondary schools is accessible to all children (OECD, 2007). Many children also attend kindergarten and pre-schools, thus enabling a good preparation for subsequent schooling and greatly reducing the risk of later illiteracy. However, while developed countries have an overall much higher rate of educational achievement compared to developing countries, Indigenous populations within countries such as Australia, New Zealand and Canada achieve significantly less than their non-Indigenous peers (Gray, Hunter, & Schwab, 1998). These countries have significant Indigenous minorities who are particularly prone to poor educational outcomes. Of those three countries, Canada has been the most successful in integrating its Indigenous Indian population, whereas school completion rates among Australian Aboriginal students lag 12 to 40 percentage points behind those of their Canadian and New Zealand counterparts (Gray, Hunter, & Schwab, 1998). In Australia, the achievement gap between Aboriginal and non-Aboriginal students remains large (SCRGSP, 2005), highlighting the significant scope for reduction of this achievement gap.

International comparison of educational outcomes

International comparisons of educational outcomes are inherently difficult, because apart from variability in how educational outcomes are measured, countries (and even systems within countries) may vary in terms of their teaching effectiveness and the age at which compulsory schooling commences and finishes. Often the only possibility of ensuring a valid comparison is through the participation in international comparative studies. There are two major ongoing international studies in which Australia takes part and which assess students' achievement during their compulsory schooling. These studies illustrate Australia's ranking relative to other nations.

The first major study is the Programme for International Student Assessment (PISA), which compares students' ability to apply their school knowledge in reading, mathematics and science in practical situations at the age of 15, and monitors outcomes over time. This study is conducted across the Organisation for Economic Co-operation and Development (OECD) and partner countries every three years, with the latest data available for 2006. The latest PISA results showed that while on the whole Australian students ranked among the top 10 OECD countries in all three educational domains, certain groups of students performed significantly worse (Thomson & De Bortoli, 2008). The achievement gap between Aboriginal and non-Aboriginal students, which amounts to about two and a half years, saw little improvement since the first testing in 2000 (Thomson & De Bortoli, 2008). A similar gap was observed for students from the lowest socioeconomic background (lowest quartile) compared to those in the highest quartile. The report also revealed a socioeconomic gradient which remained steeper than that observed in other OECD countries despite its overall decrease in Australia since 2003.

The second study, the Trends in International Mathematics and Science Study (TIMSS) assesses students' achievement in mathematics and science in two nationally representative samples of students in grades 4 and 8 (children typically aged 9 and 13 years), and monitors performance over time (Thomson, Wernert, *et al*., 2007). This study is conducted every four years, with the last cycle completed in 2006/2007. The most recent results reinforce the 2006 PISA's findings of overall above-average performance of Australian students on both a numeracy scale and against international benchmarks (measured at four levels as "advanced", "high", "intermediate", or "low"). However, the results also revealed that the wide achievement gap between Aboriginal and non-Aboriginal students has increased for both age groups since the previous testing due to improved performance of non-Aboriginal students. This highlights that there are significant educational inequalities in Australia, which can place disadvantaged students several years behind their peers and which need to be rectified so that all students can equally benefit from educational opportunities and succeed academically.

Education and school achievement in Australia

Under the Australian Constitution, school education is the responsibility of State and Territory governments. The Australian government education system is responsible for educating all children, irrespective of their race, religion, culture, learning and physical difficulties, socioeconomic background and their place of residence. However, some children (around 25%) are educated through private or home schooling and this proportion is continuously increasing.

In Australia prior to 1999, there were no standardised outcome measures of children's academic achievement over time and therefore it was difficult to evaluate the effects of any policy changes on disparities in academic achievement. This changed in 1997, when the Australian Education Ministers made an historic commitment and agreed in a declaration in Adelaide that all children, by the time they complete primary school, should be able to read, write and count at a level appropriate for their age (MCEECDYA, 1997). To be able to monitor progress towards this goal and changes in children's achievement over time, since 1999 all Australian States and Territories began the standardised testing and reporting of students' achievement in terms of both continuous marks and benchmark performance.

Australia uses benchmarks to estimate the proportion of children who fail to achieve satisfactory progress according to predefined benchmark standards. The Benchmark Standard is directly related to the sub-goal agreed at the Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA) meeting in 1997 (MCEETYA, 1997) and is used to determine whether or not at a particular point in a child's schooling, his/her achievement is adequate for continuing to make satisfactory progress at school. The National Benchmark Standard is thus used to monitor trends in children's educational performance over time and to make comparisons of children's achievement between Australian States and Territories. Such monitoring of trends over time and comparisons between different jurisdictions are important prerequisites for devising any rational prevention strategies.

The results of this monitoring are reported by State or Territory, school sector, geographical location, language background, Aboriginal descent and gender. While there has been an improvement in the percentage of students meeting the minimum standards, Aboriginal students continue to be less likely to meet the national benchmarks both across Australia and within Western Australia. The election of the Rudd Labour government in late 2007 brought a strong commitment to focus on early learning and education. In December 2008, all Australian Education Ministers agreed on new education goals for young Australians (MCEECDYA, 2009). Two major goals were set: 1) to promote equity and excellence in Australian schools, and 2) to close the achievement gap between Aboriginal and non-Aboriginal children and eliminate the social gradient in achievement (MCEECDYA, 2009). In a recent comparative review of investments in early childhood, Katz and Redmond argued that "significant gaps in our empirical knowledge" hampers the development of optimal intervention strategies to maximise children's wellbeing and promote optimal early childhood development (2009, p. 97).

Consequences of low educational achievement

There is increasing recognition that low educational achievement has long-term consequences for individuals and their families. This is because school achievement not only determines their prospects for tertiary education and employment but it also impacts on their personal, social and cultural development (Beswick & Sloat, 2006). Examples include low self esteem, social, emotional and behavioural problems, early drop out of education or unemployment, and ultimately poverty (Coltheart & Prior, 2007).

Apart from its impact on individuals, poor achievement also has direct consequences to society, including increased costs of high and often ineffective learning programs for adults, increased rates of crime, premature mortality and morbidity, loss of efficient workforce and tax revenue, and lower productivity, while at the same time there are increased expenditures on social welfare (Black, 2007; Coltheart & Prior, 2007; Heckman, 2006). The risk of unemployment, low-paid jobs, and poverty associated with educational failure has serious consequences for individuals and their families and for society as a whole, since we need an educated workforce to maintain a prosperous economy, safe and equitable society.

Moreover, poor educational outcomes can also lead to an inter-generational transmission of disadvantage with the consequent low socioeconomic status, increasing the vulnerability of children to poor developmental outcomes and bleak prospects for the future (Beswick & Sloat, 2006; Blau & Duncan, 1967). This is a vicious circle in which parents pass their disadvantage to their children, who then pass it via the same mechanism to the next generation. At the same time, it is through education that children can break from the cycle of disadvantage and poverty.

RISK FACTORS FOR LOW EDUCATIONAL ACHIEVEMENT

It is apparent that there is not one particular factor but rather many factors that interact with each other to impact on children's educational outcomes. Several individual, family and neighbourhood factors have been identified as being associated with poor educational outcomes, but less is known about their combined effects, the interaction of the individual with contextual factors, or the mechanisms underlying these associations.

Child characteristics

At the earliest stages of child development, a number of perinatal characteristics have been found to be associated with academic achievement. Research including a systematic review over the whole range of birth weight has consistently shown that perinatal characteristics are associated with neurodevelopmental and educational outcomes, with the least favourable outcomes being seen in infants who were extremely premature and had low birth weight (Bhutta, Cleves, *et al*., 2002; Bowen, Gibson, & Hand, 2002; Weindrich, Jennen-Steinmentz, *et al*., 2003; Jefferis, Power, & Hertzman, 2002; Shenkin, Starr, & Deary, 2004). Possible reasons for this disadvantage include attention difficulties, a lower non-verbal intelligence, poorer vocabulary and motor skills in children of low birth weight (Weindrich, Jennen-Steinmentz, *et al*., 2003).

Despite these findings, many previous studies reporting an association between low birth weight and subsequent educational outcomes were unable to differentiate between infants who had low birth weight due to early delivery and those due to restricted intrauterine growth. The lack of differentiation between the two causes of low birth weight has recently been overcome, as a new measure of intrauterine growth has been developed which adjusts not only for gestational duration but also for infant sex, maternal height and parity (Blair, Liu, *et al*., 2005). This improved and more accurate measure of appropriateness of intrauterine growth provides a renewed opportunity for researchers to assess its association with academic achievement.

While the relationship between perinatal characteristics (such as birth weight) and academic achievement has been reported to be robust to adjustments for socioeconomic status (Jefferis, Power, & Hertzman, 2002; Richards, Hardy, *et al*., 2001), less is known about whether contextual factors such as socioeconomic status of neighbourhood, school or family and maternal characteristics may modify the association between perinatal characteristics and academic achievement. Knowledge of whether certain groups of children may benefit differently from optimal perinatal characteristics in their effect on academic achievement may be used to develop more effective early intervention policies.

Another child characteristic mentioned in the literature is poor health, especially hearing problems. Research has shown that children who were identified with frequent ear infections (recurrent otitis media) were more likely to have repeated either kindergarten or first grade compared with their peers (Byrd & Weitzman, 1994). Timing of otitis media also had an important effect on educational outcomes. These findings were supported by Luotonen and colleagues (1998), who reported that children who frequently experienced otitis media under the age of 3 years were more likely to have poor achievement in mathematics and low concentration in the classroom than children without otitis media, whereas children who experienced recurrent otitis media after the age of 3 showed no such association. This suggests that both timing and recurrence of an illness are important contributing factors to poor educational outcomes.

Apart from hearing problems, a significant proportion of Australian children aged 0 to 14 years are admitted to hospital for respiratory conditions (17%), injury and poisoning (13%), gastrointestinal conditions (10%), perinatal conditions (10%) and infectious diseases (7%) (AIHW, 2008). The highest burden of disease, however, is borne by Aboriginal children, with respiratory illnesses (especially asthma), infections (mainly otitis media), and injury and poisoning being the three leading causes of their hospitalisation in Western Australia (Silva, Palandri, *et al*., 1999). Despite the disproportionally higher burden of disease experienced by Aboriginal children, two large surveys in Western Australia have shown a significant association between parent-reported poor physical health and below-age academic performance for non-Aboriginal children (Zubrick, Silburn, *et al.*, 1997), but not for Aboriginal children (Zubrick, Silburn, *et al*., 2006). However, these findings were based on cross-sectional and parent-reported data, thus being prone to recall bias and unable to evaluate the impact of the timing of various health problems on school performance.

There is limited research that has examined the link between child physical health and subsequent academic achievement due to the lack of suitable data. Previous review of research in this area revealed that physical health, activity and nutrition are all related to school achievement, and that this relationship is strongest for children living in poverty (Powney, Malcolm, & Lowden, 2000). This review called for longitudinal studies to confirm these associations. Focussing on overall child health status, a Canadian longitudinal study found a significant association between health status at birth and within early childhood and academic outcomes from grade 3 to 9 (Fransoo, Roos, *et al*., 2008). This study concluded that health status in early childhood is a mediator of health status at birth.

As expected, children with intellectual disabilities also have an elevated risk of poor achievement, though the risk seems to vary with age. A study by Turner and Alborz (2003) showed that children with Down syndrome improved their results on the Academic Attainment Index, a test developed for children with Down syndrome, with increasing age. After adjustment for IQ, the increase levelled off around the time children left school. However, many children with intellectual disability suffer from multiple problems, with research showing that about 8% of children with intellectual disability are also diagnosed with birth defects (Petterson, Bourke, *et al*., 2007).

While few children are identified with intellectual disability, many more children experience mental health problems. Official statistics show that nearly 20% of children are diagnosed with mental health problems before the age of 16 and current trends are projected to continue (WHO, 2001). The World Health Organisation identified non-psychotic mental disorders as one of the main contributors to the global health burden, with the most common diagnoses being depression, anxiety and substance abuse disorder (WHO, 2001). Across Australia, about 14% of children (4-17 years) have been reported in national surveys conducted in 1997/1998 to have either mental or behavioural problems (CAGNAP, 2008), which are now the second leading cause of disease among Australian children (0-14 years) today (Begg, Vos, *et al*., 2007).

The association between early child mental health and educational outcomes has received limited attention. In a comparative study, Currie and Stabile (2004) investigated the association between Attention Deficit Hyperactivity Disorder, the most common mental health problem among children, and educational outcomes in Canada and the United States. It was found that, in both countries and after adjustment for family income, children with Attention Deficit Hyperactivity Disorder had lower educational outcomes than their peers (Currie & Stabile, 2004).

Other studies considered mental health problems as a whole. Cross-sectional surveys of Western Australian children have shown that students diagnosed with mental or behavioural problems were significantly more likely to have below-age academic performance compared to their peers without such problems (Zubrick, Silburn, *et al*., 1997, 2006). Children with mental health problems were also less likely to graduate from high school (McLeod & Kaiser, 2004). However, due to the cross-sectional nature of the previous studies, the authors could not determine whether mental health problems were the cause or the consequences of poor academic performance (Zubrick, Silburn, *et al.*, 1997, 2006). Therefore, the nature of the association between academic performance and mental health problems remains unclear as to whether it reflects a real consequence of prior mental health problems.

Family characteristics

Children's closest environment is their family and there are several family characteristics which have been associated with poorer academic achievement in children. The socioeconomic status of the family is thought to be the most powerful predictor of children's academic achievement, and it is associated with many pre-determinants of educational competence, such as conversational skills, vocabulary, memory and school attendance (Brownell, Roos, *et. al.*, 2006). A large amount of research has consistently shown the existence of an association between socioeconomic status and educational attainment, irrespective of how socioeconomic status was measured. Family income and poverty were found to have an important impact on children's ability and achievement, with a far greater influence if it occurs during early childhood (Brooks-Gunn & Duncan, 1997). This suggests that both poverty and the timing of this exposure may be important. Differences in academic achievement between children from poor and rich families could be due to different experiences during school holidays. A longitudinal study has found that the achievement gap between high and low socioeconomic status students in grade 9 can be traced back to their different school holiday experiences over the first nine years, and concluded that such holiday shortfall explains more than half the difference in educational achievement between students from high and low socioeconomic statuses (Alexander, Entwisle, & Olson, 2007).

While poverty has been consistently linked with poorer achievement, parental education has been suggested to have an even stronger impact. A study in the United States showed that high school students with a higher family social status, as defined by parental education and occupation, had better educational achievement compared to their peers (Caldas & Banston III, 1997). Still stronger evidence of the importance of parental education came from an Australian study. In a random sample of students from financially disadvantaged families, parental education was identified as the main predictor of student academic achievement (Considine & Zappalà, 2002). The authors showed that students whose parents were themselves highly educated had the best chances of obtaining "outstanding" achievements. The probability of outstanding results in children diminished as the years of parental schooling decreased, with those whose parents completed less than 10 years of schooling having the lowest chances of succeeding at school. Considine and Zappalà argued that the social and the economic aspects of socioeconomic status may affect educational achievements differently.

Researchers have attempted to explain the educational achievement differences between children from poor families and those whose parents have low education by pointing to the different experiences of these children. Children whose parents had low education are more likely to be deprived of positive experiences, reassurance and social support, which are necessary for a positive attitude towards academic study and achievement, while those from poor families are more likely to lack a sense of belonging at school, be at a greater risk of suffering from stressful events, and be rejected by their mother (Felner, Brand, *et al*., 1995). Regardless of how socioeconomic disadvantage is measured, disadvantaged children are less likely to succeed in education or attain its associated social and economic advantages, thus perpetuating the cycle of disadvantage across generations. To interrupt this cycle and successfully level this gradient in educational outcomes, it is important to identify the factors that mediate the relationship with socioeconomic status, since they may be more directly amenable to intervention than socioeconomic status itself.

Maternal age is related to socioeconomic status and to the resources available to the family. It has been consistently associated with the academic achievement of children, with research showing that educational outcomes tend to increase with increasing maternal age (Levine, Emery, & Pollack, 2007; Lopez Turley, 2003). Two large population-based studies have shown that teenage mothers were more likely to have babies born preterm, with low birth weight, lower Apgar score at 5 minutes and with increased neonatal mortality (Chen, Wen, *et al*., 2007; Mohsin, Wong, *et al.*, 2003). Adjustment for weight gain during pregnancy, or restricting the analysis to white married mothers with age-appropriate education level, adequate prenatal care, without smoking and alcohol use during pregnancy did not change the results (Chen, Wen, *et al*., 2007). The authors concluded that teenage pregnancy increases the risk of adverse birth outcomes independently of other known confounders. Their findings challenge the accepted opinion that adverse birth outcomes associated with teenage pregnancy are attributable solely to low socioeconomic status, inadequate prenatal care and inadequate weight gain during pregnancy.

Another characteristic directly related to family resources is family structure. Earlier research showed that children from single-parent families were at a greater risk of poor educational outcomes than children from two-parent families (Duncan & Duncan, 1969). However, later studies revealed that the educational disadvantage of children from single-parent families could be partially attributed to single mothers having less education, income and parenting time (Cooksey, 1997; Pong, Dronkers, & Hampden-Thomson, 2003). In Australia, there is an increasing trend towards single parent families as a result of the rising numbers of divorces and family breakdowns (ABS, 2008a; Stanley, 2002). Such dramatic changes in our society affect how children are reared and their impact should be considered when designing new approaches to improve developmental outcomes of children (Hayes, 2008).

Children from disadvantaged backgrounds may experience different family environments and parenting practices compared to children whose parents are educated and of higher socioeconomic status. Researchers investigating family functioning as potential mediating processes have shown that parental practices and home environment partially mediate the link between socioeconomic status and academic achievement (DeGarmo, Forgatch, & Martinez Jr, 1999; McCulloch & Joshi, 2001).

School characteristics

School and peers are also influential in determining educational outcomes. Research has shown that the family social status of their peers significantly influences educational achievement, independently of their own family socioeconomic status, race and other background indicators (Caldas & Banston III, 1997). This suggests that students from a disadvantaged background attending schools catering to students from low socioeconomic backgrounds may be doubly disadvantaged.

Apart from socioeconomic status, other factors such as school culture and the associated expectations of students' performance and behaviour are important. An Australian study found high student motivation and good quality of school life to be associated with higher student achievement (Mok & Flynn, 1998). More recent research further reported that school cultural ethics and expectations of success have a strong impact on how students perform (Black, 2007). This therefore suggests that not only socioeconomic status and geographical location impact on achievement, but expectations and positive attitude to schooling are also important.

Neighbourhood characteristics

Neighbourhood and community characteristics have been reported to be associated with educational outcomes, with a suggestion that their effect is beyond and above that of the family. A recent study has shown that while between-family differences accounted for about 37% of variation in educational attainment (years of education), between-neighbourhood differences explained an additional 8% of that variability (Boyle, Georgiades, *et al*., 2007). This suggests that nearly half of the differences in educational attainment may be attributable to a child's family and neighbourhood characteristics.

Similar to individual, family and school factors, it is the socioeconomic status of the neighbourhood and hence neighbourhood disadvantage that has the largest impact on children's educational development. Longitudinal research in Canada has shown that pre-school children residing in areas with neighbourhood disorder, likely to be found in disadvantaged neighbourhoods, had lower verbal ability scores than those living in affluent neighbourhoods, independent of parental background (Kohen, Brooks-Gunn, *et al.*, 2002). The study attributed this difference to the availability of resources such as libraries and child care, and to parental engagement with their children. These findings were validated in the Australian context by the Longitudinal Study of Australian Children, which reported a similar association between neighbourhood disadvantage and learning outcomes of 4-5 year olds, independent of parental background (Edwards, 2005). Neighbourhood effects were found to be of a similar size to that of family income, maternal education and living in a household with at least one employed parent. Edwards argued that providing more libraries and parks within disadvantaged neighbourhoods or encouraging more affluent families to reside in less well off neighbourhoods may help to improve the negative consequences of growing up in disadvantaged neighbourhoods.

Neighbourhood disadvantage has also been associated with children's achievement at later stages of their development. Children from low socioeconomic neighbourhoods were found to be much less likely to pass the grade 3 standards test at an age-appropriate time compared to their peers (Brownell, Roos, *et al.*, 2006). This study demonstrated the presence of substantial socioeconomic gradients in grade 3, thus suggesting that the gradient in educational outcomes may be even greater than previously thought and than most studies have shown.

Larger social structures

Larger social structures, comprising political, economic and cultural factors, impact on individuals, their families and the neighbourhoods they live in. Both socially and economically, society is shaped by government policies and through the ways they promote and support the members of their society. For example, government policy may influence how much time individuals spend at work away from their families by imposing legal limits on the maximum number of hours people are allowed to work per week. A recent survey has shown that 11% of Australians work very long hours (60 hours or more) per week and that on average they work 42 hours per week (ABS, 2009). The percentages of people working long hours and during weekends in Australia are some of the highest among high-income countries (Dockery, Li, & Kendall, 2009; Shepanski & Diamond, 2007). Such atypical and demanding working patterns have been linked with a greater likelihood of dysfunctional family (Shepanski & Diamond, 2007), thus creating an environment not conducive to good parenting habits and children's learning. The authors have called for policy changes in Australia to improve the balance between family and work and thus to reduce the stress associated with a demanding work schedule.

Another factor closely related to family and work balance is parental leave. Parental leave has been traditionally provided in European countries, with each nation providing parents with paid maternal leave. One of the most flexible provisions for paid maternal leave is that of the Czech Republic. Recently introduced legislative changes give Czech mothers even greater flexibility to take maternal leave for either two, three or four years to suit the social and economic needs of their family. Such choice promotes family functioning and reduces family stress associated with caring for infants and small children while maintaining parents' involvement in the labour market. This is in contrast to Australia, which currently has no paid parental leave, though this is scheduled to be introduced in 2011.

Directly linked with the way parents and their children are supported is the extent to which the government is committed to child care and early learning. In 2004, Australia invested only 0.45% of GDP on early childhood education and care, which is significantly less than in most OECD countries (OECD, 2006A). Research has linked greater availability of child care and active parental engagement with their children with improved verbal ability in 4-

to 5-year olds (Kohen, Brooks-Gunn, *et al.*, 2002). The lack of universal provision and the inadequate funding of child care services can increase the burden placed on families caring for small children. This may particularly impact on those families who have little social support and who lack the means to pay for often expensive child care services. Consequently, those families who are most in need are the ones who are most dependent on government support, without which they are unlikely to meet the needs of their children.

Government can send a powerful message to families and communities by the way it promotes or supports those who are most vulnerable and in need. The most recent declaration on the “Educational Goals for Young Australians” made by all Australian Education Ministers in Melbourne in December of 2008 marked a new commitment to tackle the persisting inequalities and achievement gap in educational outcomes (MCEEDYA, 2009). Government commitment is the first important step in achieving the goal of enabling all children to read, write and count.

Factors associated with Aboriginal educational disadvantage

More than two decades ago, the House of Representatives Report stated that a typical Aboriginal child faces reduced access to education and smaller chances of completing schooling (HRSCAE, 1985). This situation has not improved much since then. Despite an overall improvement of Australian students, Aboriginal students continue to have alarmingly low performance compared to their non-Aboriginal counterparts and this achievement gap widens as Aboriginal students progress through the education system (SCRGSP, 2005; DEST, 2000). According to the Western Australian Aboriginal Child Health Survey (WAACHS), 58% of Aboriginal children across Western Australia were rated as having low academic achievement in 2001/2002 compared to 19% for all children (Zubrick, Silburn, *et al*., 2006). The proportion of Aboriginal children reaching the national minimum standards in literacy and numeracy dropped significantly between the ages 8 and 10 during the first and second national testing (Zubrick, Silburn, *et al*., 2006), thus confirming the widening gap for Aboriginal students as they progress through the grades.

There are many factors that are reported to contribute to Aboriginal disadvantage and the widening achievement gap. However, one of the most important is a historical reason, based on the past white colonisation of Australia. The national inquiry into the separation of Aboriginal and Torres Strait Islander children from their families investigated the impact that past forced removal of Aboriginal children continues to have today (HREOC, 1997).

The inquiry found that the legacy of the forced removal of Aboriginal children is one of ongoing trauma, despair and loss of cultural identity. The consequences are inadequate parenting skills, high levels of substance abuse and mental health problems (HREOC, 1997), which lead to poor education and employment prospects and all of which are major barriers to enabling children to learn.

In addition to the past legacy of white colonisation, other factors may contribute to the achievement gap between Aboriginal and non-Aboriginal children. A report on the National Indigenous English Literacy and Numeracy Strategy singled out poor health problems, overcrowded housing, poor access to public services and low levels of family involvement in education as the key factors leading to low educational outcomes among Aboriginal children in Australia (DEST, 2000). Another factor is the young age of the Aboriginal population, with 2004-2005 statistics showing that about half of Aboriginal Australians are aged less than 22 years compared to 37 years in non-Aboriginal population (ABS, 2007). This may increase the burden in Aboriginal families with fewer adults being available to care for an increasing number of children. A more recent report on the Overcoming Indigenous Disadvantage has pointed out that compared with non-Aboriginal mothers, Aboriginal mothers are twice as likely to give birth to children with either low or very low birth weight, which has been associated with low educational achievement (SCRGSP, 2005). This report further highlighted that the main factors resulting in low birth weight are low attendance for ante-natal care in the first trimester, lack of nutritional assessment including monitoring into prenatal care, and poor maternal nutrition. Given that attendance at maternity services is highly dependent on access to those services and that all of these factors can be linked with socioeconomic disadvantage, it could be argued that poverty may be the underlying causal factor.

Compared with the total population, Aboriginal people experience a significantly larger health burden. In particular, Aboriginal people experience more acute and chronic types of hearing loss resulting from otitis media (disorders of the middle ear) which is associated with overcrowding and poor hygiene (SCRGSP, 2005). Aboriginal children are also more likely to be admitted to hospital for treatment of infectious diseases than their non-Aboriginal counterparts. In the period between 2002 and 2003, Aboriginal children under the age of four were twice as likely to be admitted to hospital for infectious diseases compared with non-Aboriginal counterparts (SCRGSP, 2005). Intestinal infections, influenza, pneumonia and acute upper respiratory infections are the infectious diseases most commonly found in young children and these were found to be between 1.7 and 3.7

times more prevalent in Aboriginal children than non-Aboriginal counterparts (SCRGSP, 2005). However, not all Aboriginal people are equally likely to suffer from problems of poor health. Recent statistics indicate that those who live in metropolitan areas are more likely than those from remote areas to experience long-term ill health, with the most frequent problems being eye and ear problems, asthma, back disorders and heart/circulatory diseases (ABS, 2007). This suggests that for certain types of health problems, remote geographic location may have a protective effect.

A comprehensive survey which described a range of risk factors leading to poor educational performance in Aboriginal children (up to the age of 17) was undertaken in Western Australia (Zubrick, Silburn, *et al*., 2006). This survey revealed that poor academic achievement of carers, children's emotional and behavioural problems, and high rates of absence from school were strongly associated with low achievement. It was estimated that some Aboriginal children may miss out as much as a whole year due to school absences (DEST, 2000).

Other factors identified by the survey as associated with overall poor achievement included children living in areas of high and extreme relative isolation or with a primary carer who had no prior paid-work history (Zubrick, Silburn, *et al*., 2006). This survey concluded with the disturbing observation that the relative differences in educational outcomes between Aboriginal and non-Aboriginal children are actually greater than those found in physical and mental health. Although this survey provided the first comprehensive report on many possible risk factors impacting on educational achievement, the results were based on cross-sectional data and thus could only offer a snapshot view. As such, the survey could not address questions concerning the order of occurrence of the risk factors or determine whether specific factors associated with achievement occurred before or were consequences of poor attainment. Since the election of the Rudd Government in late 2007, closing the achievement gap has received increased attention in Australia. Hence, there is an urgent need to understand better the antecedent risk factors and the pathways that lead to poor achievement so that successful prevention and intervention strategies aimed at closing the achievement gap can be developed.

SUMMARY

Although the average academic achievement of Australian students is comparable to that of students from other OECD countries, not all students achieve equally well. Some groups of students, such as Aboriginal children and those of low socioeconomic status continue to lag behind their peers. For students from disadvantaged backgrounds, the achievement gap increases as they progress through the education system. Researchers have found that the disparities between Aboriginal and non-Aboriginal children in academic achievement are even greater than those found in mental and physical health. Such educational disparities are already apparent by the time children enter the school system and may have their origins in the early years or antenatally. This evidence points to the need to intervene early before any pattern of disadvantage develops so that all children can have better chances to succeed academically and participate fully in society.

However, before we can effectively develop early prevention and targeted intervention strategies, it is essential to understand the pathways to children's academic achievement. Currently, our capacity to develop appropriate interventions is limited by our lack of knowledge about children's developmental trajectories and the complex pathways involved.

The task of identifying developmental pathways is made more complex because the majority of children who are vulnerable to low academic achievement are likely to suffer from combinations of adverse factors rather than from a single risk factor. While many individual, familial, and neighbourhood factors have been suggested to contribute to poor academic achievement, little is known about how individual factors interact with contextual factors. Such knowledge would inform the development of early intervention strategies which are needed to minimise the impact of disadvantaged background.

Healthy development is generally regarded as one of the key pre-requisites for children to be ready to learn at school, yet there is limited research investigating how the absence of good early health impacts on subsequent academic achievement. Despite two large surveys being conducted in Western Australia (Zubrick, Silburn, *et al.*, 1997, 2006), a number of questions remain unanswered. These surveys were based on cross-sectional data and subject to self-report, parent-report and recall bias. The surveys were thus unable to determine if the observed problems were the cause or the consequence of poor academic achievement. In addition, not all physical health problems were considered in

the analysis, particularly those affecting small numbers. There is therefore an urgent need to investigate the relationship between early health and subsequent academic achievement in Australia using longitudinal data, which can allow the investigation of the effect of timing as well as the recurrence of health problems.

In addition, it has been hypothesised that socioeconomic disadvantage may impact on academic achievement through a biological pathway, and that disadvantage may be embedded in early health. However, to date the hypothesis has not been tested. A formal confirmation of the hypothesised biological mechanism linking socioeconomic status and academic achievement would provide evidence for integrated health and education prevention and intervention strategies. The testing of developmental pathways and hypothesised mechanisms is best accomplished by using population-based and longitudinal datasets with minimal potential biases, such as administrative government datasets.

Chapter Three

Methodology

The research described in this thesis is part of the Developmental Pathways in Western Australian Children Project, which was proposed in 2003 and started in 2005 (Stanley, de Klerk, *et al*., 2004). This project represents a unique collaboration between the Telethon Institute for Child Health Research, the University of Western Australia (Crime Research Centre) and seven government agencies in Western Australia (the Departments of Health, Education and Training, Attorney General, Corrective Services, Child Protection, Disability Services and Communities). The primary aim of this cross-agency collaboration was to pioneer population-based record linkage across multiple disciplines and to use these unique linked data to investigate pathways to health and wellbeing, education and juvenile delinquency outcomes in Western Australian children and young people.

The aim of this research is to examine how early health and socioeconomic factors influence the educational outcomes of primary school children in Western Australia. This section briefly outlines the study population and describes the various datasets that were used for this study. It then explains how the datasets were linked through the Western Australian Data Linkage System, and how the linked de-identified data were analysed. A more detailed description of how the linked population based data were utilised for specific sub-studies is provided in the methods section of each chapter devoted to a particular sub-study.

THE STUDY POPULATION

The study population comprised all children recorded by the Western Australian Data Linkage System as being born in Western Australia from 1988 to 1997 and participating in the Western Australian Literacy and Numeracy Assessment between 2000 and 2005.

DATABASES

This study used longitudinal population-based data from the Western Australian Government Departments of Education and Training and of Health, together with datasets from the Disability Service Commission. The various datasets used for this project are described below together with the chapter in which the data are used for.

The Western Australian Literacy and Numeracy Assessment (WALNA) Program

The WALNA is a Western Australian curriculum-based assessment which measures children's performance in literacy and numeracy in relation to both the Curriculum Framework and the Outcome and Standards Framework in grades 3, 5 and 7. These tests were used by the Western Australian government to evaluate all students' literacy and numeracy skills against nationally-agreed minimum acceptable levels (benchmarks) (MCEETYA, 2006). These tests ware developed in response to an agreement between the Commonwealth, State and Territory Ministers for Education to enable national comparison of children's skill and monitor trends over time (MCEETYA, 2006).

The WALNA is directly comparable to other Australian state-wide assessment programs that monitor children's progress in literacy and numeracy skills. To achieve this comparability over time, the original raw WALNA scores have been scaled and equated *via* a Rasch analysis to a historical scale by the Western Australian Department of Education and Training (Doig & Groves, 2006; Rasch, 1960/1980).

The individual WALNA literacy and numeracy tests were developed by the Western Australian Department of Education and Training, in partnership with the Catholic Education Office of Western Australia, the Association of Independent Schools of Western Australia, and the Australian Council for Educational Research. Since 1999, this program has been administered annually in the first half of August across Western Australia. In 1998, the testing of grade 3 students in literacy was piloted and in 1999 literacy and numeracy tests were administered in all government schools to children in grade 3 and grade 5 (typically aged 8 and 10 years).

Since 2001, the testing has been extended to include grade 7 students (aged 12 years). While in 2000 the program expanded to include all (government and private) schools in Western Australia, the testing has remained compulsory only for students attending government schools. In private schools, children's participation in the testing program is voluntary as parents' consent is required. In government schools, the only children exempt from WALNA are those who are intellectually disabled, lack competency in English when not their first language, and in special circumstances. In 2003, the enrolment age for children entering primary school increased by six months. Hence, in 2005 only the older half of the cohort participated in grade 3 WALNA.

The WALNA tests are marked locally and every year they are evaluated by expert judges for content and construct validity and scrutinised by psychometricians for misffiting items, precision and bias. The separation index (internal reliability) of the test has been reported to be at least 0.8, thus suggesting a good separation of student. The power of the fit has also continuously been good. However, the WALNA also has some limitations, as it may not be equally culturally appropriate for all children. While the test had been developed to be as unbiased as possible, it is possible that children whose main language at home is not English (including Aboriginal children) and those living in remote areas may be disadvantaged compared to their peers.

Since the beginning of the testing program in 1999, the Western Australian Department of Education and Training has been routinely collating pertinent socio-demographic information on participating students and schools in addition to students' achievement scores. Socio-demographic information for students includes Aboriginal status, gender and language background other than English, while information relating to schools includes geographical location and school socioeconomic status. The WALNA data provided the key outcome variables which were used for all the research reported in Chapters 4 to 9.

The Western Australian Hospital Morbidity Data System

The Hospital Morbidity Data System collects information on all hospital admissions from public and private hospitals in Western Australia. Since 1970, the database has been collecting information on admission and separation dates, principal and secondary diagnoses, external causes, procedures and complications, and since mid-1993 additionally on demographics (such as age, race and residential address). All diagnostic and procedural information is coded using the International Classification of Diseases (ICD) coding system. Hospital morbidity data were used in the research described in Chapters 6 to 9.

The Western Australian Mental Health Information System

Since 1966, the Mental Health Information System has been collecting data on all people who had contact with public or private psychiatric in-patient hospitals and wards or with public outpatient psychiatric services in Western Australia. It collects demographic information, event dates, diagnoses and other relevant clinical information. The mental health data were used in the research described in Chapters 6 to 9.

The Western Australian Midwives Notification System

The Midwives Notification System was established in the late 1970s to monitor all births in Western Australia, and from 1980 onwards it has been collecting information for every birth attended by a registered midwife in Western Australia (99.5% of all births). Under the Health Act 1911 of Western Australia (Section 335) and Midwifery Nurses' Regulations, every midwife is required to complete the Midwives Notification Form for all liveborn or stillborn births and to forward this form to the Department of Health within 48 hours. A birth is now defined as delivery following at least 20 weeks gestation or of at least 400 gram birth weight. The Midwives form collects detailed information on maternal socio-demographics, admission and separation dates, as well as characteristics of the pregnancy, labour delivery, and baby (Arturo, 1989).

The Midwives Notification database is validated by various quality checks of hospital data (for example, manual checks prior to data entry, or checks during the up-loading stage to the Oracle national database) in addition to periodic checks against the original hospital or birth medical records of randomly selected data (Holman, Bass, *et al.*, 1999). The latest validation study was based on a 2% sample of 25,258 births and it demonstrated a high level of accuracy: 96-100% for demographic variables, 89-99% for pregnancy variables, 96-100% for labour and delivery variables, and 90-100% for baby variables (Gee & Dawes, 1994). The midwives data were used in the research described in Chapters 4 to 9.

The Western Australian Birth Registrations

The Birth Registration contains data for all births registered in Western Australia. It collects information on parental age, country of birth, parental occupation and marital status, as well as the number of previous pregnancies. Since 1980, it has been a statutory requirement that every birth greater than 20 weeks of gestation or 400 grams in weight is registered by both parents within 60 days of birth. The Birth Registration Forms are collected by the Department of the Attorney General. The birth data were used in the research described in Chapters 4 to 9.

The Western Australian Mortality Database

The Mortality Database provides information on all deaths that have been registered in Western Australia. The database collects date of death, including underlying causes of death and other conditions present at death. For every death that occurs in a hospital, a registered doctor is required to complete a death certificate and to forward it to the Department of the Attorney General. The data are then coded by the Australian Bureau of Statistics according to the ICD coding system. The mortality data were used only during the data preparation stage to determine whether the reason why a child had no WALNA record was because he/she had died.

The Intellectual Disability Exploring Answers Database (IDEA)

The IDEA is a Western Australian population-based register of individuals with intellectual disability. IDEA collates demographic and medical information as well as the reason for referral to medical and disability services. Since 1953, data on individuals with intellectual disability and those who have accessed the disability services provided by the State government have been collated by the Disability Service Commission of Western Australia (Petterson, Leonard, *et al.*, 2005). In addition, the Department of Education and Training periodically transfers information on school-aged children (5 to 17 years) with intellectual disability to the database, with the first transfer being in 1999, followed by another in 2002 and then again in 2004.

The IDEA database includes records of all individuals whose full IQ score is less than 70 and who show signs of developmental delay before reaching the age of 18 years. Young children (less than 6 years old) who are classified by the Disability Service Commission as "vulnerable" and whose IQ score falls in the borderline range (70-84) are also included in the database, though their IQ is reassessed later at school age (Petterson, Leonard, *et al*., 2005). The IDEA classifies the level of intellectual disability as mild (with IQ score between 55 and 69), moderate (between 40 and 54) or severe (less than 40). By comparison, the Department of Education and Training distinguishes only between mild-moderate and severe level of intellectual disability. The IDEA data were used to identify children with intellectual disability in the research described in Chapters 6 to 9.

Western Australian Family Connections Genealogy System

The Western Australian Family Connections Genealogical system contains parent-child links for the Western Australian population (Holman, 2006; Holman, Bass, *et al*., 2008; Glasson, de Klerk, *et al*., 2008). It enables the linkage of children to their mothers and fathers. Information on parental mental health was also provided and these genealogical data were used in the research described in Chapters 6 to 9.

Geocoding of Residential Addresses

The residential addresses of individuals recorded in the Midwives Notifications, Hospital Morbidity System and Death Register are matched to a local residence and geocoded (Holman, Bass, *et al*., 2008). These geocodes can be linked to Census Collection Districts (200 households) (Holman, 2006), which can then be linked with social disadvantage indices (such as the Australian Bureau of Statistics Socioeconomic Indices for Areas (SEIFA)) (ABS, 2008b). The goecoding was used in the research described in Chapters 4 to 9.

RECORD LINKAGE OF EDUCATIONAL AND HEALTH DATA

The health and educational databases described above were linked for this study by the Health Information Linkage Branch in Western Australia, using the Western Australian Data Linkage System (WADLS). The WADLS was established by Professor D'Arcy Holman and colleagues in 1995 as collaboration between the Western Australian Department of Health, the University of Western Australia, Curtin University of Technology and the Telethon Institute for Child Health Research. In the absence of a unique individual identifier for each member of the Western Australian population, its main purpose is to create and maintain a system of links between health and other datasets for all individuals in Western Australia, thus enabling linked data to be used for research while maintaining individual privacy (Holman, Bass, *et al*., 2008).

The process of data linkage consists of five phases, as outlined by Holman (2006). The key feature of this process is that only identifying data (but none of the clinical data) are used for the record linkage. In the first phase, identifying data are checked, corrected, recoded and transformed. The second phase involves sorting and ordering data for subsequent matching. During the third phase, the ordered records are matched and scrutinised to determine whether or not they relate to the same individual. This matching process finishes when the established links between datasets are accepted as true links. The fourth phase involves the storage of those established links for future data merging. In the final phase, the datasets are linked together and, at this stage, the linked datasets may be further checked for any linkage errors.

The WADLS uses probabilistic matching which follows complex decision rules and employs weights which account for similarities occurring by chance (Holman, 2006). The computerised probabilistic process matches records based on full names, date of birth, gender and detailed residential address. This technique usually identifies 95% to 99% of true matches (Holman, 2006). If doubt exists, a clerical review is used for checking the matches manually, which increases the true matches to more than 99%. The probabilistic matching is the only possible way to link data in Western Australia, as there are no unique identifiers available for each individual.

Following the best-practice protocol, only accredited linkage officers who undertake these linkages have access to the identifying information (Kelman, Bass, & Holman, 2002). Such confidential information is stored in an isolated, secure computer and used by the officers during the initial linkage stage to create an encrypted linkage key (Kelman, Bass, & Holman, 2002). Once the data linkage is completed, all identifiers are destroyed. The linked de-identified data are then encrypted and passed on to researchers with an encryption key to prevent any possibility of re-identifying individuals (Kelman, Bass, & Holman, 2002).

To access the linked data, researchers have to obtain ethical clearance and permission from the data custodians. All identifying information is removed. Researchers are provided only with demographic information, clinical data and a unique encrypted linkage key for each individual, which can be used to link records across the different datasets.

ETHICS CLEARANCE

The use of the linked de-identified data for this study was approved by the University of Western Australia Human Research Ethics Committee, the Health Department of Western Australia's Confidentiality of Health Information Committee, and the Western Australian Aboriginal Health Information and Ethics Committee through the Office of Aboriginal Health.

DATA ANALYSIS

In this study, individual children were analysed as nested within schools, which created the hierarchical structure characteristic of educational data. The statistical techniques used were multilevel logistic regression (for binary outcomes) and multilevel linear regression (for continuous outcomes). All initial data manipulation, coding and cleaning as well as preliminary analyses such as cross-tabulations and frequencies were performed using SAS, while multilevel models were fitted using MLwiN. In some analyses, interactions were explored, while in all analyses I accounted for a large number of potential confounders and data were stratified by Aboriginal status. For each following chapter, the specific analysis of the data is explained in the corresponding methods section.

Chapter Four

Relationship between birth outcomes, maternal, school and neighbourhood characteristics and subsequent numeracy achievement

This chapter has been published and the published article is included in Appendix A.

Abstract

This study investigated the relationship between birth characteristics and numeracy attainment at age 8 years. Using a multilevel approach, the authors analysed all non-Aboriginal singletons born in Western Australia who attended government schools and participated in a Western Australian-wide numeracy test in grade 3 between 1999 and 2005. Appropriateness of intrauterine growth was expressed as the proportion of optimal growth parameters for gestational duration, infant sex and maternal height and parity, which was derived from a total population of births without risk factors for growth restriction. After the authors controlled for socio-demographic factors, term birth and proportion of optimal head circumference at birth were associated with higher numeracy scores. Increasing proportion of optimal birth length and being firstborn were associated with relatively higher numeracy scores among children born to mothers residing in the most educationally deprived area. The relative advantage of being born first was also higher for children born to single mothers. In contrast, higher Apgar scores and greater proportion of optimal birth weight were associated with a lower relative advantage for children born to single mothers. In summary, term birth and increased growth in head

circumference and length are key birth characteristics associated with higher numeracy scores, especially among disadvantaged children.

Keywords: cohort studies; fetal growth retardation; medical record linkage; mothers; residence characteristics; social class; Western Australia

Introduction

Children born preterm or at low birth weight tend to have poorer educational outcomes, including numeracy scores, than children of normal birth weight born at full term (Bhutta, Cleves, *et al*., 2002; Bowen, Gibson, & Hand, 2002; Buck, Msall, *et al*., 2000; Weindrich, Jennen-Stenmentz, *et al*., 2003). This disadvantage remains after accounting for family and child characteristics, such as social class at birth, maternal age, parental education, gender, birth order, and breastfeeding duration (Jefferis, Power, & Hertzman, 2002).

Lower educational attainment has also been associated with higher birth order (Black, Devereoux, & Salvanes, 2005; Booth & Kee, 2005; Iacovou, 2001). However, in large families, the effect of birth order on educational outcomes is U-shaped, with both last- and firstborns having better outcomes (Iacovou, 2001; Hanushek, 1992).

Nevertheless, birth outcomes are not the only determinants. Although children of both teenage mothers and mothers older than 35 years of age are at increased risk of preterm birth and low birth weight (Chen, Wen, *et al*., 2007; Mohsin, Wong, *et al*., 2003), educational outcomes tend to increase with increasing maternal age (Kantarevic & Mechoulan, 2005), often accounted for by maternal education, family income, and marital status (Hollander, 1995; Levine, Emery, & Pollack, 2007; Lopez Turley, 2003). Similarly, the educational disadvantage of children from single-parent families (Duncan & Duncan, 1969) has been partially attributed to single mothers having less education, income, and parenting time (Cooksey, 1997; Ginther & Pollak, 2004; Pong, Dronkers, & Hampden-Thomson, 2003). Neighbourhood characteristics are also important (Brownell, Roos, *et al*., 2006) because their associations with achievement scores are comparable with those of family income, maternal education, and living in a household with at least one employed parent (Edwards, 2005).

Few studies have examined the effect of individual birth and contextual characteristics on educational outcomes simultaneously. Most were based on small samples and were analysed without the multilevel approach required to account for similarities between students from the same school (Diez Roux, 2001; Bingenheimer & Raudenbush, 2004). They have also investigated associations with birth weight alone rather than appropriateness of intrauterine growth and length of gestation at delivery, which are different in terms of both aetiologies and outcomes. Blair and colleagues have pointed out that birth weight is not an adequate indicator of intrauterine growth, and they have derived formulae for calculating optimal birth weight, birth length, and head circumference that account for gestational age, birth order, maternal height, and infant sex (Blair, Liu, *et al.*, 2005). Appropriateness of intrauterine growth can be expressed as the proportions of optimal birth dimensions achieved, and they have been used previously (Leonard, Nassar, *et al.*, 2008).

Cognitive functioning, intellectual ability, and educational achievement are separate dimensions of neurocognitive development. Numeracy, one key indicator of children's school performance (Bowen, Gibson, & Hand, 2002; Doig, McCrae, & Rowe, 2003), is related to specific aspects of neurocognitive functioning. Those with inadequate numeracy skills are more likely to leave school early, experience prolonged unemployment, and endure poverty in later life (AIHW, 2005).

It is likely that specific perinatal risk factors are associated with specific neurocognitive deficits. This present study therefore focussed on numeracy with the aim of investigating the association of birth characteristics, maternal socio-demographic characteristics at birth, and school and neighbourhood socioeconomic status with numeracy attainment in grade 3 in non-Aboriginal singletons. We hypothesised that birth characteristics are more strongly associated with numeracy attainment for children from socially disadvantaged backgrounds. This study was part of a major population record linkage study on developmental pathways in Western Australian children.

Methods

Subjects

Subjects included all non-Aboriginal singletons born in Western Australia between 1990 and 1997 who attended government schools and participated in the annually administered, curriculum-based numeracy test of the WALNA program in grade 3 between 1999 and 2005 (MCEETYA, 2008; WADET, 2008). Of 203,402 Western Australian births 1990-1997, 80,118 eligible children were included in the study (Table 1).

Table 1: Data selection for the analysis of numeracy among non-Aboriginal singletons born in Western Australia in 1990-1997 (n=203,402) who participated in the Western Australian numeracy test between 1999 and 2005.

Exclusion criterion	Subjects excluded		Subjects remaining (no.)
	No.	%	
Stillbirth	1459	0.7	201943
Multiple pregnancy	5489	2.7	196454
Do not have grade 3 WALNA* record†	66731	34.0	129723
Non-government schools	30109	23.2	99614
Aboriginal and Torres Strait Islander child	7297	7.3	92317
Aboriginal and Torres Strait Islander mother	390	0.4	91927
Western Australian Numeracy Assessment score missing	2315	2.5	89612
Socioeconomic Indexes for Areas missing	8479	9.5	81133
School socioeconomic status missing‡	521	0.6	80612
Gestational age missing	1	0.001	80611
Apgar score missing	79	0.1	80532
Mother's height missing	357	0.4	80175
Proportion of optimum birth weight <50 or >200	33	0.04	80142
Proportion of optimum birth length missing or <50	18	0.02	80124
Proportion of optimum head circumference missing	6	0.01	80118

* WALNA, Western Australian Literacy and Numeracy Assessment.

† Children had no grade 3 WALNA record if they were absent during the testing period, they were temporarily/permanently disabled, they were moved out of Western Australia, or their Midwives Notification System and WALNA records did not link. The majority of children born in 1990 and 1997 (because of changes in school starting age in 2003) were too old or young to have a grade 3 WALNA record between 1999 and 2005.

‡ This information was missing for 22 government schools.

Sources of data

Three existing databases were used. The WALNA data set was provided by the Western Australian Department of Education and Training. WALNA is a state-wide test used by the Australian government for a national comparison of children's skills across Australia, and it is directly comparable to other Australian state-wide assessment programs that monitor children's progress in literacy and numeracy skills. WALNA was developed in keeping with standards of best psychometric practice, and every year it is evaluated by expert judges for content and construct validity and scrutinised by psychometricians for misfitting items, precision and bias. The separation index (internal reliability) of the test has been reported to be at least 0.8, thus suggesting a good separation of students. The power of the fit has also continuously been good. The Western Australian Midwives Notification System provided by the Western Australian Department of Health contained information on maternal and infant characteristics for all Western Australian midwife-attended births (99.5% of all Western Australian births) of at least 20 weeks gestation or 400 grams weight (Gee & Dawes 1994). Neighbourhood socioeconomic status was available from the Australian Bureau of Statistics census (ABS, 2006a, 2008b).

These datasets were linked by the Health Information Linkage Branch at the Western Australian Department of Health by using established protocols (Kelman, Bass, & Holman, 2002). This study was approved by the University of Western Australia and Confidentiality of Health Information committees and was conducted in consultation with a community representative from Armadale primary school. As part of the privacy rules of the Linkage Branch and the Western Australian Department of Health ethics committee, no individual identifiable data were given to the researchers (Kelman, Bass, & Holman, 2002).

Measures

Outcome measure. Numeracy was defined as the ability to effectively apply mathematics in everyday life. The test consists of multiple-choice, short- and open-response questions. The raw numeracy scores were originally reported on an ordinal scale. These were then converted *via* a Rasch measurement model (Rasch, 1960/1980; Dog & Groves, 2006) by the Department of Education and Training into an interval scale to enable an easier interpretation of the results. These converted numeracy scores ranged from -87 to 735 in our study. Negative values in attainment arose from adjusting test scores to ensure comparability over time.

Predictors at student and school level. At the student level, there were six neonatal characteristics, two maternal characteristics at birth, and three indicators of neighbourhood socioeconomic status at birth (Table 2). At school level, there was one indicator of school socioeconomic status in grade 3. In addition, six potential confounders were considered.

Table 2: Predictor variables at each level in the analysis of numeracy among non-Aboriginal singletons born in Western Australia who participated in the Western Australian numeracy test between 1999 and 2005.

Type of predictor	Predictor	Category
Infant characteristics at birth	Birth order	No older siblings alive (firstborn)*
		1 older sibling alive†
		2 or 3 older siblings alive
		≥4 older siblings alive
	Percentage of optimal birth weight	Centred at 98.3%
	Percentage of optimal birth length	Centred at 100.5%
	Percentage of optimal head circumference	Centred at 100.6%
	Gestational age	0 for Preterm birth (<37 weeks) †
		1 for Term birth (≥37 weeks)
	Apgar score at 5 minutes	0 for lower (score of <8) †
		1 for higher (score of 8-10)
Maternal characteristics at birth	Mother's age	<20 years
		20-24 years
		25-29 years†
		30-34 years
		≥35 years
	Mother's marital status	0 for married/de facto†
		1 for single/other
Neighbourhood characteristics at birth	SEIFA‡ index of relative	Lowest (SEIFA <10%)
	socioeconomic disadvantage	Low (10%< SEIFA <25%)
	(quantile)	Low middle (25%≥ SEIFA <50%)
		High middle (50%≥ SEIFA <75%)
		High (75%≥ SEIFA <90%)
		Highest (SEIFA ≥90%)†
	SEIFA‡ index of education and occupation	Lowest (SEIFA <10%)
	(quantile)	Low (10%< SEIFA <25%)
		Low middle (25%≥ SEIFA <50%)
		High middle (50%≥ SEIFA <75%)
		High (75%≥ SEIFA <90%)
		Highest (SEIFA ≥90%)†
	SEIFA‡ index of economic	Lowest (SEIFA <10%)
	resources (quantile)	Low (10%< SEIFA <25%)
		Low middle (25%≥ SEIFA <50%)
		High middle (50%≥ SEIFA <75%)
		High (75%≥ SEIFA <90%)
		Highest (SEIFA ≥90%)†
School characteristics in grade 3	School socioeconomic status	Centred at a score of 101.4

* Refers to all births with no older sibling alive (therefore, *socially* firstborn).
† Reference category.
‡ SEIFA, socioeconomic indexes for areas; WALNA, Western Australian Literacy and Numeracy Assessment.

Table 2: continued.

Type of predictor	Predictor	Category
Control variables	Child's gender	0 for boys†
		1 for girls
	Child's age	Centred at 98.5 months
	Language background	0 for English†
		1 for non-English
	Mother's ethnicity	0 for Caucasian†
		1 for others
	Calendar year of WALNA‡ test	1999†
		2000
		2001
		2002
		2003
		2004
		2005
	Geographic location of school	Metropolitan†
		Rural
		Remote
		Very remote

* Refers to all births with no older sibling alive (therefore, *socially* firstborn).
† Reference category.
‡ SEIFA, socioeconomic indexes for areas; WALNA, Western Australian Literacy and Numeracy Assessment.

Neighbourhood socioeconomic status was measured by three socioeconomic indices for areas (SEIFA) at the collection district level using census data collected closest to the birth, 1991 or 1995 (ABS, 2006a, 2008b). Collection districts usually consist of about 200 households. The SEIFA indices were categorised into six quantiles with the first quantile (lowest 10%) being the most disadvantaged (ABS, 2006a). Similarly, the school socioeconomic status score was derived from 2001 Australian census data aggregated across the collection districts in which families, whose children attended the school, lived. The collection district scores were based on the five dimensions: education, occupation, Aboriginality, single-parent family, and family income, with the first three dimensions being double weighted. The school socioeconomic status scores ranged from 60 to125.

Statistical analysis

Two-level models for numeracy score were fitted using MLwiN (version 2.02) statistical software (Rasbash, Steele, *et al*., 2004), with one level each for students and schools. This method explicitly accounts for the dependency of lower-level observations on higher-level variables by apportioning the overall variance between levels.

All variables were fitted simultaneously, and then variables not statistically significantly associated with numeracy score were excluded. Hypothesised interactions between all variables were tested for statistical significance at $p \leq 0.05$. The interactions tested included all two-way interactions between: percentage of optimal birth weight (POBW) (including squared term), percentage of optimal birth length (POBL), percentage of optimal head circumference (POHC), Apgar score, birth order (firstborn) and gestational age with mother's marital status, mother's age, SEIFA of education (lowest quantile), SEIFA of disadvantage (lowest quantile), and school socioeconomic status (including squared term). In addition, nonlinearity of continuous variables was assessed by adding polynomial terms to the model.

RESULTS

The study included 80,118 students in 610 schools, whose mean age was 8.2 years and mean numeracy score was 340 (Table 3). Centred percentage of optimal birth weight ranged from -48.3 to 99.7, with most between -24.4 and 24.4 (±2 standard deviations from the mean) (Figure 2).

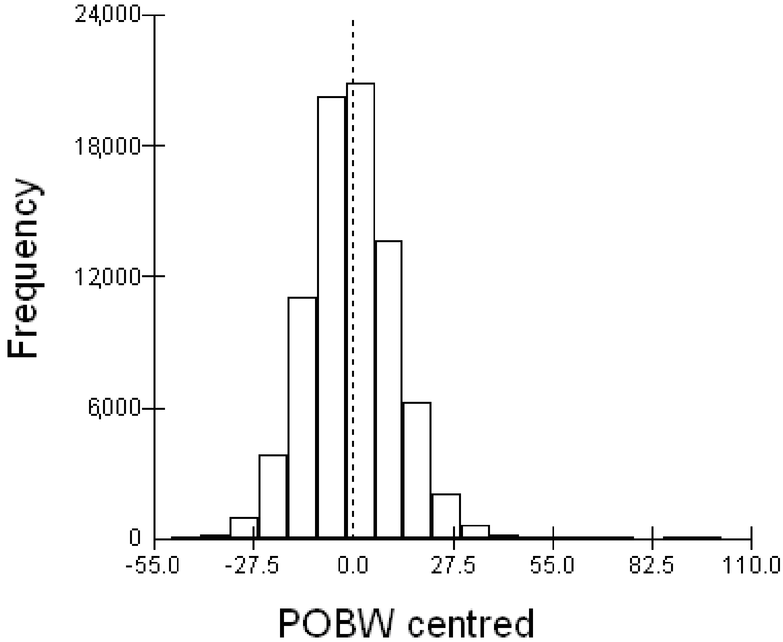
Table 3: Summary statistics for continuous variables in the analysis of numeracy among non-Aboriginal singletons born in Western Australia who participated in the Western Australian numeracy test between 1999 and 2005 (n=80,118).

Variable	Mean (SD*)	Minimum	Maximum
Numeracy score	340.3 (75.2)	-87.0	735.0
Child's age in months	98.5 (3.8)	80.0	121.0
Percentage of optimal birth weight	98.3 (12.2)	50.0	198.0
Percentage of optimal birth length	100.5 (4.3)	65.0	125.0
Percentage of optimal head circumference	100.6 (3.9)	73.0	148.0
School socioeconomic status score	101.4 (7.9)	60.4	125.0

* SD, standard deviation.

There was little difference in mean numeracy scores between non-English-speaking and English-speaking children (Table 4). However, girls; children who were born preterm; children who were at least third-born in a birth order of three or more; children who were born to young, single or Caucasian mothers; or children who had a lower Apgar score (<8) tended to have lower numeracy scores. Mean numeracy attainment was positively associated with all three measures of socioeconomic status and was higher in metropolitan than non-metropolitan schools.

Figure 2: Distribution of proportion of optimal birth weight among non-Aboriginal singletons born in Western Australia who participated in the Western Australian numeracy test between 1999 and 2005.



Of the total variance in numeracy score in the null model, multilevel model that did not include any predictors (not presented), 19.2% (95% CI: 16.8, 21.6) could be attributed to the school level and 80.8% (95% CI: 80.0, 81.6) to the student level.

Compared with preterm birth, term birth was associated with a 7.83-point increase in numeracy attainment (Table 5). Two percent of optimal birth weight interaction terms were significant in the final model, indicating that the effect of POBW varied between sub-groups of children. For children born to married mothers or to mothers in more educationally privileged areas, a one percentage point increase in POBW was associated with a 0.26-point increase in numeracy. The negative squared term indicated that lower and higher POBWs were associated with an increasingly lower numeracy score than would be expected from a linear association; further increases of more than 2 standard deviations above the optimum proportion of birth weight were associated with a sharp decrease in numeracy scores, but this finding applied to only very few children (Figure 3).

Table 4: Mean numeracy score and standard deviation for all categorical variables in non-Aboriginal singletons born in Western Australia who undertook Western Australian numeracy test between 1999 and 2005.

Variable	No. of children	Mean (SD*)	*p* value†
Language background			
Non-English	7794	340 (76)	
English	72324	340 (75)	0.420
Gender			
Girl	38811	337 (72)	
Boy	41307	343 (78)	<0.001
Gestational age (weeks)			
Preterm birth (<37)	3759	329 (75)	
Term birth (≥37)	76359	341 (75)	<0.001
Apgar score			
<8 (lower)	2447	330 (76)	
8-10 (higher)	77671	341 (75)	<0.001
Birth order			
First	32285	343 (75)	
Second	27815	343 (75)	
Third or fourth	18101	335 (75)	
Fifth or more	1917	314 (75)	<0.001
Mother's age (years)			
<20	3514	309 (72)	
20-24	15443	323 (72)	
25-29	26431	339 (74)	
30-34	23958	351 (75)	
≥35	10772	354 (76)	<0.001
Mother's marital status			
Married/de facto	71651	343 (75)	
Single/other	8467	319 (74)	<0.001
Mother's ethnicity			
Caucasian	74719	340 (75)	
Non-Caucasian	5399	350 (80)	<0.001
SEIFA* - index of relative socioeconomic disadvantage (quantiles)			
<10% (lowest)	7758	317 (76)	
10-25% (low)	12732	329 (75)	
25-50% (low middle)	22062	336 (74)	
50-75% (high middle)	20128	343 (73)	
75-90% (high)	11165	355 (74)	
>90% (highest)	6273	373 (72)	<0.001

* SD, standard deviation; SEIFA, socioeconomic indexes for areas.

† The *F* test was used for trend across categories or for difference (when only two categories).

Table 4: continued.

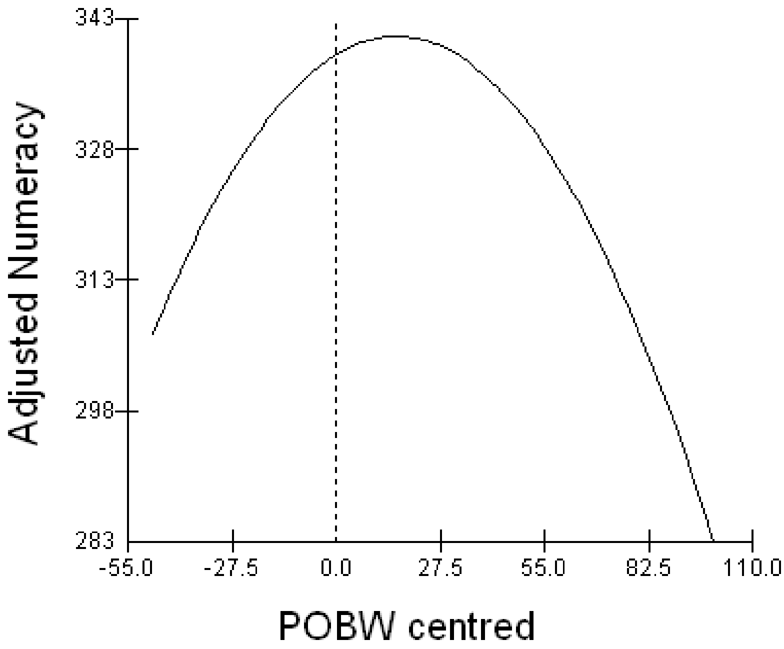
Variable	No. of children	Mean (SD*)	*p* value†
SEIFA* – index of education and occupation (quantiles)			
<10% (lowest)	9010	317 (75)	
10-25% (low)	13537	326 (74)	
25-50% (low middle)	20556	334 (73)	
50-75% (high middle)	21752	346 (72)	
75-90% (high)	10203	361 (74)	
>90% (highest)	5061	381 (73)	<0.001
SEIFA* - index of economic resources (quantiles)			
<10% (lowest)	5885	320 (76)	
10-25% (low)	10188	331 (76)	
25-50% (low middle)	18742	335 (75)	
50-75% (high middle)	24044	340 (73)	
75-90% (high)	13906	350 (73)	
>90% (highest)	7353	366 (73)	<0.001
Geographical location			
Metropolitan	58141	344 (76)	
Rural	16890	332 (74)	
Remote	3803	332 (73)	
Very remote	1284	324 (75)	<0.001

* SD, standard deviation; SEIFA, socioeconomic indexes for areas.
† The *F* test was used for trend across categories or for difference (when only two categories).

Any advantage associated with higher POBW was, however, reduced among children born to single mothers or to mothers in the most educationally deprived areas. Higher POBL was associated with increasing numeracy scores. In contrast to the finding for POBW, this relative advantage was higher for children born to mothers in the most educationally disadvantaged areas but lower for children attending higher-socioeconomic status schools. For every percentage point increase in POHC, children achieved 0.4 points more, irrespective of maternal and neighbourhood characteristics. There was also a positive association between Apgar scores and numeracy attainment, except for children born to single mothers.

Birth order was negatively associated with numeracy attainment, with children born fifth or later having the lowest attainment. Statistically significant positive interactions between birth order and marital status or SEIFA suggested that the advantage associated with being firstborn was enhanced for children born to single mothers or to mothers in the most educationally disadvantaged areas.

Figure 3: Adjusted numeracy as a function of proportion of optimum birth weight among non-Aboriginal singletons born in Western Australia who participated in the Western Australian numeracy test between 1999 and 2005.



Numeracy scores increased with higher maternal age, reaching an additional 9 points for children born to mothers older than 35 years of age. School socioeconomic status was positively associated with numeracy attainment and accounted for the association with geographical location in univariate analysis. However, children whose school socioeconomic status was either lower or higher performed slightly better than would have been expected given a linear trend. Children's numeracy was positively associated with SEIFA quantiles for education and occupation, which accounted for much of the variation observed with other SEIFA measures. However, being in an area with a SEIFA score below the 10th percentile remained a significant independent, negative predictor of numeracy. The overall fit of the model (Table 5) was assessed by calculating explained variance at the school and student level (Snijders & Bosker, 1999). The final model explained 52% of the variability between schools but, despite the large number of predictors in the model, only 16% of variability between students.

Table 5: Parameter estimates (and 95% Confidence Intervals) for the analysis of numeracy in the final model among non-Aboriginal singletons born in Western Australia who undertook Western Australian numeracy test between 1999 and 2005.

Variable	**β***	**95% CI***
Fixed		
Intercept	339	334, 344
Gestational age (weeks) (vs preterm)		
Term birth (≥37)	7.83	5.57, 10.1
POBW*		
POBW (centred)	0.26	0.20, 0.32
POBW (centred)^{squared}	-0.008	-0.010, -0.006
POBL*		
POBL (centred)	0.26	0.11, 0.41
POHC*		
POHC (centred)	0.40	0.25, 0.55
Apgar score (vs lower)		
Higher Apgar score (8-10)	7.61	4.63, 10.6
Birth Order (vs second)		
First	4.38	3.17, 5.59
Third or fourth	-8.40	-9.70, -7.10
Fifth or more	-23.6	-26.8, -20.3
Mother's marital status (vs married)		
Single/other[†]	-2.68	-10.8, 5.40
Mother's age (years) (vs 25-29)		
<20	-21.0	-23.6, -18.4
20-24	-10.8	-12.2, -9.40
30-34	6.74	5.52, 7.97
≥35	9.02	7.40, 10.6
SEIFA* – index of relative socioeconomic		
disadvantage (quantiles) (vs SEIFA >10%)		
<10% (lowest)	-4.44	-6.58, -2.30
SEIFA – index of education and occupation		
(quantiles) (vs highest)		
<10% (lowest)	-18.0	-21.3, -14.6
10-25% (low)	-12.7	-15.4, -10.0
25-50% (low middle)	-10.2	-12.8, -7.63
50-75% (high middle)	-6.99	-9.48, -4.50
75-90% (high)	-4.15	-6.69, -1.61
School socioeconomic status		
School socioeconomic status (centred)	1.80	1.55, 2.05
School socioeconomic status (centred)^{squared}	0.04	0.02, 0.05

* β, parameter estimate; CI, confidence interval; POBW, percentage of optimal birth weight; POBL, percentage of optimal birth length; POHC, percentage of optimal head circumference; SEIFA, socioeconomic indexes for areas.

† Single/other marital status became non-significant only after the inclusion of interactions with POBW, firstborn and Apgar score.

Table 5: continued.

Variable	**β***	**95% CI***
Calendar year (vs 1999)		
2000	-8.61	-10.3, -6.89
2001	20.9	19.2, 22.6
2002	-9.32	-11.0, -7.60
2003	-3.56	-5.27, -1.84
2004	-2.15	-3.88, -0.42
2005	-1.04	-3.14, 1.06
Gender (vs boy)		
Girl	-5.95	-6.89, -5.00
Child age (months)		
Age (centred)	2.18	2.01, 2.36
Age $(\text{centred})^{\text{squared}}$	-0.17	-0.20, -0.14
Age $(\text{centred})^{\text{cubic}}$	-0.02	-0.03, -0.02
Language background (vs English)		
Non-English	-6.18	-8.01, -4.34
Mother's ethnicity (vs Caucasian)		
Non-Caucasian	12.2	9.98, 14.3
Interactions		
POBW x single mothers	-0.23	-0.35, -0.10
POBW x SEIFA education (<10%)	-0.22	-0.37, -0.07
POBL x SEIFA education (<10%)	0.58	0.15, 1.00
POBL x school socioeconomic status	-0.02	-0.03, -0.002
First born x single mothers	5.56	2.25, 8.87
First born x SEIFA education (<10%)	5.55	2.44, 8.67
Apgar (8-10) x single mothers	-10.1	-18.0, -2.27
Random		
Remaining variance between schools	540	468, 612
Remaining variance between students	4,594	4,549, 4,639
-2 log likelihood	904,389	

* β, parameter estimate; CI, confidence interval; POBW, percentage of optimal birth weight; POBL, percentage of optimal birth length; POHC, percentage of optimal head circumference; SEIFA, socioeconomic indexes for areas.

† Single/other marital status became non-significant only after the inclusion of interactions with POBW, firstborn and Apgar score.

DISCUSSION

Our results show that birth characteristics are associated with numeracy attainment of children in grade 3 independent of their socioeconomic context. Our finding that term birth was associated with improved numeracy outcome is in line with a meta-analysis by Bhutta, Cleves, *et al*. (2002) and research investigating the relationship between extreme prematurity and numeracy attainment at age 8 years (Bowen, Gibson, & Han, 2002). The positive association of head growth with numeracy is also consistent with previous studies, which reported a direct link between head circumference at birth and subsequent intelligence quotient and logical reasoning (Ivanovic, Leiva, *et al*., 2004; Lundgren, Cnattingius, *et al*., 2003). We found that term birth and head growth were associated with numeracy attainment independently of all other characteristics. If these associations are causal, then these results suggest that longer gestation and greater head growth have the potential to benefit all children, irrespective of their background, and that faster skeletal growth (but not faster growth in mass) tends to reduce the disadvantage associated with being born in the most disadvantaged neighborhoods.

Our analysis of birth weight and numeracy differed in three important ways from the study by Jefferis, Power and Hertzman (2002). The latter did not differentiate preterm birth from growth restriction, test for interactions between variables, or account for clustering of students within schools. In overcoming these limitations, our results showed a curvilinear association between POBW and numeracy attainment, with both lower and higher (up to 2 standard deviations) POBWs being associated with lower numeracy scores than would be anticipated from a purely linear association, and with additional increases in POBW having a negative association with achievement (as shown in Figure 3). This difference may be the result of the marked increase in prevalence of maternal obesity since the time of the Jefferis *et al*. cohort, which has been particularly acute in areas of socioeconomic deprivation (Heslehurst, Ells, *et al*., 2007). High POBW may reflect either greater skeletal growth or greater accumulation of adipose tissue, or both.

Apgar scores of >7 (97% of children) were positively associated with numeracy attainment. However, for children born to single mothers, unexpectedly, higher Apgar scores were associated with a lower relative advantage. If this association reflects a causal association with a better condition at birth, then the attainment disparities between children born to single mothers and those born to married mothers were exacerbated by higher Apgar scores. We found a strong, negative association between numeracy attainment and birth order. This finding is consistent with earlier evidence that firstborn children are advantaged in terms of educational achievement (Black, Devereoux, & Salvanes, 2005; Booth & Kee, 2005), but we found no evidence of U-shaped association between birth order and numeracy attainment, as reported in other studies (Iacovou, 2001; Hanushek, 1992). However, these studies relied on comparisons within families, whereas our comparisons were essentially between families. In addition, we found that the relative advantage associated with being firstborn was greater for those born to single mothers or to mothers residing in the most educationally disadvantaged areas.

In line with previous evidence (Fransoo, Roos, *et al*., 2008; Brownell, Roos, *et al*., 2006; Edwards, 2005), we have shown that the socioeconomic statuses of school and areas were more important predictors of numeracy attainment than birth characteristics. We have further shown that socioeconomic status interacts with birth characteristics in their effect on numeracy. In multivariate analysis, language background and mother's ethnicity were also important predictors of numeracy. In Australia, a large proportion of non-Caucasian and immigrant mothers are now of Asian origin. Children of these parents have been reported to be more successful in educational testing compared with their peers (Marks, McMillan, & Hillman, 2001). This difference may stem from the high regard that Asian parents have for educational attainment, although it could also reflect the policies of actively targeting immigration of well-educated and well-qualified Asian migrants. Child age was positively associated with numeracy attainment, but higher-powered terms indicate that very young age was associated with higher numeracy scores than would have been expected, whereas some of the oldest children scored worse than expected on the basis of a purely linear association. It is likely that the group of the very young children (less than age 7.5 years) who participated in WALNA systematically differed from their older class mates in their readiness to learn at the start of their schooling.

This study has several strengths. We considered several birth characteristics simultaneously, analysed a total population, accounted for the multilevel nature of the data, and considered interactions between maternal, school, and neighbourhood characteristics. Because our study was based on administrative data from two Western Australian government departments, we minimised possible selection bias. Our findings highlight the importance of social contexts for a better understanding of the impact of child biologic characteristics on numeracy achievement. In contrast, previous studies were often based on small samples and failed to consider interaction effects or the correlation between students in the same school (Bowen, Gibson, & Hand, 2002; Weindrich, Jennen-

Stenmentz, *et al*., 2003; Black, Devereoux, & Salvanes, 2005; Booth & Kee, 2005). Because uniform numeracy testing was used across Western Australia from 1999 onwards, we have confidence that our comparisons over time are valid.

A limitation of this study was exclusion of the one quarter of children attending non-government schools, because permission to access the socioeconomic status of these schools was denied. Non-government schools consist of private schools to which parents pay fees and schools affiliated with religious or educational institutions. Children attending the former are likely to be the most economically advantaged, but those attending the latter are from more socioeconomically mixed environments. Similarly, disadvantaged children may have been overrepresented in the small number of children absent during the testing week, since they tend to miss school more often. Children were exempt from taking the test if they were intellectually impaired, lacked competency in English when it was not their first language, and in special circumstances. Further exclusions consisted of the small number of Western Australia-born children who moved out of Western Australia and children whose Midwives Notification Systems records did not link to WALNA data (many of whom would not have been born in Western Australia), all of which apply only to small number of children and are unlikely to have had an appreciable effect on our findings.

In conclusion, this multilevel study is the first known to investigate the associations between numeracy achievement in primary school children and characteristics of the newborn, mother, school, and neighbourhood at birth simultaneously and their interactions. Term birth, faster intrauterine head growth, male gender, and lower birth order were all independently associated with increased numeracy scores. The associations with other birth characteristics varied with maternal and neighbourhood characteristics and may either buffer or exacerbate the negative influence of socioeconomic disadvantage on numeracy attainment, but mechanisms underlying these effects require further investigation. Our analysis also suggests that much of the school variation in numeracy outcomes is explained by these early factors; hence, an excessive focus on schools, which ignores the pathways into school, may be limited in its ability to improve numeracy. Future research should also consider other factors likely to affect numeracy at the individual level, such as early stimulation in the home environment, family resources, parenting quality, parental and child mental health and nutrition, and prior numeracy attainment. Our findings have important implications for the future development of evidence-based strategies aimed at improving educational outcomes for all children by integrating both public health approaches and social interventions.

Chapter Five

Neighbourhood socioeconomic status and maternal factors as moderators of the association between birth characteristics and school attainment

This chapter has been published and the published article is included in Appendix A.

Abstract

Background: This article investigates whether reading and writing skills among children of equivalent perinatal characteristics differ by neighbourhood socioeconomic status and maternal factors.

Methods: Notifications of births for all non-Aboriginal singletons born in 1990-1997 in Western Australia subsequently attending government primary schools were linked to the State literacy tests in grade 3 and with information on socioeconomic status of the school and the residential area. Using multilevel modelling, the associations between birth characteristics (gestational age, intrauterine growth, birth order and Apgar score at 5 minutes) and literacy attainment in grade 3 were examined in models that included socioeconomic and demographic factors of the child, mother and community.

Results: Higher percentages of optimal head circumference and birth length and term birth were positively and independently associated with literacy scores. A higher percentage of optimal birth weight was associated with higher reading scores especially for children born to mothers residing in educationally advantaged areas. First birth was positively associated with reading and writing attainment: this association was stronger for children born to single mothers and additional advantage in writing was also associated with first birth in children living in disadvantaged areas.

Conclusions: These findings suggest that having sub-optimal growth *in utero* or an older sibling at birth increases vulnerability to poor literacy attainment especially among children born to single mothers or those in disadvantaged neighbourhoods. These data provide evidence for advocating lifestyles compatible with optimum fetal growth and socioeconomic conditions conducive to healthy lifestyles, particularly during pregnancy.

Keywords: appropriateness of intrauterine growth; birth outcomes; socioeconomic factors; literacy; multilevel modelling; Western Australia;

Introduction

Research including a systematic review over the whole range of birth weight has consistently shown that perinatal characteristics are associated with neurodevelopmental, cognitive and educational outcomes, particularly in infants who were extremely premature and low birth weight (Leonard, Nassar, *et al*., 2008; Bhutta, Cleves, *et al*., 2002; Malacova, Li, *et al*., 2008; Shenkin, Starr, & Deary, 2004). Yet, previous studies of low birth weight infants seldom differentiate between infants with low birth weight due to early delivery and those with restricted intrauterine growth (Shenkin, Starr, & Deary, 2004; Silva, Metha, & O'Callaghan, 2006; Yang, Lynch, *et al*., 2008). Studies also rarely estimate the extent to which non-biological risk factors, such as maternal socio-demographic factors and the social environment at birth, modify the relationship between perinatal characteristics and neurocognitive development (Bhutta, Cleves, *et al*., 2002; Malacova, Li, *et al*., 2008; Breslau, Dickens, *et al*., 2006).

Educational outcomes, mental health and intellectual disability represent different aspects of neurocognitive development. Recently, three measures of intrauterine growth adjusted for gestational duration, infant sex, maternal height and parity have been developed (Blair, Liu, *et al*., 2005), and have been shown to be associated with mental health outcomes and intellectual disability (Leonard, Nassar, *et al*., 2008). We have recently used these measures for the first time to examine the association of perinatal characteristics with numeracy outcomes and how this association varied across different socioeconomic and demographic groups of children (Malacova, Li, *et al*., 2008). We found that neighbourhood socioeconomic status at birth modified the connection between perinatal characteristics (intrauterine growth in terms of birth weight, birth length, first birth and Apgar scores) and numeracy attainment in children. It is now accepted that boys perform better in numeracy and girls do so in literacy. It is possible that social environmental factors and birth outcomes as well as their interactions may also have a differential impact on literacy and numeracy.

In the present study we have analysed total population-based linked data of non-Aboriginal singleton children at age eight attending government schools in Western Australia to determine the associations of perinatal characteristics with literacy outcomes (reading and writing skills) and whether literacy achievement among children of equivalent perinatal characteristics differed by children's neighbourhood socioeconomic status and maternal factors. As this was a total population-based study and children were not selected by birth weight or gestational age, bias due to missing data is minimal and the results are generalisable to all non-Aboriginal single born children later attending government schools in Western Australia.

Methods

Sources of data

Data from three existing statutory state-wide databases were linked by the Health Information Linkage Branch (Holman, Bass, *et al*., 1999). The Midwives' Notification System contains records of all non-Aboriginal singleton live births in Western Australia attended by a midwife between 1990 and 1997 (Midwives data contain 99.5 % of all births which were of 20 weeks gestation or >400 gram) (Gee & Dawes, 1994). The Western Australian Literacy Assessment program is a curriculum-based test administered annually to all children in grade 3 in Western Australia. It is used by the Australian government for national monitoring and reporting on children's progress in literacy skills across Australia. This literacy dataset, which has been obtained from the Western Australian Department of Education and Training (MCEETYA, 2008; WADET, 2008), contains individual Rasch-transformed test scores for reading and writing for the period of 2000-2005, which are comparable over time within the same school subject (reading or writing).

In the final analyses, however, records for year 2001 were removed because the 2001 test results unexpectedly differed from other years for reasons which were unknown and not able to ascertain. In addition, writing scores were unavailable for that year at the time of this analysis. The Australian census data included neighbourhood socioeconomic characteristics expressed as SEIFA (ABS, 2006a, 2008b).

Subjects

Of 96,653 non-Aboriginal children in Western Australia who had been born between 1990 and 1997 and subsequently attended Western Australian government schools during 2000-2005, 77,950 had a school record for grade 3 (Figure 4). We excluded multiples and the 7,948 children with missing predictor variables, of which the majority was missing due to neighbourhood socioeconomic status, and 12,704 children who had a grade 3 record in year 2001, a year for which it was not possible to obtain writing scores at the time of data extraction and in which mean reading scores displayed considerable differences compared to other years. After excluding those with missing outcome data (n=1,766 for reading and n=2,058 for writing attainment), the final dataset contained 55,533 students in 596 schools who had reading and 55,240 students in 594 schools who had writing scores.

Measures

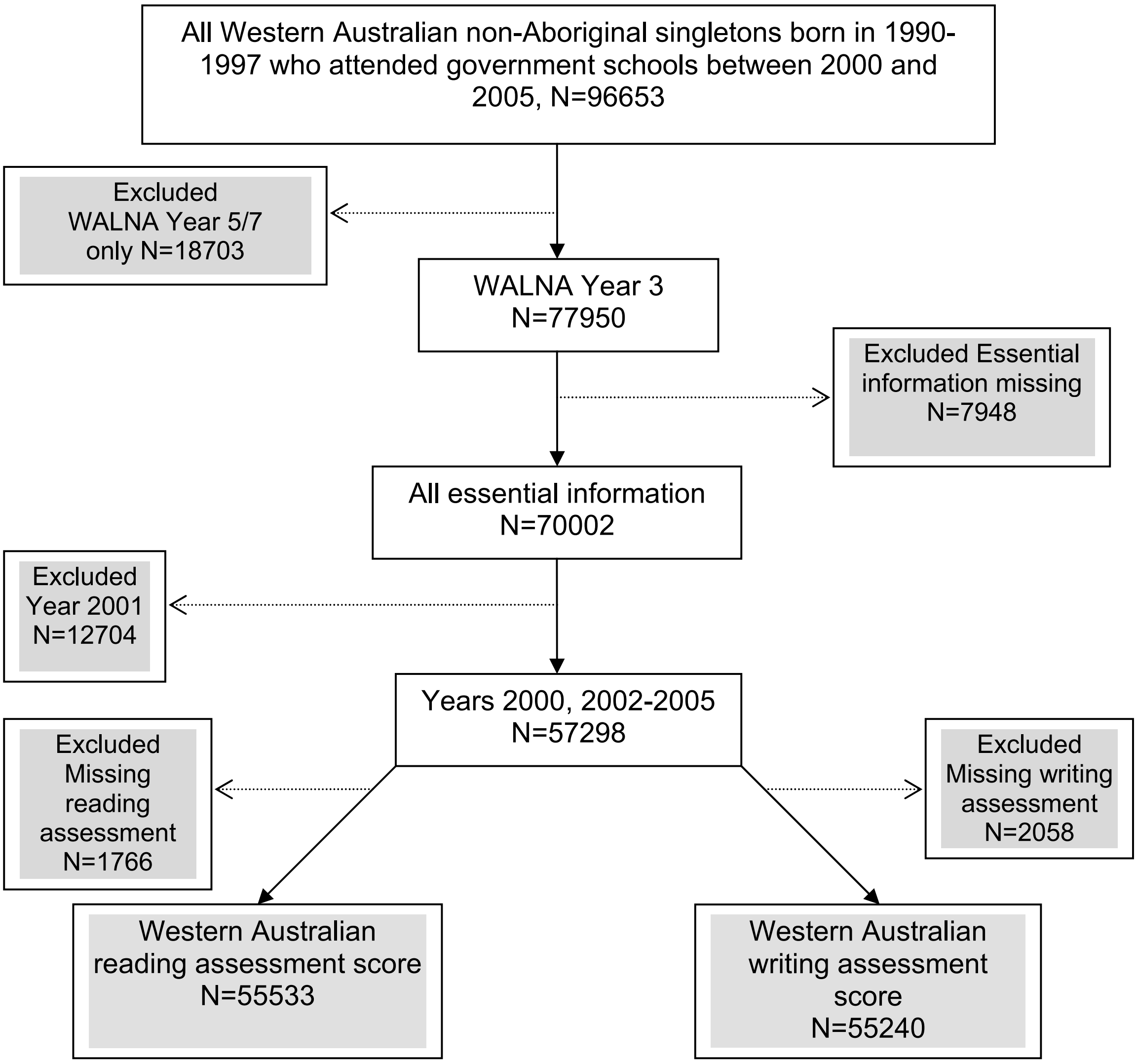
Outcome measures

The reading and writing tasks assessed children's ability to effectively read and write in everyday life and were measured in two literacy test scores. The reading test consisted of multiple-choice, short- and open-response questions, whereas the writing test required writing a short story, fable or an anecdote.

Predictors at the student and school levels

Preterm birth was defined as a gestational age of less than 37 completed weeks. Appropriateness of intrauterine growth was assessed by calculating the POBW, POBL and POHC achieved by each neonate. The optimum value for each measure for a given gestational duration, gender, maternal height, parity and age is estimated from models derived from Western Australian neonatal survivors unaffected by the most frequently occurring pathological determinants of intrauterine growth in the Western Australian population (Blair, Liu, *et al.*, 2005).

Figure 4: The flow diagram of data selection for the analysis of reading and writing achievement among non-Aboriginal singletons born in Western Australia between 1990 and 1997 who undertook the Western Australian reading and writing tests in grade 3 in 2000, 2002-2005.



Apgar scores of less than 8 at five minutes were defined as low. Birth order was categorised as having none, one, two or three, or four or more surviving older siblings. Maternal age was grouped as <20 years, 20-24 years, 25-29 years, 30-34 years, or >34 years. Mother's marital status was classified as single (never married, widowed, divorced and separated) and married (including *de facto* relationships).

Socioeconomic and educational disadvantage of the child's residential area at birth was measured using the Indices of Relative Socioeconomic Disadvantage and of Education and Occupation (SEIFA) from the Australian Bureau of Statistics (ABS, 2006a, 2008b). The indices attributed to each birth at the census collection district level were derived from the census data for 1991 or 1996 whichever is the closest to a child's birth year. In this study, SEIFA values were divided into six quantiles, with the first quantile (lowest 10%) being the most disadvantaged.

Additional variables

We adjusted for the year in which the reading and writing tests were taken and for child language background, which was self reported at the time of testing, indicating English or non-English language background at home. We also adjusted for child gender, age and mother's ethnicity (Caucasian or non-Caucasian, with non-Caucasian mothers being predominantly of Asian origin). School socioeconomic scores were obtained from the 2001 Australian Census data at the collection district level, where families whose children attended the school lived. These scores were created by combining five socioeconomic indicators using principal component analysis and included dimensions of parental education, occupation, Aboriginality, single parent family, and family income, with the first three dimensions being double weighted (based on an unofficial document by the Western Australia Department of Education and Training).

Statistical analysis

The associations between literacy scores and maternal, socio-demographic and infant factors at birth and their interactions were analysed using a two-level model, with a lower level ascribed to students and a higher one to schools (Rasbash, Steele, *et al*., 2004). Only variables that significantly (p<=0.05) predicted literacy score were retained for testing two-way interactions, and these included: POBW, POBL, POHC, Apgar score, first birth and term birth with marital status ("single"), teenage pregnancy, SEIFA Educational disadvantage (<10%) and, in the case of writing attainment, with SEIFA Disadvantage (<10%).

Ethical approval

The study was approved by the University of Western Australia Human Research Ethics Committee and Confidentiality of Health Information Committee of Western Australia.

Results

The average age of students at testing was 8.2 years and the reading scores ranged from -90 to 632, with a mean of 280 (SD=83), while the writing scores varied from -97 to 665, with a mean of 267 (SD=97). Negative values were due to adjustments of test scores to ensure comparability over time. The means of POBW, POBL, POHC and school socioeconomic status were 98.3% (SD=12.2), 100.5% (SD=4.3), 100.6% (SD=3.9) and 101.4% (SD=7.9), respectively. In order to improve the model fit, we included a squared term for POBW and squared and cubic terms for child age in models predicting both reading and writing scores.

In univariate analysis, higher mean scores in both reading and writing were obtained by female students and children born at term, those with Apgar score 8-10, being first birth, or born to mothers who were aged over 20 years old, married and from non-Caucasian backgrounds. Non-English speaking children had higher mean writing but lower mean reading scores (Table 6). The mean of reading and writing scores was also significantly associated with both SEIFA Indices.

In multilevel multivariate analysis, children born with a gestational age of 37 weeks or more had higher scores in both reading and writing compared to children born preterm (Table 7), irrespective of their neighbourhood socioeconomic background. Similarly, POHC and POBL were positively associated with literacy attainment, independently of socioeconomic and demographic factors. In contrast, the association between POBW and reading and writing attainments varied by the educational status of the residential area. While POBW was positively associated with reading attainment among children born to mothers residing in both educationally privileged (>10% SEIFA) and deprived (<10% SEIFA) areas, the association was much weaker for children born into educationally deprived areas (Figure 5). In the latter, increases in POBW were associated with only limited improvement in reading scores.

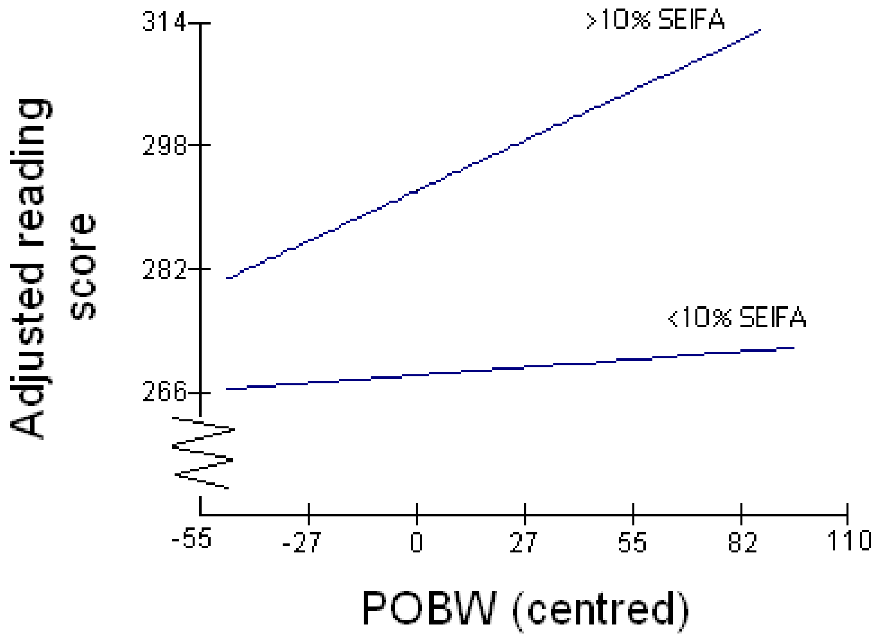
Table 6: Mean reading and writing scores, standard deviations and p-values for difference for all categorical variables in non-Aboriginal singletons born in Western Australia who undertook the Western Australian literacy test in 2000, 2002-2005.

Variable	Reading				Writing			
	N	Mean	SD*	p value†	N	Mean	SD*	p value
Gender								
Girl	26898	304	77		26696	281	94	
Boy	28635	289	79	<0.001	28544	242	99	<0.001
Gestational age (weeks)								
Preterm (<37)	2660	289	79		2645	246	103	
Term birth (37+)	52873	297	78	<0.001	52595	262	99	<0.001
Apgar score at 5 minutes								
<8 (lower)	1675	288	79		1665	243	104	
8-10 (higher)	53858	297	78	<0.001	53575	261	99	<0.001
Birth order								
First born	22546	305	79		22439	267	99	
Second born	19241	296	77		19160	264	97	
Third or fourth born	12389	285	77		12296	248	99	
Fifth born or more	1357	262	77	<0.001†	1345	224	104	<0.001
Mother's age (years)								
<20	2425	268	75		2418	218	100	
20-24	10574	279	76		10560	240	98	
25-29	18119	294	77		18026	260	98	
30-34	16617	308	78		16503	273	97	
35+	7798	312	79	<0.001	7733	278	96	<0.001
Mother's marital status								
Married/de facto	49661	299	78		49362	264	98	
Single/other	5872	277	78	<0.001	5878	232	100	<0.001
Mother's ethnicity								
Caucasian	51715	296	79		51435	259	99	
Non-Caucasian	3818	303	76	<0.001	3805	281	100	<0.001
Language background								
Non-English	5061	293	74		5030	265	97	
English	50472	297	79	<0.001	50210	260	99	<0.001
SEIFA* – index of relative socioeconomic disadvantage (quantiles)								
<10% (lowest)	5409	271	78		5372	229	101	
10-25% (low)	9167	283	78		9135	245	100	
25-50% (low middle)	15511	291	77		15438	255	98	
50-75% (high middle)	13881	301	76		13819	268	96	
75-90% (high)	7473	314	77		7406	282	95	
>90% (highest)	4092	332	74	<0.001	4070	298	91	<0.001
SEIFA* – index of education and occupation (quantiles)								
<10% (lowest)	6350	269	77		6297	228	102	
10-25% (low)	10102	281	77		10081	245	99	
25-50% (low middle)	14336	291	76		14251	255	98	
50-75% (high middle)	14524	303	76		14462	270	95	
75-90% (high)	6855	320	76		6801	287	93	
>90% (highest)	3366	342	75	<0.001	3348	303	91	<0.001
Total	55533				55240			

* SEIFA, Socioeconomic Indexes for Areas; SD, Standard deviation.

† Analysis of Variance (ANOVA) F-test for linear trend across categories or t-test for difference.

Figure 5: Adjusted effect of POBW on reading achievement for different SEIFA Education groups among non-Aboriginal singletons born in Western Australia who undertook the Western Australian reading test in 2000, 2002-2005.



The negative squared term suggested that POBW had a curvilinear association with literacy attainment and that increases beyond two standard deviations above (and below) the optimal birth weight were associated with a sharp decrease in literacy scores (Table 7). However, such increases beyond two standard deviations applied to very few children (3%), which perhaps explain why the squared term did not reach statistical significance in the interaction model.

There was a positive association between Apgar scores and literacy attainment, independent of maternal and area socio-demographic characteristics (Table 7). Birth order was strongly and negatively associated with literacy attainment, but its effect varied with mothers' marital status. Being first born was more positively associated with literacy attainment in children born to single mothers (Figure 6), narrowing the deficit in attainment of these children. The same positive association between being first born and writing attainment was also observed for children born to mothers residing in disadvantaged areas.

Table 7: Mutually adjusted parameter estimates (and 95% Confidence Intervals) from the fixed and random parts of multilevel multivariable analysis of reading and writing achievement among non-Aboriginal singletons born in Western Australia who undertook the Western Australian literacy test in 2000, 2002-2005.*

Variable	**Reading**		**Writing**	
	β*	**95% CI***	**β***	**95% CI***
Fixed effects				
Intercept	292	286, 297	227	220, 234
Gestational age (weeks) (vs preterm)				
Term birth (37+)	4.20	1.39, 7.03	9.07	5.54, 12.6
Percentage of optimal birth weight (POBW)				
POBW (centred)†	0.24	0.16, 0.31	0.24	0.15, 0.32
POBW(centred)^{squared}	-0.008	-0.010, -0.005	-0.009	-0.012, -0.006
Percentage of optimal birth length (POBL)				
POBL (centred)	0.35	0.17, 0.52	0.51	0.30, 0.73
Percentage of optimal head circumference (POHC)				
POHC (centred)	0.46	0.27, 0.64	0.37	0.14, 0.60
Apgar score (vs lower)				
Higher Apgar score (8-10)	4.74	1.24, 8.24	9.87	5.50, 14.2
Birth Order (vs second born)				
First	15.1	13.6, 16.5	10.6	8.74, 12.5
Third or fourth	-11.9	-13.5, -10.2	-15.9	-17.9, -13.8
Fifth or more	-30.0	-34.1, -26.0	-34.7	-39.7, -29.6
Mother's marital status (vs married)				
Single/other	-13.0	-16.3, -9.68	-19.7	-23.9, -15.6
Mother's age (years) (vs 25-29)				
<20	-22.5	-25.8, -19.3	-32.1	-36.2, -28.0
20-24	-11.3	-13.1, -9.54	-13.7	-15.9, -11.4
30-34	10.3	8.79, 11.9	9.20,	7.26, 11.1
35+	15.2	13.2, 17.2	14.8	12.2, 17.3
SEIFA* – index of relative socioeconomic disadvantage (quantiles) (vs SEIFA>10%)				
<10% (lowest)	-	-	-6.54	-10.6, -2.52
SEIFA – index of education and occupation (quantiles) (vs highest)				
<10% (lowest)	-23.8	-27.5, -20.2	-22.7	-27.7, -17.6
10-25% (low)	-17.9	-21.3, -14.4	-16.7	-21.0, -12.4
25-50% (low middle)	-13.9	-17.2, -10.6	-13.3	-17.4, -9.16
50-75% (high middle)	-11.0	-14.2, -7.82	-8.42	-12.4, -4.42
75-90% (high)	-6.80	-10.1, -3.54	-4.61	-8.69, -5.29
School socioeconomic status				
School socioeconomic status (centred)	1.93	1.17, 2.15	2.17	1.86, 2.49
Calendar Year (vs 2000)				
2002	-	-	15.4	13.1, 17.6
2003	-	-	9.72	7.48, 12.0
2004	-	-	10.6	8.29, 12.8
2005	-	-	6.93	4.15, 9.71
Gender (vs boy)				
Girl	14.6	13.4, 15.8	38.0	36.5, 39.4

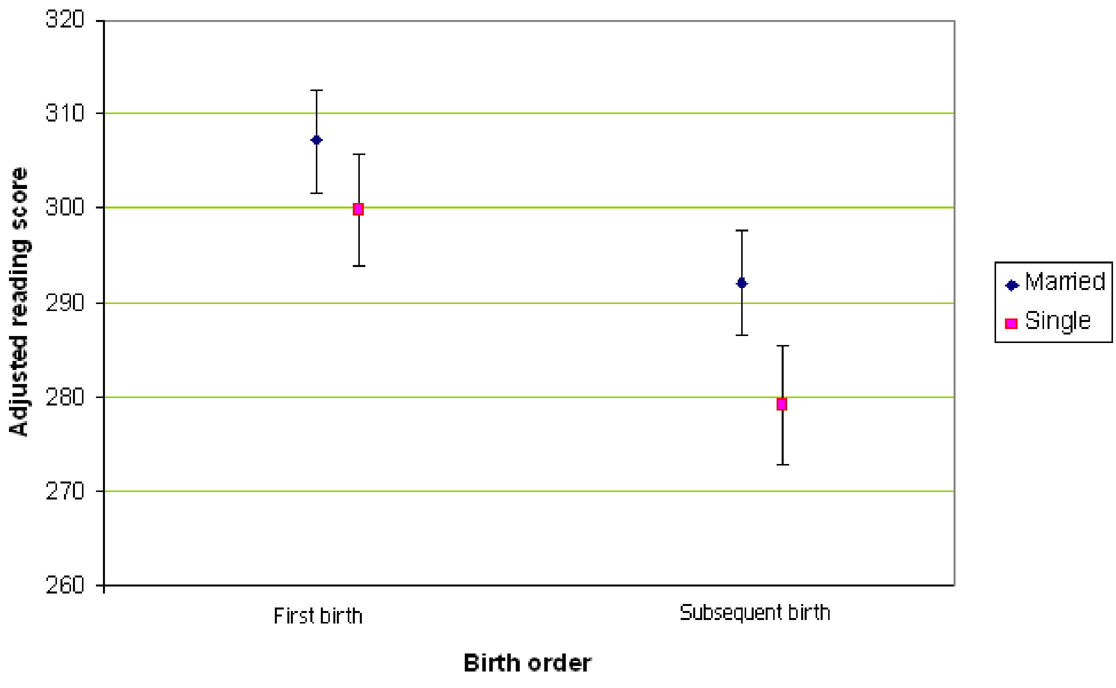
* β, parameter estimate; CI, confidence interval; SEIFA, Socioeconomic Indexes for Areas; All results were significant at the 5% confidence level.
† Centred around mean value.

Table 7: continued.

Variable	Reading		Writing	
	β*	95% CI*	β*	95% CI*
Fixed effects				
Child age (months)				
Age (centred)	1.97	1.75, 2.19	2.54	2.26, 2.82
Age (centred)^{squared}	-0.15	-0.19, -0.11	-0.20	-0.25, -0.15
Age (centred)^{cubic}	-0.021	-0.025, -0.017	-0.029	-0.034, -0.023
Language background (vs English)				
Non-English	-9.28	-11.7, -6.90	-6.60	-9.59, -3.60
Mother's ethnicity (vs Caucasian)				
Non-Caucasian	7.90	5.20, 10.6	21.3	17.9, 24.7
Interactions				
POBW x SEIFA Education (<10%)	-0.20	-0.35, 0.50	-	-
First born x Single mothers	5.64	1.49, 9.79	9.21	4.02, 14.4
First born x SEIFA Disadvantage (<10%)	-	-	5.59	0.40, 10.8
Random effects				
Remaining variance between schools	325	277, 374	742	637, 847
Remaining variance between students	5056	4996, 5116	7832	7739, 7925

* β, parameter estimate; CI, confidence interval; SEIFA, Socioeconomic Indexes for Areas; All results were significant at the 5% confidence level.

Figure 6: Adjusted effect of mother's marital status on reading achievement for first born or subsequently born among non-Aboriginal singletons born in Western Australia who undertook the Western Australian reading test in 2000, 2002-2005.



Discussion

We found a significant positive association between the literacy skills of children in grade 3 and both gestational age and head growth, independent of neighbourhood socioeconomic status. This was consistent with our previous study that examined numeracy outcomes using the same record-linked population data for Western Australian children (Malacova, Li, *et al*., 2008). This is also in agreement with two meta-analyses of studies that examined the association between preterm birth and later cognitive outcomes (Bhutta, Cleves, *et al*., 2002; Saigal & Doyle, 2008), and with reports of the association between head circumference at birth and subsequent IQ and reasoning skills (Ivanovic, Leiva, *et al*., 2004; Esposito, Horn, *et al*., 2008). Our results also show that skeletal growth is associated with improved literacy skills, irrespective of maternal socio-demographic characteristics and neighbourhood socioeconomic status. Thus a greater length of gestation and appropriate growth *in utero* appear to be beneficial for all children regardless of their place of residence and maternal socio-demographic characteristics.

However, some children do not reach optimum birth outcomes due to pathological and physiological factors. Smoking tobacco during pregnancy is the most easily preventable risk factor of adverse birth outcomes (Peltier, 2003), which influences, for example, infants' length of gestation *via* immunological and fetal infection pathways (AIHW, 2008). Data from a recent national survey indicate that smoking and drinking among 14-49 year-old women continues to be widespread across Australia, with about 1 in 6 women smoking daily (Greene & Solomon, 2005). Unfortunately, the population-based administrative data used for our analyses have no information on maternal smoking in pregnancy (before 1999). Hence we were unable to investigate the extent to which this known risk factor for poor birth outcomes and low school achievement played a role in the associations that we found. It will be possible to investigate the role of smoking in future cohorts using these linked data, when those born after 1999 enter school.

Literacy attainment was not linearly associated with increase in birth weight, with values beyond two standard deviations (above or below the optimal growth) being increasingly negatively associated with both reading and writing skills. This is similar to our previous findings for numeracy outcomes (Malacova, Li, *et al*., 2008) and another study reporting an association between high birth weight and more adverse neurocognitive outcomes in the long term (Leonard, Nassar, *et al*., 2008). Not all pathological determinants of intrauterine growth decrease fetal body mass. Maternal impaired glucose tolerance can expose the fetus to high levels of insulin, increasing the tendency to fat deposition without a similar increase in skeletal growth. The prevalence of maternal obesity and its attendant tendencies to glucose intolerance and type II diabetes (Heslehurst, Ells, *et al*., 2007) has increased markedly since the 1960s, particularly in socioeconomically disadvantaged communities (Odd, Rasmussen, *et al*., 2008). The curvilinear association with POBW (but not POBL or POHC) and the reduced association between POBW and literacy skills in disadvantaged areas suggests that the causes of increased birth weight may vary with neighbourhood socioeconomic status. In births to mothers living in socioeconomically advantaged areas, increased birth weight may be more likely to be associated with increased skeletal growth, while in socioeconomically disadvantaged areas it is more likely to be associated with excess adipose deposition. It is well-established that parental socioeconomic status, such as education, occupation and income, is strongly associated with offspring's educational attainment. What is much less well understood is how the socioeconomic status of a neighbourhood or a residential area influences children's educational achievement. Due to the lack of information about socioeconomic status at the individual or familial level (maternal and paternal), we were unable to investigate if our results would still hold once parental educational level was controlled for in the analysis. Previous studies have revealed that both the socioeconomic status of family and of neighbourhood have a distinct influence on cognitive outcomes. However, the relative contribution of each factor remains unresolved. While some studies have shown that the estimated neighbourhood effects tend to be generally smaller in comparison to maternal or paternal influences (McCulloch & Joshi, 2001), others have reported that the neighbourhood effect is the most influential with respect to changes in intelligence quotient (Breslau, Chilcoat, *et al*., 2001). Our results are not directly comparable to studies reporting association of birth weight alone and educational outcomes (Weindrich, Jennen-Stenmentz, *et al*., 2003; Black, Devereux, & Salvanes, 2005), as birth weight is dependent on both appropriate growth *in utero* and gestation length and aetiologies and outcomes differ between those born too small and those born too soon (Blair, Liu, *et al*., 2005). However, in line with previous evidence (Fransoo, Roos, *et al*., 2008; Brownell, Roos, *et al*., 2006; Edwards, 2005), we have shown that the socioeconomic statuses of school and areas were more important predictors of numeracy attainment than birth characteristics.

Higher Apgar scores at five minutes after birth were associated with better reading and writing skills in grade 3, as would be expected from the extensive literature showing better cognitive outcomes in this group (Peltier, 2003). This underscores the importance of monitoring Apgar scores, as low values may indicate suboptimal oxygenation immediately after birth, and also reflect more long standing neurological deficits.

The positive association of first birth with literacy skills is consistent with earlier evidence that first births have an educational advantage (Black, Devereux, & Salvanes, 2005; Booth & Kee, 2005). However, we found no support for a curvilinear relationship between birth order and literacy skills (as suggested by testing for a quadratic relationship) as documented in previous studies that made comparisons within families (as opposed to between families) (Iacovou, 2001). Consistent with results for numeracy skills, the relative advantage of being first born was greater in children born to single mothers. This may be due to relatively fewer resources available to subsequent children rather than reflecting a positive advantage for the first born child. This is consistent with the “resource-dilution hypothesis” which is supported by ample research on sibship and educational attainment in Western societies (Downey, 1995; Lu & Treiman, 2008). Single mothers would have less access to most resources that can assist parenting. For writing skills, we found that the relative advantage associated with being first born was more pronounced for children born to mothers residing in disadvantaged areas. As in the case of higher birth order children born to single mothers, children of higher birth order born to mothers residing in educationally deprived areas are likely to suffer similar disadvantages, which may have influenced the outcomes. This suggests that providing additional support such as targeted enriched programs for single parent families with more than one child may improve literacy results among disadvantaged groups of children.

This study, which underscores the importance of socioeconomic contextual factors in understanding the association between child birth characteristics and literacy skills, overcomes many of the limitations of previous studies. It is a large study using 5 years of administrative data from two State government departments. Thus, it ensures the inclusion of the total eligible population of non-Aboriginal grade 3 singletons attending government schools in Western Australia, thereby minimising participation bias. We found no indication of bias in terms of birth characteristics for those with missing essential information (of which 90% were due to missing SEIFA values). The use of a multilevel model accounted for the underlying correlation between children’s performance attending the same school by explicitly modelling variance between and within schools (Snijders & Bosker, 1999), and multivariate and interaction analyses allowed for the possibility of differential effects between socioeconomic strata. Finally, the study population was sufficiently large to allow separate analyses to be run for each year, confirming that the observed trends were consistent across years.

Of all 96,653 non-Aboriginal singletons born in Western Australia between 1990 and 1997 who also attended government schools (2000 and 2005), there were 39,355 children who were excluded on the basis of either being too old when the WALNA program started and hence they had no grade 3 scores, or because they had missing information on essential variables or having a grade 3 record in year 2001 (see Figure 4). Since we have no reason to believe that these children systematically differ from their peers and younger cohorts, it seems unlikely that their exclusion would have introduced a systematic bias in our study. However, children who had missing either reading (3.1%) or writing (3.6%) scores were those either absent during the testing week or exempted due to intellectual impairment, lack of competency in English or in special circumstances. Although these children were likely to have come from more disadvantaged backgrounds, their small proportion would have unlikely introduced any significant bias in our results.

In conclusion, our study of a large cohort of primary-school children suggests that term birth, high Apgar scores and optimal intrauterine head and skeletal growth are all independently associated with better literacy outcomes, while the association with greater intrauterine growth in terms of birth weight (for reading skills) and being first born vary with maternal (for both reading and writing skills) and neighbourhood characteristics (for writing skills). Further research is needed to explore the causal mechanisms underlying these associations. Our findings, along with our previous study on numeracy skills, highlight both the need to optimise intrauterine growth and birth outcomes and the importance of addressing neighbourhood socioeconomic disadvantage, which has a strong modifying influence on later educational achievement. Efforts to optimise health in pregnancy by provision of adequate pre-conception and antenatal care should be now both a health and an educational priority, as these are likely to improve outcomes especially among the most vulnerable children from disadvantaged neighbourhoods.

Chapter Six

Patterns of prior hospital admissions and academic achievement in Western Australian primary school children in grade 3

Abstract

Objective: To examine the possible relationships between the timing, frequency and length of prior hospital admissions and the risk of below benchmark performance in Western Australian school children.

Methods: This study used linked health and education data to analyse all singletons born in Western Australia between 1989 and 1997 and who participated in the Western Australian Literacy and Numeracy Assessment in grade 3 (mean age 8 years and 2 months) during 2000-2005. Children with known intellectual disability were excluded from the analysis.

Results: Both before and after school entry, children who were admitted more frequently or for longer cumulative periods of time were at a greater risk of not reaching the benchmarks in literacy and numeracy. However, the relationship between the longest stay in hospital and educational performance of Aboriginal children appeared to be U-shaped, with those with either very short or very long hospital admission achieving the best educational outcomes. For non-Aboriginal children, the detrimental effect of having a long hospital admission was significant only after school entry.

Conclusions: Prior frequent and prolonged cumulative duration of hospital admissions have adverse consequences for subsequent educational performance in primary school. However, while Aboriginal children have much lower educational performance and have more frequent hospital admissions, these admissions do not seem to be primarily responsible for the lower educational scores. Our findings suggest that to improve educational performance, particularly for Aboriginal children, it is essential to encourage school attendance and provide appropriate environments that are conducive to children's learning.

Introduction

There is continued concern about the number of children in Australia whose school performance falls short of the national benchmarks, with about 7% of all children and at least 20% of Aboriginal children failing to reach grade 3 benchmarks in literacy and numeracy skills in 2007 (MCEETYA, 2007). These benchmarks correspond to the nationally agreed minimum level of achievement that is deemed necessary for students to make successful progress at school. Failure to meet these benchmarks can lead to a poor educational outcomes trajectory through primary and secondary schooling. This in turn will have negative implications for further educational opportunities and employment prospects. To reduce the number of children failing to attain the minimum levels in literacy and numeracy skills, it is important to identify those who are at risk well before they start formal schooling, as research shows a compelling evidence that early interventions are more effective than later ones and have longer-lasting effects on cognitive development (Heckman, 2006; Karoly, Kilburn, & Cannon, 2005).

Frequent or prolonged admissions to hospital before school admission (as markers of overall poor health) may play an important role in children's school performance. Research in early child development stresses the adverse impact of poor health during early years on later health and wellbeing (Shonkoff & Phillips, 2000). However, episodes of illness at a later stage may also affect educational achievement through school absence, which has also been implicated in low educational performance (Zubrick, Silburn, *et al*., 2006). To our knowledge, no previous studies have investigated the influence of timing, frequency, and length of overall hospitalisation pattern on subsequent educational outcomes in Australia. Two major cross-sectional surveys in Western Australia have reported significant association between parent-reported poor physical health and below-age academic performance for non-Aboriginal children (Zubrick, Silburn, *et al*., 1997), but not for Aboriginal children (Zubrick, Silburn, *et al*., 2006). Internationally, there have been studies in Canada which found a significant association between health status within early childhood and academic outcomes (Fransoo, Roos, *et al*., 2008). This study used longitudinal administrative data and composite measures of health status to differentiate between major and minor health problems, but they did not distinguish between long hospitalisation due to a large number of admissions and that due to a single long hospital admission.

The aim of our study was to investigate the relationship between patterns of prior hospitalisation in early and mid childhood and educational outcomes in grade 3 for both Aboriginal and non-Aboriginal children in Western Australia. We hypothesised that:

1) Children who have been admitted to hospital are more likely to fail to reach literacy and numeracy benchmarks than children who have not been hospitalised;
2) The risk of not meeting educational benchmarks in grade 3 increases with cumulative duration, longer single admission and frequency of prior hospitalisation; and
3) Hospitalisations after school entry (6 years or older) have a greater effect on the risk of failing to meet benchmarks than admissions prior to school entry (5 years or younger).

Methods

Study population

This was a retrospective cohort study of all singletons born in Western Australia from 1989 to 1997 who participated in the WALNA in grade 3 during 2000-2005. The mean age at testing was 8 years and 2 months. We excluded all children with identified intellectual disability. Although such children are generally exempt from taking the WALNA test, those who do are less likely to meet benchmark standards. Furthermore, a study by Williams, Leonard, e*t al*. (2005) showed that children with intellectual disability have higher rates of hospitalisation.

Sources of data

We used de-identified administrative data linked across the Western Australian Government Health and Education Departments and the IDEA database. Health data included the Midwives Notifications System, Birth Registrations, Mental Health and Hospital Morbidity. Midwives Notifications and Birth Registrations data contained information on maternal and infant characteristics for all midwife-attended (99.5% of all births) and registered births. Mental Health data included all in- and public out-patient admissions associated with mental health problems for all mothers, including diagnostic information which was coded using the ICD 9 and 10 coding system. Hospital Morbidity data contained information on all in-patient hospital admissions at all public and private hospitals in Western Australia.

The IDEA database provided information on intellectual disability that is collected by the Disability Services Commission and the Western Australian Department of Education and Training. The education data included records on academic achievement in the WALNA in grade 3 from 2000 to 2005. All these datasets were linked by the Health Information Linkage Branch in Western Australia, using an established protocol (Kelman, Bass, & Holman, 2002). Only de-identified data were released to the researchers for analysis.

Measures

Numeracy and literacy skills

Numeracy was defined as the ability to effectively apply mathematics in everyday life, while reading attainment as the ability to read effectively. Both tests are administered by the Education Department to all children in grade 3 and consisted of multiple-choice, short-response and open-response questions. Ordinal numeracy and reading scores had been initially converted *via* a Rasch measurement model by the Education Department into an interval scale before they were converted into a binary variable, indicating whether or not the score met the benchmark performance using the Australian benchmarks for grade 3. The Western Australian cut-off score for the benchmark in grade 3 is 170 for reading and 245 for numeracy.

Child hospital admissions

The frequency of hospital admissions was examined for children of up to 8 years of age. Since only the month and year of birth were included in the linked data for privacy reasons, a child's date of birth was defined as day 15 of each month after assuming an even distribution of birthdays throughout each month. To ensure that only legitimate hospitalisations were counted, all normal birth-related admissions, which were defined as a hospital discharge within the first 17 days after birth, were excluded. In this way, a child born at the end of the month who was discharged two days later would have been included in the normal birth-related admission, whereas others may have had a hospital discharge prior to their assigned birth date. The length of stay in hospital was calculated as the sum of all days spent in hospital based on admission and discharge dates. Admissions with the same date for discharge were treated as a hospital stay of 1 day.

Child characteristics

Child characteristics included preterm birth, percentage of optimum birth weight, birth order, language background and age. Preterm birth was defined as a gestational age of less than 37 completed weeks. In accordance with an algorithm derived by Blair and colleagues, the percentage of optimal birth weight was constructed as a measure of appropriateness of intrauterine growth and was grouped as follows: 50-80; 80-87; 87-95; 95-105 (reference group); 105-115; 115-199 (Blair, Liu, *et al*., 2005). Birth order was categorised as having none, one, two, three, four, or at least five older siblings alive. Child language background was self reported at the time of testing, indicating English or non-English language background at home. Child age at the time of WALNA testing was coded as “less than 7 years and 7 months”, “from 7 years and 7 months to 8 years and 8 months” (reference group), “from 8 years and 9 months to 9 years and 3 months”, or “9 years and 3 months and older”.

Maternal and paternal characteristics

Maternal characteristics included marital status and age, place of birth, the socioeconomic status of area at time of child birth, mental health related hospital admissions and skill level. Marital status was coded as single (never married, widowed, divorced, or separated) or married. Maternal age was grouped as <20 years, 20-24 years, 25-29 years, or ≥30 years. A place of birth was assigned to one of the country groupings using the Standard Australian Classification of Countries 1998 Revision 2.03 (ABS, 2008c). Country groupings included Oceania and Antarctica, North-West Europe, Southern and Eastern Europe, North Africa and the Middle East, Asia (including both South-East and North-East Asia), Americas, or Sub-Saharan Africa. The level of socioeconomic deprivation of the mother’s residential area at birth was measured by the Index of Education and Occupation at the census collection district, as defined by the Australian Bureau of Statistics (ABS, 2008b). The socioeconomic deprivation values were divided into six groups based on Western Australian quantiles (ABS, 2006a), with the first category (lowest 10%) being the most disadvantaged. Missing values were included as an "unknown" category in the analysis. Mothers' mental health admissions were identified using ICD 10 diagnostic codes: ICD-10 'F00' - 'F99' and ICD-9 '290' - '319'. Maternal and paternal skill levels were defined using the Australian and New Zealand Standard Classification of Occupations and involved recoding of occupations and classifications from one to five based on both work experience and qualifications (ABS, 2006b). Missing or unclassifiable skill levels were included in the analysis as "unclassified".

School characteristics

School characteristics included the calendar year in which the WALNA test was taken, geographic location and the type of school. School geographic location was classified as metropolitan, provincial (non-remote), remote, and very remote using the Schools Geographic Location Classification, which is used by the Education Department. School types were coded as government and non-government (Independent and Catholic) schools.

Statistical analysis

Two-level logistic regression, with students nested within schools, was used to determine whether children who were hospitalised more frequently or for longer cumulative periods of time had a greater risk of falling below the reading and numeracy benchmarks. We also examined the effect of covariates on the odds ratio (OR) estimates and these included child age, birth order, appropriateness of intrauterine growth, preterm birth, gender, language background, maternal age, maternal marital status, maternal place of birth, maternal mental health, maternal and paternal skill level, socioeconomic disadvantage at the neighbourhood level, school geographic location and type of school. In addition, calendar year was included to adjust for cohort effects. Data were analysed using SAS (version 9.1) and MLwiN (version 2.02) statistical softwares.

Ethics approval

This study was approved by the University of Western Australia Human Ethics Committee, the Confidentiality of Health Information Committee and the Western Australian Aboriginal Human Information and Ethics Committee.

Results

There were 114,450 singletons born in Western Australian hospitals between 1989 and 1997 who participated in the WALNA in grade 3 over the period of 2000 to 2005. After exclusion of children with intellectual disability, there were 113,446 (99.1%) eligible children in total. Of those, 106,030 were non-Aboriginal children, of whom 102,890 completed the reading test and 103,537 the numeracy test. The remaining 7,416 children were of Aboriginal descent, of whom 6,282 participated in the reading test and 6,794 in the numeracy test.

Frequency of hospital admissions

Overall, 76% of Aboriginal and 58% of non-Aboriginal children who participated in the WALNA had at least one hospital admission by the age of 8 years. Aboriginal children were more frequently hospitalised with a mean of 2.3 hospital admissions before the age of 5 and a mean of 0.4 admissions between ages 6 and 8, compared to non-Aboriginal children who had a mean of 1.0 hospital admission before the age of 5 and 0.3 between ages 6 and 8.

The number of hospital admissions for children under the age of 5 ranged from 0 to 70, with a mean of 1.1 and median duration of 1.0 days, while admissions for children between 6-8 years ranged from 0 to 72, with a mean of 0.3 admissions and median of 0 days. Since between 50% and 90% of children who were hospitalised before the age of 5 and between 90% and 99% of children who were hospitalised between 6-8 years were admitted for 1-3 days, hospital admissions were categorised as none, 1-3, or ≥4. The risk of being below the reading or numeracy benchmarks increased with a greater number of hospital admissions (Table 8). Compared to children with no admission, those who had 1 to 3 admissions before the age of 5 and at least 4 admissions between ages 6 and 8 years had the highest odds of falling below the benchmark for reading attainment (OR 1.9, 95% CI 1.2-2.9) for non-Aboriginal children, and for numeracy (OR 3.2, 95% CI 1.4-7.0) for Aboriginal children. Children who had at least 4 admissions before and after the age of 5 had the highest odds of falling below the benchmark for numeracy: if they were non-Aboriginal (OR 1.9, 95% CI 1.3-2.7) and for reading attainment: if they were Aboriginal (OR 3.1, 95% CI 1.6-5.8), compared to those with no admission. After adjusting for child, maternal and school characteristics, the odds ratios associated with hospital admission attenuated but the majority of them remained statistically significant (Table 8).

Table 8: Odds ratios of being below reading and numeracy benchmark (2000-2005) for number of hospital admissions.

NON-ABORIGINAL CHILDREN									
Frequency of hospital admissions		**READING**				**NUMERACY**			
		Total	**Below benchmark**	**Univariate**	**Multivariate*** N=102423	**Total**	**Below benchmark**	**Univariate**	**Multivariate*** N=103065
≤ 5 years	**6-8 years**	**N = 102890**	**(%)**	**OR (95% CI)**	**OR (95% CI)**	**N = 103537**	**(%)**	**OR (95% CI)**	**OR (95% CI)**
None	None	42822	6.6	Ref	Ref	43082	7.7	Ref	Ref
None	1-3	7004	7.8	1.2 (1.1-1.3)	1.1 (1.0-1.3)	7018	9.1	1.2 (1.1-1.3)	1.2 (1.1-1.3)
None	≥4	83	7.2	1.1 (0.5-2.5)	0.9 (0.4-2.2)	83	10.8	1.5 (0.7-2.9)	1.7 (0.8-3.4)
1-3	None	37051	7.7	1.2 (1.1-1.2)	1.1 (1.1-1.2)	37275	8.9	1.2 (1.1-1.2)	1.2 (1.1-1.2)
1-3	1-3	9690	8.2	1.3 (1.2-1.4)	1.2 (1.1-1.3)	9774	10.2	1.3 (1.3-1.5)	1.3 (1.2-1.4)
1-3	≥4	208	12.5	1.9 (1.2-2.9)	1.7 (1.0-2.6)	212	11.8	1.5 (1.0-2.3)	1.4 (0.9-2.2)
≥4	None	3634	9.2	1.4 (1.2-1.5)	1.2 (1.0-1.3)	3657	12.5	1.6 (1.4-1.8)	1.4 (1.3-1.6)
≥4	1-3	2157	9.9	1.4 (1.2-1.7)	1.2 (1.1-1.5)	2192	13.5	1.7 (1.5-2.0)	1.6 (1.4-1.8)
≥4	≥4	241	11.2	1.6 (1.1-2.4)	1.4 (0.9-2.2)	244	14.8	1.9 (1.3-2.7)	1.6 (1.1-2.4)

ABORIGINAL CHILDREN									
Frequency of hospital admissions		**READING**				**NUMERACY**			
		Total	**Below benchmark**	**Univariate**	**Multivariate*** N=5926	**Total**	**Below benchmark**	**Univariate**	**Multivariate*** N=6509
≤ 5 years	**6-8 years**	**N = 6282**	**(%)**	**OR (95% CI)**	**OR (95% CI)**	**N = 6794**	**(%)**	**OR (95% CI)**	**OR (95% CI)**
None	None	1569	20.0	Ref	Ref	1636	26.1	Ref	Ref
None	1-3	325	24.9	1.4 (1.0-1.8)	1.5 (1.1-2.1)	333	27.0	1.0 (0.8-1.4)	1.0 (0.7-1.3)
None	≥4	3	66.7	6.8 (0.6-72.6)	30.0 (2.2-410.2)	3	0.0	-	-
1-3	None	2271	24.9	1.3 (1.1-1.5)	1.1 (0.9-1.3)	2448	31.5	1.2 (1.1-1.4)	1.0 (0.9-1.2)
1-3	1-3	786	27.0	1.4 (1.1-1.7)	1.3 (1.1-1.7)	840	36.2	1.4 (1.2-1.7)	1.2 (1.0-1.5)
1-3	≥4	21	28.6	1.7 (0.6-4.5)	1.4 (0.5-4.0)	26	53.9	3.2 (1.4-7.0)	2.8 (1.2-6.7)
≥4	None	759	35.4	1.9 (1.5-2.3)	1.3 (1.1-1.7)	866	47.0	2.1 (1.7-2.5)	1.5 (1.2-1.8)
≥4	1-3	506	41.9	2.5 (2.0-3.2)	2.0 (1.5-2.6)	590	49.0	2.2 (1.8-2.7)	1.4 (1.2-1.8)
≥4	≥4	42	45.2	3.1 (1.6-5.8)	1.9 (0.9-4.1)	52	51.9	2.9 (1.6-5.1)	2.5 (1.3-4.9)

* Adjusted for gender, gestational age, birth order, percentage of optimal birth weight, language background other than English, child age, marital status, maternal age, maternal skill level, maternal country of birth (for non-Aboriginal children), maternal socioeconomic status of area, maternal mental health, maternal and paternal skill level, calendar year, school geographical location and non-government type of school.

Further analyses showed that for non-Aboriginal children, maternal mental health, child gender, socioeconomic disadvantage, school geographical location, maternal age, cohort and paternal skill level contributed to the decrease in the odds ratios for reading attainment, while maternal mental health, child age and paternal skill level did so for numeracy attainment. Similar variables also contributed to the association between educational outcomes and hospital admission pattern for Aboriginal children, but there were some important differences. For example, maternal mental health admissions appeared to have a less important effect, while both maternal and paternal skill level contributed to the attenuation of the odds ratios for Aboriginal children.

Cumulative length of stay

Non-Aboriginal children spent a mean of 3.5 cumulative days in hospital before the age of 5 and 0.6 days between 6 and 8 years, compared to Aboriginal children who stayed a mean of 11 days before the age of 5 and 1.2 days at ages 6 to 8. Children who stayed at least 7 days in hospital before and after the age of 5 were at the highest odds of falling below the benchmark for reading (OR 2.0, 95% CI 1.5-2.6) and for numeracy (OR 2.1, 95% CI 1.7-2.7) in non-Aboriginal children and for numeracy in Aboriginal children (OR 2.8, 95% CI 2.1-3.9) (Table 9). In comparison, Aboriginal children were at the highest odds of falling below the reading benchmark either if they stayed at least 7 days in hospital before the age of 5 and 1-6 days between ages 6 to 8 (OR 2.3, 95% CI 1.8-2.8) or if they had no hospital admission before the age of 5 and stayed at least 7 days in hospital after the age of 5 (OR 2.3, 95% CI 1.0-5.5) compared to those with no admission at all. After adjusting for the major confounding factors, the ORs decreased but the majority remained statistically significant. In addition, the OR for reading attainment among Aboriginal children with no hospital admission before the age of 5 and who stayed at least 7 days in hospital between ages 6-8 increased after adjustment for the confounders.

The distribution of cumulative hospital stay is positively skewed, with small numbers of children having significantly longer hospital stays, with a maximum of 932 days (and a mean of 4.0 and median of 1) for children before the age of 5 and a maximum of 191 days (and a mean of 0.6 and median of 0) for those between 6-8 years. As we set a cut-off of 7 days' hospitalisation (corresponding to one week) for the cumulative length of stay, it was important to ascertain if the results thus far would also hold true for much longer hospital stays. We therefore repeated the same analysis for a cumulative length of stay of at least 14 days (two weeks).

Table 9: Odds ratios of being below reading and numeracy benchmark (2000-2005) for cumulative length of stay in hospital.

NON-ABORIGINAL CHILDREN									
Cumulative length of stay (in days)		**READING**				**NUMERACY**			
≤ 5 years	**6-8 years**	**Total N = 102890**	**Below benchmark (%)**	**Univariate OR (95% CI)**	**Multivariate* N=102423 OR (95% CI)**	**Total N = 103537**	**Below benchmark (%)**	**Univariate OR (95% CI)**	**Multivariate* N=103065 OR (95% CI)**
None	None	42822	6.6	Ref	Ref	43082	7.7	Ref	Ref
None	≤6	6737	7.8	1.2 (1.1-1.3)	1.2 (1.0-1.3)	6748	9.1	1.2 (1.1-1.3)	1.2 (1.1-1.3)
None	≥7	350	7.1	1.1 (0.7-1.6)	0.9 (0.6-1.4)	353	10.2	1.3 (0.9-1.8)	1.3 (0.9-1.8)
≤6	None	28948	7.6	1.2 (1.1-1.2)	1.1 (1.0-1.2)	29110	8.9	1.2 (1.1-1.2)	1.1 (1.1-1.2)
≤6	≤6	7387	8.0	1.2 (1.1-1.3)	1.2 (1.1-1.3)	7441	10.0	1.3 (1.2-1.4)	1.3 (1.2-1.4)
≤6	≥7	417	9.6	1.4 (1.0-1.9)	1.2 (0.9-1.8)	422	11.4	1.4 (1.0-1.9)	1.3 (0.9-1.7)
≥7	None	11737	8.3	1.3 (1.2-1.4)	1.2 (1.1-1.3)	11822	10.1	1.3 (1.3-1.4)	1.3 (1.2-1.4)
≥7	≤6	3981	9.0	1.4 (1.2-1.5)	1.2 (1.1-1.4)	4039	11.7	1.5 (1.4-1.7)	1.5 (1.3-1.6)
≥7	≥7	511	13.5	2.0 (1.5-2.6)	1.7 (1.3-2.3)	520	16.5	2.1 (1.7-2.7)	1.9 (1.5-2.4)
ABORIGINAL CHILDREN									
Cumulative length of stay (in days)		**READING**				**NUMERACY**			
≤ 5 years	**6-8 years**	**Total N = 6282**	**Below benchmark (%)**	**Univariate OR (95% CI)**	**Multivariate* N=5926 OR (95% CI)**	**Total N = 6794**	**Below benchmark (%)**	**Univariate OR (95% CI)**	**Multivariate* N=6509 OR (95% CI)**
None	None	1569	20.0	Ref	Ref	1636	26.1	Ref	Ref
None	≤6	304	24.3	1.3 (1.0-1.8)	1.5 (1.0-2.0)	313	27.5	1.1 (0.8-1.4)	1.0 (0.8-1.4)
None	≥7	24	37.5	2.3 (1.0-5.5)	2.8 (1.1-7.6)	23	17.4	0.6 (0.2-1.7)	0.5 (0.1-1.5)
≤6	None	1544	22.7	1.2 (1.0-1.4)	1.0 (0.8-1.2)	1638	28.3	1.1 (1.0-1.3)	1.0 (0.8-1.2)
≤6	≤6	509	25.0	1.3 (1.0 1.6)	1.3 (1.0-1.7)	535	32.0	1.2 (1.0-1.5)	1.1 (0.9-1.4)
≤6	≥7	61	31.2	1.8 (1.0-3.3)	1.3 (0.6-2.5)	65	38.5	1.5 (0.9-2.6)	1.2 (0.7-2.1)
≥7	None	1486	32.6	1.7 (1.4-2.1)	1.3 (1.0-1.6)	1676	42.7	1.8 (1.5-2.1)	1.3 (1.1-1.6)
≥7	≤6	617	38.7	2.3 (1.8-2.8)	1.8 (1.4-2.3)	710	46.6	2.0 (1.7-2.5)	1.4 (1.2-1.8)
≥7	≥7	168	38.1	2.2 (1.5-3.1)	1.5 (0.9-2.4)	198	54.0	2.8 (2.1-3.9)	1.9 (1.3-2.7)

* Adjusted for gender, gestational age, birth order, percentage of optimal birth weight, language background other than English, child age, marital status, maternal age, maternal skill level, maternal country of birth (for non-Aboriginal children), maternal socioeconomic status of area, maternal mental health, maternal and paternal skill level, calendar year, school geographical location and non-government type of school.

The results were similar to those for 7-day admissions, except that non-Aboriginal children were at the highest risk of being below the reading benchmark if they stayed less than 14 days before the age of 5 and at least 14 days in hospital between ages 6-8. Since a cumulative length of stay is a function of the number of hospital admissions, we have further investigated whether a single variable, such as the average length of stay, may explain a greater proportion of the variance than frequency of admissions alone. However, we found that frequency of hospital admissions provided a better fit of the model and explained a larger proportion of the variance than the average length of stay.

Longest length of stay

A further exploration of the hospitalisation pattern using continuous measures of educational outcomes revealed some differences between Aboriginal and non-Aboriginal children. For Aboriginal children only, the relationship between the single longest admission and the mean test scores was not linear but U-shaped (Figure 7). This pattern was most pronounced during early childhood, before school entry.

Non-Aboriginal children whose single longest admission lasted 1 to 2 weeks (7 to 13 consecutive days) between ages 6 and 8 had lower mean test scores than those hospitalised for the same length before the age of 5 (Figure 8). This relationship was found to be much weaker for Aboriginal children.

Discussion

Our results confirm that children who are admitted to hospital more frequently or for longer cumulative periods of time are generally at a greater risk of not reaching the minimum standards in literacy and numeracy. However, the relationship between hospitalisation and educational outcomes of Aboriginal children may differ from that of non-Aboriginal children.

The risk of failing to attain benchmark performance increased with a greater number of admissions and longer cumulative days spent in hospital, and the relative effect tended to be greater for Aboriginal children who already had a 3-fold increased risk of failing the benchmark in the absence of any hospitalisation.

Figure 7: Longest hospital admission and the mean reading score for Aboriginal children.

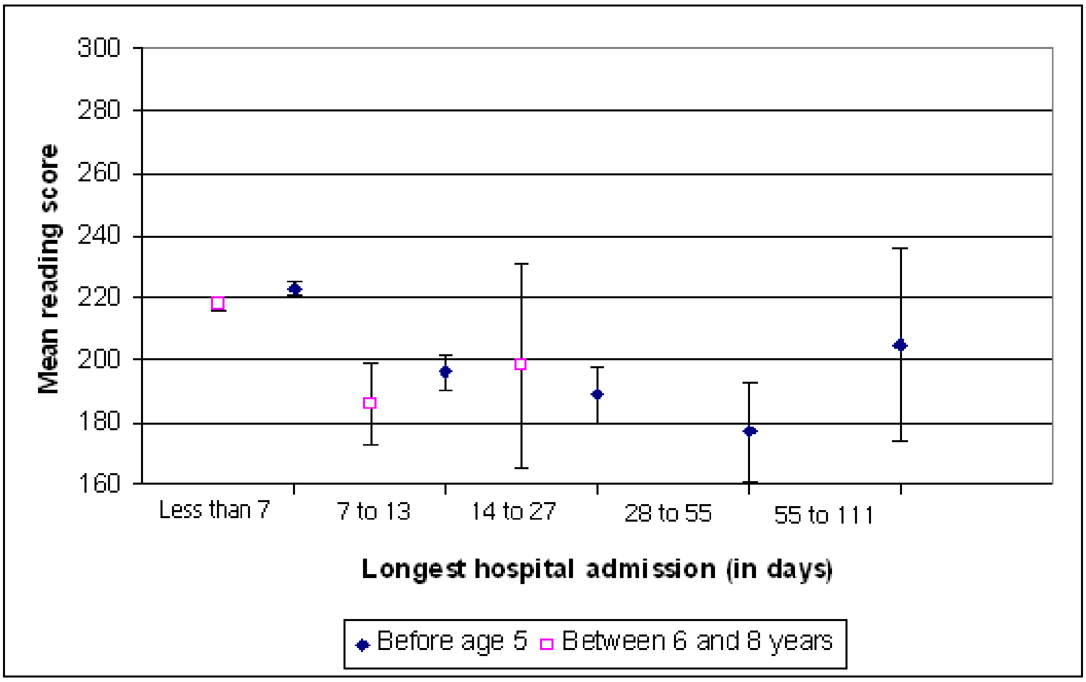
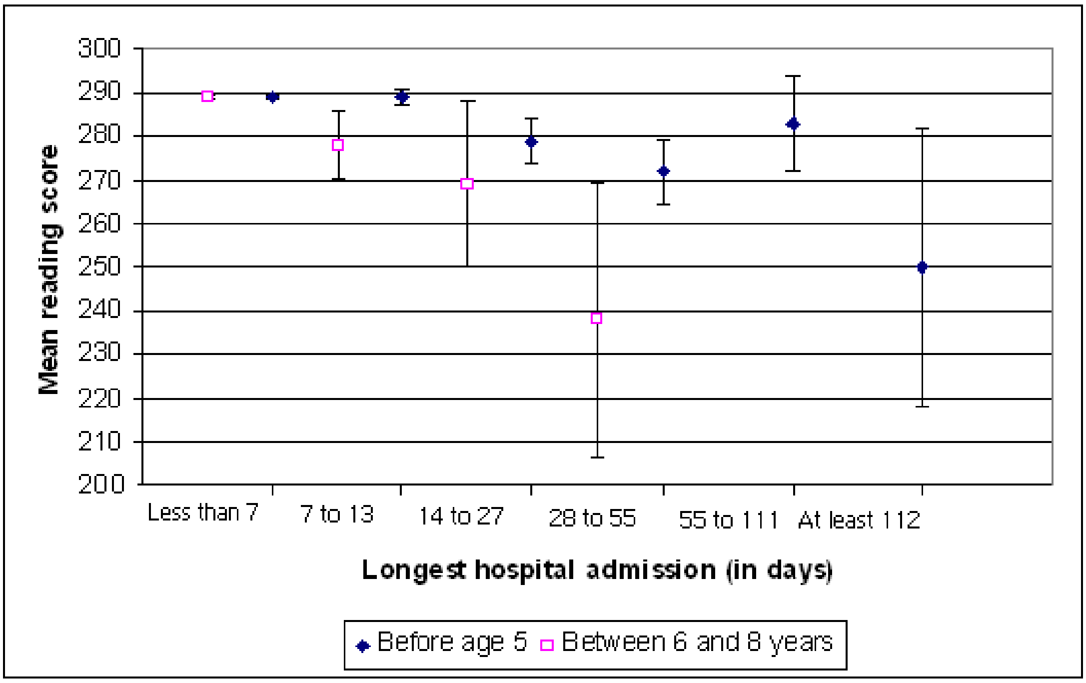


Figure 8: Longest hospital admission and the mean reading score for non-Aboriginal children.[1]



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[1] There were fewer data points for 6-8 year olds due to fewer hospital admissions in this age group.

This is consistent with the findings of previous studies which investigated the association between overall health status and school performance and progress of children born in Winnipeg (Fransoo, Roos, *et al.*, 2008), and with a review of studies reporting a stronger association between physical health and school performance for children from disadvantaged background (Powney, Malcolm, & Lowden, 2000).

Analysis of the relationship between the single longest admission and educational outcomes showed that non-Aboriginal children aged <6 years required the longest single admission of >14 days before mean WALNA score decreased. After 5 years of age, and for Aboriginal children both before and after age 5 years, the longest admission of >7 days was sufficient to lower the mean WALNA scores. One unexpected finding is that the relationship between mean WALNA score and duration of longest single admission for Aboriginal children appeared to be curvilinear (U-shaped). For this group, mean WALNA score initially decreased with increasing duration of longest hospital stay, but with very long hospital stays, mean WALNA scores improved. One possible explanation for this phenomenon could be that while in hospital children receive obligatory educational opportunities within a protected environment which is conducive to learning. This finding is in contrast to recent research by Zubrick and colleagues (2006) who reported no statistically significant association between lower levels of general health and educational performance of Aboriginal children. In their survey, however, the longest stay in hospital was not considered, some serious and chronic conditions could not be included in their analysis due to small numbers and, in contrast to hospitalisation records, the general health of the child was based on retrospective parental reporting and was thus prone to recall bias.

Our finding that the longest hospitalisation of one-to-two-weeks had a greater negative effect on the mean performance test scores of non-Aboriginal children than shorter hospitalisations occurring only after school entry suggests that absence from school is a possible mediator of the effect of hospital admissions on educational outcomes for non-Aboriginal children. This difference was significantly reduced in Aboriginal children whose mean WALNA scores were decreased by admissions of one-to-two-weeks occurring both before and after school entry. This is not inconsistent with recent findings from a Western Australian survey (Zubrick, Silburn, *et al.*, 2006) which cited school absence as a key risk factor for the lower educational performance of Aboriginal children, because they considered all Aboriginal children, 46% of whom were absent from primary school for at least 10 days each year, compared to 4% of non-Aboriginal children. Most of these school absences in Aboriginal children could not be due to hospitalisations since in our study only 19% of 6-8 year olds were hospitalised. We had no information on children's school absences other than those due to hospitalisation, and thus could not investigate the extent to which other reasons for school absence affected educational outcomes. Our research supports previous findings of Fransoo, Roos, et al. (2008) by showing that socioeconomic factors are also far stronger predictors of educational attainment than patterns of hospitalisation.

This study was only possible because de-identified administrative data relating to the total population of Western Australia could be linked across education and health sectors. Linking population data for education and health has enabled a longitudinal investigation of prior hospital patterns in primary school children, with minimal selection bias. We considered three different measures of hospitalisation (frequency of admissions, cumulative length of stay and the single longest stay in hospital), accounted for the correlation of students within the same school and adjusted for a wide range of confounding factors.

However, these linked administrative data were limited to those children who had been identified in both health and education databases and for whom all the information required for the record linkage across the two jurisdictions was available. It should be acknowledged that certain groups of children may have been under-represented. Children from disadvantaged backgrounds and those who experienced hospitalisations were more likely to be absent from school over the testing period. Also, children who recently arrived in Australia and who are lacking English competency are generally exempt from taking the test and these children are likely to have lower educational attainments.

Nonetheless, the above described findings highlight the adverse effects of frequent or longer hospitalisations during childhood on later school achievement and indicate the need for providing additional support to prevent hospitalised children from falling behind their peers in academic achievement. However, the discovery of a U-shaped relationship with duration of longest hospital stay for Aboriginal children suggests that, consistent with Zubrick, Silburn, *et al*. (2006), encouraging school attendance and providing an environment conducive to learning is urgently required for all Aboriginal children. Further work will explore whether specific groups of diseases are associated with the elevated risk of academic failure, with a particular focus on preventable but common diseases.

Chapter Seven

Prior hospital admissions for physical health problems and early academic achievement

Abstract

Objective: To investigate whether children hospitalised for either respiratory, non-respiratory infections, non-infectious respiratory diseases, or external causes (such as injury and poisoning) are more likely to fail to attain benchmark standards in literacy and numeracy in grade 3 than children who had no hospital admissions, and if so, whether the effect was dependent on frequency of hospital admissions.

Methods: Using linked health and education data, a retrospective cohort study was conducted for all singleton born children in Western Australia between 1989 and 1997 and who participated in the Western Australian Literacy and Numeracy Assessment in grade 3 over the period of 2000-2005. Logistic multilevel models were used to calculate the odds ratios of below benchmark performance associated with hospital admissions for physical health conditions. Children identified with intellectual disability were excluded.

Results: Children with hospital admissions for physical health problems were at a greater risk of not reaching the benchmark standards in literacy and numeracy in grade 3 compared to those with no admission. Aboriginal children were least likely to reach the benchmark standards if they had at least four admissions for infectious diseases, whereas non-Aboriginal children displayed the highest risk of not meeting the benchmark if they had at least four admissions for non-respiratory infections.

Conclusions: These findings provide evidence for the link between hospital admissions for non-infectious respiratory diseases, respiratory infections, non-respiratory infections, and external causes, their frequency and subsequent educational outcomes. This suggests that to improve educational outcomes as well as to promote child physical health, strategies are needed to prevent the diseases for which children are hospitalised. These should include a combination of universal prevention strategies for common diseases with targeted interventions for less common conditions that are strongly associated with low educational attainment.

Introduction

In Australia, children under the age of 14 are most commonly hospitalised for respiratory conditions (17%), followed by injury and poisoning (13%), gastrointestinal conditions (10%), perinatal conditions (10%) and infectious diseases (7%) (AIHW, 2008). This health burden is disproportionately borne by Aboriginal children. A health survey in Western Australia revealed that Aboriginal children are predominantly admitted to hospital for respiratory illnesses (especially asthma), followed by infections (mainly otitis media) and injury and poisoning (Silva, Palandri, *et al*., 1999), despite most of these being preventable conditions.

Poor child health can have many consequences for further development. In particular, the possible impact on neurocognitive development and academic achievement is of significant concern. Children with major or recurrent health problems are likely to have less energy, concentration and motivation compared with healthy children, and to be more frequently absent from school, thus further adding to their educational disadvantage. Aboriginal children have not only the highest burden of disease but also the lowest educational outcomes (Zubrick, Silburn, *et al*., 2006). To overcome this multiple disadvantage, the MCEETYA Taskforce on Indigenous Education (2001) in Australia has identified nine key health issues that are faced by Aboriginal children during early childhood and which are thought to contribute to low participation rates and poor performances in school. These potential health barriers to school achievement included, among other conditions, childhood injuries and chronic ear and respiratory infections (MCEETYA, 2001).

However, despite the need for investigating the link between major health problems in childhood and academic achievement, these assumptions have not been subjected to rigorous scrutiny, and the scientific evidence in support of these assumptions has been scant due to lack of suitable data. Earlier studies reported that children with frequent ear infections (recurrent otitis media) had an increased likelihood of repeating first grade (Byrd & Weitzman, 1994), and that children who experienced frequent otitis media under the age of 3 years, though not above 3 years, were more likely to have low academic achievement (Luotonen, Uhari, *et al*., 1998). In contrast, more recent Australian research found no significant association between ear infections and the academic performance of Aboriginal children (Zubrick, Silburn, *et al*., 2006), even though Aboriginal children generally experience more acute and chronic types of otitis media than non-Aboriginal children (SCRGSP, 2005). Given the importance of health on children's development, the possibility of health being a barrier to academic achievement and based on the findings reported in Chapter 6, there is an urgent need to determine whether certain types of diseases may be contributing to the risk of low academic achievement and thus acting as a potential barrier to education, using population-based data and objective indicators of significant physical health problems.

Using Western Australian administrative data linked across government departments, the aim of this study was to compare the rate at which children hospitalised for respiratory and non-respiratory infections, non-infectious respiratory diseases, or external causes (such as injury and poisoning) fail to attain benchmark standards in literacy and numeracy in grade 3, with the rate in children who had not been hospitalised at all.

Methods

Study population

We conducted a retrospective cohort study of all children who were born singletons in Western Australia between 1989 and 1997 and who participated in the WALNA in grade 3 over the period of 2000-2005. All children with intellectual disability were excluded as they are exempt from taking the WALNA test and the few with intellectual disability who nonetheless do are less likely to meet the benchmark standards. Since these children have also been found to have higher hospitalisation rates (Williams, Leonard, *et al*., 2005), intellectual disability is likely to confound the association between physical health problems and failing to meet the benchmark standards.

Sources of data

De-identified linked data which have been routinely collected by the Western Australian Health and Education Government departments was used. Health data consisted of the Midwives Notifications System, Birth Registrations, Hospital Morbidity and Mental Health datasets. Midwives Notifications and Birth Registrations data contained information on maternal and infant characteristics for all births which were either attended by a midwife (99.5% of all births) or registered. Hospital Morbidity data contained information on all in-patient hospital admissions at both public and private hospitals, including diagnostic information coded according to the ICD coding system. Mental Health data included information on all maternal mental health in- and out-patient admissions. Education data provided individual achievement scores in the WALNA in grade 3 (for children typically aged 8 years) from 2000 to 2005. All the above datasets were linked for this study by the Health Information Linkage Branch in Western Australia, using probabilistic matching (Kelman, Bass, & Holman, 2002).

Indicators of numeracy and literacy skills

The WALNA test measures the ability to effectively read and apply mathematics in everyday life. The ordinal numeracy and reading scores had been initially converted *via* a Rasch measurement model by the Education Department into an interval scale. These achievement scores were then classified as meeting or failing to meet the Western Australian benchmark performance for grade 3.

Child hospital admissions for physical health problems

The focus was on four major groups of physical health conditions which were identified in the literature as both common and potentially preventable. The frequency of hospital admissions was examined for children up to 8 years of age. Since only the month and year of birth were included in the linked data for privacy reasons, a child's date of birth was defined as the 15^{th} day of the month (the middle of the month). For the calculation of the total number of hospital admissions up to the age of 8, all normal birth-related admissions were excluded, provided they were not related to infections, non-infectious respiratory diseases or external causes. For the cumulative length of stay in hospital, admissions with the same date for discharge were treated as a hospital stay of 1 day.

Child, parental and school characteristics as possible confounders

Previous research (including the one described in Chapters 4-6) has shown that the following child, maternal and school characteristics influence school achievement. Since these factors may also be associated with hospital admissions for physical health, they are likely to be confounders and hence they need to be adjusted for in this analysis. Child characteristics included presence or absence of preterm birth, percentage of optimum birth weight (Blair, Liu, *et al.*, 2005), birth order, language background, and age. Maternal characteristics included marital status and age, place of birth, the socioeconomic status of area at time of child birth, mental health related hospital admissions and skill level. In addition, maternal and paternal skill level was used as a proxy measure of parental socioeconomic status at child birth. School characteristics included calendar year in which the WALNA test was taken, geographic location and the type of school which the child attended (government or non-government schools). All of these variables were categorised in the same way as described in Chapter 6.

Statistical analysis

Two-level (children nested within schools) logistic regression was used to investigate the pattern of hospital admissions for non-infectious respiratory, infectious respiratory and other infectious diseases, as well as admissions for external causes and their risk of not meeting the benchmark in literacy and numeracy. Adjustments were made for child age, birth order, intrauterine growth, preterm birth, gender, language background, maternal age, maternal marital status, maternal place of birth, maternal mental health, maternal and paternal skill level, educational disadvantage of the residential area, school geographic location, type of school and calendar year. Data were analysed using SAS (version 9.1) and MLwiN (version 2.02).

Ethics approval

This study was approved by the University of Western Australia Human Ethics Committee, the Confidentiality of Health Information Committee and the Western Australian Aboriginal Human Information and Ethics Committee.

Results

Of 114,450 singletons born in Western Australian hospitals between 1989 and 1997 who participated in the WALNA in grade 3 over the period of 2000 to 2005, there were 113,446

(99.1%) children who had no known intellectual disability. Of those, 106,030 were non-Aboriginal children, of whom 102,890 completed the reading test and 103,537 the numeracy test. The remaining 7,416 children were of Aboriginal descent: of them 6,282 participated in the reading test and 6,794 in the numeracy test.

The most common reason for hospitalisation was respiratory infections (54% of Aboriginal and 40% of non-Aboriginal children), followed by non-respiratory infections in Aboriginal children (41%) and external causes in non-Aboriginal children (23%) (Table 10). Admissions of non-Aboriginal children for respiratory infections were predominantly related to middle ear and mastoid and other chronic upper respiratory infections, while for Aboriginal children the majority of admissions for respiratory infections were related to middle ear and mastoid, other acute lower respiratory diseases, influenza and pneumonia. Admissions of Aboriginal children for non-respiratory infections were predominantly related to intestinal infectious diseases, pediculosis, acariasis and other infestations. In comparison, admissions of non-Aboriginal children for non-respiratory infections were predominantly related to intestinal infectious diseases and other viral diseases.

All children with hospital admissions for non-infectious respiratory diseases, respiratory infections, non-respiratory infections, or external causes had an elevated risk of failing to attain the benchmark standards in reading and numeracy (Table 11). After adjusting for confounding variables, both Aboriginal and non-Aboriginal children who had been admitted up to three times for these conditions had a similar increase in the odds of not meeting the benchmark standards (for non-Aboriginal children: OR=1.2 for reading, and OR=1.2 to 1.3 for numeracy; and a slightly wider range for Aboriginal children: OR=1.2 to 1.5 for reading, and OR=1.1 to 1.3 for numeracy). Although children with 4 or more hospital admissions were generally at a higher risk of failing to meet the benchmark standards than children with less frequent admissions, after adjusting for child, family and school characteristics, the odds associated with non-infectious respiratory diseases decreased much more for frequent than for less frequent admissions.

Table 10: Number of children who had one or more hospital admissions with a specific type of diagnosis**.**

Label	**ICD10 codes**	**Types of main diseases**	**Major groups of diseases**	**All children***	**Non-Aboriginal**	**Aboriginal**
				N (%)	**N (%)**	**N (%)**
NIR1	J40-J44.9, J47	Chronic lower respiratory diseases	Non-infectious respiratory diseases	6873 (10.2)	6060 (9.8)	813 (14.4)
NIR2	J45-J45.9, J46	Asthma				
IR1	B00-B09	Viral infections characterised by skin and mucous membrane lesions	Respiratory infections	27997 (41.5)	24954 (40.4)	3043 (54.0)
IR2	J00-J06	Acute upper respiratory infections				
IR3	J30-J39	Other diseases of upper respiratory infections (chronic)				
IR4	J20-J22	Other acute lower respiratory diseases				
IR5	J09-J18.9	Influenza and pneumonia				
IR6	H65-H75	Diseases of middle ear and mastoid				
OI1	B15-B19.9	Viral hepatitis	Non-respiratory infections	11678 (17.3)	9384 (15.2)	2294 (40.7)
OI2	B25-B34.9	Other viral diseases				
OI3	B85-B89	Pediculosis, acariasis and other infestations				
OI4	A00-A09	Intestinal infectious diseases				
E1	S00-T98	Injury, poisoning and certain other consequences of external causes	External causes	15980 (23.7)	14192 (23.0)	1788 (31.7)
E2	V01-Y98	External causes of morbidity and mortality				
-	-	Any diseases other than the above	Other diseases	22208 (33.0)	21175 (34.3)	1037 (18.4)
TOTAL		Any hospital admission (% of all children)		67395 (59.4)	61763 (58.3)	5632 (75.9)
		No hospital admission (% of all children)		46051 (40.6)	44267 (41.7)	1784 (24.1)

*Children could have been in more than one category, thus counting more than once.

In non-Aboriginal children, admissions for non-respiratory infections had the largest absolute and relative effect. Children with at least 4 admissions had the largest odds of falling below the benchmark in reading (OR 2.0, 95% CI 1.0-4.0) and in numeracy (OR 2.3, 95% CI 1.3-4.2), compared with those with no hospital admission at all (Table 11). After adjusting for the confounding variables, the odds of not reaching the benchmark for reading attainment increased marginally, while that for numeracy attainment decreased slightly but remained statistically significant.

In Aboriginal children, frequent hospital admissions (at least 4) for non-respiratory infections were associated with the greatest relative risk of falling below the benchmark in reading (OR 2.6, 95% CI 1.8-3.7) and numeracy (OR 2.9, 95% CI 2.1-4.0), compared with those with no admission at all (Table 11). This was closely followed by frequent hospital admissions (at least 4) for respiratory infections which were associated with an OR of 2.3 of falling below the benchmark in reading (95% CI 1.8-3.0) and an OR of 2.7 in numeracy (95% CI 2.1-3.5), compared with those with no admission at all. After adjustment, these relative risks decreased but remained statistically significant.

Of the non-respiratory infections, admissions for viral hepatitis, pediculosis, acariasis and other infestations were associated with the lowest mean score for reading attainment (Figure 9). However, in non-Aboriginal children, this represented only a very small number of children, with the majority of children with admissions related to non-respiratory infections being hospitalised for either other viral diseases or intestinal infectious diseases. While admissions for viral hepatitis were also rare in Aboriginal children, admissions for pediculosis, acariasis and other infestations were more prevalent.

Of the Aboriginal children hospitalised for respiratory infections, those who were admitted for influenza and pneumonia had a lower mean score for reading attainment, whereas those who were hospitalised for chronic upper respiratory infections had the highest mean score for reading attainment (Figure 9).

Table 11: Odds ratios of falling below reading and numeracy benchmark (2000-2005) for hospital admissions by diagnosis.

NON-ABORIGINAL CHILDREN		READING				NUMERACY			
Admission for	Number	Total N = 102890	Below benchmark (%)	Univariate OR (95% CI)	Multivariate* N=102423 OR (95% CI)	Total N = 103537	Below benchmark (%)	Univariate OR (95% CI)	Multivariate* N=103065 OR (95% CI)
No hospitalisation	-	43090	6.6	Ref	Ref	43352	7.8	Ref	Ref
Non-infectious respiratory	None**	53998	7.7	1.2 (1.1-1.2)	1.1 (1.1-1.2)	54311	9.4	1.2 (1.2-1.3)	1.2 (1.1-1.3)
	1-3	5253	9.6	1.4 (1.3-1.6)	1.2 (1.1-1.3)	5306	10.7	1.3 (1.2-1.5)	1.3 (1.1-1.4)
	≥4	549	9.3	1.3 (0.9-1.7)	0.9 (0.7-1.3)	568	12.2	1.5 (1.1-1.9)	1.3 (1.0-1.7)
Respiratory infections	None**	35697	7.6	1.2 (1.1-1.2)	1.1 (1.0-1.2)	35905	9.0	1.2 (1.1-1.2)	1.2 (1.1-1.2)
	1-3	22824	8.4	1.3 (1.2-1.3)	1.2 (1.1-1.3)	22990	10.0	1.3 (1.2-1.4)	1.2 (1.2-1.3)
	≥4	1279	9.9	1.4 (1.2-1.7)	1.2 (1.0-1.5)	1290	14.3	1.8 (1.5-2.1)	1.6 (1.6-1.9)
Non-respiratory infections	None**	50752	7.9	1.2 (1.2-1.3)	1.1 (1.1-1.2)	51058	9.2	1.2 (1.2-1.3)	1.2 (1.1-1.2)
	1-3	8971	7.9	1.1 (1.1-1.3)	1.2 (1.0-1.3)	9048	11.1	1.4 (1.3-1.5)	1.3 (1.2-1.4)
	≥4	77	14.3	2.0 (1.0-4.0)	2.1 (1.0-4.3)	79	19.0	2.3 (1.3-4.2)	1.9 (1.0-3.4)
External causes	None**	46082	7.6	1.2 (1.1-1.2)	1.1 (1.0-1.2)	46391	9.2	1.2 (1.1-1.2)	1.2 (1.1-1.2)
	1-3	13596	8.9	1.3 (1.3-1.4)	1.2 (1.1-1.3)	13670	10.7	1.4 (1.3-1.5)	1.3 (1.2-1.4)
	≥4	122	8.2	1.0 (0.5-2.1)	0.8 (0.4-1.6)	124	15.3	1.8 (1.1-2.9)	1.5 (0.9-2.5)

* Adjusted for gender, gestational age, birth order, percentage of optimal birth weight, language background other than English, child age, marital status, maternal age, maternal skill level, maternal country of birth (for non-Aboriginal children), maternal socioeconomic status of area, maternal mental health, maternal and paternal skill level, calendar year, school geographical location and non-government type of school.

** "None" includes children with no admission for this disease category, but they may have admissions for other disease categories.

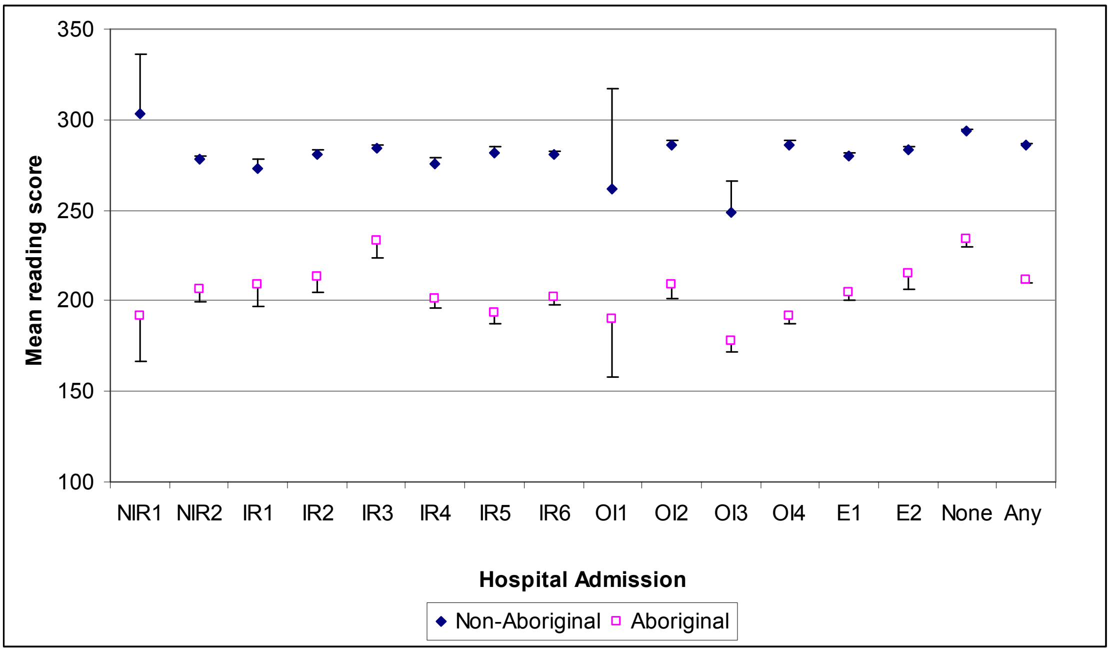
Table 11: continued.

ABORIGINAL CHILDREN		READING				NUMERACY			
Admission for	Number	Total N = 6282	Below benchmark (%)	Univariate OR (95% CI)	Multivariate* N=5926 OR (95% CI)	Total N = 6794	Below benchmark (%)	Univariate OR (95% CI)	Multivariate* N=6509 OR (95% CI)
No hospitalisation	-	1609	20.4	Ref	Ref	1677	26.1	Ref	Ref
Non-infectious respiratory	None**	4009	28.3	1.4 (1.2-1.7)	1.2 (1.0-1.4)	4387	37.1	1.5 (1.3-1.7)	1.2 (1.0-1.4)
	1-3	552	33.0	1.8 (1.4-2.2)	1.5 (1.1-1.9)	606	36.0	1.4 (1.1-1.7)	1.1 (0.8-1.3)
	≥4	112	33.9	1.8 (1.5-2.7)	1.2 (0.7-2.0)	124	37.1	1.5 (1.0-2.3)	1.1 (0.7-1.6)
Respiratory infections	None**	2208	27.1	1.4 (1.2-1.6)	1.2 (1.0-1.5)	2373	32.5	1.3 (1.1-1.5)	1.0 (0.9-1.2)
	1-3	2154	29.2	1.5 (1.3-1.8)	1.2 (1.0-1.5)	2379	38.8	1.6 (1.4-1.8)	1.2 (1.1-1.4)
	≥4	311	40.5	2.3 (1.8-3.0)	1.6 (1.2-2.2)	365	54.0	2.7 (2.1-3.5)	1.7 (1.3-2.3)
Non-respiratory infections	None**	2852	25.6	1.3 (1.1-1.5)	1.2 (1.0-1.4)	3069	31.5	1.2 (1.1-1.4)	1.1 (0.9-1.2)
	1-3	1672	33.3	1.7 (1.5-2.1)	1.4 (1.1-1.6)	1858	43.8	1.9 (1.6-2.2)	1.3 (1.1-1.6)
	≥4	149	45.6	2.6 (1.8-3.7)	1.6 (1.0-2.4)	190	57.9	2.9 (2.1-4.0)	1.6 (1.1-2.4)
External causes	None**	3246	27.9	1.4 (1.2-1.6)	1.2 (1.0-1.4)	3521	35.8	1.4 (1.2-1.6)	1.1 (1.0-1.3)
	1-3	1405	31.3	1.6 (1.4-1.9)	1.4 (1.2-1.7)	1568	39.4	1.6 (1.4-1.9)	1.2 (1.0-1.4)
	≥4	22	31.8	1.7 (0.7-4.5)	0.9 (0.3-2.7)	28	53.6	2.8 (1.3-6.2)	1.4 (0.6-3.6)

* Adjusted for gender, gestational age, birth order, percentage of optimal birth weight, language background other than English, child age, marital status, maternal age, maternal skill level, maternal country of birth (for non-Aboriginal children), maternal socioeconomic status of area, maternal mental health, maternal and paternal skill level, calendar year, school geographical location and non-government type of school.

** "None" includes children with no admission for this disease category, but they may have admissions for other disease categories.

Figure 9: Mean reading achievement by hospital diagnosis for Aboriginal and non-Aboriginal children. *



*For different disease groups refer to Table 10
None – no hospital admission; Any – any hospital admission

Discussion

This population-based study found that children who were hospitalised at least once for non-infectious respiratory diseases, respiratory infections, non-respiratory infections, or external causes had a greater risk of not reaching the benchmark standards in reading and numeracy compared to those with no hospital admission. This association was stronger for hospital admissions related to infections and for numeracy attainment.

Previously, it was found that frequent hospital admissions for all conditions were associated with poorer educational attainment in both Aboriginal and non-Aboriginal children (Chapter 6), suggesting an association between overall poor health and academic attainment. This study extends these findings and provides evidence supporting the discussion paper released by the MCEETYA (2001), which identified chronic ear and respiratory infections and childhood injuries as major health barriers preventing Aboriginal children from academic success. The results presented in this paper confirm that children, and especially Aboriginal children, admitted for injuries and infections had an elevated risk of not meeting the benchmark standards. The highest risk was associated with admissions for non-respiratory infections, and in particular, for infestations which are commonly associated with poverty and deprivation. Interestingly, after adjustment for major confounding variables, the relative (but not absolute) risk of failing to meet the benchmark standards associated with admissions for infections and external causes was comparable between Aboriginal and non-Aboriginal children. In line with previous evidence (Fransoo, Roos, *et al.*, 2008), we have found that socioeconomic factors were stronger predictors of educational attainment than any particular type of hospital admission.

Previous research based on cross-sectional surveys of Western Australian children found no association between ear and respiratory infections and academic performance in Aboriginal children (Zubrick, Silburn, *et al.*, 2006), and between having asthma and academic performance in non-Aboriginal children (Zubrick, Silburn, *et al.*, 1997). However, in those studies children with a specific disease were compared to children without that disease, many of whom may had a variety of other (including more serious) diseases. In this study it was possible to overcome this limitation by comparing children hospitalised for a particular type of disease with those who had no hospitalisation at all. This study also differs from previous research in that it analyses hospital admissions which are often robust indicators of more serious conditions.

To evaluate the full impact of diseases on academic achievement, it is important to consider not only the risks of the presence of these diseases but also how many and how often children are being affected by them (Frohlich & Potvin, 2008). While such risks may be large, when only a few children are exposed to a disease, the overall effect is likely to be small, whereas even a moderate risk if it occurs in large numbers of children may have a strong impact on school achievement in a population. The findings reported in this paper showed that despite non-respiratory infections having the largest adverse effect on academic achievement, the majority of non-Aboriginal children are not affected by such infections, but rather by respiratory infections and external causes.

The strength of this study is that de-identified administrative data were used, collected for the total population of Western Australia and linked across education and health sectors. The use of linked population-based databases from both education and health enabled the investigation of the relationship between prior hospitalisations for distinct groups of diseases and the subsequent risk of failing to meet the benchmark for reading and numeracy, with no recall and minimal selection bias. It was thus possible to compare children with hospital admission to those who had no hospitalisation, thereby enabling a more accurate comparison than has been previously possible. This study also accounted for the similarities in outcomes of students attending the same school and adjusted for a wide range of confounding factors, including parental socioeconomic status.

While there are several advantages of using routinely collected data, there are also some limitations. In particular, this research was limited to those children who had been identified in both health and education databases. As the WALNA test was administered each year over a one-week period, children who were absent during that week, although a very small minority, were not included in our analysis and these children tended to come from more disadvantaged backgrounds. Children lacking English competency (when not their first language) also would have been under-represented, since they are generally exempt from taking the test. Despite these limitations, this study has contributed to new knowledge about the link between early child health and school achievement.

In conclusion, children with frequent hospitalisation for non-infectious respiratory diseases, respiratory infections, non-respiratory infections, or external causes were at a greater risk of not reaching the benchmark standards in grade 3 compared to their peers who had no hospital admission. Although infections as well as external causes of morbidity and non-infectious respiratory diseases are often preventable, they continue to contribute a large burden of disease, especially in Aboriginal children. If the aim is to prevent children from suffering from these diseases and, at the same time, to improve their educational opportunities, it is important to have in place universal public health approaches for common diseases and targeted strategies for less common diseases that are associated with greater risks of poor academic achievement. Future research should investigate the extent to which different types of diseases may mediate the association between socioeconomic disadvantage and the academic performance of children.

Chapter Eight

Contact with mental health services before and after school entry and performance in standardised school testing

Abstract

Objective: To examine the association between contact with mental health services (before school entry or after school entry) and the risk of below benchmark performance in literacy and numeracy.

Methods: A retrospective cohort study of all singletons born in Western Australia between 1989 and 1997 who participated in the Western Australian Literacy and Numeracy Assessment in grade 3 during 2000-2005. Logistic multilevel models were used to calculate the odds ratios of failing to meet the benchmark standards associated with mental disorder and its interrelationship with intellectual disability.

Results: All children with medical contact for a mental health problem before school entry continued to have mental health-related problems after school entry. Children admitted with a primary diagnosis of a physical condition and a secondary mental health diagnosis were most likely to fall below the benchmarks in literacy and numeracy. Unexpectedly, Aboriginal children who were admitted for a mental health problem as the primary diagnosis were more likely to achieve these benchmarks than those without a mental health diagnosis. Children had the greatest relative risk of falling below the benchmark if mental health problems were diagnosed before the age of five. Those with intellectual

disability in addition to admission for mental health problems were at highest risk of failing to achieve benchmark standards.

Conclusions: Mental health problems recognised before the age of five are associated with worse academic performance than those recognised after school entry and all children with mental health problems before school entry continued to have mental health problems. To improve children's educational performance better treatments need to be provided to these children and their families at the earliest possible opportunity, particularly for children suffering from chronic mental conditions such as anxiety and depression.

Introduction

Across developed countries, an increasing number of children are affected by mental or behavioural problems (Li, McMurray, & Stanley, 2008; WHO, 2003). Recent official statistics show that nearly 20% of children are diagnosed with mental health problems before the age of 16 and current trends are projected to continue (WHO, 2001). This increase is partly related to changes in lifestyles over the past few decades, which have diminished the capacity of families to respond to the needs of their children (Li, McMurray, & Stanley, 2008). The World Health Organisation identified non-psychotic mental disorders as one of the main contributors to the global health burden, with the most common diagnoses being depression, anxiety and substance abuse disorder (WHO, 2001). Across Australia, about 14% of children (4-17 years) have been reported in national surveys conducted 1997-1998 to have either mental or behavioural problems (CAGNAP, 2008), which are now the second leading cause of disease among Australian children (0-14 years) today (Begg, Vos, *et al*., 2007).

Of the many consequences of mental or behavioural problems, their effects upon developmental outcomes, such as diminished cognitive ability and academic performance, have received increasing attention. Cross-sectional surveys of Western Australian children have shown that students diagnosed with mental or behavioural problems were significantly more likely to have below-age performance compared to their peers without such problems (Zubrick, Silburn, *et al*., 1997, 2006). Children with mental health problems were also less likely to graduate from high school (McLeod & Kaiser, 2004). However, due to the cross-sectional nature of the previous studies the authors could not determine whether mental health problems were the cause or the consequences of poor academic performance (Zubrick, Silburn, *et al*., 1997, 2006). Another limitation of previous research is that a disproportionate number of socially disadvantaged children were included in the analysis (McLeod & Kaiser, 2004). Therefore, the nature of the association between academic performance and mental health problems remains unclear.

Using Western Australian population-based linked data, the first aim of this study was to determine whether or not contact with mental health services increases the risk of not meeting the literacy and numeracy benchmarks. The second aim was to investigate whether children who had a first contact with mental health services before the school entry (age of 5) were at a greater risk of not meeting these benchmarks than those whose first contact occurred after school entry. The third aim was to determine whether children who were admitted with mental health problems diagnosed as secondary diagnosis were more likely to have lower educational performance than those admitted to hospital primarily for mental health problems. In addition, it was aimed to explore the inter-relationship between mental health admission, intellectual disability and educational performance.

Methods

Study population

A retrospective cohort study was conducted of all singletons born in Western Australia from 1989 to 1997 who participated in the WALNA in grade 3 during 2000-2005. This study consists of two parts. In the first part of this study, all children with intellectual disability were excluded. While such children are generally exempt from taking the WALNA tests, those that do are less likely to meet benchmark standards. A recent study showed that children with intellectual disability have higher rates of hospitalisation as a result of comorbidities associated with intellectual disability (Williams, Leonard, *et al*., 2005). In the second part of the analysis, all children who participated in the WALNA tests were considered, including children with intellectual disability.

Sources of data

De-identified administrative data linked across several Western Australian agencies was used. Health data included the Midwives Notifications System, Birth Registrations, and Mental Health Information System. Midwives Notifications and Birth Registrations data contained information on maternal and infant characteristics for all midwife-attended (99.5% of all births) and registered births. Mental Health data included information on all in- and public out-patient contact with mental health services for children, mothers and fathers.

The IDEA dataset contained information on children born in Western Australia who have been identified with intellectual disability by the Disability Services Commission or the Department of Education and Training. The education data included individual standardised achievement scores in grade 3 (for children aged 8 years) from 2000 to 2005. All these datasets were linked by the Health Information Linkage Branch in Western Australia, using established protocols (Kelman, Bass, & Holman, 2002). Only de-identified data were released to the researchers for analysis.

Measures

Numeracy and literacy skills

Numeracy was defined as the ability to effectively apply mathematics in every day life, while reading attainment as the ability to read effectively. The original scores of numeracy and reading had been standardised by converting them into an interval scale *via* a Rasch measurement model at the Education Department. These standardised achievement scores were then converted into a binary variable, indicating whether or not the score met the Western Australian benchmark performance for grade 3.

Child mental health and intellectual disability

The effect of child mental disorder was defined as having an admission for a mental health disorder or a mental health comorbidity recorded when admitted for another illness. Mental health-related hospital admissions were identified for children up to the age of 8, using the following ICD diagnostic codes: ICD-10 'F00' - 'F99' and ICD-9 '290' - '319'. Information was obtained from all in- and public out-patient hospital admissions. The indicator of intellectual disability was obtained from the IDEA dataset, with intellectual disability being defined as IQ <70 (Leonard, Petterson, *et al*., 2004).

Child, family and school characteristics

Child characteristics included in the analysis were whether the birth was preterm, POBW, birth order, language background and age at the time of testing. Preterm birth was defined as a gestational age of less than 37 completed weeks. The POBW was constructed in accordance with an algorithm derived by Blair and colleagues and has been categorised as follows: 50-80, 80-87, 87-95, 95-105 (reference group), 105-115, or 115-199 (Blair, Liu, *et al.*, 2005). Birth order was categorised as having none, one, two, three, four, five or more older siblings alive. Child language background was self reported at the time of testing, indicating English or non-English language background at home. Child age at the time of WALNA testing was coded as "less than 7 years and 7 months", "from 7 years and 7 months to 8 years and 8 months" (reference group), "from 8 years and 9 months to 9 years and 3 months", or "from 9 years and 3 months". The level of socioeconomic disadvantage of the child's residential area at birth was determined using the Index of Education and Occupation at the census collection district, as defined by the Australian Bureau of Statistics (ABS, 2008b). This measure was obtained from the linkage between Midwives Notifications and Census information. The neighbourhood socioeconomic disadvantage values were divided into six categories (ABS, 2006a), with the first category (lowest 10%) being the most disadvantaged. Missing values were included as "unknown".

Family characteristics included in the analysis were maternal age, maternal marital status, maternal place of birth, maternal and paternal skill level and mental health related hospital admission (ever). Maternal age was grouped as <20 years, 20-24 years, 25-29 years, or ≥30 years. Mother's marital status was coded as single (never married, widowed, divorced, or separated) or married. A maternal place of birth was recoded to country groupings using the Standard Australian Classification of Countries 1998 Revision 2.03 (ABS, 2008c). Country groupings included Oceania and Antarctica, North-West Europe, Southern and Eastern Europe, North Africa and the Middle East, Asia, Americas, or Sub-Saharan Africa. Maternal and paternal skill levels were recoded from occupational groups and classified from one to five based on both work experience and qualifications (ABS, 2006b), while missing or unclassifiable skill levels were included in the analysis as "unclassified". Maternal and paternal mental health admissions were identified using the same ICD diagnostic codes as for children's mental health contact.

School characteristics included the calendar year in which the test was taken, geographic location and the type of school. School geographic location was classified as metropolitan, provincial (non-remote), remote, or very remote zone using the MCEETYA Schools Geographic Location Classification. School types were coded as government or non-government (Independent and Catholic) schools.

Statistical analysis

The effect of child mental disorder and its interrelationship with intellectual disability on the risk of falling below the reading and numeracy benchmark were investigated using two-level multivariate logistic regression models (children nested within schools). These models accounted for the effect of the following covariates: child age, birth order, intrauterine growth, preterm birth, gender, language background, maternal age, maternal marital status, maternal place of birth, parental skill level and mental health related admission, educational disadvantage of neighbourhood, school geographic location, type of school and calendar year (to adjust for cohort effects). All analyses were carried out using SAS (version 9.1) and MLwiN (version 2.02).

Ethics approval

This study was approved by the University of Western Australia Human Ethics Committee, the Confidentiality of Health Information Committee and the Western Australian Aboriginal Human Information and Ethics Committee.

Results

Between 1989 and 1997, there were 114,450 singletons who were born in Western Australia and who participated in the WALNA in grade 3 during 2000 and 2005. After excluding those with intellectual disability (0.9%), there were 113,446 children in total. Of those, 106,030 were non-Aboriginal children, of whom 102,890 completed the reading test and 103,537 the numeracy test. The remaining 7,416 children were of Aboriginal descent, of these 6,282 participated in the reading test and 6,794 in the numeracy test.

Children with mental disorders

Children who had a contact with mental health services were more likely to be born to single or teenage mothers and to parents who themselves had mental health-related problems or were of the lowest or unclassified skill level. These children were more likely to be boys, have poor intrauterine growth, be born prematurely or live in a deprived area.

The prevalence of the most common mental health problems for which children were admitted to hospital (both as primary and secondary diagnoses) were similar for Aboriginal and non-Aboriginal children (Table 12). Severe stress and adjustment disorders were the most common primary diagnoses (with 22.6% among non-Aboriginal and 19.3% among

Aboriginal children), whereas specific developmental disorders of speech and language were the most common secondary diagnoses (with 25.5% among non-Aboriginal and 48.6% among Aboriginal children).

Children who were admitted with a primary non-mental health diagnosis but also had a mental health problem as a secondary diagnosis were most likely to fail the literacy and numeracy benchmark standards (Table 13). However, unexpectedly, Aboriginal children who had a primary diagnosis of mental health disorder were less likely to fall below those benchmarks than those who had no recognised mental health problems. Stratification by parental mental health status did not change this pattern for Aboriginal children; however, children were least likely to fail to meet the benchmark standards when neither of their parents had a mental health-related diagnosis (Table 13).

An analysis of continuous scores was consistent with the above finding, showing that Aboriginal children with a primary mental health related diagnosis achieved a higher mean WALNA score than those without recognised mental health problems (Figure 10). A similar pattern was found for numeracy attainment.

Figure 10: Type of mental health admission and an associated mean reading achievement score of Aboriginal and non-Aboriginal children (born 1989-1997) without known intellectual disability.

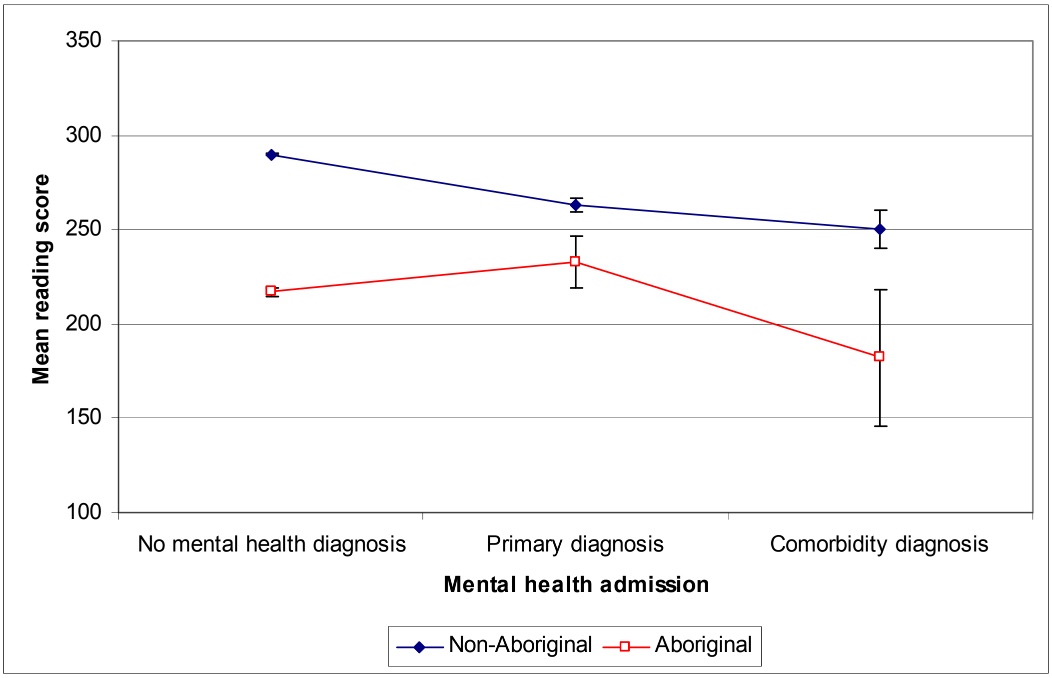


Table 12: Three most common mental health problems in children (0-8 years) born 1989-1997 in Western Australia, with no known intellectual disability.

ICD 10 codes	Description	NON-ABORIGINAL		ABORIGINAL	
		PRIMARY DIAGNOSIS	COMORBIDITY	PRIMARY DIAGNOSIS	COMORBIDITY
F43	Reaction to severe stress, and adjustment disorders	Most common (22.6%)	(1.0%)	Most common (19.3%)	(0%)
F80	Specific developmental disorders of speech and language	(1.4%)	Most common (25.5%)	(1.9%)	Most common (48.6%)
F84	Pervasive developmental disorders (autism)	(1.2%)	Second most common (16.0%)	(0%)	(0%)
F90	Hyperkinetic disorders, including Attention Deficit	(6.1%)	Third most common (14.4%)	Third most common (8.7%)	Second most common (24.3%)
F91	Conduct disorders	Third most common (9.4%)	(10.5%)	Second most common (11.2%)	Third most common (8.1%)
F93	Emotional disorders with onset specific to childhood (mostly unspecified and other childhood emotional disorders, such as identity and overanxious disorders; sibling rivalry disorder and separation anxiety disorder of childhood)	Second most common (14.6%)	(3.6%)	(6.2%)	(0%)

Table 13: Mental health related admissions in parents and their children and child benchmark performance.

Child with mental health condition	Parents with mental health related admission	NON-ABORIGINAL CHILDREN				ABORIGINAL CHILDREN			
		READING		NUMERACY		READING		NUMERACY	
		Total N	Below benchmark (%)	Total N	Below benchmark (%)	Total N	Below benchmark (%)	Total N	Below benchmark (%)
No admission	**None**	76727	6.5	77141	7.7	3003	23.9	3194	30.8
	One parent	21018	9.2	21169	10.9	2457	29.6	2690	36.9
	Both parents	2553	12.8	2585	14.7	663	29.1	727	40.6
	Total	100298	7.2	100895	8.6	6123	26.8	6611	34.4
Primary diagnosis	**None**	1081	13.5	1106	14.9	36	19.4	41	14.6
	One parent	1066	14.3	1079	17.6	81	22.2	91	34.1
	Both parents	205	16.6	211	20.4	17	29.4	21	38.1
	Total	2352	14.1	2396	16.6	134	22.4	153	29.4
Comorbidity	**None**	134	14.9	134	19.4	7	42.9	9	55.6
	One parent	85	12.9	90	24.4	15	46.7	17	35.3
	Both parents	21	23.8	22	31.8	<5	100.0	<5	25.0
	Total	240	15.0	246	22.4	25	52.0	30	40.0

All children with a mental health diagnosis before the age of 5 continued to receive care for mental heath problems after school entry. Both Aboriginal and non-Aboriginal children were equally likely to be admitted for mental health problems (2.5%), with the majority of first time admissions occurring between 6-8 years (after school entry) (Table 14). After adjusting for maternal age, marital status, parental skill level and parental mental health problems, child gender, child age at testing, POBW, gestational age, non-English language background, birth order, socioeconomic deprivation, geographical location of school, calendar year and type of school, non-Aboriginal children had the highest odds of falling below the benchmark if they had received care for mental health problems before the age of 5 (OR 1.7, 95% CI 1.2-2.4 for reading, and OR 2.0, 95% CI 1.5-2.7 for numeracy attainment), compared to those who had not (Table 14). Aboriginal children who received care for a mental health problem before the age of 5 had slightly lower odds of falling below the benchmark (OR 1.6, 95% CI 0.6-4.2 for reading, and OR 1.1, 95% CI 0.4-2.6 for numeracy). Odds ratios for Aboriginal children did not reach statistical significance; however, numbers were small and confidence intervals wide (Table 14).

Children with mental disorder and intellectual disability

An analysis including all children taking the WALNA tests revealed that Aboriginal children were far more likely to be diagnosed with intellectual disability than non-Aboriginal children. There were twice as many Aboriginal children diagnosed with intellectual disability as those diagnosed with mental health problems only. The odds of failing the benchmark standards for Aboriginal children with intellectual disability was three times higher than for those with mental health problems alone (Table 15). After adjustment, Aboriginal children had the highest relative risk of falling below the benchmark if they had both a mental health admission and known intellectual disability (OR 7.5, 95% CI 0.4-127.0 for reading, and OR 20.3, 95% CI 1.9-220.6 for numeracy), compared to those with no mental health admission or intellectual disability (Table 15). However, the associated confidence intervals were very wide due to small case numbers.

Table 14: Risk of below benchmark performance in reading and numeracy at age 8 years by age of mental health admissions in children born 1989-1997 without known intellectual disability.*

NON-ABORIGINAL CHILDREN							
Mental disorder		**READING**			**NUMERACY**		
before 5 y.	**6-8 years**	**Number of children N= 102890 N**	**Below Benchmark N=102890 N (%)**	**Multivariate** N=102423 OR (95% CI**	**Number of children N= 103537 N**	**Below Benchmark N=103537 N (%)**	**Multivariate** N=103065 OR (95% CI)**
No	No	100298	7316 (7.3)	Ref	100895	8766 (8.7)	Ref
No	Yes	1781	243 (13.6)	1.4 (1.2-1.8)	1821	286 (15.7)	1.5 (1.2-1.8)
Yes	Yes	811	130 (16.0)	1.7 (1.2-2.4)	821	165 (20.1)	2.0 (1.5-2.7)
ABORIGINAL CHILDREN							
Mental disorder		**READING**			**NUMERACY**		
before 5 y.	**6-8 years**	**Number of children N= 6282 N**	**Below Benchmark N=6282 N (%)**	**Multivariate** N=5926 OR (95% CI)**	**Number of children N= 6794 N**	**Below Benchmark N=6794 N (%)**	**Multivariate** N=6509 OR (95% CI)**
No	No	6123	1636 (26.7)	Ref	6611	2269 (34.3)	Ref
No	Yes	91	23 (25.3)	0.8 (0.3-2.0)	103	32 (31.1)	1.2 (0.6-2.5)
Yes	Yes	68	25 (36.8)	1.6 (0.6-4.2)	80	24 (30.0)	1.1 (0.4-2.6)

* All children who had a mental health hospital admission before the age of 5 continued to have mental health problems between ages 6-8.

** Adjusted for gender, gestational age, birth order, percentage of optimal birth weight, language background other than English, child age, marital status, maternal age, maternal skill level, maternal country of birth (for non-Aboriginal children only), maternal socioeconomic status of area, maternal and paternal mental health, maternal and paternal skill level, calendar year, school geographical location and type of school.

For non-Aboriginal children, those with intellectual disability were significantly more likely to fall below the benchmark for reading and five times more likely for numeracy as those with mental health problems only (Table 15). After adjustment, a lower relative risk, compared to that for Aboriginal children, was found for non-Aboriginal children (OR 5.7, 95% CI 3.1-10.5 for reading, and OR 11.5, 95% CI 6.8-19.4 for numeracy) to fall below the benchmark standards if they had both mental health problems and intellectual disability (Table 15).

Further analysis (not presented) showed that children receiving care for mental health problems before the age of 5 were significantly more likely to be diagnosed with intellectual disability (12.9% among non-Aboriginal and 13.5% among Aboriginal children) than those who commenced receiving care for mental health problems after school entry (2.7% among non-Aboriginal and 6.8% among Aboriginal children).

Discussion

This population study identified the most common mental health conditions for which children below the age of 8 are admitted for either primary ('reaction to severe stress and adjustment disorder') or secondary diagnosis ('specific developmental disorders of speech and language'). The results reported here show that all children who received care for mental health problems before school entry continued to receive care for mental health problems between ages 6 and 8. Children who had a mental health diagnosis secondary to a physical health problem had the lowest mean WALNA scores and were most likely to fall below the benchmark. However, Aboriginal children who had a primary diagnosis of mental health problems had better educational outcomes than those with no recognised mental health problems. This is in contrast to non-Aboriginal children with a primary mental health diagnosis who were at a higher risk of falling below the benchmark in literacy and numeracy compared to those with no mental health admission, with the risk being greatest for mental health admissions occurring within the first five years of life. As anticipated, the risk of falling below the benchmark was markedly higher for those with intellectual disability than those with no mental health problems or intellectual disability.

Table 15: Risk of below benchmark performance in reading and numeracy at age 8 years by mental health admissions and presence of intellectual disability in children born 1989-1997.

NON-ABORIGINAL CHILDREN							
Diagnosed with		**READING**			**NUMERACY**		
Mental disorder	**Intellectual disability**	**Number of children N=103575 N**	**Below Benchmark N=103575 N (%)**	**Multivariate* N=103106 OR (95% CI)**	**Number of children N=104301 N**	**Below Benchmark N=104301 N (%)**	**Multivariate* N=103827 OR (95% CI)**
No	No	100298	7316 (7.3)	Ref	100895	8766 (8.7)	Ref
Yes	No	1988	286 (14.4)	1.5 (1.3-1.9)	2001	342 (17.1)	1.7 (1.4-2.0)
No	Yes	1178	455 (38.6)	5.6 (4.6-6.8)	1276	721 (56.5)	8.6 (7.2-10.2)
Yes	Yes	111	45 (40.5)	5.7 (3.1-10.5)	129	87 (67.4)	11.5 (6.8-19.4)
ABORIGINAL CHILDREN							
Diagnosed with		**READING**			**NUMERACY**		
Mental disorder	**Intellectual disability**	**Number of children N=6386 N**	**Below Benchmark N=6386 N (%)**	**Multivariate* N=6022 OR (95% CI)**	**Number of children N=6937 N**	**Below Benchmark N=6937 N (%)**	**Multivariate* N=6513 OR (95% CI)**
No	No	6123	1636 (26.7)	Ref	6611	2269 (34.3)	Ref
Yes	No	99	30 (30.3)	1.1 (0.6-2.0)	106	32 (30.2)	1.1 (0.6-2.1)
No	Yes	156	89 (57.1)	3.2 (2.0-5.1)	208	137 (65.9)	3.6 (2.4-5.4)
Yes	Yes	8	<5 (50.0)	7.5 (0.4-127.0)	12	10 (83.3)	20.3 (1.9-220.6)

* Adjusted for gender, gestational age, birth order, percentage of optimal birth weight, language background other than English, child age, marital status, maternal age, maternal skill level, maternal country of birth (for non-Aboriginal children only), maternal socioeconomic status of area, maternal mental health, paternal skill level, calendar year, school geographical location and type of school.

Our study showed that only ~4% of Aboriginal and ~3% of non-Aboriginal children received care for a mental health problem or were diagnosed with intellectual disability. This is much lower than the prevalence of mental health problems reported in various surveys and cohort studies (Zubrick, Silburn, *et al*., 1997, 2007; Robinson, Oddy, *et al*., 2008; Robinson, Mattes, *et al*., 2009). A cross-sectional representative survey of Western Australian children found that around 1 in 6 Aboriginal children (16.8%) were assessed by their teachers to be at high risk of significant emotional or behavioural difficulties, with a further 14.0% of children being at a moderate risk (Zubrick, Silburn*, at al*., 2006). Almost 21% of non-Aboriginal children were assessed by their caregivers and teachers as being at a high risk of having mental health problems (Zubrick, Silburn, *et al*.,1997). The number of mental health-related admissions is thus likely only the tip of the iceberg of all children who experience mental health problems in the community.

The finding that children with prior mental health admissions were at a higher risk of falling below the benchmark in literacy and numeracy compared to those with no admission at all corroborates the findings of Zubrick, Silburn, *at al*. (2006). These authors showed that children who were at a high risk of significant emotional and behavioural difficulties were more likely to have low academic performance compared with students who were rated as being at a low risk of such difficulties. However, their survey could not distinguish whether mental health problems were the cause or consequence of poor academic performance. The authors implicated a number of life stress events as a strong predictor of emotional or behavioural difficulties, the most common stress events being family problems and fear, poor health, and financial difficulties.

It has not been previously reported that the risk of failing the benchmark standards was greatest for mental health problems receiving care within the first five years of life and that these children continue to receive care for these problems between ages 6 and 8. In agreement with statistics showing that the most frequent mental health diagnosis is a combination of anxiety and depression (CAGNAP, 2008), the most frequently observed mental health diagnosis in this study was ‘reaction to severe stress and adjustment disorder’, including depression, anxiety or worry, the continuing necessity for care suggests that the underlying problems were not being successfully addressed. Therefore, it is possible that these children will continue to suffer from their mental health problems throughout childhood. Further analysis could investigate in which way children with mental health admission before school entry differ to those with admissions after school entry.

Children with a mental health diagnosis whose primary admission was for an illness other than a mental health problem most often had 'specific developmental disorders of speech and language', including disorders such as lisping. These children who were admitted with a secondary diagnosis of a mental disorder had the highest absolute risk of being below the benchmark in literacy and numeracy. However, unexpectedly, Aboriginal children who were admitted primarily for mental health problems had a lower absolute risk than those with no admission for mental health problems, and the risk was lowest when neither parent had received care for mental health problems. Given the much larger prevalence of mental health problems in Aboriginal children (Zubrick, Silburn, *et al*., 2006), it is possible that children who were diagnosed and treated for mental health disorders may have been compared with a group that includes a significant proportion of children with untreated mental health problems and their parents may be more committed to academic achievement. Further work is therefore needed to establish the robustness of this finding and investigate the likely reasons for it.

The strength of this study is that de-identified population-based data was used, linked across education and health sectors, to investigate the risk of not meeting the benchmarks in literacy and numeracy for children who have had prior care for mental health problems. Using de-identified routinely-collected data, it was possible not only to avoid recall and minimise selection bias, but also to protect individual privacy (Holman, Bass, *et al*., 2008). This study also accounted for the similarities in outcomes of students attending the same school and adjusted for a wide range of confounding factors, including parental mental health and socioeconomic status.

However, linked administrative data are limited to those children who had been identified in both health and education databases. It should be acknowledged that certain groups of children may have been under-represented. Children from a disadvantaged background are more likely to be absent over the testing period and children who are lacking English competency (when not their first language) are generally exempt from taking the test, and these children are likely to have lower educational attainment. It is also not known how many children have accessed out-patient mental health services in the private sector and thus these results should not be generalised to this group of children. The in- and out-patient data are limited to those children who have accessed the hospital system, which represents only a small proportion of all children with mental health problems.

In conclusion, it has been found that children receiving hospital care for mental health problems are at higher risk of falling below the benchmark and that this risk is highest for mental disorders recognised prior to school entry. The findings reported here highlight the importance of early intervention for mental health problems and the shortcomings of the current interventions in these children before they reach school age, and of assisting families to respond to the emotional, behavioural and cognitive needs of their children. These children represent a particularly vulnerable group, since early mental and behavioural problems are associated with later mental health problems, and many of these children also have other conditions such as intellectual disability. Therefore, the success of such children in the education system will crucially depend on early and sustained efforts to help them to develop their cognitive as well social, emotional and behavioural skills.

Chapter Nine

What mediates the association between socioeconomic status and early academic achievement?

Abstract

Objective: To investigate the extent to which, both independently and jointly, a range of child health and parental factors may mediate the effect of socioeconomic status on numeracy achievement.

Methods: An analysis was done of all singletons born in Western Australia from 1989 to 1997 whose birth records could be linked with numeracy attainment record in the Western Australian Literacy and Numeracy Assessment in grade 3, aged approximately 8 years, during 2000-2005. Linear multilevel models were used to explore the potential mediators underlying the relationship between socioeconomic status at birth and numeracy achievement. All children with intellectual disability were excluded.

Results: The social gradient in numeracy attainment was partially mediated by maternal characteristics, such as teenage motherhood and, to a smaller extent, single marital status. Parental mental health, as measured by contact with mental health services, had only a small additional effect. None of the individual health factors of the child (including birth characteristics, mental and physical health) had any significant mediating effect on numeracy attainment.

Conclusions: This study suggests that while child health factors are associated with both academic achievement and socioeconomic status, they do not significantly mediate this

relationship. Instead, maternal characteristics and, to some extent, parental mental health seem to partially mediate the social gradient in numeracy attainment. The identification of potential mediators is an important step in breaking the cycle of disadvantage and closing the achievement gap of disadvantaged children.

Introduction

The association between low socioeconomic status and poor academic achievement is well established (Brownell, Roos, *et al*., 2006; Sirin, 2005). Socioeconomically disadvantaged children are therefore less likely to succeed in education or to attain its associated social and economic advantages, perpetuating the cycle of disadvantage across generations. To break this cycle and successfully level this social gradient in educational outcomes, it is important to identify the factors that mediate the relationship with socioeconomic status and that may be more directly amenable to intervention than socioeconomic status itself.

There is a small but growing body of research investigating the mediating processes through which socioeconomic status impacts on academic achievement. Previous studies have investigated parenting practices (DeGarmo, Forgatch, & Martinez Jr, 1999) and home environment (McCulloch & Joshi, 2001); but none have so far considered child health or parental characteristics. Based on the association between various health and biological factors and school achievement (Malacova, Li, *et al*., 2008; Zubrick, Silburn, *et al*., 1997), it is hypothesised here that individual health and birth characteristics may represent some of the mediators between socioeconomic status and academic achievement.

The aim of this study was therefore to investigate the extent to which individual health factors of the child and its parents, previously reported as important predictors of poor educational outcomes (Malacova, Li, *et al*., 2008, Chapters 7 and 8), may mediate the effect of socioeconomic status on numeracy achievement in grade 3.

Methods

Study population

A retrospective cohort study was conducted of all non-Aboriginal singletons without intellectual disability, born in Western Australia from 1989 to 1997 who participated in the numeracy component of the WALNA in grade 3 during 2000-2005. Children with intellectual disability were excluded: these children are exempt from taking the WALNA test, and those that do are both more likely to perform poorly and to have higher rates of hospital admissions (Williams, Leonard, *et al.*, 2005). Aboriginal and Torres Strait Islander children were also excluded because the current socioeconomic status of area is not considered to be an accurate measure of socioeconomic status for Aboriginal families and the majority of parents of Aboriginal children had an unclassified or missing skill level.

Sources of data

De-identified administrative data linked across the Western Australian Health and Education government departments were used. Health data included the Midwives Notifications System, Birth Registrations, Mental Health contacts and Hospital Morbidity admissions. Midwives Notifications and Birth Registrations data contained information on maternal and infant characteristics for all midwife-attended (99.5% of all births) and registered births. Mental Health data included information on all child, maternal and paternal contacts with mental health services (all in- and public out-patient admissions). Available data included diagnostic and procedural information which were coded using the ICD coding system. The Hospital Morbidity data contained information on all in-patient hospital admissions at both public and private hospitals.

Education data provided individual numeracy achievement scores in the WALNA in grade 3 (for children typically aged 8 years) from 2000 to 2005. All these datasets were linked by the Health Information Linkage Branch in Western Australia, using probability modelling and following established protocols to protect privacy, which ensured that clinical data are separated from identifying information (Kelman, Bass, & Holman, 2002). Only de-identified data were released to me for analysis.

Indictor of numeracy skills - Outcome variable

Numeracy was defined as the ability to effectively apply mathematics in every day life. Potential mediating factors for numeracy attainment were investigated, not only because more children participated in the numeracy than the reading test, but also because more children failed to attain the benchmark standards in numeracy than in reading. The original raw numeracy scores had been scaled by the Education Department to enable comparisons over time. To enable analysis of below benchmark performance, scaled achievement scores were classified as either meeting or failing to meet the Western Australian benchmark performance in numeracy for grade 3.

Socioeconomic status of area and parental skill levels - Socioeconomic indicators

The level of socioeconomic disadvantage of the mother's residential area at birth was measured by the Index of Education and Occupation at the census collection district, as defined by the Australian Bureau of Statistics (ABS, 2008b). Socioeconomic deprivation values were divided based on Western Australian cut off scores (ABS, 2006a) into six quantiles, with the last category (lowest 10%) being the most disadvantaged. Missing values were included as an "unknown" category in the analysis. Parents' skill level, a paternal- and maternal-level measure, was defined using the Australian and New Zealand Standard Classification of Occupations and involved recoding of occupations and classifications into one of five categories based on both work experience and qualifications (ABS, 2006b). Missing or unclassifiable skill levels were included in the analysis as "unclassified".

Child and parental characteristics – Mediators

Preterm birth was defined as a gestational age of less than 37 completed weeks. POBW and POHC were constructed in accordance with an algorithm derived by Blair and colleagues (Blair, Liu, *et al*., 2005). Low POBW was defined as <87% (bottom 10%), while low POHC as <96% (bottom 10%). A low Apgar score at 5 minutes was defined as a score <8. High birth order was defined as having at least four older siblings alive at the time of birth.

Children were identified as having admissions for non-infectious respiratory, respiratory infectious, non-respiratory infectious diseases and external causes using the ICD 10 diagnostic codes, as shown in Table 16. Parental and child mental health admissions were identified using ICD 10 diagnostic codes 'F00' - 'F99' and were measured as having ever a contact with mental health services. Mothers' marital status was coded as single (never married, widowed, divorced or separated) or married (married or de facto). Maternal age was grouped as <20 years, 20-24 years, 25-29 years, or ≥30 years.

Table 16: ICD 10 codes associated with different types of diseases.

Types of main diseases	ICD10 CODES
Non-infectious respiratory diseases	J40-J47
Respiratory infections	B00-B09, J00-J39, H65-H75
Non-respiratory infections	A00-A09, B15-B19, B25-B34, B85-B89
External causes	S00-Y98
Mental health problems	F00-F99

Covariates

Child language background was self reported at the time of testing, indicating English or non-English language background at home. Child age at the time of WALNA testing was coded as “less than 7 years and 7 months”, “from 7 years and 7 months to 8 years and 8 months” (reference group), “from 8 years and 9 months to 9 years and 3 months”, or “9 years and 3 months and older”.

School characteristics included the calendar year in which the WALNA test was taken, geographic location and the type of school. School geographic location was classified as metropolitan, provincial (non-remote), remote, and very remote using the Schools Geographic Location Classification, which is used by the Education Department. School types were coded as government and non-government (Independent and Catholic) schools.

Statistical analysis

Two-level (students nested within schools) linear regression was used to investigate the potential mediators underlying the relationship between socioeconomic status and numeracy achievement, where birth characteristics, child physical and mental health, parental mental health, maternal age and maternal marital status at time of birth were considered potential mediators. Adjustment was made for the following variables: child age, gender, language background, maternal ethnicity, school geographic location, type of school and calendar year of testing (to adjust for cohort effects). These variables are shown in Table 17. Numeracy scores were centred at their grand mean of 345.5 (min=-87, max=735) and child age was centred at 98.6 months (SD=3.8, min=81, max=145). The method of Baron and Kenny (1986) was followed to investigate the extent to which child and parental characteristics independently and jointly mediated the relationship between socioeconomic status and numeracy attainment. According to this method, there are four steps that need to be satisfied to demonstrate mediation: 1) establish association between the predictor and the outcome variable; 2) establish association between the predictor and the mediator variable; 3) establish association between the mediator and the outcome variable while holding the predictor variable constant; and 4) establish whether complete, partial or no mediation has occurred. Complete mediation is demonstrated if, after controlling for potential mediating variables, the association between the predictor and the outcome variables reduces to zero. Data were analysed using SAS (version 9.1) and MLwiN (version 2.02).

Ethics approval

This study was approved by the University of Western Australia Human Ethics Committee, the Confidentiality of Health Information Committee.

Results

Of the 106,870 non-Aboriginal singleton births attended by a midwife in Western Australia between 1989 and 1997 who participated in the WALNA in grade 3 over the period of 2000 to 2005, there were 106,030 (99.1%) children who had no known intellectual disability. Of those, 103,537 completed the numeracy test.

Measures of numeracy attainment are shown by characteristics of the child, parent and school in Table 17. Lower numerical attainment was associated with female gender, older age at the time of testing, non-English background, high birth order (5+), suboptimal intrauterine growth (POHC and POBW), preterm birth, 5 minute Apgar score <8, prior contact with mental health services, hospital admissions. In addition, children tended to have poorer numeracy outcomes if they were born to young, single mothers, mothers residing in educationally deprived areas, or to parents who had contact with mental health services or whose occupational skill levels were low.

Social gradient in academic attainment

Each of the three measures of socioeconomic status (Index of Education and Occupation, maternal and paternal skill levels) was associated with numeracy attainment (Table 17), showing a clear gradient. The percentage of children who failed to reach the numeracy benchmark was significantly higher in the most deprived areas or for those whose parents have the lowest skill level (11.7% for maternal skill level, 11.6% for paternal skill level, and 14.3% for neighbourhood disadvantage), compared to 4.0%, 4.4% and 2.8%, respectively, among the least deprived and the highest skill level groups.

Potential mediators

To be able to argue that a factor lies on the pathway between socioeconomic status and numeracy attainment, it is important to demonstrate that the factor is associated with both numeracy attainment and socioeconomic status. It has already been shown in this research (Malacova, Li, *et al*., 2008, Chapters 7 and 8) that birth characteristics (birth order, POBW, POHC, gestational age, and Apgar score at 5 minutes), child's contact with mental health services, child physical health (child's admissions for infectious respiratory and non-respiratory diseases, admissions for non-infectious respiratory diseases, and admissions for external causes), maternal characteristics (maternal age, and maternal marital status), and parental contact with mental health services were all significantly associated with numeracy attainment in the expected directions.

The social gradient in birth characteristics, child mental and physical health, maternal and paternal characteristics is shown in Table 18. The percentage of children with suboptimal birth characteristics, contact with mental health services, admissions for physical health problems, younger and single mothers, and having parents with contact with mental health services was progressively higher for the more deprived groups. All three socioeconomic measures were thus also significantly related with all potential mediating factors in the expected directions.

Table 17: Study characteristics and association with numeracy attainment, 2000-2005.

Variable	Categories	N (%)	% Below the benchmark	Mean	SD
Child gender	Male	53038 (51.2)	8.7	349.1	76.4
	Female	50499 (48.8)	8.8	341.8	70.1
Child age at testing	<= 7 years and 7 months	115 (0.1)	0.9	418.0	82.2
	7 years and 7 months - 8 years and 8 months	100951 (97.5)	8.6	346.2	73.4
	8 years and 9 months - 9 years and 3 months	2249 (2.2)	17.6	317.1	75.9
	9 years and 3 months+	222 (0.2)	23.4	297.6	75.2
Child non-English language background	No	92970 (89.8)	8.7	345.5	73.3
	Yes	10567 (10.2)	9.3	345.8	76.1
Birth order	0-4	101042 (97.6)	8.7	346.0	73.6
	5+	2495 (2.4)	13.8	325.9	74.2
Percentage of optimal head circumference	96+	95108 (91.9)	8.6	346.3	73.5
	<96 (bottom 10%)	8429 (8.1)	11.2	336.5	74.9
Percentage of optimal birth weight	87+	88248 (85.2)	8.3	347.5	73.4
	<87 (bottom 10%)	15289 (14.8)	11.7	334.1	73.9
Gestational age	37+ weeks	98660 (95.3)	8.6	346.1	73.6
	<37 weeks	4876 (4.7)	11.4	334.7	74.3
Apgar score at 5 minutes	8-10	102282 (98.9)	8.7	345.6	73.6
	<8	1151 (1.1)	11.9	335.8	73.6
Child's contact with mental health services	No	102449 (98.9)	8.7	345.8	73.5
	Yes	1088 (1.1)	17.1	320.6	77.0
Child's admission for infectious non-respiratory diseases	No	94410 (91.2)	8.5	346.4	73.5
	Yes	9127 (8.8)	11.2	336.5	74.7
Child's admission for infectious respiratory diseases	No	79257 (76.6)	8.3	347.4	73.5
	Yes	242280 (23.5)	10.3	339.5	73.9
Child's admission for non-infectious respiratory diseases	No	97663 (94.3)	8.7	345.9	73.6
	Yes	5874 (5.7)	10.8	338.6	74.4
Child's admission for external causes	No	89743 (86.7)	8.5	346.6	73.4
	Yes	13794 (13.3)	10.7	338.7	74.7

Table 17: continued.

Variable	Categories	N (%)	% Below the benchmark	Mean	SD
Maternal ethnicity	Caucasian	95942 (92.7)	8.9	344.7	73.2
	Non-Caucasian	7595 (7.3)	7.8	355.8	78.2
Calendar year at testing	2000	18468 (17.8)	9.6	337.3	67.7
	2001	18220 (17.6)	3.3	365.2	64.0
	2002	18709 (18.1)	12.1	336.4	74.7
	2003	18802 (18.2)	9.3	342.5	78.2
	2004	18552 (17.9)	10.4	344.4	78.0
	2005	10786 (10.4)	7.1	349.4	74.3
School type	Government	75225 (72.7)	9.8	341.8	74.0
	Non-Government	28312 (27.3)	6.2	355.5	71.7
School location	Metro	73283 (70.9)	8.1	348.9	73.9
	Provincial	23157 (22.4)	10.2	337.7	71.9
	Remote	5374 (5.2)	10.5	338.3	72.7
	Very remote	1532 (1.5)	14.8	326.1	73..3
Maternal age	<20	3504 (3.4)	16.8	313.9	70.7
	20-24	17203 (16.6)	12.5	327.3	70.6
	25-29	34429 (33.3)	8.8	343.8	72.7
	30+	48401 (46.8)	6.8	355.5	73.6
Maternal marital status	Married/de facto	94710 (91.5)	8.3	347.6	73.4
	Single	8827 (8.5)	14.3	323.1	72.8
Mother’s contact with mental health services	No	85180 (82.3)	8.0	348.7	73.2
	Yes	18357 (17.7)	12.2	330.5	73.6
Father’s contact with mental health services	No	93920 (90.7)	8.5	346.9	73.6
	Yes	9617 (9.3)	11.8	331.6	72.5

Table 17: continued

Variable	Categories	N (%)	% Below the benchmark	Mean	SD
SEIFA of Education and Occupation	0 - Least disadvantaged	6705 (6.5)	2.8	382.4	72.0
	1	13082 (12.6)	5.0	364.6	72.4
	2	26459 (25.6)	7.4	349.8	71.4
	3	23813 (23.0)	10.0	338.4	71.9
	4	15405 (14.9)	12.1	331.1	72.6
	5 – Most disadvantaged	9361 (9.0)	14.3	322.0	72.5
	6 - Unclassified	8712 (8.4)	8.2	345.7	72.1
Maternal skill level	1 - Highest	18976 (18.3)	4.0	373.1	72.3
	2	5385 (5.2)	6.7	354.5	72.0
	3	8688 (8.4)	7.5	346.2	69.7
	4	18146 (17.5)	7.3	347.4	70.3
	5 - Lowest	9977 (9.6)	11.7	331.6	71.2
	6 - Unclassified	42365 (40.9)	11.4	334.4	73.6
Paternal skill level	1 - Highest	24084 (23.3)	4.4	369.9	72.6
	2	10792 (10.4)	6.6	353.6	70.6
	3	27683 (26.7)	9.8	337.4	70.7
	4	17826 (17.2)	10.0	336.8	71.4
	5 - Lowest	11206 (10.8)	11.6	332.6	72.8
	6 - Unclassified	11946 (11.5)	12.7	332.9	76.5

Table 18: Proportion of children with suboptimal characteristics of birth, child or parents by categories of each of the three measures of socioeconomic status.

	MODEL																
	I %	II %	III %	IV %	V %	VI %	VII %	VIII %	IX %	X %	XI %	XII %	XIII %	XIV %	XV %	XVI %	XVII %
SEIFA – Index of Education and Occupation																	
1 - Least disadvantaged	1.3	6.4	0.8	11.8	4.4	0.9	5.4	20.0	73.7	0.8	6.8	20.5	4.7	13.7	5.0	6.1	11.0
2	1.5	7.2	0.8	12.9	4.5	1.5	8.3	27.5	62.7	0.8	7.6	21.3	4.8	12.4	6.0	6.8	13.2
3	1.9	8.1	1.0	14.3	4.6	2.7	13.8	34.0	49.5	1.1	8.0	22.6	5.5	12.3	7.1	8.3	16.2
4	2.5	8.4	1.1	15.5	5.1	3.7	19.3	36.4	40.7	1.0	9.3	24.1	6.0	12.8	9.0	9.6	18.7
5	3.2	8.6	1.4	15.8	4.8	4.78	23.3	36.3	35.9	1.3	10.0	25.3	6.1	14.3	11.1	11.4	21.3
6 - Most disadvantaged	3.9	9.5	1.4	17.8	5.2	7.9	28.3	34.2	29.6	1.5	10.9	26.7	7.2	15.3	16.6	14.1	26.0
- Unclassified	3.0	8.0	1.3	14.0	4.0	2.3	14.7	35.2	47.8	0.8	8.9	22.9	5.2	15.2	5.1	8.6	16.6
Maternal Skill Level																	
1 – Highest	1.2	6.9	0.9	12.3	4.4	0.3	5.3	27.4	67.0	0.7	7.7	21.1	4.8	12.6	3.5	6.5	11.2
2	1.2	7.9	0.9	14.1	5.4	0.8	10.3	34.1	55.0	0.7	7.9	22.5	5.0	13.0	5.0	7.4	14.8
3	0.8	8.6	1.2	14.2	4.6	1.7	17.7	37.9	42.8	0.9	8.6	23.5	5.1	12.3	7.3	8.1	15.2
4	0.8	8.8	1.1	14.8	4.9	1.8	18.2	39.3	40.7	1.0	9.1	24.3	5.6	12.8	8.3	8.7	16.2
5 – Lowest	0.9	8.9	1.4	15.7	5.2	7.5	27.8	34.8	30.0	1.3	9.5	25.0	6.0	13.5	14.3	10.7	20.1
- Unclassified	4.5	8.2	1.1	15.9	4.6	5.2	19.0	31.9	44.0	1.2	9.2	23.9	6.3	14.1	10.2	11.0	21.7
Paternal Skill Level																	
1 – Highest	2.1	7.0	0.9	12.3	4.2	0.5	6.9	29.2	63.4	0.6	7.5	21.1	4.8	12.6	2.5	5.7	11.8
2	2.1	8.4	0.9	13.1	4.7	0.8	10.9	34.6	53.7	1.0	8.1	22.7	5.2	12.8	3.6	7.5	14.2
3	2.3	8.2	1.2	15.4	4.9	3.4	20.1	36.2	40.3	1.0	9.0	23.8	5.5	13.2	7.7	10.1	18.5
4	2.4	8.9	1.1	15.8	4.7	2.74	18.94	36.96	41.4	1.02	9.01	25.2	6.3	13.0	7.1	10.9	18.6
5 – Lowest	2.6	8.4	1.4	16.4	4.8	5.9	24.4	33.9	35.8	1.4	9.3	24.5	6.5	14.1	10.3	13.2	21.5
- Unclassified	3.5	8.7	1.4	16.9	5.4	10.1	22.6	27.3	40.1	1.9	11.1	24.5	6.6	15.2	27.6	10.2	26.2

I High birth order (5+); **II** Low POHC (<96); **III** Low Apgar score at 5 minutes (<8); **IV** Low POBW (<87); **V** Low gestational age (<37 weeks); **VI** Maternal age (<20 years); **VII** Maternal age (20-24 years); **VIII** Maternal age (25-29 years); **IX** Maternal age (30+ years); **X** Child contact with mental health services; **XI** Admissions for infectious non-respiratory diseases; **XII** Admissions for infectious respiratory diseases; **XIII** Admissions for non-infectious respiratory diseases;
XIV Admissions for external causes; **XV** Maternal marital status (non-married); **XVI** Father's contact with mental health services; **XVII** Mother's contact with mental health services

Mediating pathways underlying socioeconomic gradient in academic attainment

Table 19 shows the different multilevel linear models fitted to estimate the independent (as well as joint) mediating effect of the different child and parental characteristics. Model 0 contained only the three measures of socioeconomic status. Once all current confounders were accounted for (Model I), the parameter estimates decreased slightly across all three measures. Models II – V (testing for mediation by birth characteristics, child mental health, child physical health, and parental mental health) showed little change in the parameter estimates. However, Model VI, in which maternal characteristics were added to Model I, showed that the parameter estimates decreased for the most deprived or lowest skill groups (from -17.9 to -16.4 for neighbourhood deprivation, from -21.3 to -18.8 for maternal skill level, and from -17.7 to -16.1 for paternal skill level). Further analysis revealed that the changes were mainly due to maternal age rather than to maternal single status at birth. When adding parental mental health to the model already containing maternal characteristics (Model VIII), the parameter estimates dropped slightly further for the most deprived or lowest skill groups (from -16.4 to -15.8 for neighbourhood deprivation, from -18.8 to -18.6 for maternal skill level, and from -16.1 to -15.5 for paternal skill level). The further addition of all child characteristics to model VIII showed little further reduction in parameter estimates (Model IX).

Discussion

This is the first population-based study to investigate, both independently and jointly, a range of child and parental health factors as potential mediators between socioeconomic status and academic achievement. The results presented here highlight that the social gradient in numeracy attainment was partially mediated by maternal characteristics (teenage motherhood and, to a lesser extent, single marital status). Parental contact with mental health services had a small additional effect. However, none of the child factors (including birth characteristics, mental and physical health) had any significant mediating effect on numeracy attainment.

Table 19: Parameter estimates and standard errors from fixed part of multilevel analysis of numeracy achievement among non-Aboriginal singletons (n=103,241) born in Western Australia who undertook the Western Australian Numeracy test, 2000-2005.

	MODEL									
	0	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**
FIXED	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)
SEIFA – Index of Education and Occupation										
1 - Least disadvantaged	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
2	-4.86 (1.12)	-4.80 (1.10)	-4.72 (1.10)	-4.81 (1.10)	-4.82 (1.10)	-4.74 (1.10)	-4.78 (1.10)	-4.74 (1.10)	-4.72 (1.10)	-4.64 (1.09)
3	-6.83 (1.10)	-6.97 (1.08)	-6.84 (1.08)	-6.96 (1.08)	-6.97 (1.08)	-6.85 (1.08)	-6.75 (1.08)	-6.84 (1.07)	-6.64 (1.08)	-6.48 (1.07)
4	-10.2 (1.13)	-9.95 (1.12)	-9.70 (1.12)	-9.95 (1.12)	-9.88 (1.12)	-9.75 (1.12)	-9.45 (1.12)	-9.65 (1.11)	-9.29 (1.12)	-8.96 (1.11)
5	-13.4 (1.20)	-12.3 (1.18)	-12.1 (1.18)	-12.3 (1.18)	-12.2 (1.18)	-12.0 (1.18)	-11.6 (1.18)	-11.9 (1.18)	-11.3 (1.18)	-10.8 (1.18)
6 – Most disadvantaged	-18.7 (1.29)	-17.9 (1.28)	-17.5 (1.27)	-17.9 (1.28)	-17.6 (1.28)	-17.2 (1.28)	-16.4 (1.28)	-17.2 (1.27)	-15.8 (1.28)	-15.1 (1.27)
- Unclassified	-10.6 (1.30)	-9.78 (1.29)	-9.60 (1.29)	-9.80 (1.29)	-9.69 (1.29)	-9.75 (1.29)	-9.69 (1.29)	-9.52 (1.29)	-9.64 (1.29)	-9.32 (1.29)
Maternal Skill Level										
1 – Highest	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
2	-10.4 (1.08)	-10.2 (1.06)	-9.94 (1.06)	-10.1 (1.06)	-10.1 (1.06)	-9.91 (1.06)	-9.67 (1.06)	-9.93 (1.06)	-9.53 (1.06)	-9.36 (1.05)
3	-15.3 (0.90)	-15.4 (0.90)	-15.3 (0.89)	-15.4 (0.89)	-15.3 (0.89)	-15.2 (0.89)	-14.2 (0.89)	-15.2 (0.89)	-14.1 (0.89)	-13.9 (0.89)
4	-12.2 (0.74)	-11.9 (0.73)	-11.9 (0.73)	-12.0 (0.73)	-11.9 (0.73)	-11.8 (0.73)	-10.8 (0.73)	-11.7 (0.73)	-10.7 (0.73)	-10.4 (0.73)
5 - Lowest	-21.6 (0.89)	-21.3 (0.87)	-21.2 (0.87)	-21.3 (0.87)	-21.2 (0.87)	-20.9 (0.87)	-18.8 (0.88)	-21.0 (0.87)	-18.6 (0.88)	-18.3 (0.88)
- Unclassified	-21.2 (0.64)	-21.5 (0.63)	-21.1 (0.63)	-21.4 (0.63)	-21.3 (0.63)	-20.8 (0.63)	-20.3 (0.64)	-20.9 (0.63)	-19.7 (0.64)	-19.2 (0.64)
Paternal Skill Level										
1- Highest	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
2	-8.87 (0.82)	-8.85 (0.80)	-8.81 (0.80)	-8.80 (0.80)	-8.74 (0.80)	-8.68 (0.80)	-8.66 (0.80)	-8.65 (0.80)	-8.52 (0.80)	-8.35 (0.80)
3	-15.9 (0.65)	-15.5 (0.64)	-15.4 (0.64)	-15.5 (0.64)	-15.4 (0.64)	-15.1 (0.64)	-14.5 (0.65)	-15.2 (0.64)	-14.2 (0.64)	-14.0 (0.64)
4	-15.4 (0.72)	-15.3 (0.71)	-15.2 (0.71)	-15.3 (0.71)	-15.1 (0.71)	-14.9 (0.71)	-14.7 (0.71)	-15.0 (0.71)	-14.3 (0.71)	-14.0 (0.71)
5 - Lowest	-17.9 (0.83)	-17.7 (0.81)	-17.5 (0.81)	-17.6 (0.81)	-17.4 (0.81)	-16.9 (0.81)	-16.1 (0.82)	-17.2 (0.81)	-15.5 (0.82)	-15.1 (0.81)
- Unclassified	-19.0 (0.81)	-18.6 (0.80)	-18.2 (0.80)	-18.4 (0.80)	-18.2 (0.80)	-17.6 (0.80)	-15.4 (0.82)	-17.7 (0.79)	-14.9 (0.81)	-14.4 (0.81)
RANDOM										
- 2 log likelihood	1168196	1162340	1161938	1162271	1162079	1162020	1161906	1161651	1161659	1161045

0 – all three SES measures;
I – potential confounders (child gender, child age at testing, child non-English language background, maternal ethnicity, calendar year at testing, school sector, and school geographical location) and all three SES measures
II – potential confounders, all three SES, and birth characteristics (high birth order, low POBW, low POHC, low gestational age, and low Apgar score at 5 minutes)
III – potential confounders, all three SES, and child mental health (child's contact with mental health services)
IV – potential confounders, all three SES, and child physical health (child's admissions for infectious respiratory and non-respiratory diseases, admissions for non-infectious respiratory diseases, and admissions for external causes)
V – potential confounders, all three SES, and parental mental health (maternal and paternal contact with mental health services)
VI – potential confounders, all three SES, and maternal characteristics (teenage maternal age at time of birth, and single maternal status at time of birth)
VII – potential confounders, all three SES, and child birth characteristics and mental and physical health
VIII – potential confounders, all three SES, and family characteristics (maternal characteristics and parental contact with mental health services)
IX – potential confounders, all three SES, all child and family characteristics

While there is robust evidence of the socioeconomic gradient in academic outcomes, few studies have explained this association. A socialisation model of divorced mothers (n=238) identified effective parenting and, specifically, skill-building activities at home as mediating factors between maternal education and academic achievement in 6-9 year-old boys (DeGarmo, Forgatch, & Martinez Jr, 1999). Other research found the home environment to mediate the relationship between family poverty and cognitive ability of 10-18 year olds (McCulloch & Joshi, 2001). Our population-based study confirmed that maternal characteristics partially mediate the social gradient in academic achievement, with the most significant mediator being maternal age at birth.

The association between teenage motherhood and suboptimal numeracy achievement in her child could be due to the mother's lack of maturity and experience, and a greater likelihood of less education and living in disadvantaged neighbourhoods. Mothers who live in disadvantaged neighbourhoods are also more likely to be single and to suffer from mental health problems (Lipman, Offord, & Boyle, 1997). These results therefore indicate that teenage or single mothers and those with a history of mental health problems may benefit from extensive support to improve their parenting skills, such as Nurse Home Visiting programs (Olds, Henderson, *et al*., 1999) and on-going parenting support groups.

While early child mental and physical health problems and poor birth characteristics were found to be associated with academic achievement (Malacova, Li, *et al*., 2008, Chapters 7 and 8), none of these child characteristics significantly mediated the link between social disadvantage and numeracy attainment. This is an important finding, as it suggests that improving child physical and mental health alone is unlikely to greatly contribute to closing the achievement gap between the highly disadvantaged and advantaged children and that the hypothesised pathway (McLoyd, 1998) through early child health may be incorrect, at least for the health characteristics explored in this research.

The strength of this study is that we used de-identified data, linked across education and health, to investigate the potential mediators of the socioeconomic gradient in numeracy attainment. The use of population-based data which have been routinely collected by the government departments allowed the analysis of the data with no recall and minimal selection bias. By accounting for the hierarchical structure of the education data, it was possible to control for the correlation of students attending the same school. Adjustments were also made for a wide range of covariates.

While the use of administrative databases is associated with many advantages, there are also some limitations. Linked administrative data are limited to those children who had been identified and successfully linked across both health and education sectors. Although there is minimal selection bias, some children are more likely to be absent over the testing week and these are more likely to be children from a disadvantaged background. Equally, children whose English is not their first language may be exempt from taking the WALNA if they lack language competency. In addition, some of the secondary diagnostic codes as well as the external cause of morbidity (E-codes) may have been under-reported (Preen, Holman, *et al*., 2004; Winn, Agran, & Anderson, 1995).

In conclusion, this study indicates that maternal characteristics and, to a small extent, parental mental health partially mediate the social gradient in numeracy attainment, as measured by socioeconomic status of area and parental skill levels. Although child factors (such as birth characteristics, mental and physical health) are associated with both academic achievement and socioeconomic status, none of these factors had any significant mediating effect. The present study suggests that potential interventions to reduce the social gradient in education may need to include support for teenage, single mothers and for parents with a history of mental health problems, such as the Nurse Visiting Program and on-going parenting support groups. The identification of potential mediators is an important step to breaking the cycle of disadvantage and closing the achievement gap between those who “have” and those who “have not”.

Chapter Ten

Discussion and Conclusions

The research described in this thesis has pioneered the use of longitudinal, population-based data linked across health and education to investigate developmental pathways to numeracy and literacy skills through the examination of a range of early health factors. In particular, this work investigated associations between numeracy and literacy skills as indicated by the WALNA tests administered in grade 3 (at age approximately 8 years) and the following antecedents:

- birth characteristics and their interplay with maternal characteristics and neighbourhood and school socioeconomic status;
- patterns of prior hospital admissions with respect to frequency, duration and indication;
- contact with mental health services.

In addition, this research investigated factors that may mediate the strong association between socioeconomic status and numeracy attainment.

Interaction between birth characteristics and contextual factors

Given strong evidence of socioeconomic status being the prime determinant of educational outcomes (Sirin, 2005), it is likely that biological and early health factors do not act in isolation. The associations between low educational attainment in non-Aboriginal children and the interactions between birth and socioeconomic characteristics were explored for numeracy (Chapter 4) and literacy performance (Chapter 5). These analyses found that improved educational attainment is associated with appropriate intrauterine growth rates, particularly for those from disadvantaged socioeconomic backgrounds. These findings therefore suggest that good pre-conception and antenatal care should be provided to promote and optimise the health of mother and child during pregnancy and outcomes at birth, with a particular focus on pregnant women in disadvantaged areas. This study also highlights the need to provide additional support, such as targeted enriched numeracy programs, to children of single parent families and to children born in areas of disadvantage, particularly in families with more than one child.

Prior hospital morbidity

Findings from the study of prior hospital admissions (Chapter 6) confirmed that children who had hospital admissions were less likely to reach the minimum standards in literacy and numeracy in grade 3 than those who had no hospital admissions at all, particularly those who had been admitted to hospital more frequently or for longer cumulative periods of time. This relative educational disadvantage associated with hospitalisations was found to be larger for Aboriginal children. It is likely that hospitalisation (or the reasons for its necessity) is an important pathway to low educational achievement in all children.

An unexpected finding from this study was the discovery of a U-shaped relationship between the single longest stay in hospital and the mean academic achievement of Aboriginal children. Aboriginal children with either very short or very long hospital admissions achieved better academic outcomes than those with medium to long stays. It is possible that the increased educational achievement of Aboriginal children with very long hospital admissions relative to those with shorter admissions may be explained by the obligatory education that children receive within the protected hospital environment.

The final finding from the study of hospital admissions showed a difference in impact on educational outcomes between Aboriginal and non-Aboriginal children of the timing of hospitalisation relative to school entry. Findings indicated that non-Aboriginal children who stayed at least 7 days in a single hospital admission *after* they had started their schooling had lower mean academic performances compared to those with a shorter stay. In contrast, Aboriginal children who stayed at least 7 days in a single hospital admission had lower mean academic performance compared to those with a shorter stay, *regardless* of whether the hospitalisation occurred before or after the start of their schooling.

This finding suggests that school absence may mediate the effect of hospital admissions on educational outcomes for non-Aboriginal children. However, it seems unlikely that the majority of school absences in Aboriginal children are due to hospitalisations, as suggested by a similar reduction in the mean achievement irrespective of when hospitalisations occurred. A recent representative survey of all Aboriginal children in Western Australia reported that 46% of Aboriginal children were absent from primary school for at least 10 days each year (Zubrick, Silburn, *et al.*, 2006), while our own analysis showed that only 19% of Aboriginal children aged 6-8 years had been hospitalised. This indicates that factors other than hospitalisation must be responsible for such high school absenteeism among Aboriginal children.

Specific diseases

The association between specific diagnoses for common but preventable diseases and the risk of not reaching literacy and numeracy benchmark standards was investigated in Chapter 7. This is the first study to show that children who had been hospitalised for any of the diseases investigated (respiratory non-infectious diseases, respiratory infections and non-respiratory infections, and for external causes) were at a greater risk of falling below the benchmark standards, compared to those with no hospitalisations at all. Respiratory and non-respiratory infections were the two strongest predictors of poor academic performance. Frequent hospital admissions (four or more) for both respiratory and non-respiratory infections for Aboriginal children, and for non-respiratory infections for non-Aboriginal children, were associated with the highest risks of not reaching the benchmark standards when accounting for major child and family characteristics.

The MCEETYA Taskforce on Indigenous Education (2001) in Australia has identified nine potential key health problems faced by young Aboriginal children that may contribute to low participation and poor performance in school. These health problems include, among others, chronic ear and respiratory infections, and childhood injuries (MCEETYA, 2001). However, the relationship between these health problems and educational attainment had not previously been the subject of rigorous scientific scrutiny due mainly to a lack of available linked longitudinal data. The research described in this thesis contributes to addressing this important issue. This study highlights that although non-respiratory infections (such as infestations and viral diseases) have the largest adverse effect on academic achievement, the majority of non-Aboriginal children are not hospitalised for such infections, but rather for respiratory infections and external causes. Therefore, to both promote child health and improve educational outcomes, it is important to have prevention strategies in place including both universal prevention strategies for common diseases and targeted interventions for diseases which are less common but are strongly associated with poor academic achievement.

Mental health

Mental health is central to child development and this was confirmed in one study of this thesis that investigated the effect of child contact with mental health services on subsequent academic achievement (Chapter 8). The main finding was that all children who had contact with mental health services before school entry continued to have contact between ages 6 to 8 years. Since the most common causes of mental health admissions were related to depression, anxiety or worry, continuing admissions may indicate that the underlying problems were not addressed. While the numbers of children who had contact with mental health services represent only a minority of all children experiencing mental health problems in the community (Robinson, Oddy, *et al*., 2008; Robinson, Mattes, *et al*., 2009; Zubrick, Silburn, *et al*., 1997, 2006), these children are likely to suffer from more severe and persistent mental health problems throughout childhood.

This same study also demonstrated that children who were admitted to hospital and received a secondary diagnosis for a mental health problem (most frequently related to developmental disorders of speech and language) were least likely to attain the benchmark standards. However, Aboriginal children with a primary admission diagnosis of mental health problems (most frequently a combination of stress, anxiety, depression or "worry") had better educational outcomes than those with no mental health admission at all. A recent survey of Aboriginal children in Western Australia found that about 16% of students were "rated at high risk of clinically significant emotional and behavioural difficulties by their teachers" (Zubrick, Silburn, *et al*., 2006, p. 293). This result is compatible with many Aboriginal children experiencing mental health problems in the community but having no contact with mental health services; however, those that do receive such services may be benefiting from the attention and services provided. This study therefore highlights the critical need for screening and treating Aboriginal children for possible mental health problems as early as possible before these problems become too entrenched and difficult to overcome. However, to tackle the roots of the mental health problem, it is essential to provide support for "at-risk" families to help them build their capacity to better respond to the emotional needs of their children and to create a more positive home environment.

Potential mediators between socioeconomic status and numeracy attainment

The final study investigated potential mediators that account for the association between three measures of socioeconomic status and numeracy attainment of non-Aboriginal children (Chapter 9). This study showed that the social gradient in numeracy attainment was partially mediated by maternal characteristics (such as teenage motherhood and, to a lesser extent, single motherhood at birth). In combination with maternal characteristics, parental mental health had a minimal additional mediating effect. However, none of the child factors (including birth characteristics, mental and physical health) had any significant mediating effect on numeracy attainment. Since teenage mothers are less likely to complete their education and are more likely to live in disadvantaged neighbourhoods, their children are therefore doubly disadvantaged. This therefore highlights that teenage mothers would benefit from extensive support such as parental support groups and Nurse Home Visiting programs (Olds, Henderson, *et al*., 1999). The lack of mediation of early health factors between socioeconomic status at the community and family level at the time of birth and educational outcomes suggests that the hypothesis of biological embedding of socioeconomic disadvantage in educational outcomes may not hold for physical and mental health. Rather this research provided some evidence that parental characteristics, especially maternal factors may lie on the pathway between socioeconomic circumstances at birth and child educational outcomes.

Strengths of this research

The main strength of the research described in this thesis is the use of large de-identified population-based datasets which have been linked across education and health sectors. The use of administrative data for research has been made possible by recent advances in computer technology. In Australia, Western Australia is currently the only place with linked population-level data across different agencies, and it is one of very few “information-rich” centres in the world in which researchers can access such data (Roos, Menec, & Currie, 2004).

The use of linked de-identified data has allowed the tracking of children’s hospital admissions, contacts with mental health services, birth characteristics and subsequent academic performance, without recall bias and with minimal bias in subject participation. The administrative data thus allowed the investigation of a large number of factors related to early child health over an extended period of time.

One major advantage of this research was the direct participation of various Western Australian government agencies, in particular the involvement of the Department of Education. Government agencies only collect data of interest for monitoring of trends in outcomes and for policy making; this, together with the active involvement of these agencies in this research, ensured that the research questions investigated in this thesis were relevant to the current aims of these departments and that they have the potential to contribute to evidence-based development of strategies aimed at improving educational outcomes in children. Therefore, this work is an example of successful collaboration between researchers and government agencies to answer research questions that are of direct relevance to policy development, as evidenced by a briefing paper for the Department of Education (Appendix B).

The use of cross-agency data also carries some important practical advantages. Compared to other traditional data sources, such as longitudinal studies and surveys, accessing linked administrative data is relatively inexpensive and avoids the need for identifying confidential information, thus protecting the privacy of individuals (Holman, Bass, *et al*., 2008).

The academic achievement data analysed and presented in this thesis were standardised using a Rasch model and thus were independent of year to year variation in both students' ability and item difficulty. The standardised achievement scores can be validly compared across different grades and over time, and they are comparable with other international tests, such as the Programme for International Student Assessment and Trends in International Mathematics and Science Study. The findings from this thesis have implications for and can be compared across different jurisdictions in Australia and across other developed nations in the future.

Limitations of this research

The main limitation of using administrative data is that they do not include many of the variables that would have been useful, as they were not created with these particular research objectives in mind. Currently, there are no administrative data related to family functioning, child wellbeing and social support, variables which are typically collected by questionnaire or interview in prospective cohort studies. However, new protocols have been recently established which should now enable administrative datasets to be linked with the detailed information collected by such studies for consenting study participants.

When estimating the influence of physical and mental health on academic achievement, there was only information available for those individuals who had accessed the hospital system or who had contact with mental health services. Thus they most likely represent those individuals most severely affected by mental and physical health problems in the community. For example, the population-based study reported in this thesis found a significantly smaller number of children who had contact with mental health services compared to the prevalence of mental health problems revealed in a representative survey of Western Australian children aged 0-17 years (Zubrick, Silburn, *et al*., 1997, 2006). Even though collection of this information from visits to general practitioner records has the potential to improve the ascertainment of individuals with mental and physical health problems in the community, a retrospective collection of general practitioner data, at least in Australia, is currently hampered by a “higher occurrence of false positives” in reporting of certain types of illnesses, particularly for mental disorders (Preen, Holman, *et al*., 2004, p. 1300).

While the recording of primary diagnoses in the hospital morbidity data seems generally accurate, the quality of secondary diagnoses is less adequate. A recent comparability study has showed that about 55% of secondary diagnoses reported in hospital charts were not recorded in the administrative data (Preen, Holman, *et al*., 2004). Thus the accuracy of secondary diagnoses in administrative data could be enhanced by clinical chart reviews. This would improve the validity of any future studies similar to those described in this thesis. In addition, the use of SEIFA as a community-level variable may not reveal the true variation among collection districts and among individual families. It is possible that families with a significantly different socioeconomic background may live in a similar or even the same neighbourhood.

There were some limitations in trying to estimate the impact of risk factors on the educational outcomes of the total population on account of in- and out-migration before the age of eight years. There are currently no means of linking individual hospital records across Australian states and territories. However, since 2008 the National Assessment Program of Literacy and Numeracy is administered to all children across Australia and all children are now assessed in their levels of literacy and numeracy against a common set of items. While such a unified national test is likely to help to account for children migrating out, it will not be possible to account for all migrating children, as it is unlikely that birth records for children migrating in from overseas will be available.

Another issue was the lack of available information on school enrolment and attendance, as currently such data are not made available for research purposes, despite this information being collected by the Department of Education and Training. It was thus not possible to estimate the effect of high absenteeism and to identify children who should have undertaken the academic test but did not participate due to grade repetition. It is therefore likely that the results presented in this thesis underestimated the true proportion of children failing at school (Brownell, Roos, *et al*., 2006).

Finally, in some of the analyses reported in this thesis benchmark standards were used in the same way as used for reporting purposes by the agencies in order to dichotomise educational achievement between those children who failed to reach and those who reached the standards. By using the benchmark as an outcome variable, it is possible to have treated children performing just above or below the benchmark as dramatically different, when in fact they may have had a similar achievement. As with all assessments taken at a given point in time, the results may not adequately reflect their true abilities and skills.

Current education system in Australia

In 1999 in Adelaide, the Australian Ministers of Education made a commitment to work jointly towards improving educational outcomes of Australia's children (MCEETYA, 1997). These commitments are summarised in the "National Goals for Schooling in the 21st Century", including that every child should achieve the minimum benchmark standards in literacy and numeracy within four years. However, across Australia, about 7% of all children and at least 20% of Aboriginal children fail to reach grade 3 benchmarks in literacy and numeracy skills every year (MCEETYA, 2007). Similar proportions of children not meeting the benchmarks have also been reported in Western Australia.

The major concern is that once children fall behind their peers, they are unlikely to ever catch up. The percentage of children who fail to reach the WALNA benchmark standards increases from grade 3 to grade 5, and again to grade 7. The challenge faced by the education system is that when children fall behind, it becomes increasingly more difficult for any intervention efforts to enable them to catch up. Research has confirmed that children who are developmentally delayed learn at a rate that is not sufficient to compensate for their entry-level delays or to allow them to fully "catch up" (Ramey &

Ramey, 2004). An American study found that children from disadvantaged backgrounds are additionally more likely to fall behind their peers over the school holiday (Entwisle & Alexander, 1995; Ramey & Ramey, 2004), thus adding to their disadvantage.

Intervening when children are behind their peers is not only less efficient than prevention but is also more costly, especially as generally greater and more prolonged efforts are required to achieve the same results. Furthermore, children who remain behind their peers are highly likely to drop out of school early, be unemployed and less likely to fully participate in society. There is now compelling evidence that investing in the early years is a good social and economic policy. Research in the United States has estimated that early intervention programs can save up to US$240,000 per child over a lifetime, and that for every US$1 spent on intervention there is a saving of up to US$17 (Karoly, Kilburn, & Cannon, 2005). It is however recognised that even with optimal prevention strategies, some children, such as those with intellectual disability, will nonetheless be unable to acquire the required minimum skills.

Irrespective of a child's innate abilities, the best time to intervene is within early childhood, when intervention strategies are most effective. A prominent economist, James Heckman, has demonstrated that investments in early child development during the first three years of life bring the highest rates of return, especially in disadvantaged children (2006). It is therefore argued here that ensuring that all children can succeed academically is not only a matter of social justice but is also economically advantageous.

Following the election of a new Australian government in late 2007, the Education Ministers formulated new major goals with a specific focus on the promotion of equity and excellence in Australian schools and on the elimination of the existing achievement gap and the social gradient (MCEECDYA, 2009). The current Australian government has recently committed several millions of dollars to closing the achievement gap in literacy and numeracy between Indigenous and non-Indigenous students through evidence-based approaches. The aim is to develop individual learning plans, using intensive learning approaches, and to provide books free of charge for disadvantaged children. However, much less attention has been given to prevention programs. The development of effective prevention strategies has been so far hampered by the lack of evidence-based research (Katz & Redmond, 2009).

An integrated education and health approach to childhood literacy and numeracy

The research presented in this thesis and the existing literature demonstrate that developmental pathways to literacy and numeracy skills are complex, involving many factors that interact with each other over time. In summary, children are less likely to succeed academically if they have poor intrauterine growth, higher rates of hospitalisation admissions, chronic and infectious diseases, mental health problems, and intellectual disability. Such children are more likely to be reared in families with young or single mothers, with parental mental health problems, domestic violence, substance abuse, financial problems and stress (Zubrick, Silburn, *et al*., 1997, 2006). These children tend to attend schools with insufficient resources, low socioeconomic status, low parental involvement and a lack of discipline (Willms & Sommers, 2001). They often live in communities with maternal and social deprivation. Many of these risk factors are reported to have increased over time, such as the proportion of children who live in deprived areas, the proportion of single parent families, families experiencing stress and those with high risk alcohol consumption (ABS, 2008a). Therefore, if the current rising trends continue, it is likely that more children will start school within an environment that is not conducive to learning and hence will have reduced chances of succeeding academically. While some of these factors may impact on educational outcomes in isolation of intervening circumstances via the latent pathways, most factors influence educational attainment either cumulatively or jointly by interacting with related risk factors, such as poverty with social deprivation or single mothers.

Given the complexity of the developmental pathways to educational achievement, it is improbable that a single prevention or intervention strategy alone would be sufficient to reverse those adverse developmental pathways and to reduce the proportion of children who fail to reach benchmark standards. This thesis argues that the best approach to tackle achievement gaps in primary school is through integrated education and health prevention and intervention strategies. This approach is an extension of a public health model which has been successfully applied to a wide range of health problems, including cancer and heart disease (Goldie, 2006).

Primary prevention services for all children and families

The findings reported in this thesis, along with extensive previous research, have confirmed that the early years form the foundation for later child development and that a positive healthy start to life is a pre-requisite for good developmental outcomes (Shonkoff & Phillips, 2000). The main aim of primary prevention is to maximise the potential for child health and wellbeing and reduce social and behavioural problems in children by tackling the fundamental causes of social inequalities, thereby promoting children's readiness to learn and enabling them to succeed academically.

To ensure that all children are provided with the best possible start to life, universal maternal and child health services need to be accessible to all, with sufficient resources and health personnel. While currently in Australia, basic maternal and child health care such as routine check-ups and immunisation and hospital care in public hospitals is provided free to all families, health services that require visits to specialists and laboratory tests incur large costs that is out of reach for many families. Many mothers simply forgo such services due to cost. This suggests that there is a need to also make specialised health services available for free to all families. Other areas for improvement may include the right for all mothers to stay in a public hospital obstetric unit until breast feeding is established. Moreover, in Australia, parenting programs for all prospective parents could be more cost effective than the "baby bonus", which can be spent at the discretion of either parent on items unrelated to an infant's wellbeing. Even with small benefits for each individual, this has the capacity to generate overall improvement in the population (Rose, 1992). Universal and adequate health care provision needs to be supplemented by paid parental leave to enable parents to care appropriately for their babies during the critical stages of their development and to avoid new mothers being forced back into the workforce out of financial necessity. The time that parents spend with their babies is critical for the promotion of parent-child bonding and the reduction of family stress associated with adjustments faced by families with a new baby.

Other services that should be provided to all families include accessible and affordable high quality child care, kindergarten and pre-primary education, affordable and adequate housing, and access to high quality parental support. Although there is evidence that pre-primary education is beneficial in enabling a smoother transition to school (AIHW, 2005), this presents a number of challenges in Australia. Currently, many children do not attend pre-primary schools, and these children are typically Aboriginal, from remote areas and disadvantaged background (AIHW, 2005). Another concern is that Australian pre-primary education is currently publicly under-funded compared to other developed countries (OECD, 2006a). A recent comparative study has revealed that the Australian Government spends more than twice as much on cash support for families than on investments in early child care and learning centres (Katz & Redmond, 2009). Since families may spend such cash transfers on items unrelated to children, a better way may be for the Government to subsidise early child care services and make them available for free to all children.

However, there are some promising initiatives, such as the Stronger Families and Communities Strategy, 2004-2009. This is an excellent example of a holistic approach to “improving early childhood outcomes through engaging stronger community involvement and improving service delivery in disadvantaged communities” (OECD, 2006b, p.272). Another example is the Sure Start program in the United Kingdom, which provides early education, childcare, health and family support to increase children’s chances to succeed academically and, at the same time, to ensure that they are not socially or economically excluded.

Secondary targeted intervention services for children and families at risk

Since virtually all expectant mothers in Australia have contact with health care professionals, it should be possible to identify vulnerable families to whom interventions could most productively be targeted to reduce the likelihood of their children falling behind their peers and to reverse the pathways to underachievement. There are some highly successful initiatives in the United States, such as the Nurse Home Visitation Program, which aims to improve mothers’ prenatal health, to reduce dysfunctional parenting and to improve mothers’ future life prospects (Olds, Henderson, *et al.*, 1999). This program is offered to vulnerable mothers (those on low income, unmarried, and teenage mothers) during their pregnancy, with nurse visits continuing until the baby reaches two years of age. A modified version of this program has been successfully implemented in some States across Australia: South Australia, Western Australia, Queensland and New South Wales. This is an example of a proactive approach to secondary prevention.

Another good example is the Home Interaction Program for Parents and Youngsters, which promotes cognitive and social development in pre-school children and targets families from a disadvantaged background, geographically isolated, of Aboriginal status, or refugees (Gilley, 2003). This program, which was developed and initially implemented in

Israel and has been used in seven countries since 2001 including Australia, aims to increase children's readiness to learn and help them to develop a positive attitude to schooling.

While early learning should be provided to all children, a special focus needs to be given to disadvantaged children not only to improve health and wellbeing, but also to enable a positive and easier transition to school. More services are needed for children and families with multiple risk factors, especially those living in disadvantaged communities. This thesis provides information on significant risk factors associated with school underachievement which should be targeted in secondary interventions to optimise their impact.

Tertiary intervention services for children at school

It is nonetheless likely that some children will fail to reach the minimum academic standards in literacy and numeracy, requiring additional assistance despite all the prevention efforts described above. These children will need easily accessible and timely help on a one-to-one basis to best tackle their individual problems and to identify effective ways to help them to close the achievement gap with their peers. An example of a tertiary intervention is the Getting it Right Literacy and Numeracy Strategy in government schools in Western Australia, which aims to improve students' literacy and numeracy skills through a more effective teaching (Meiers, Ingvarson, *et al*., 2005).

Another example is the Reading Recovery Program used in Winnipeg, Canada, which aims to help students in grade 1 to overcome their reading problems. However, such high quality programs are not currently accessible to all children in need due to insufficient funding provided to schools, especially of low socioeconomic status, that may opt for programs with a wider reach but less effectiveness (Brownell, Roos, *et al*., 2004).

Most resources should be therefore directed towards prevention so that as few children as possible fall behind in the first place. Since it becomes increasingly more difficult and more resource-intensive for children who fall behind to ever catch up with their peers, it is important and economically rational to ensure that all children are assisted as early as possible to succeed academically. A sense of achievement at school builds a healthy confidence in children and encourages them to be creative and motivated.

Conclusions

The findings reported in this thesis indicate that optimal intrauterine growth increases children's chances of academic success in primary schools, and that having favourable birth outcomes is even more important for those children born to single mothers and to mothers residing in deprived areas. As children grow older, those with more frequent hospitalisations, particularly admissions for infections, are less likely to reach the education benchmark standards. Aboriginal children are more affected by hospitalisations, but of those who are hospitalised, those who stay for very long periods seem to do better than those with medium to long stays, and equally well as those who have very short hospital stays. As children enter the school system, the risk of developing mental health problems also increases, but some have their first contact with mental health services even before the age of five. These children are not only less likely to attain benchmark standards, but also continue to have mental health problems after school entry and they are more likely to be diagnosed with intellectual disability. However, it seems that the effect of socioeconomic disadvantage on educational achievement is mediated primarily by maternal characteristics, mainly maternal age and parental mental health.

The implication is, therefore, that it is critical to optimise health in pregnancy for all women and for all children at birth. It is essential to develop targeted strategies to support mothers residing in deprived areas, especially single and young mothers, so that adverse developmental pathways can be interrupted. It is also important to improve screening of young children for mental health problems and to support vulnerable families to promote better parenting practices and to reduce excessive stress, especially in Aboriginal families. Finally, it is necessary to have in place prevention programs for common preventable diseases and to introduce targeted strategies for less common diseases that nonetheless have a strong influence on children's academic achievement.

It is evident from the findings reported in this thesis that to ensure that all children can successfully develop their literacy and numeracy skills, they need to be given the best opportunities from infancy for maximising their physical and mental health. The best way to achieve this goal is through the collaborative work of government and non-government sectors using a combination of prevention and intervention strategies, with sufficient resources. On-going evaluation of those programs should provide vital information on what works the best.

Future research should investigate the potential role of school absenteeism in mediating suboptimal educational achievement in Aboriginal children. More research is needed to investigate other potential mediators of the social gradient in academic achievement, with a particular focus on the psychological wellbeing of families, in particular stress levels in the families.

Australia has made a commitment, along with other countries around the world, to achieve literacy and numeracy for all by 2015. In 1999, Australian Education Ministers declared that all children should attain the minimum literacy and numeracy skills within four years (MCEETYA, 1997). Therefore, it is essential that a strategy be developed based on an integrated health and education approach with universal prevention for all children and families, secondary intervention for at-risk children and families, and tertiary interventions for children who need help to catch up with their peers while at school. The findings reported in this thesis can inform this process and contribute to what the current Australian Prime Minister Kevin Rudd and Education Minister Julia Gillard have termed the “education revolution” (Marginson & James, 2008).

Society can never achieve true social justice if some of its members cannot fully participate and succeed simply because they were born into the “wrong” family background. Health and education are the vehicles for children’s future life chances and for breaking through the intergenerational cycle of disadvantage. If we accept that education is not only necessary for the economic development of a nation, but is also a public good, then we must dedicate ourselves to assisting all children to achieve basic literacy and numeracy.

Summary of key findings and policy implications

- Optimal growth of a baby in the uterus was associated with better academic achievement compared with either very poor or excessive growth. However, single motherhood and low socioeconomic status of neighbourhood exacerbate the influence of some of the birth outcomes on educational achievement. *Recommendations:* To ensure that all children can have a healthy start to life, it is essential to promote and optimise health in pregnancy, especially in areas of socioeconomic disadvantage and for single mothers. It is also important to promote healthy lifestyles especially in expectant mothers.

- Frequent hospitalisations were associated with an increase in the likelihood of not reaching the minimum standards in literacy and numeracy. Aboriginal children who were hospitalised for at least 7 consecutive days had lower mean academic outcomes compared to those hospitalised for fewer days, regardless whether the admissions occurred before or after school entry. However, Aboriginal children with single long hospital admissions had better mean academic outcomes than those with medium-long stays. In contrast to Aboriginal children, non-Aboriginal children who were hospitalised for the same single duration of at least 7 days had lower mean academic outcomes only for hospital admissions occurring after school entry, but not for admissions occurring in early childhood. *Recommendations:* The promotion of early child health will lead to lower hospitalisations and hence to improvements in the academic outcomes of both Aboriginal and non-Aboriginal children. For non-Aboriginal children, this will be through reduction of absenteeism at school, but the underlying mechanism is less clear for Aboriginal children but possibly through improved health status and the social environment.
- Children who were hospitalised for respiratory non-infectious diseases, infections (both respiratory and non-respiratory) and for external causes (mainly injuries and poisoning) were at a greater risk of not reaching the benchmark standards compared to those who had no hospitalisations. Aboriginal children were least likely to reach the benchmark standards if they had ≥4 admissions for any infections, while non-Aboriginal had the highest risk if they were more frequently admitted for non-respiratory infections. *Recommendations:* To improve both health and academic performance for all children, it is important to have universal prevention strategies in place for common diseases as well as targeted strategies for less common diseases that have a strong adverse effect on academic achievement.
- All children who had contact with mental health services before school entry continued to have contact between ages 6 to 8. Children were the least likely to attain the benchmark standards if they had a secondary diagnosis for mental health problems. However, Aboriginal children who had a primary diagnosis of mental health problems were more likely to have better educational outcomes than those who had no mental health contact at all. *Recommendations:* Children should be screened for possible mental health problems as early as possible to allow intervention programs before these problems become too entrenched and difficult to overcome. Targeted strategies should be provided for "at-risk" families to help

them build their capacity to better respond to the emotional needs of their children and to make their home environment more positive, stress free and conducive to learning.

- The social gradient in numeracy attainment was partially mediated by maternal characteristics (such as teenage motherhood and, to a lesser extent, single marital status). In combination with maternal characteristics, parental mental health had a small additional mediating effect. However, none of the child factors (including birth characteristics, mental and physical health) had any significant mediating effect on numeracy attainment. *Recommendations:* Targeted strategies should be specifically available to teenage and single mothers to provide extensive support. To reduce any stigma attached to targeted strategies and increase the chances of successful collaboration with those mothers, strategies, such as the Nurse Visiting Program, should start already during pregnancy.

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Appendix A

Published manuscripts related to this thesis:

Malacova, E., Li, J., Blair, E., Leonard, H., de Klerk, N, & Stanley, F. (2008). Association of birth outcomes and maternal, school, and neighborhood characteristics with subsequent numeracy achievement. *American Journal of Epidemiology*, 168(1), 21-29.

Malacova, E., Li, J., Blair, E., Mattes, E., de Klerk, N, & Stanley, F. (2009). Neighbourhood socioeconomic status and maternal factors at birth as moderators of the association between birth characteristics and school attainment: a population study of children attending government schools in Western Australia. *Journal of Epidemiology and Community Health*, 63(10), 842-849.

Appendix A ‘Published manuscripts related to this thesis’ could not be included in this digital thesis for copyright reasons.

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Appendix B

Government briefing paper:

Malacova, E., Li, J., Blair, E., Leonard, H., Mattes, E., de Klerk, N., & Stanley, F. (2009). *Interrelationship between birth characteristics, socio-demographic factors and educational achievement.* Government briefing paper.

Appendix B ‘Government briefing paper’ could not be included in this digital thesis for copyright reasons.

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