How Health Status At Birth and Through Childhood Affects Progress and Performance in School: A Population-Based Study

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A thesis submitted to the Faculty of Graduate Studies in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

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DOCTOR OF PHILOSOPHY

Dedication

To alison mcLean,

my best friend forever, and my inspiration.

To Ben and Will,

our boys.

To Gerard and Angele Fransoo

my first and everlasting support system.

Abstract

How Health Status At Birth and Through Childhood Affects Progress and Performance in School: A Population-Based Study

Objective: This study examined how health status at birth and through childhood affects educational outcomes, controlling for social, economic, and demographic factors.

Methods: Administrative data were used to follow all children born to Winnipeg mothers in 1990, and remaining in Winnipeg until June 1999 (N = 5,873). A structural equation model was developed with many predictors, including: each child's sex and exact age, health status at birth and through childhood, experience with major illness, and a variety of social, economic, and demographic characteristics of the family. The outcome was a combination of Grade 3 Standards Tests scores and enrolment records.

Results: Health status had a statistically significant but substantively modest influence on progress and performance in school. Of the three health constructs used (health status at birth, health status through childhood, and major illness), major illness was most strongly related to the outcome ($p<.001$), followed by health status through childhood ($p<.01$). Health status at birth was not directly associated with progress and performance in school, but had significant indirect effects through health status through childhood and major illness. Supplementary analyses revealed that among the minority of children with major illness, both health status at birth and health status through childhood were significantly related to the outcome. However, among the majority of children without major illness, no health factors were significantly related to progress and performance in school. Several of the social, economic, and demographic factors were strong predictors for all children. In particular, child age, area-level income, mother's age at first childbirth, family receipt of income assistance, and the child's sex were among the strongest predictors in all models (all $p<.001$). Breastfeeding initiation, family size, and maternal depression were also significant contributors in the final model.

Conclusion: Health status made a statistically significant but substantively modest contribution to explaining progress and performance in school in a population-based cohort. The effect was important only among children with a major illness. The strong influence of social, economic, and demographic factors on all children suggests that efforts to improve schooling outcomes should focus on addressing challenges in the social environment. Interventions in the early childhood years for at-risk children have proven effective, and offer promise for improving outcomes.

Acknowledgements

It is a pleasure to write this note of thanks to those who helped me complete this project. No doubt some names are missing from the list below, and for that I apologize.

My advisory committee was instrumental in helping me shape and refine my initial research questions and formulate a coherent project. My supervisor Noralou Roos, and committee members Patricia Martens, Maureen Heaman (Nursing), and Benjamin Levin (Education) were extremely helpful and constructive from start to finish. In particular, I am thankful for Noralou's unwavering support, even when it might have seemed like I might never finish. Pat Martens suffered the consequences of being in the office more often, so I hereby bestow on her the title 'Honorary Supervisor' for her frequent, sometimes challenging, and always thoughtful feedback which helped me get over many bumps along the way.

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Chapter 1: Introduction and Background

1.1 Statement of the problem

Education plays a fundamental role in human development and in new knowledge creation. Therefore, establishing a solid educational foundation for all children is important for several reasons: for the children themselves, to educate them for their own benefit and fulfillment, but also to empower them to contribute productively to their society and the world (1-3). Meeting this objective requires identification of potential barriers to educational success, so that programs and services can be designed to help all students overcome whatever challenges they face. From this perspective, the impact of health status on educational outcomes has not received adequate attention.

Conversely, the strong impact of socioeconomic factors on health outcomes is among the most robust findings in the social sciences, having been demonstrated in settings around the world, and over decades, even centuries in some places (2;4-11). Epidemiological studies and related research have shown that education is among the key drivers of this phenomenon, at both the individual and aggregate levels (12-15). That is, those with higher educational attainment live longer, healthier lives than those with less education.

Education is related to health outcomes directly, but also through intermediate factors like employment and income. So educational attainment is well understood to be an important determinant of population health, and improving educational outcomes can be seen as a primary potential means of improving population health status. All of these observations, however, address the circumstances of adults, and less is known about how these factors relate to each other in early childhood. The objective of this research was to determine whether health status in childhood might affect educational attainment, which in turn affects socioeconomic status and health status throughout adulthood.

The published literature documents the many educational, psychological, and sociological factors that affect cognitive and educational outcomes. As with health outcomes, socioeconomic characteristics are among the key determinants of educational success (see Chapter 2). However, there is little research on how health status directly affects educational achievement, except for research on birth characteristics, which shows that poor health status at birth (low birthweight, preterm birth, etc) is related to poorer health outcomes. Most studies of educational outcomes either ignore health status completely (assuming equal health among all participants), or 'include' health only by excluding those with severe health or developmental problems that limit educational participation or success. Few studies address the influence of the less severe, chronic and/or clustered health problems on educational outcomes. This is perhaps not surprising when consideration of the data requirements for such a study are fully appreciated: most children are in very good to excellent health status, so large samples and extensive data are required to determine the impact of health status on educational outcomes. This study may be the first population-based examination of the relationship between health status and educational outcomes, controlling for key social, economic, and demographic factors including breastfeeding, which has been shown to be associated with both health and educational outcomes.

1.2 Setting and context for the study

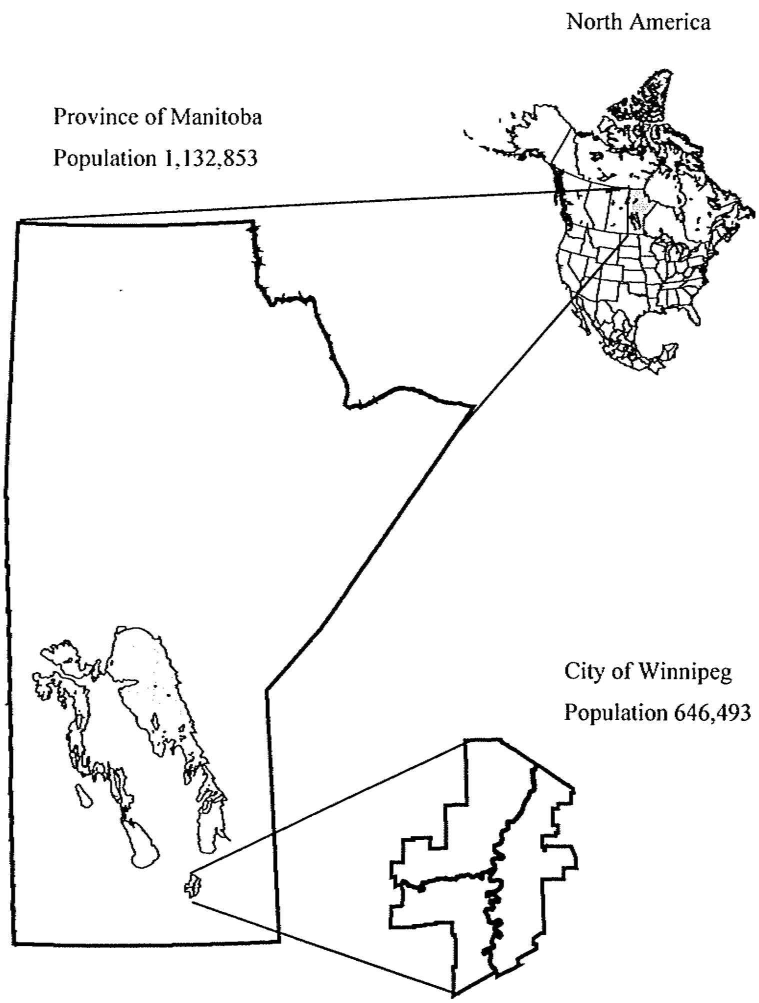
This study was undertaken in the province of Manitoba, Canada. In 1990, Manitoba had a population of 1,132,853 residents, of which 646,493 lived in the capital city of Winnipeg, from which the study group was drawn (see Figure 1.1).

Manitoba, like all other Canadian provinces, is required to operate a health insurance system which provides coverage for all residents, in accordance with the principles of the Canada Health Act (16;17). The system is jointly funded by federal and provincial tax revenues, largely without deductibles or co-payments from patients. The system provides and pays for all services defined as 'medically necessary', and includes services provided by medical doctors, by publicly-owned and operated hospitals, as well as home care and other services, in addition to partial coverage for nursing homes (called personal care homes), and prescription drugs (18).

Manitoba also operates a universal system of schools for elementary and secondary education, at which attendance is mandatory for all children from age seven through 16 years (19). Public schools throughout the province offer education from Kindergarten through Grade 12, funded by provincial and property tax revenues. The system includes the Provincial Assessment Program, a series of assessments of student learning and competencies throughout the school years (20). Key assessments are conducted at the end of the early years (Grade 3), as well as through middle and senior years. The exact nature and details of the assessments have changed over the course of time. In the 1998/99 school year (the Grade 3 year for children included in this study), the Grade 3 assessment took the form of two Standards Tests: one in Language Arts, and the other in Mathematics (with separate instruments for those in the English, French

Immersion, and Francais programs). These tests were developed by a team of teachers and consultants to ensure congruency with the Grade 3 Curriculum and Standards, and pilot tested before implementation (21;22). The 1998/99 school year was the only year that both Language Arts and Mathematics tests were completed; the form of testing changed the following year, to a system of teacher-based assessment of students.

Figure 1.1: Setting: City of Winnipeg, capital of Manitoba, Canada



1.3 Purpose of the study

This study will determine whether health status at birth and through early childhood affects educational outcomes through age nine years, for the entire cohort of children born in 1990 to mothers living in Winnipeg. The analysis will control for key social, economic and demographic characteristics of the child, the mother, the family, and the neighbourhood in which they live.

1.4 Data sources

This research project was a secondary analysis of data routinely collected by government departments during the administration of programs for health, education, and social services. The data are housed in the Population Health Research Data Repository (hereinafter referred to as 'the Repository') at the Manitoba Centre for Health Policy (MCHP), in the University of Manitoba's Faculty of Medicine. All data were either collected by, or encrypted through the provincial department of health. No names or addresses are contained in the files at MCHP, and individual identifiers (e.g. personal health information numbers) are encrypted before transfer from Manitoba Health to MCHP. Use of this data is permissible only after approval from the University of Manitoba Health Research Ethics Board, and the Provincial Health Information Privacy Committee, and only for the duration of the project. Appendix 1 contains copies of letters approving data use for this project. Appendix 2 describes the extensive procedures in place at MCHP to ensure security, privacy and confidentiality of data.

1.5 Study group and outcome measure

The study group comprised the entire cohort of children born to Winnipeg mothers in 1990, and who remained living in Winnipeg through June 1999 and in Manitoba through September 2004. The majority (82%) of these children were in Grade 3 during the 1998/99 school year, as expected, and wrote the Grade 3 Standards Tests in Language Arts and Mathematics. However, not all cohort children wrote the tests: some were exempted for a number of reasons (see Chapter 3 for details); some were absent on the test dates; and some started but did not complete the tests; in addition, others were enrolled in Grade 2 or lower during the 1998/99 school year. Since the objective of this study was to conduct a population-based analysis, all these children were included. The outcome measure is referred to as 'Progress and Performance In School to Age 9 Years.'

1.6 Research questions

1.6.1 Primary research question:

1) Does health status at birth and through childhood affect progress and performance in school, in the Winnipeg 1990 birth cohort?

1.6.2 Secondary research questions:

2) Does socioeconomic status influence progress and performance in school, in the Winnipeg 1990 birth cohort?

3) Does breastfeeding initiation influence progress and performance in school, in the Winnipeg 1990 birth cohort?

1.7 Limitations and Delimitations

1.7.1 Limitations:

The key limitations in this study arise from the nature of the variables being used, because they are based on routinely collected administrative data, not primary data collected for purposes of this research project. Quantifying a child's health status is a significant challenge, so multiple variables will be used to capture key concepts. Similarly, one aspect of socioeconomic status, family income, will be measured using aggregate (area-level) information, not individual family-level data. Finally, the outcome measure has limitations, because it was (for most children) determined by performance on a pair of standards tests in Grade 3 – and a child's performance on any given test may be different from their 'true' ability.

1.7.2 Delimitations:

The study cohort was delimited to children born to Winnipeg mothers in 1990, and who lived in the city through June 1999, and in the province through September 2004 (approximately 6,000 children; regardless of their enrolment level in the school system). The 'residence in Winnipeg' requirement was applied for several reasons, including the fact that social stratification by location of residence is more homogenous in urban settings than rural areas (which is important because the income measure used is an area-based measure), and because First Nations students attending so-called 'Band-Operated' schools were not required to write the standards tests which form the basis of the outcome measure for this study (there are no Band-Operated schools within the city of Winnipeg).

Children of multiple births (i.e. twins and triplets) were excluded, because they are not 'statistically independent' observations, as required by the analysis technique.

1.8 Ethical Issues

No significant ethical issues were anticipated for the study, as it was conducted on anonymous research data derived from administrative records available in the Repository. This study was approved by the MCHP Research Review Committee, the University of Manitoba Health Research Ethics Board, the provincial Health Information Privacy Committee, and the other government departments whose data were included (standards test scores and school enrolment from the Department of Education, Citizenship and Youth; records of Income Assistance receipt from the Department of Family Services and Housing). Copies of the letters indicating approvals are shown in Appendix 1.

1.9 Significance of the study

The determinants of 'success in school' have been studied extensively for decades, from a variety of perspectives. However, only a very small portion of this work explicitly incorporates health issues. This study may provide new insights into the influence of health on children's progress and performance in school. In particular, it may reveal whether the documented association between health status at birth and educational outcomes is independent of, or mediated by, health status through childhood. No published study has incorporated longitudinal measures of health status.

Adding health and other social characteristics to the list of factors already studied may reveal policy sensitive influences in the health, education, and social systems which might be used to improve educational outcomes. Health characteristics may also help explain some of the majority of unexplained variance in studies of educational outcomes.

This study will also provide a population perspective for understanding the nature and timing of health problems and their effect on educational outcomes. Knowing more about how and when a child's health and social environments affect their educational outcomes could be helpful in planning health, social, and educational interventions. In addition, schools may be able to better serve their students and organize their services if they knew in advance about particular challenges resulting from the health status of incoming students.

The use of a population-based perspective, as compared with samples or surveys, provides important advantages. The fact that all children born in 1990 were included means that the analysis will not be biased by sample selection or recruitment issues. Furthermore, if routinely collected administrative data can identify significant relationships, they provide a universal, relatively low-cost method of further follow-up of these issues. This could prove invaluable in evaluating past, present, or future programs or services in the health, education or social sectors, and shedding light onto new opportunities for intervention to improve the outcomes of all children.

Chapter 2: Review of related literature

2.1 Introduction: Determinants of schooling outcomes

There is a large and diverse body of research documenting the many factors which influence children's progress and performance in school. Wang, Haertel and Walberg (23) provides a comprehensive review. Many important factors have been identified, from several key areas:

- psychological factors including cognitive ability, motivation, and attitude and engagement in school

- sociological factors, most importantly, the socioeconomic status of the child's family and, to a lesser extent, of the neighbourhood in which the family lives; also parenting practices, and family structure and dynamics

- the education system, including teaching practices, class size, class and school composition and processes, parental involvement in school, and school and division policies and programs.

Issues regarding the health status of students are largely absent from these studies, providing the motivation for this research project. This study focused on how health status affects schooling outcomes, and includes a number of social, economic, and demographic variables known to influence schooling outcomes. The importance of family background cannot be overstated: in almost all studies, it is found to be the strongest single predictor of schooling outcomes.

These large bodies of research reflect the fact that student outcomes are multi-factorial, and difficult to fully 'explain' in terms of predictors such as those listed above. White's 1982 review of over 100 studies of educational outcomes showed that in most studies, the proportion of variation in the outcome explained is typically 10-20% (24), and recent work suggests this has not changed dramatically since then (25;26).

This study will attempt to determine whether health factors can significantly add to our understanding of, and ability to predict, educational outcomes.

2.2 Social, economic and demographic factors

The characteristics of the family in which a child is being reared are often the most important factors in determining student performance. Many different measures have been studied, using different variables and forms. The following list includes those which were found to be important in previous studies of cognitive and/or educational outcomes of young children, and available in the Repository at the Manitoba Centre for Health Policy.

- income, whether measured at the level of the individual household/family, or area-based measures (e.g. taken from census data), income is often the strongest single predictor of student outcomes (23;24;27-32); cognitive and schooling outcomes are higher for children from higher-income families, and these effects are evident from early childhood (33;34)
    - measures can include receipt of social assistance ('welfare') programs, or area-based measures such as the proportion of families living below a given cutoff value (27;30;35-40). Long-term poverty appears to be particularly strongly related to poor outcomes (27;37)

- other measures of social class: occupational classifications or indexes created from numerous variables including employment rates and educational levels (23;29;35;41-51)
- mother's age: children born to young (especially teen) mothers generally have poorer outcomes than those born to older mothers (27;28;41;45;52-55)
- family size: children from smaller families generally have better outcomes than children from larger families (27;35;41;42;44-49;52;56-58)
- number of times the child changes schools and/or the family moves, which are negatively related to schooling outcomes (27;45;58)
- family structure, including whether both parents are living together, and/or are married (27;30;35;45;52;57); children from single-parent families generally have poorer outcomes than children in two-parent families
- mental status of the parents, especially maternal depression, which has been associated with poorer outcomes in children (27;35;59-61)
- the exact age of the child: in the early years of school, those born earlier in the year have somewhat better outcomes than those born later (58;62-64); however, some studies showed no effect (65;66)
- the child's sex: in the early years of school, girls score higher than boys, especially in language skills (31;47;50;51;58;67)
- breastfeeding: children who were breastfed have better cognitive / educational outcomes than those who were not (28;49;68-75)

2.3 Measuring the health status of children

In developed countries, the vast majority of young children tend to be in very good health: surveys and studies consistently show that 75-85% of children have no significant health issues or diagnosed diseases (76-79). Many different measures have been used to assess child health status, and the measures used vary with age. At birth, common measures include the child's weight, gestational age, Apgar scores at 1 and 5 minutes, use of mechanical ventilator for breathing support, and length of stay in hospital. Numerous indexes comprised of medical and biochemical measures have also been developed (80-83). However, the kinds of data used in these measures (e.g. blood chemistry values) are not available in the administrative data used for this study. Interestingly, most of these indexes were validated by testing how well they predict the baby's length of hospital stay at birth – implying that length of stay is the 'gold standard' or best available single measure of a newborn's health status. Therefore, the inclusion of length of hospital stay in this study helps overcome the limited availability of clinical data. Independent studies have compared the various indexes, and found them to be significantly correlated with each other, and with birthweight and length of stay (84;85).

In the preschool and early school years, health measures are usually based on diseases diagnosed in the child (76), as well as health service use – a validated proxy for illness (79;86-88). Furthermore, illness can cluster in the same individuals, so those that have an illness sometimes have multiple illnesses, also known as co-morbidities (88-93). Finally, there is the issue of chronicity, or how long a child is affected by a given health problem. Some diseases, for example asthma, can be short-term or 'grown out of' (94), whereas other diseases, including many neurological disorders and congenital anomalies, can have long-lasting, even life-long consequences (78;95;96).

Two statistical considerations are also relevant to the measurement of health status in children: normality, and linearity. Many health status measures show 'non-normal' distributions. That is, the majority of children often score low on indexes of ill-health, and the remaining (less healthy) minority of children get higher scores. Linearity refers to how two variables are related to each other: if one increases or decreases in proportion to the other, the relationship is said to be linear. Many kinds of statistical analyses require the data being analyzed to be normally distributed, and with linear relationships to each other. Since many of the variables in this study are not normally distributed, transformations of the variables will be employed. These considerations will be addressed more fully in Chapter 3: Methods.

2.4 Cross-sectional research on health and education

2.4.1 Introduction

There is a comparatively small body of research describing the relationship between health status and educational outcomes (97), because this area of research is relatively new.

Before reviewing previous studies in detail, a few preliminary notes are required. First, in older studies, no precise differentiation was made between preterm birth and low birth weight (LBW) (98); the latter was taken as an obvious marker of the former. This has changed over time, and the two are now understood as distinct, and combine to create indicators like 'small for gestational age.' Of the two, birthweight has been used far more frequently, probably because of its precise measurement and near universal recording (99). However, the two indicators remain correlated: many children born before 37 weeks of gestation (defined as 'preterm' birth) weigh less than 2,500 grams (defined as 'low birthweight) (100).

Second, survival rates of preterm and low birthweight babies have increased substantially in recent decades, largely the result of advances in medical care. In particular, the introduction of surfactant therapy in the late 1980s significantly improved lung function, increasing survival rates and improving the health status of many children born preterm (99). Since the mid 1990s, infants born at 26-28 weeks (typically 750-1,250 grams) usually survive, though frequently with significant disabilities (99).

The third consideration follows directly from the improved survival rates: in older studies, 'preterm birth' often meant children born between 32 and 37 weeks, because few children born before 32 weeks survived, whereas recent studies can include surviving children from as early as 24 weeks. This means that newer studies will likely show larger effects of preterm birth, because the distribution is shifting and the categories 'low birthweight' and 'preterm birth' now contain many more children surviving extremely preterm birth at very low weights. Related to this, a higher number of long-term developmental problems are becoming more prevalent in the population, because a higher number of comparatively 'under-developed' infants are surviving.

Fourth, low birthweight and preterm birth are more frequent among lower socioeconomic groups (101-104), though this difference has decreased over time (105). Remaining differences have been partially attributed to cigarette smoking, as it is a significant cause of preterm birth and fetal growth problems, and is more prevalent among lower income groups (101;103;104).

Finally, children of multiple births (i.e. twins, triplets) present a challenge to many research studies. Because they share the same 'unusual' environment in utero (42;56), they are not statistically independent observations, which is a requirement for most analytic methods. Children of multiple births are often delivered preterm and at low birthweights, and their cognitive performance has been shown to be slightly but statistically lower than single births (56). For these reasons, most research studies of this kind use only singletons.

2.4.2 Studies of 'general' health status and schooling outcomes

A number of cross-sectional studies have shown that poor health status and school performance are related. However, most of these studies found only weak effects (106;107), or effects that may have been related to differences in socioeconomic characteristics rather than health status (108). Numerous reviews in this area confirm the general finding of weak associations between child health status and schooling outcomes (97;109-113).

However, several well-designed recent studies suggest the association might be stronger than previously suggested. Fowler et al (114) found that children with chronic health conditions performed less well on standard tests, though the difference was large only for children with major disabilities (spina bifida, epilepsy, or sickle cell disease). Wolfe (115) reported that significant physical illness is related to school attendance but not performance, while psychological problems were the opposite: they affected school performance to some degree, but not attendance rates. Gortmaker et al (116), using data from a large survey, found that children with chronic health conditions were more likely to have been placed in special education programs or to have repeated a grade.

2.4.3 Studies of specific diseases and schooling outcomes

In studies involving children with specific chronic diseases, the results are mixed.

2.4.3.1 Asthma

Asthma is the most common chronic disease among children (76;79;89), and therefore has received more attention than other diseases. Several studies show that children with asthma have more absences from school (117-120), but studies of their cognitive / academic performance have reported that they perform as well as or better than others (30;109;119;120).

2.4.3.2 Middle Ear Infection (Otitis media)

Otitis media is a common infection among preschool and young school-aged children (121). Children who experience repeated ear infections may be at risk of later hearing and speech problems, and related schooling difficulties. However, there remains uncertainty in the literature; some studies report large differences (121), while others find only small (122) differences, or differences related to behaviour but not achievement in school (123).

2.4.3.3 Type I (Insulin Dependent) Diabetes Mellitus

Early studies on children with Type I diabetes showed no differences in academic and school performance compared to children without diabetes (97;109;124;125). However, a more recent study found somewhat lower academic performance among those whose diabetes was either severe or poorly managed (126).

2.4.3.4 Summary of findings from disease-specific studies

These inconclusive findings relating to specific diseases may be due to the fact that within every disease, some children are affected much more than others – either because of severity of illness, or poor management, or both. A number of studies suggest that the diagnostic category itself is less important than the severity of the consequences of the illness for the child (114;127;128). That is, it may not matter whether a child has disease X or disease Y, but rather, how seriously the child's functioning is compromised.

2.4.4 School absence

A logical connecting path between health problems and educational outcomes may be school absence due to sickness. Several articles deal directly or primarily with the issue of school absence, including studies of children with chronic disease. They suggest that sick children indeed have more absences from school, but that the number of absences was not related to educational outcomes (except for children with major disabilities) (28;114;127). While sickness is a cause of many absences, the major drivers of school absence are not health-related factors (114;127;129;130). Moreover, research indicates that while lower absence rates have been shown to be related to achievement for healthy children, they were not related to achievement among those with chronic illnesses, even though absences are higher among the sick (97;131). Despite this, some have advocated for more intense physician involvement among children with high absence rates, arguing that some of their absences may be caused by undiagnosed health problems (130;132).

2.5 Follow-up and longitudinal studies of health and education

This section reviews in detail the studies most closely related to the areas of interest in this study. Key characteristics and information for each study are found in Table 2.1.

2.5.1 Health status at birth and cognitive/educational outcomes

This section and section 2.5.2 will review in detail the key studies most closely related to the subject matter of this study. Descriptive information for the studies reviewed are summarized in Table 2.1, shown at the end of section 2.5.2.

2.5.1.1 Studies relating both birthweight and gestational age to outcomes

This section summarizes results from studies that measured both birthweight and gestational age, including a number of small-sample studies (44;105;133), as well as some with much larger samples (42;46;47;52).

The earliest set of studies merit special attention. They were published from a data linkage project in Birmingham, England almost forty years ago (42;56;134). Information from all births had been recorded on punched cards starting in 1950, and five years of these records were linked with school test results when the children reached the sixth grade. The outcome measure was the score on a test of verbal reasoning, part of a standardized examination. These were among the very first studies in the area, and they established connections between birth circumstances and later cognitive outcomes.

During this time there were 86,630 births, and 50,172 of these were successfully linked using a very strict matching algorithm. The difference between the two numbers is accounted for "mainly by those who moved away or died before age 11, who did not take the test because they were in private schools or special schools for the handicapped, or, though in ordinary schools, had been assessed as *borderline subnormal*." (42). Unfortunately, exact numbers and comparisons for each of these categories are not given, so it is impossible to determine the strength of any biases introduced.

Countering this concern, the results show clear coverage of a large range of families, by size and social class. However, the results appear consistent with a systematic bias excluding children with lower performance: across a wide range of values of both birthweight and gestational age, the test scores cover only a very small range of outcome scores (92-104), all near the average of 100. It would seem likely that, for example, the 'borderline subnormal' group would have had lower scores, but their exclusion makes it impossible to determine the true impact.

Among the 50,172 children included, the results suggested that low birthweight and abnormally short or long gestations were associated with lower test scores. They revealed a mild linear relation with birthweight, with no ceiling effect (the largest group was 4,500g and higher) (42). This trend did not apply to those born at shortest gestational age, for whom higher weight conferred no advantage. Trends with gestational age showed an inverted 'U' shape: the highest scores were recorded among those born between 39 and 41 weeks, while those with shorter or longer gestations did less well. However, the authors recognized that all of these trends in fact represented very modest differences in the actual outcome scores. They concluded, "for normal single births, the variation in scores in relation to birthweight and duration of gestations is very small."

The Birmingham studies used only a single outcome measure (score on a verbal reasoning test), but many other studies have shown that, as a group, low birthweight children score lower on a variety of cognitive tests and outcomes (see reviews (135-

137)). When both birthweight and gestational age are included in multivariate analyses, birthweight usually shows a stronger relationship, and gestational age often becomes statistically non-significant (133). Other studies have shown broadly similar results, though several reveal that the linear increase in outcome scores often levels off or decreases at high birthweights (46;47;52).

Studies that combine gestation and weight at birth have shown that the group with highest risk for poor schooling outcomes are children born small for gestational age. This includes test results (133) as well as broader measures like graduation rates (44). Children born at weights appropriate for their gestational age performed better, even when their birth was preterm.

2.5.1.2 Studies relating birthweight alone to outcomes

Many studies include measures of birthweight only, without measures of gestational age. The literature addressed in this section includes several small (51;138;139) and several large studies (35;45;140;141).

Overall, the results show that children born at low birthweight generally have poorer performance and lower academic achievement than normal birthweight children (45;141). However, the grouping together of all children born under 2,500 grams masks large differences within this group. Children born at 2,000 grams or higher usually perform at par with normal birthweight children (51). The very low birthweight children (under 2,000g) seem to have very poor outcomes, which brings down the average for whole low birthweight group. Children born at less than 2,000 grams have been shown to perform less well on school tests (139), to need extra help or special education services more often (35), and to be retained in grade more often (35;138).

2.5.1.3 Studies relating gestational age alone to outcomes

Several studies examined only preterm births, showing a relationship with cognitive/educational outcomes. A small, early study showed that preterm children had lower scores on perceptual and visual tests, but not on verbal scores, social measures, or school performance indicators – in which preterm children scored lower, but still within the normal range (57). This is consistent with the results of the earlier and much larger Birmingham studies, in which verbal reasoning scores were only slightly lower among those born after short or long gestations (56).

A recent longitudinal study from Germany showed that children born 'very preterm' (less than 32 weeks gestation) frequently showed more than one developmental problem, and did worse on a battery of tests (142). A smaller American study found mild motor delays and lower academic achievement scores among preterm births, particularly among those with higher perinatal morbidity (143). Preterm birth has also been linked to deficits in attention and self-regulatory capabilities, which are thought to contribute to problems with behaviour and schooling (144).

2.5.1.4 Studies using longitudinal designs (outcomes measured at several times)

Perhaps the most compelling evidence comes from longitudinal analyses incorporating repeated outcome measurements on the same individuals. In these cohort studies, longitudinal data were used to assess the relationship between birthweight and cognitive and educational outcomes, controlling for social status and other key variables.

The first report came from the 1946 British birth cohort study (the National Survey of Health and Development). This study involved a large sample (5362) of births occurring in England, Scotland and Wales during one week in March, 1946. It collected data on a broad variety of measures at birth, and ages 8, 11, 15, 26, and most recently 43 years, at which time the sample size was 3262, and still considered representative of the population born at the time.

In a paper published in 2001, Richards et al (48) analyzed the relationship between birthweight and both cognitive test scores (at all ages), and schooling outcomes (high school graduation equivalent). Although gestational age values were not available, the analysis did control for sex, father's social class, mother's education and birth order. The longitudinal aspect of this analysis meant multiple outcome measures, not multiple measures of the predictor / control variables. The results revealed a linear relationship between birthweight and cognitive outcomes at ages 8, 11, 15, and 26. The effect was weaker at the older ages, and no longer significant by age 43. The relationships with tests scores were significant when unadjusted, but became even stronger after controlling for the social factors listed. Analysis of other school outcomes also showed significant results: higher birthweight was associated with higher educational attainment, and this effect was also strengthened by the addition of covariates to the analysis. All analyses were replicated excluding children of low birthweight, which confirmed that the effects were not driven by the poor outcomes for that group. Significant relationships were still found across the 'normal' birthweight range. Thus the study provides impressive evidence of the effect of birthweight on cognitive outcomes, controlling for social class and other key variables.

In an interesting sub-analysis, the effect of test results at previous ages were taken into account in predicting next-age results. This revealed a number of fascinating findings. First, results at age 8 were a strong predictor of outcomes at every other age (except age 43). Cognitive growth from ages 8 through 26 were similar among all birthweight groups, suggesting that birthweight has its main effect early in life, after which time most people learn and progress at roughly similar rates. This is consistent with findings from many early childhood studies, as will be described in more detail in the Discussion chapter.

Overall, this was a very well designed and conducted study. However, there are a few issues worth discussion. The first two could create a bias: 762 of the cohort members did not participate in the cognitive testing at any age. To the extent that these non-participants are systematically different from participants, their absence may affect the relationships seen (this effect could be large, as this represents almost 20% of the cohort assessed at age 8). The authors did note that those who became non-participants after early involvement scored lower on the cognitive tests. Secondly, the analysis excluded children born to unwed mothers, as birth data were not recorded (though the number excluded is not given). This could introduce a significant bias, as single mothers in Britain in 1946 would likely have been a distinctly at-risk group. Finally, and most importantly, while the results showed consistently high statistical significance ($p<0.001$) the substantive differences were modest (though the LBW group did show markedly lower scores). These results are similar to those from the Birmingham studies (42;56). In the case of the Richards study, the high significance levels were more likely driven by the large sample size rather than large differences in results.

A second UK birth cohort study launched in 1958 provides more compelling results, because the study size is almost three times larger, and it included measures of gestational age and breastfeeding at birth (49). The analysis excluded those with missing data, multiple births, those born before 34 weeks of gestation, and those born to unwed mothers (missing birth data), but still included 10,845 participants.

Results showed a similar trend of increasing cognitive scores with increasing birthweights, across all values of birthweight, though in this sample, the relationship was still significant at age 33. Educational outcomes (using a 5-point scale from dropout to bachelor's degree) were also significantly associated with birthweight. However, social class at birth was shown to have a stronger relationship with outcomes. The proportion of variance in mathematics scores explained by birthweight was consistently about 1%, whereas that explained by social class was 3% at age seven and 12% at age 16. Similarly for adult educational outcomes, social class explained 10% of the variance, whereas birthweight explained less than 1%. This analysis is consistent with previous results regarding the effect of birthweight, but shows that social class has a stronger influence.

Also in this study, a separate multi-level analysis was performed to examine trajectories of cognitive performance over time. The multi-level model accounted for expected correlation among repeated measurements for each individual over time. This analysis revealed that the effect of social class also outweighs the disadvantage associated with low birthweight. Those born into higher social classes had higher scores at age seven, and improved further at ages 11 and 16, whereas for lower social classes, scores started lower and decreased over time. The overwhelming social policy implication from this study is that more effort should be put on addressing problems in the social environment than on birthweight, which has a very small (but statistically significant) effect.

Like the 1946 UK birth cohort study, this analysis was well designed and conducted. Again, births to unwed mothers were not included in the study because of missing data. For this study, this meant that 2,843 children were excluded, representing about 15% of all births. However, analyses showed that this group of births was not systematically different on birthweight, suggesting no significant bias was operating. The exclusion of 'very preterm' births, however, remains a possible concern, as this group would certainly have included those with mild to severe disabilities, whose results might have impacted the analyses.

Finally, a very recent (and much smaller) study from a single Scottish county used longitudinal data to compare children of very low birth weight (VLBW <1,500g) with matched controls (145). The study included all VLBW children born in the county in 1980 and 1981 (N=399 births, of which 219 survived 20 years, of which 167 had complete data). VLBW children showed significantly lower scores on secondary education exams in mathematics, but not in science, English, history or geography. The matching procedure selected children from the same elementary and secondary schools, to control for changes in the social environment over time (the study and control children lived in similar neighbourhoods during their childhoods). The authors conclude that the fetal environment was more important than the social environment.

2.5.1.5 Synthesis: health status at birth and later outcomes

In light of all the results discussed above, the weight of the evidence clearly shows that, excluding cases of severe disability, birthweight and gestational age are statistically significant predictors of later cognitive and educational outcomes, but their effects are outweighed by the influence of the social environment. Studies that include measures of both show that socio-economic characteristics explain between two and five times more variation in outcomes than does birthweight (35;46;49;51;140;141;146;147). The few exceptions come from Scandinavian countries: in these studies, socioeconomic status was related to the outcomes, but much less strongly than elsewhere, likely because there is much less inequality in these countries (43;52;133). However, there are also studies which suggest that birthweight has limited influence on outcomes, and that other factors outweigh the apparent importance of birthweight (148).

Synthesizing the findings of all these studies is challenging, with some showing that birthweight and/or gestational age, even through the 'normal' range, are strong determinants of later cognitive outcomes, while others show that social factors are much more important. However, the study groups and limitations of the studies themselves leave open a possible unifying explanation.

The studies reporting that the effects of birthweight were significant through the normal range had some combination of the following issues:

- they excluded or did not show results for the children with the shortest gestations or lowest birth weights (47;49).
- they excluded a significant number of high-risk children (those born to single mothers, approx 20%) (48;49;140)
- they were among the studies with substantial loss to follow-up or non-linkage (42;46;56)

Interestingly, close examination of one set of these results actually shows that the very small/preterm children did demonstrably worse than those within the normal range, though this was not commented upon by the authors (56).

By contrast, the studies that show strong effects of birthweight cutoffs (e.g. LBW or VLBW) or preterm birth, with a limited role for social factors, were those that only studied those extreme groups, comparing them to 'normals' but not examining results within the normal range. (35;43;57;98;105;133;138;139;141;142;145;149-151).

Therefore, it is possible that these seemingly contrary conclusions are compatible with each other. It could be that short gestations or low birthweights have strong, long-lasting effects, which are less modifiable by social circumstances, consistent the latter group of studies. Then, as one moves toward and into the normal range of birthweights and gestations, the effect of birthweight and gestation become weaker, and the role of social factors stronger, consistent with the earlier group of studies. This explanation is also consistent with findings suggesting that the impact of being born 'heavy low birthweight' (2000-2499g) or 'later preterm' (34-37 weeks) carries considerably less risk than being born below 2,000 grams or at less than 34 weeks of gestation (35;42;47;51;56;99;105;150;151).

The existing evidence is also consistent with the hypothesis that it is not birthweight or gestational age themselves that matter, but rather whether the child is born with a significant disability or health problem, which is much more common in very small, preterm children. (42;51;105;138;139;151). A parallel line of thinking suggests that the categorization of "Small for Gestational Age (SGA)" may be more closely connected to these issues. Studies have shown that cognitive / educational outcomes for children born SGA are lower than others (44;133;138;146;147). They note that even children born very prematurely can have normal outcomes, as long as they were born at weights Appropriate for Gestational Age (AGA) (133;146).

These results also point to the limitations of using only birthweight and/or gestational age as indicators of health status at birth: these two indicators simply cannot provide a comprehensive assessment. Furthermore, no published studies have incorporated longitudinal measures of health status both at birth and in subsequent years in early childhood in relation to educational outcomes. Existing literature suggests a significant, if modest, association between health status at birth and later outcomes. However, this relationship might be partially or completely explained by health status later in childhood. That is, children who are 'unhealthy' at birth may have poorer outcomes in school not just because they were born in poorer health, but because their poor health status at birth predisposed them to poorer health status through childhood, which in turn is related to educational outcomes.

2.5.2 Health Status at School Entry

Only four empirical studies have been found which examine the relationship between health status at or just before school entry, and subsequent school achievement. The first was a small (N=176), study from North Carolina (152). Parent surveys collected information on medical and other problems experienced by children before school entry, and school outcome data were provided directly by the school division. Half of the medical questions were about the birth (weight, gestational age, length of hospitalization), and the others described health after birth (hospitalizations, anemia, and ear infections). Results showed that medical problems were unrelated to school achievement, though a variety of social, behavioural, family and developmental variables were. The authors suggested that the lack of association may be related to the low prevalence of medical problems in their study group, resulting in a lack of statistical power to detect relationships. However, another factor could have been bias in study group membership: this was a convenience sample of parents who volunteered to participate in the study at the time of a pre-kindergarten orientation session. Two hundred ten (210) children were evaluated, but no indication is given regarding how many were asked to participate, so the response rate is unknown. Therefore, it is possible that the participants in the sample were not representative of the full spectrum of children and families in the area.

A larger Canadian study started from the entry cohort of kindergarten students around Niagara, Ontario in the 1980/81 school year (153). In one district, all children were included; in two other districts, a random sub-sample was used. The total starting sample size was 2,761 children, and complete information was available for 1,999. Children were identified as having a 'health problem' based on parental report of chronic illnesses in the child. 'School problems' included being retained in grade, placement in a special education class, presence of a learning problem, or scoring below the 10th percentile in a reading test. Overall, 18.4% of children were judged by teachers as having a school problem at the end of their third year in school. Several logistic regression models consistently found that 'having a health problem' was not a significant predictor of school problems, whereas several of the social and behavioural variables were.

This lack of association is somewhat surprising, but may have resulted from methodological issues. The measure of health problems might be problematic: the report is unclear about exactly how the parent report of chronic illness was done (i.e. was this an open-ended question, or was a checklist of common child health problems provided?). This kind of measure can also be affected by recall bias. Another possibility is that children's health problems might have been identified by the parents as 'neurodevelopmental' or 'behavioural' problems, which were also included in the survey. Both of these measures were significant predictors of school problems, so may have accounted for some variation that was actually health-related (at some point, the distinction between a 'health' problem and a 'developmental' problem disappears). Finally, sample size may have been an issue, given the multiple predictors involved and the relative rarity of health problems in children. Reports of the prevalence of chronic illnesses in children vary from 10-20% (77;78;89), but are lower (7-10%) for younger children (79). Working with a rough prevalence of 10%, even if half of these children were also identified as having school problems, this would have affected only about 100 children in this study, perhaps insufficient to reach statistical significance.

Positive evidence of association comes from the 1988 Child Health Supplement to the U.S. National Health Interview Survey. The large multi-stage stratified design provides a representative sample of the civilian, non-institutionalized U.S. population. This study involved data from 9,996 children aged 7-17, and found a number of health problems were associated with a history of repeating kindergarten or first grade (7.6% overall) (30). The most important health variables were deafness, speech defects, and low or very low birthweight, though several others were also significant. Important non-health-related predictors included behaviour problems and poverty (the two strongest predictors), low maternal education, and single parenthood.

Strong evidence is also provided by another large American study (154). The Early Childhood Longitudinal Study is a prospective design involving 22,000 children who entered kindergarten in the 1998/99 school year. This is a nationally representative sample of children in the U.S.A., and is following them through to completion of fifth grade. It found that the 85% of children in Very Good or Excellent health (by parental report) at kindergarten entry performed better than the 15% in Good, Fair, or Poor health using a variety of reading and mathematics knowledge and skills. This finding persisted after controlling for family poverty status.

Table 2.1: Summary and characteristics of closely related studies

Author (year)	Place & time of births	Focus/Objective	Design	Data
A) Studies associating birthweight and/or gestational age with a single later outcome				
1. Barker & Edwards (1967) (56)	England 1950-54	Obstetric complications and school performance	Historical Prospective	Admin
2. Record, McKeown & Edwards (1969) (42)	England 1950-54	Birthweight & gestational age and later intelligence	Historical Prospective	Admin
3. Drillien, Thomson, & Burgoyne (1980) (51)	Scotland 1966-70	Low birthweight and very low birthweight children at early school-age	Prospective	Study
4. Calame, Fawer et al (1986) (138)	Switzerland 1972-76	Neurodevelopmental outcome and school performance of VLBW infants	Prospective	Study
5. Casiro, Kamaya et al (1987) (139)	Winnipeg 1978	Cognitive & academic performance of VLBW children	Prospective	Clinical
6. McCormick, Gortmaker, & Sobol (1990) (35)	US 1964-77	School difficulty among LBW children	Historical Prospective	US Natl Survey
7. Lagerstrom, Bremme et al (1991) (133)	Sweden 1955	IQ and school performance as related to BW and GA	Historical Prospective	Longitudinal Study
8. Lagerstrom, Bremme et al (1991) (43)	Sweden 1953	School marks and IQ scores for LBW children	Historical Prospective	Longitudinal Study
9. Paz, Gale et al (1995) (44)	Israel 1971	Cognitive outcome of Full-Term Small for Gestational Age infants in late adolescence	Historical Prospective	Admin & Army
10. Martyn, Gale et al (1996) (140)	Scotland 1920; 1943	Growth in utero and cognitive function in adulthood	Historical Prospective	Survey & Admin
11. Sorensen, Sabroe et al (1997) (52)	Denmark 1973, 1975	Birthweight and cognitive function in young adult life	Historical Prospective	Admin & Army

Table 2.1: Summary and characteristics of related studies (continued)

Author (year)	Place & time of births	Focus/Objective	Design	Data
12. Seidman, Buka et al (2000) (141)	US 1959-1965	Relationship of LBW to cognitive function at age 7	Prospective	Study
13. Shenkin, Starr et al (2001) (46)	Scotland 1921	Birthweight and cognitive function at age 11	Prospective	Study & Admin
14. Matte, Bresnahan et al (2001) (47)	8 US cities 1959-1966	Influence of BW within the normal range and IQ at 7	Prospective	Study
15. McGrath & Sullivan (2002) (105)	US city 1992	BW, neonatal morbidities, and school outcomes in Preterm and full-term infants	Prospective	Study
B) Studies associating birthweight and/or gestational age with several later outcome measures (i.e. at different ages)				
16. Richards, Hardy et al (2001) (48)	UK 1946	Birthweight and cognitive function through age 43	Prospective	Study
17. Jefferis, Power & Hertzman (2002) (49)	UK 1958	Birthweight, childhood socioeconomic environment, and cognitive development	Prospective	Study
18. Pharoah, Stevenson, & West (2003) (145)	Scotland 1980-1981	Very low birthweight and performance in secondary education	Prospective	Study
C) Studies of health status at school entry and later schooling outcomes				
19. Fowler & Cross (1986) (152)	US 1975-77	Preschool problems and school performance	Prospective	Study
20. Cadman et al (1988) (153)	Ontario 1975	Preschool health, development, and behavior problems and school performance	Prospective	Study
21. Byrd & Weitzman (1994) (30)	US 1971-1981	Predictors of early grade retention	Historical Prospective	Study
22. Denton & West (2002) (154)	US 1993	Early childhood longitudinal study	Prospective	Study

Table 2.1: Summary and characteristics of related studies (continued)

Author (year)	Sample Characteristics	Sample Size	Control SES	Analysis Type	Outcome Measure	Age
1. Barker & Edwards (1967) (56)	Linked singletons Excl 'subnormal' IQ	48,795	N	Descriptive	Verbal Reasoning test	11+
2. Record, McKeown & Edwards (1969) (42)	Linked singletons Excl 'subnormal' IQ	41,534	N	Descriptive	Verbal Reasoning test	11+
3. Drillien, Thomson, & Burgoyne (1980) (51)	All children born LBW (<2000g) in community	261 LBW 111 Control	Y	Descriptive	Several standardized IQ & ability tests	6-7
4. Calame, Fawer et al (1986) (138)	VLBW and controls	83 VLBW 41 Control	N	Descriptive	Grade repetition	8
5. Casiro, Kamaya et al (1987) (139)	VLBW without Major handicap	48 VLBW 48 Control	Y	Descriptive	Several assessments, + teacher evaluations	7
6. McCormick, Gortmaker, & Sobol (1990) (35)	Sample representative of US population	68 VLBW 790 HLBW 9,664 NBW	Y	Multiple Regression	Special Education, Repeating grade, School difficulty	4-17
7. Lagerstrom, Bremme et al (1991) (133)	Grade cohort in a Community; (non-inst)	30 LBW 843 NBW	Y	ANOVA	IQ, test scores, school marks	13
8. Lagerstrom, Bremme et al (1991) (43)	Births in a community; Not institutionalized	484 LBW 11,468 NBW	Y	ANOVA	IQ, school marks	13
9. Paz, Gale et al (1995) (44)	Community birth cohort Full term singletons Excl congenital anomalies	64 SGA 1,694 AGA	Y	Multiple Logistic Regression	High school completion	17
10. Martyn, Gale et al (1996) (140)	Births in 3 communities Singletons	1576	N	Descriptive	IQ test, vocabulary	63-76
11. Sorensen, Sabroe et al (1997) (52)	Community birth cohort Some exclusions-health	171 LBW 4,129 NBW	Y	Multiple Regression	IQ test	18
12. Seidman, Buka et al (2000) (141)	Births at 2 teaching Hospitals in New England	11,889	Y	Linear Model	Several standardized IQ & ability tests	7-8

Table 2.1: Summary and characteristics of related studies (continued)

Author (year)	Sample Characteristics	Sample Size	Control SES	Analysis Type	Outcome Measure	Age
13. Shenkin, Starr et al (2001) (46)	Singleton births at 2 hospitals in Scotland	428	Y	Structural Eqn Model	IQ test	11
14. Matte, Bresnahan et al (2001) (47)	Full term; 1500-3999 g, less than 4 sibs	3,484	Y	Multiple Regression	IQ test	7
15. McGrath & Sullivan (2002) (105)	NICU patients	151 preterm 37 full-term	Y	Multiple Regression	IQ tests, achievement test, school service use	8
B) Studies associating birthweight and/or gestational age with several later outcome measures (i.e. at different ages)						
16. Richards, Hardy et al (2001) (48)	Stratified sample of single, legitimate births	5,362 at start 3,262 at 43yr	Y	Multiple & Logistic Regression	Variety of IQ & cognitive tests at different times	8,11,15, 26,43
17. Jefferis, Power & Hertzman (2002) (49)	Stratified sample of single, legitimate births; excluded very preterm births	13,980 births 2,843 excluded	Y	Multiple Regression; Multilevel	School tests; Highest education Achieved (33)	7,11,16, 23,33
18. Pharoah, Stevenson, & West (2003) (145)	Births in a community	167 VLBW 167 controls	Y	Paired t-tests	IQ at age 8; school tests at age 16	8,16
C) Studies of health status at school entry and later schooling outcomes						
19. Fowler & Cross (1986) (152)	Convenience sample from preschool orientations	176	N	Regression	School reading & math tests; retention	6,7
20. Cadman et al (1988) (153)	Kindergarten entrants	2,761 started 1,999 final	Y	Logistic Regression	Reading test; retention; special education class	7
21. Byrd & Weitzman (1994) (30)	Representative sample of US children age 7-17 yrs	9,996	Y	Logistic Regression	Retention after Kindergarten or Grade 1	7-17
22. Denton & West (2002) (154)	Representative sample of US Kindergarten children	22,000	Y	Regression	Numerous assessments and tests	7

Table 2.1: Summary and characteristics of related studies (continued)

Author (year)	Key Finding(s)	Notes
A) Studies associating birthweight and/or gestational age with a single later outcome measure		
1. Barker & Edwards (1967) (56)	Shorter gestation modestly related to lower test scores Looks like SES much stronger influence than GA	Exclusion issue; 60% linkage LBW predominantly low SES
2. Record, McKeown & Edwards (1969) (42)	Higher BW somewhat related to higher test scores Short & long gestations trivially related to lower test scores Looks like SES much stronger influence than GA	Exclusion issue; 60% linkage LBW predominantly low SES
3. Drillien, Thomson, & Burgoyne (1980) (51)	Majority (92%) of LBW children were indistinguishable from controls. Social class had a strong influence on outcomes	Small sample
4. Calame, Fawer et al (1986) (138)	School failure occurred more frequently among VLBW, particularly children with neurodevelopmental problems (SGA)	Small sample
5. Casiro, Kamaya et al (1987) (139)	VLBW scored somewhat lower on all tests, repeated a grade more often, and had lower teacher evaluations	Small sample; disabilities excluded
6. McCormick, Gortmaker, & Sobol (1990) (35)	VLBW more special ed; more retention; more school difficulty heavy LBW no different from normal birthweight	Strong study design & analysis
7. Lagerstrom, Bremme et al (1991) (133)	LBW children had lower IQ, test scores, school marks	Controlled for SES, but study is in Sweden, so much less SES variation
8. Lagerstrom, Bremme et al (1991) (43)	LBW had lower school marks and lower IQ scores	Controlled for SES, but study is in Sweden, so much less SES variation
9. Paz, Gale et al (1995) (44)	IQ score were NSD; male SGAs had lower rates of high school completion; also more neurological abnormalities	Small SGA group; differences modest
10. Martyn, Gale et al (1996) (140)	Test scores increased with higher BW, but not significant	Survey response 50%; IQ measured after age 60; excluded single mothers
11. Sorensen, Sabroe et al (1997) (52)	LBW had lowest IQ scores; scores increased with BW, but dropped slightly at HBW; GA only weakly related to IQ	Exclusions: 522 because of asthma or joint problems
12. Seidman, Buka et al (2000) (141)	LBW related to lower IQ scores; effects small	Unknowns: Number of LBW children; SES details

Table 2.1: Summary and characteristics of related studies (continued)

Author (year)	Key Finding(s)	Notes
13. Shenkin, Starr et al (2001) (46)	BW, social class, and age are all independent predictors of IQ BW explains 3.8%; social class 6.6% (under-estimated)	Linkage rate 45%; "illegitimates"; survival rate much lower in 1921
14. Matte, Bresnahan et al (2001) (47)	Within normal BW range, BW mildly related to IQ	Good analysis & SES control
15. McGrath & Sullivan (2002) (105)	Normal BW children performed better than VLBW children; Morbidities contributed independently to poor outcomes	NICU kids; measures of neonatal morbidity included (not just BW)
B) Studies associating birthweight and/or gestational age with several later outcome measures (i.e. at different ages)		
16. Richards, Hardy et al (2001) (48)	BW is related to cognitive outcomes for the whole population (not just LBW), and into adulthood; the difference was apparent by age 8, then continued	Legitimacy issue; representativeness of sample: 60% still involved; BW related to social class in 1950s UK
17. Jefferis, Power & Hertzman (2002) (49)	Cognitive scores increased with BW through entire range; all ages, both sexes (control for SES); social class a strong independent predictor – much stronger than BW	Social class explained 3% of outcome at age 7; 12% at age 16; BW was about 1% at both times
18. Pharoah, Stevenson, & West (2003) (145)	VLBW had lower IQs and test scores than NBW at both 8 and 16 years (controlling for SES); biology more important than social factors for VLBW group	Small sample; unstated attrition; exclusions for disabilities (20%)
C) Studies of health status at school entry and later schooling outcomes		
19. Fowler & Cross (1986) (152)	Birthweight, gestational age, length of birth hospitalization, frequency of post-birth admissions, and frequency of ear infections were not related to schooling outcomes	Convenience sample likely biased toward healthier children; health measures were by parental report, so subject to recall bias
20. Cadman et al (1988) (153)	Presence of chronic disease was not significantly related to schooling outcomes; presence of neurodevelopmental disease was significant (Odd Ratio 3.2), as was socioeconomic status (Odds Ratio 2.0)	Chronic diseases were by parental report (form of information not described)

Table 2.1: Summary and characteristics of related studies (continued)

Author (year)	Key Finding(s)	Notes
21. Byrd & Weitzman (1994) (30)	Socioeconomic and behavioral factors were strongest predictors of retention (along with male sex), followed by deafness, speech problems, and low birthweight	Retention alone a relatively crude outcome
22. Denton & West (2002) (154)	Children in poorer health status at Kindergarten entry had lower scores on several tests through Kindergarten and Grade 1 (statistical testing/significance not reported, but differences were substantial, and sample size was very large)	Health status was general measure, by parental report (Likert scale); children who repeated Kindergarten were excluded from study

2.6 Breastfeeding

A large and growing body of research demonstrates that breastfeeding is related to better short- and long-term health outcomes: for recent reviews, see (73-75;155). Breastfeeding has also been shown to be correlated with cognitive development and educational outcomes in children and young adults. A meta-analysis published in 1999 found an adjusted average difference of 3.2 IQ points for breastfed infants (69). This effect was evident in both 'normal' and low birthweight infants, though the low birthweight group showed a larger difference (5.2 vs. 2.7 points). Similar findings, including the larger difference among at-risk infants (low birthweight or preterm) have been supported by more recent studies and reviews as well (70-75).

2.7 Conclusion

Existing research examining the effect of health status on educational outcomes in childhood shows mixed results. Cross-sectional studies of children in schools show weak but statistically significant associations between health status and schooling outcomes. Conversely, studies of children with specific diseases (e.g. asthma, diabetes) suggest that overall, such groups are at no disadvantage for educational outcomes. However, the designs, sample sizes, and measures used in these studies limit their potential for informing the full scope of the relationship.

Health status at birth has been shown to be statistically but modestly related to schooling outcomes, particularly compared to the influence of the social environment. The same is true for the few studies measuring health status at the time of school entry.

No published studies have incorporated longitudinal measures of health status – for example, measures of health status at birth and into the early childhood years – to assess how health status at different times affects educational outcomes. Furthermore, 'generic' indicators of health status might prove more useful than specific diagnostic categories, as children with diverse medical conditions can have similarities in life experiences (91). Researchers have called for studies incorporating this kind of approach, in addition to better measures of neonatal illness, co-morbidities, and subsequent interventions (35;105).

Chapter 3: Methods

3.1 Introduction

This study was designed to determine whether health status during childhood, in addition to health status at birth, has an impact on schooling outcomes in the 1990 Winnipeg birth cohort, controlling for social, economic, and demographic factors. Given the large number of observations involved (approximately 6,000 children), the threshold for statistical significance was set at $p<0.01$, meaning that in order to be judged as significant, relationships had to be less than 1% likely to have been found by chance.

3.2 Research Hypotheses

The following hypotheses will be tested using a multivariate approach, such that the independent contribution of each variable on the outcome will be determined.

Hypothesis 1) Health status at birth and through childhood will be associated with progress and performance in school among the Winnipeg 1990 birth cohort.

Hypothesis 2) Family socioeconomic status will be associated with the child's progress and performance in school.

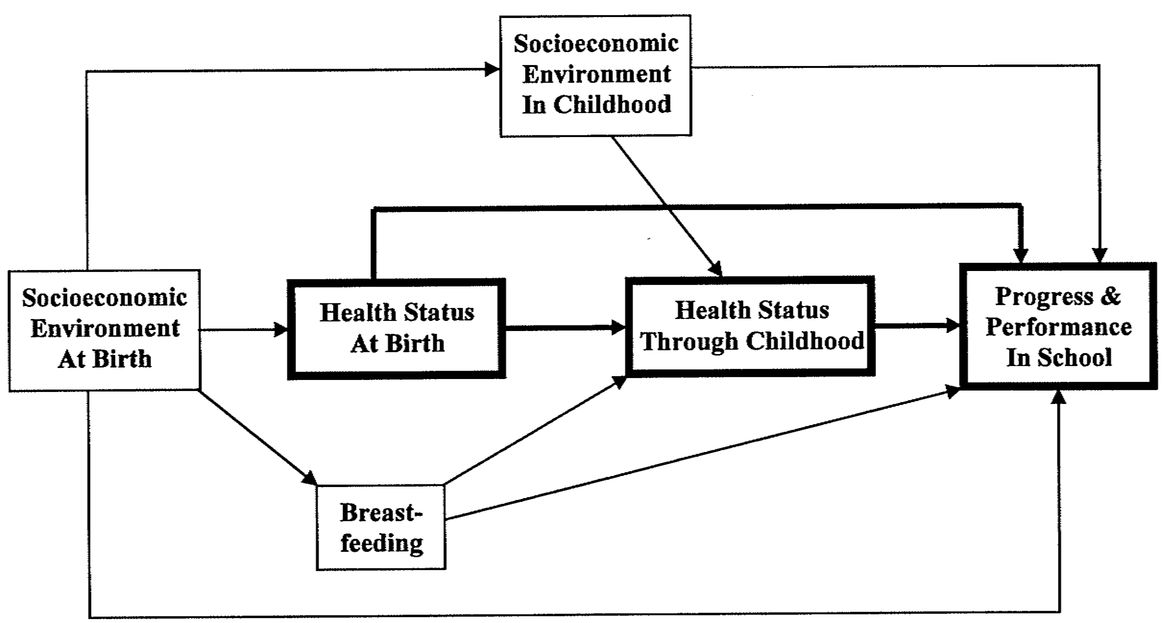
Hypothesis 3) Breastfeeding will be associated with progress and performance in school.

3.3 Conceptual model

Figure 3.1 shows the initial conceptual model used to guide the analysis for this study, which was based on the results of previous research (as discussed in Chapter 2). The variables and relationships of particular interest for this study are emphasized in bold: the relationships among health status at birth and health status through childhood, and the educational outcome of progress and performance in school through age 9 years.

The key new idea being proposed in this study is the 'Health Status Through Childhood' factor, which is proposed to mediate the association between health status at birth and the educational outcome.

Figure 3.1: Initial Conceptual Model



The figure also shows how socio-economic status and breastfeeding are proposed to influence the other factors in the model. The child's sex and exact age also influence several of these factors and were included in the study, but excluded from this initial figure for simplicity. The final (full) model is shown in section 3.9 Main Analysis.

3.4 Type of research design and data sources used

This study used a historical prospective design, in which a birth cohort was followed forward in time. It involved secondary analysis of existing data in the Population Health Research Data Repository ('the Repository') housed at the Manitoba Centre for Health Policy (MCHP) at the University of Manitoba. The data were derived from administrative records routinely collected by provincial government departments (listed in section 3.5 below) for managing programs and services. Public-use data files from the Canadian Census of Population were also used. All individual identifiers (e.g. name, address, identification numbers) are either removed or encrypted before transfer to MCHP, to ensure anonymity. MCHP employs rigorous procedures to ensure the confidentiality, security, and privacy of data are maintained at all times, in accordance with relevant legislation. Appendix 2 contains a description of the key policies and procedures enforced at MCHP.

The data system is comprehensive and universal, reflecting the health insurance system provided by the government for all Manitoba residents. The quality, integrity, and validity of the data have been verified by numerous studies, and recently summarized in Roos et al (156).

3.5 Approvals

The protocol for this study was approved by the following organizations:

- the Manitoba Centre for Health Policy
- the Health Research Ethics Board, Faculty of Medicine, University of Manitoba
- the Health Information Privacy Committee, Manitoba Health

- the Department of Education, Citizenship, and Youth, Government of Manitoba
- the Department of Family Services and Housing, Government of Manitoba

Copies of approval letters from these organizations are in Appendix 1.

3.6 Study participants

This study followed the entire cohort of children born to Winnipeg mothers in 1990. Children of multiple births (twins and triplets) were excluded, as they are not 'independent' observations. To be included in the final analysis, children had to be continuously resident in Winnipeg until June 1999 (the date of the tests in Grade 3), and resident in Manitoba until September 2004 (when they would have been expected to enrol in Grade 9 – which was used later in the analysis as described below). The exact numbers involved were:

9,103	records for births to mothers living in Winnipeg
- 200	records for surviving twins (191) and triplets (9)
8,903	records for singleton births
- 86	deaths before September 2004
-1,806	children who moved out of Manitoba before September 2004
-1,056	children who moved out of Winnipeg before June 1999
- 82	children missing data on health or education variables used
5,873	children in the final analysis

The final analysis included 5,873 live single births to Winnipeg mothers in 1990, and represented the full spectrum of children and families. Moving was the dominant reason for exclusion (2,862 of 3,030, or 95%). Key characteristics of the children who moved, those who died, and those with missing data are shown in Chapter 4.

3.7 Analytic method

Given the nature of the relationships shown in the conceptual model, this study required a method which allowed for intervening variables: variables which are both outcomes of prior variables in the model, and predictors of subsequent variables. For example, 'Health Status Through Childhood' was proposed to be affected by the preceding 'Health Status at Birth', and to influence the final outcome measure of progress and performance in school.

3.7.1 Operationalizing the latent constructs

Another requirement was the ability to incorporate latent variables: variables which represent theoretical constructs which are not directly measurable, but can be estimated by combining information from related variables. These related measures are called manifest variables, and these were the items for which observed values were available. Several of the key variables of interest in this study (the health status variables and the socio-economic variable) were proposed as latent constructs, to be measured by a number of related manifest variables. For example, no single, directly measurable variable can fully capture a child's health status at birth. However, there are a number of related measures which provide valid indications about the infant's health status, including: gestational age, birthweight, Apgar scores, length of stay in hospital, and others. Values of these various manifest variables were used to calculate values for the latent variables, which were then used in the final analysis. The analytic method chosen, Structural Equation Modeling (SEM), is the most appropriate choice for analyses incorporating both intervening variables and latent variables (157-161). This method also allows statistical estimation of the overall explanatory power of the model, and provides goodness of fit indices, to indicate how well the final model fits the empirical data being analyzed.

3.8 Data, variables, and definitions

The variables described below were derived from data in the Repository at MCHP, using the population registry, medical claims, hospital abstracts, and prescription drug records. Sometimes children born at, or admitted to, one hospital can be transferred to another hospital for specialized services. In such cases, information from both hospitals were combined in creating the data to be used in this study. For example, if a child spent two days in hospital A before being transferred to hospital B for five days, the variable for length of stay would contain seven days. If there was one day or more between the two hospitalizations, then they were counted as two separate episodes.

3.8.1 Predictor (Independent) Variables

Each child's sex and exact age were used, in addition to the following variables:

3.8.1.1 Breastfeeding

An indicator (0/1) variable was created from data in each child's birth hospital record to indicate whether breastfeeding was initiated in hospital. The data include 3 categories, one each to indicate exclusive breastfeeding, breastfeeding mixed with artificial feeding, and exclusive artificial feeding. Martens showed that the most valid estimates are produced when exclusive breastfeeding and mixed feeding are combined to indicate 'any breastfeeding' (162).

Health Status Measures

For this study, 'health status at birth' and 'health status through childhood' were intended to capture a broad understanding of a child's health status. As noted earlier, these concepts were represented in the model by latent variables, because there is no single, comprehensive measure that could adequately represent either of these constructs.

3.8.1.2 Health status at birth

For each child, data from six manifest variables were entered into the analysis to create the latent variable representing health status at birth:

- Birthweight (grams)
- Gestational age (maternal self-reported number of weeks since last menstrual period)
- Total length of stay for birth hospitalization (in days, excluding Intensive Care)
- Length of Stay in intensive or intermediate care nursery (days)
- Apgar score at 5 minutes after birth (scaled score: 0-10)
- Delivery by emergency Caesarean section (indicator: 0/1)

3.8.1.3 Health status through childhood

To capture health status through childhood, several variables were measured in each year of the child's life, from birth to age 5 years. These measures were summed to form cumulative measures of the child's health status throughout the preschool period. The endpoint of the 5th birthday was chosen to provide an equal time period for each child, and to occur before the child progresses far in Kindergarten, because from that point forward, use of the health care system could potentially have been related to their participation in the school system, creating a 'reverse causation' problem. For example, after a period of time in the school system, a child might be suspected of having a health or developmental problem (e.g. Attention Deficit Disorder) which could subsequently 'cause' a number of visits to physicians for assessment. In this case, the health care use is related to participation in school, which represents a form of 'reverse causality.' Such issues need to be avoided to be certain that the health problems ('causes') precede the educational outcomes ('effects'). Previous studies have used the same kind of endpoint to address these issues (142).

For each child, data from five manifest variables were entered into the analysis to estimate health status through childhood. Two of these variables were derived from data generated by the Johns Hopkins ACG Case-Mix system (version 6), a computer program which classifies patients by level of illness and anticipated cost of care. This software has been extensively validated as a reliable measure of morbidity (88;163), including within Manitoba (164). The ACG system is based on the assignment of patients to any number of 32 Adjusted Diagnostic Groups (ADGs), which are listed in Appendix 3. The ADGs represent clusters of illnesses of comparable intensity and health care use. There are 32 ADGs, of which 8 are considered Major for children, and 24 Minor, although the Minor ADGs for 'Prevention/Administration', 'Dental', and 'Pregnancy' were excluded for this study. Each year, every child could be assigned to any number of ADGs, based on diagnoses attributed to them from physician visits or hospital episodes. For each child, the number of major and minor ADGs to which they were assigned each year were counted, and then summed over the entire preschool period (birth to 5^{th} birthday). This resulted in two variables for each child: the number of Minor ADG-years, and the number of Major ADG-years from birth to age 5. These variables essentially provide a cumulative measure combining the number of different kinds of illnesses the child experienced, in addition to the number of years over which they were experienced.

In addition to the ADG variables, measures related to the volume of health services used were also developed. These measures help differentiate among children assigned to the same ADG(s), but who have different intensity of illness, reflected in the use of hospitals and physician services. Three variables were created to capture the volume of health service use from birth discharge until their 5th birthday: the number of physician visits, the number of days spent in hospital (excluding Intensive Care), and the number of days spent in Intensive Care. These three measures were adjusted to account for differences in length of birth hospitalization.

The five manifest variables used to create the latent variable for health status through childhood were:

- number of Minor ADG-years: a cumulative measure combining the number of Minor ADG groups the child was assigned to, for each year between birth and 5th birthday
- number of Major ADG-years: a cumulative measure combining the number of Major ADG groups the child was assigned to, for each year between birth and 5th birthday
- number of visits to physicians (excluding services received while in hospital)
- number of days spent in hospital
- number of days spent in Intensive Care Units

3.8.1.4 Social, Economic and Demographic Characteristics

Social, economic, and demographic factors are known to be strongly related to both health and educational outcomes, as noted in Chapter 2. Therefore, it was important to control for these influences. The following variables were used in this analysis:

Economic Status:

There were two measures of economic status used in this study. For all children, economic status of the area in which the family lived was estimated using data from the 1996 Canadian Census of Population (average household income of the Enumeration Area).[1] The second economic variable was family-specific data indicating whether the family received Income Assistance benefits at any time from the child's 5th through 8th birthdays (data were not available for previous years). Family-level income data were not available.[2]

Social and Demographic Characteristics of the Child and Family:

- Sex of the child (0 for female, 1 for male)
- Age of the child (number of days from birth to June 1, 1999 test date)
- Family residential mobility: the number of times the family's postal code changed (in the health registry file[3]), from the child's birth to their 8th birthday
- Family size: the number of children born to the mother, as of the child's 8th birthday
- Mother's age at the birth of her first child

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[1] In 44 cases, income data for the Enumeration Area were unavailable, so a larger area was used, corresponding to the first 3 digits of the postal code area in which the family lived. An Enumeration Area is small geographic area comprising 500-600 residents.

[2] Had family-level income data been available, they would have made an excellent addition – allowing the estimation of family-level and area-level income effects.

[3] The population registry file is updated twice per year, so the actual number of residential moves may be higher than can be captured from this data source.

- Marital status: an indicator of whether the child's mother was registered as 'married'
- Whether the child's mother was diagnosed with depression at any time from the child's birth to their 8th birthday. The definition of depression was based on previous work at MCHP(165), but adapted to an 8-year rather than a 5-year period. A person was defined as Depressed[4] if they satisfied any of the following criteria:
  - at least one physician visit with an ICD-9-CM code of 311 (depressive disorder), 296 (affective psychoses), or 309 (adjustment reaction), or
  - at least one physician visit with an ICD-9-CM code of 300 (neurotic disorders) in conjunction with a prescription for an antidepressant medication or mood stabilizer (but excluding anti-anxiety medications)
  - at least one hospitalization with an ICD-9-CM code of 296.2-296.8, 300.4, 300, 309, or 311, in conjunction with a prescription for an antidepressant medication or mood stabilizer (but excluding anti-anxiety medications)

The analysis plan called for these social, economic, and demographic factors (excluding child age and sex) to be entered into a factor analysis, to be reduced into a smaller number of factor scores (2 or 3) for use in the final analysis. This plan was chosen because factor scores can provide better estimation of underlying characteristics, and also simplify the analysis by reducing the number of variables involved.

[4] This definition includes, but is not limited to, post-partum depression.

3.8.2 Outcome (Dependent) Variable:

The main outcome variable was created as a combined measure of progress and performance in school through the end of the 1998/99 school year. For the majority of children (n=4,821 or 82%), the outcome score was determined by the average of their marks on mandatory Standards Tests in Language Arts and Mathematics written in late May and early June 1999. These tests were carefully developed by a team of teachers and educational consultants to ensure congruency with the Grade 3 Curriculum and Standards, and were pilot tested and validated prior to implementation (21;22), though their predictive ability has not been assessed. The tests incorporated several kinds of questions (multiple choice and open answer forms), and covered the various topic areas and domains of learning specified in the provincial curriculum. The testing protocol specified a 40-65 minute testing period, though additional time (up to 20 minutes) was allowed if required for students to complete the test. Among students completing the tests, the average mark was 72% for Language Arts, and 68% for mathematics.

Because this study was based on the entire birth cohort, not just students with valid scores on the Standards Tests in 1998/99, there were other groups of students to be incorporated into the final outcome. These included: those who started but did not complete the test (n=189), those absent on either of the two test days (n=197), those exempt from writing because of substantial modifications[5] (n=281), those exempt because of psychological/emotional problems (n=64), those exempt because English was their Second Language (n=15), those exempt for other reasons (n=31), and those enrolled in Grade 2 or lower at the time (n=275). These categories were combined with the test

[5] These were children with major cognitive disabilities preventing them from writing the same test as other students, so had substantial modifications made to the test.

marks using a LOGIT transformation (166;167) summarized below. This transformation was performed in order to produce results for all children on a single, continuous outcome measure which was normally distributed (mean=0, standard deviation=1).

To perform the LOGIT transformation, the children with test marks and those in the groups without test marks (i.e. absent, exempt) needed to be ordered on a relevant criterion. For this purpose, all children were followed up in the education records for an additional six years, to determine what proportion were enrolled in Grade 9 on time[6] (by September 2004). Students with test marks were separated into decile groups according to their mark on the test (0-10%, 11-20%, ... 91-100%). The ordering of all groups was then determined by the percentage of students in each group reaching Grade 9 on time, with the exception of the group "Exempt for substantial modifications", which was assigned to be the lowest-scoring group.[7] The transformation process is essentially like 'filling in' a normal distribution from lowest to highest values, with the size of each group occupying a proportional amount of the area under the bell-shaped curve. The graphs in Figure 3.2 illustrate the idea in a series of steps.[8] The analysis revealed that the proportion of children reaching Grade 9 on time was lower for all the groups without test marks (absent, exempt, etc) than all groups with test marks. Therefore, the grouping of children with test marks into deciles was undone, and they were entered into the LOGIT ordering according to their actual test mark (e.g. 72%).

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[6] Grade 9 entry was chosen because this is a key 'gate keeping' time. A substantial number of retentions happen in the two years leading up to Grade 9 enrollment, and many fewer occur thereafter, as shown by Guevremont et al (64).

[7] These children often progress through the school system year by year, though with modified education plans – so this group would have scored disproportionately high on the ranking system.

[8] The graphs in Figure 3.2 are not precisely to scale, and are meant to be illustrative only.

Figure 3.2: Ranking of groups in LOGIT transformation

Figure 3.2a

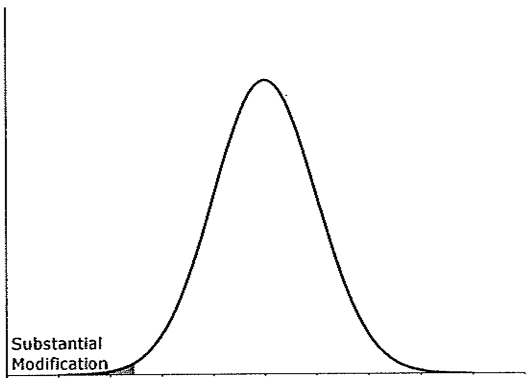


Figure 3.2b

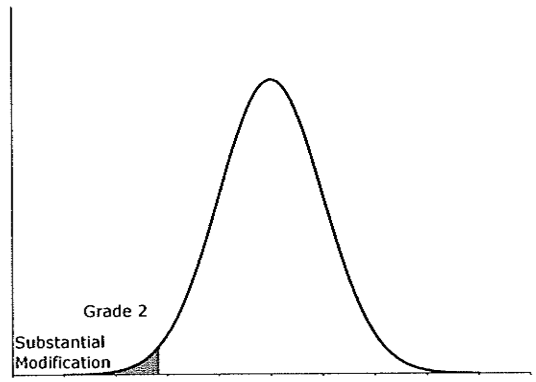


Figure 3.2c

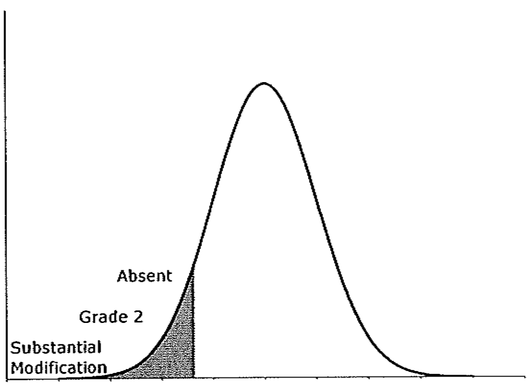
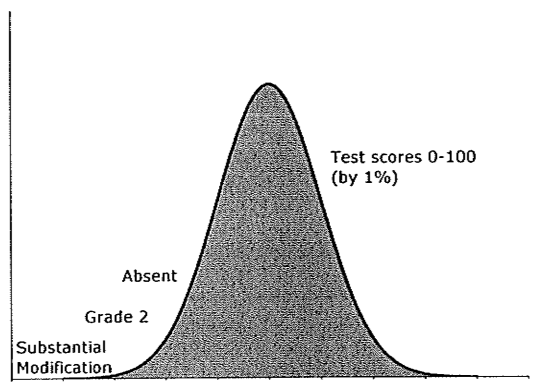


Figure 3.2d



These transformations were done separately for the Language Arts and the Mathematics tests, and each child's outcome score for the final analysis was determined by the average of their values on the two LOGIT-transformed scales.

3.8.3) Transformation of predictor variables

As noted previously, many variables relating to health status and health services for children, as well as social and demographic characteristics, show non-normal distributions. In preparing the data for the final analysis, a number of variables originally measured as continuous values or on ordinal scales had to be transformed. There were two reasons for these transformations. First, some variables did not contain continuous values that followed normal distributions (e.g. number of Major ADGs assigned, number of days in hospital), so had to be transformed to satisfy statistical requirements. Second, a number of variables have been shown to have non-linear associations with educational or cognitive outcomes, suggesting their influences were more pronounced among children with extreme values, rather than smaller differences within the 'normal' range. For example, the synthesis of studies on birthweight and cognitive outcomes (see Chapter 2) suggested that its effect may stronger for those born at low birthweights, but that its effect diminishes as birthweight increases into the normal range.

Transformations into dichotomous form (0/1) were based on established cutoff values from the literature whenever possible. For example, low birthweight was defined as 0-2,499 grams; preterm birth meant less than 37 weeks of gestation completed. For variables without established cutoff values, a multi-step approach was used. First, the distribution of the variable was used to identify 'natural' breaks in the data. Alternatively, cutoffs were chosen to distinguish the highest or lowest 10% of children on a given scale. In all such cases, sensitivity analyses were performed using slightly higher and slightly lower cutoff values, to ensure stability of results. The following variables were transformed as noted:

- length of hospital stay at birth was dichotomized into 'long stay' or not, using the 90^{th} percentile value, with separate cutoffs for vaginal and caesarean deliveries (5 days and 8 days, respectively)
- length of stay in intermediate or intensive care units was dichotomized using the 95^{th} percentile value of 3 (i.e. 0-2 days versus 3 or more days)

- number of Minor ADG-years was dichotomized using the 90th percentile value of 24 (i.e. 0-23 versus 24 or more)
- number of Major ADG-years was dichotomized using the 90th percentile value of 2 (i.e. 0-1 versus 2 or more)
- hospital days used in the preschool period was dichotomized as 0-5 days versus 6 or more days, based on the natural break in the frequency distribution (this was near the 95th percentile of the distribution)
- family size was dichotomized at the 95th percentile of 5 or more children
- number of family moves was dichotomized at 5 or more moves (95th percentile)

Transformations were also performed on several variables that showed normal or near-normal distributions but for which previous studies (noted in Chapter 2) reported significant threshold effects: birthweight, gestational age, Apgar score at 5 minutes after birth, family size, and number of family moves. For the birthweight variable, two different dichotomous versions were created: one using the standard definition of Low Birthweight (0-2499 grams), and another with an even lower cutoff (0-1999 grams). This lower cutoff was created in response to findings in the literature which show that children born at the upper end of the low birthweight group (2000-2499 grams) often do not experience the same deleterious consequences that lower birthweight children do(35;42;99;151), likely as a result of recent advances in medical care. Similarly, for preterm birth, two dichotomous variables were created: one indicating birth at less than 37 weeks, and the other indicating birth at less than 34 weeks. For Apgar scores, dichotomous versions were created using cutoffs of 7 or higher, and 8 or higher (out of 10).

Separate measurement models (described below) were developed using the continuous and the dichotomous versions of these variables. The results of these models indicated that the dichotomous versions were required for family size and number of moves, because the non-normality of their distributions caused errors in the analyses. Birthweight and gestational age were brought forward in both forms, with the final decisions to be made by results of further analyses, described below.

3.8.4 Preparatory analysis of social, economic, and demographic variables

As noted above, the social, economic, and demographic variables (excluding child age and sex) were entered into a factor analysis to reduce the number of variables required to represent these influences in the final analysis. However, the factor analysis revealed that the variables did not co-vary as closely as expected, and could not be reduced to less than four factor scores. In addition, the factors created did not offer significantly improved description of the underlying characteristics, beyond that offered by the individual variables. As a result, the variables were all maintained as separate variables in the model, to maintain the ability to determine the independent contributions of each variable, and to allow easier interpretation of the findings.

3.8.5 Revised analysis plan

The inability to combine information from the numerous social, economic, and demographic variables into a smaller number of factor scores posed a challenge to the proposed analysis. To proceed as planned, the model would have had to include a large number of additional relationships: those between each of the social, economic, and demographic factors at the time of the child's birth in 1990, and changes in those values through 1999. This would have made the model considerably more complex, and potentially infeasible. Therefore, the analysis plan was revised, to proceed using each of the social, economic, and demographic variables entered into the model only once (using the measures collected at or near the child's fifth birthday). After a satisfactory model was developed, the omitted variables (at the time of the child's birth) would be re-introduced, to test their potential contribution to the analysis.[9]

3.9 Main analysis

The main analysis was based on the widely accepted two-step procedure developed by Anderson and Gerbing(168). In the first step, confirmatory factor analysis was used to develop and refine a 'measurement model' that provided acceptable fit to the data. In Step 2, the measurement model was modified into a 'causal' model which reflects the theorized cause-and-effect relationships among the variables in the model. In practical terms, the measurement model was used to optimize the measurement of the latent constructs from their related manifest variables, and the causal model analyzed the relationships among the latent constructs and the outcome. These steps are described in detail below. For all of the social, economic, and demographic control variables (except child age), the direct and indirect (through Major illness and Health status through childhood) influences on the final outcome were assessed. Child age was excluded because all measures were used over the same age period for all children, e.g. birth to fifth birthday.

Data were analyzed using the SAS© system's CALIS procedure (SAS Institute Inc, Version 9), and the models tested were 'covariance structure analysis' models with

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[9] This revised analysis plan was approved in principle by two members of the Biostatistical Consulting Unit at the University of Manitoba.

multiple indicators for the latent constructs. All models were estimated using the Maximum Likelihood method and the full Newton-Raphson technique. Full listings of the programs submitted, the SAS log files, and the output from the analyses are provided in Appendix 4.

3.9.1 Step 1: Create and refine the Measurement Model

3.9.1.1 Introduction

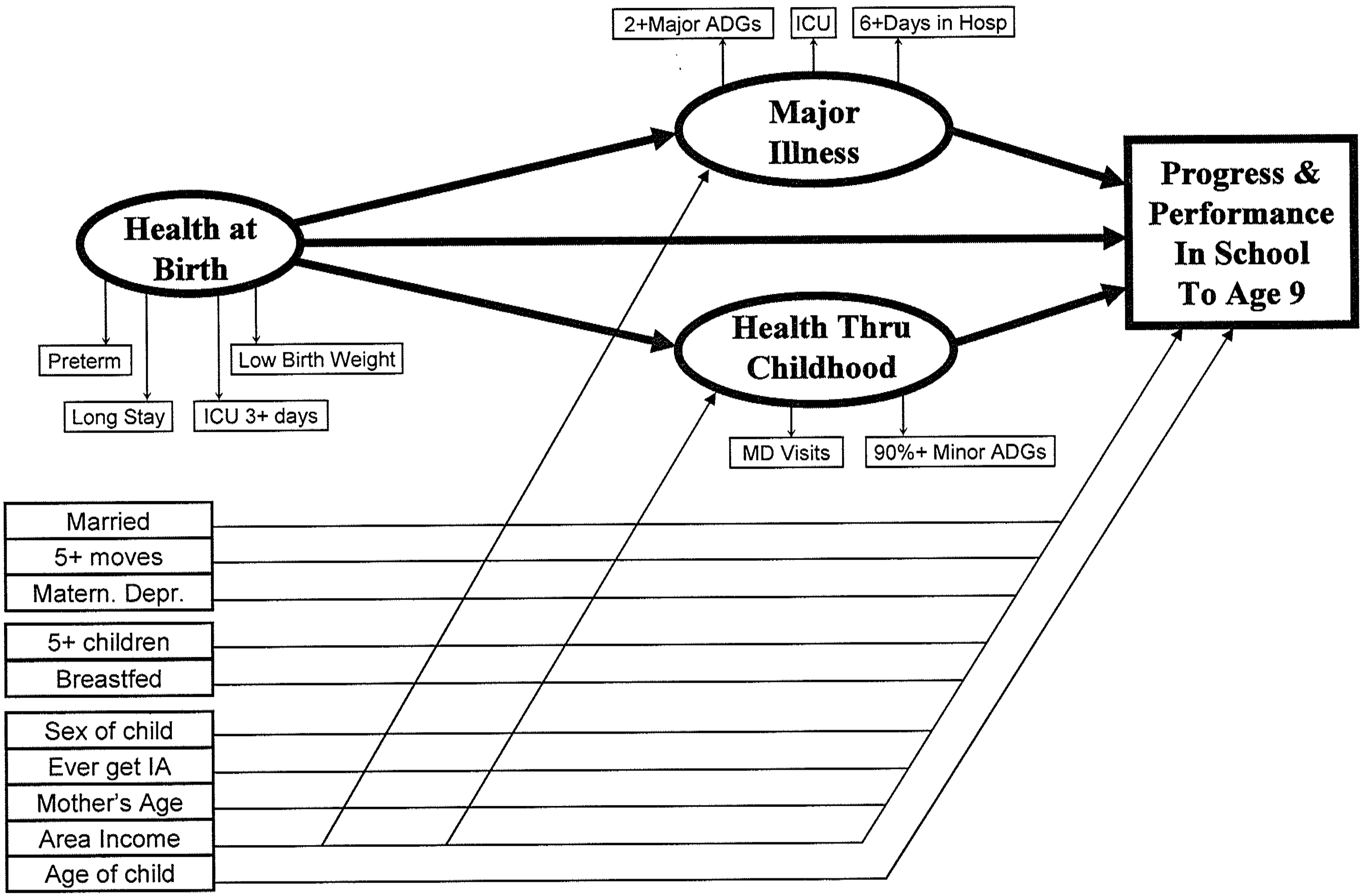
The need for the creation and refinement of a measurement model (before proceeding to the causal model) is fundamental, because it is not known in advance how each of the manifest variables are related to the latent constructs in the analysis. The measurement model is essentially a confirmatory factor analysis, and its purpose is to determine how well the manifest variables capture the proposed latent construct, and to allow the researcher to refine the variables to more accurately reflect the latent construct. In developing a measurement model, modifications to manifest variables are often undertaken to optimize the contributions of these variables to the estimation of the latent constructs. For example, manifest variables can be transformed to maximize their 'loading' on the latent constructs. The goal is to ensure all manifest variables in the model are strongly related to the latent constructs: loading values below 0.4 are considered unacceptable, those from 0.4 to 0.6 acceptable, and those above 0.6 are considered strong (169). Low loading values indicate that the manifest variable may not be related to the theorized construct; such a variable may need to be removed from the analysis. In addition to variable loadings, attention should also be paid to other aspects of the measurement model, including residual values and fit indices, which provide indications of how well the variables are being estimated, and how well the model is describing the underlying relationships in the empirical data.

3.9.1.2 Refining the measurement model

The output of the initial measurement model indicated that the five manifest variables proposed to be related to Health Status Through Childhood construct were not, in fact, all closely related to each other. The variables coding physician visits and Minor ADG-years were highly correlated with each other, as were the variables for Major ADG-years, days in hospital, and days in ICU. However, the first 2 variables were not related to the latter three variables. This suggested that there were two distinct phenomena being measured by the two sets of variables. Therefore, a new latent construct was added to the analysis, referred to as 'Major Illness,' incorporating the following variables: number of Major ADG-years, days in hospital, and use of intensive care. The remaining variables (number of physician visits and number of Minor ADG-years) were used to estimate the latent construct of 'Health Status Through Childhood.'

The revised conceptual model is shown in Figure 3.2.

Figure 3.2: Revised Conceptual Model



Labels used in Figure 3.2:

Age of child: the child's exact age, as of the test date (June 1, 1999)
Sex: sex of child (female=0, male=1)
Health Status At Birth: a latent construct created using data from four variables:

- Preterm: a dichotomous measure of whether the child was born 'preterm' (before 37 complete weeks of gestation)
- Low BirthWeight: a dichotomous measure of whether the child weighed 0-2499 grams, versus 2500 or more at birth
- Longstay: a dichotomous measure of whether the length of the birth hospitalization was above the 90^{th} percentile
- ICU 3+ days: a dichotomous measure of whether the child spent 3 or more days in an intermediate or intensive care nursery

Health Status Through Childhood: a latent construct created using data from two variables:

- Visits: a continuous measure of the number of times the child had an 'ambulatory visit' with a physician (GP or specialist).
- Minor ADG: a dichotomous measure of whether the child accumulated, from birth to their 5^{th} birthday, more than the 90^{th} percentile value (24) of Minor ADG-years.

Major Illness: a latent construct created using data from three variables:

- 2+ Major ADG: a dichotomous measure of whether the child had 2 or more Major ADG-years, from birth to their 5^{th} birthday
- 6+ Days in Hosp: a dichotomous measure of whether the child spent six or more days admitted to hospital, from birth discharge to their 5^{th} birthday
- ICU: a dichotomous measure of whether the child was ever admitted to an intensive care unit, from birth discharge to their 5^{th} birthday

Income: the average household income for the area in which the child's family lived, as of the child's fifth birthday
Mother's Age: the age of the child's mother at the birth of her first child
EveronIA: a dichotomous measure of whether the child's family received Income Assistance between the child's 5^{th} and 8^{th} birthday
Breastfed: a dichotomous measure of whether breastfeeding (exclusive or partial) was initiated during birth hospitalization
5+ children: a dichotomous measure of whether the child's mother had 5 or more children, as of the child's 8^{th} birthday
Matern Depr: a dichotomous measure of whether the mother was depressed, from the child's birth to their 8^{th} birthday
5+ Moves: a dichotomous measure of whether child's family moved 5 or more times, from the child's birth to their 8^{th} birthday
Married: a dichotomous measure of whether the mother was registered as married or not (legal or common-law), as of the child's 5^{th} birthday

A second problem with the initial measurement model was that two of the six manifest variables related to the Health Status At Birth construct (Apgar score at 5 minutes, and the indicator for delivery by emergency c-section) showed low loading values. The loading for the emergency c-section variable was 0.11, so it had to be removed from the analysis.[10] The 0.22 loading value for Apgar score corresponded to that for the dichotomous form with the cutoff value of 8 or higher. Both other forms (continuous, and dichotomous using 7 or higher as the cutoff) showed even lower loading values. Therefore, the variable for Apgar score was also removed from the analysis.

The revised model converged to an valid solution; that is, there were no errors or warnings, and all manifest variables had loadings above the minimum of 0.4 With those basic milestones achieved, the focus of further refinements of the measurement model shifted to consideration of residual values and model fit indices. Residuals represent the difference between the actual relationships among variables in the model, and how the analysis is estimating those relationships. Large residuals indicate problems with the model which should be addressed. Fit indices are used to inform the overall ability of the model to replicate the relationships in the empirical data (see section 3.12).

To improve loading values which remained below the preferred value of 0.6, and to address issues of large residuals, additional models were analyzed in which the dichotomous versions of birthweight and gestational age were used instead of the

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[10] Not all births identified as 'emergency' cesarean sections were medical emergencies. The coding of the variable in the database distinguishes only 'scheduled' vs. 'emergent' procedures. Scheduled means that the procedure was arranged several days in advance. All other procedures were coded as 'emergent.' For example, a woman could have been admitted without any consideration of c-section (i.e. not 'scheduled') but end up delivering via c-section (e.g. after stalled labour or breech presentation). Such a birth would have been coded as 'emergent', but this could not be interpreted as an indication of poor health of the fetus. This likely explains why this variable did not correlate well with the other variables in the health status at birth construct, resulting in the low loading value.

continuous values (in turn, and in combination). The model using dichotomous versions of both variables (gestational age coded as 'preterm' indicating less than 37 weeks of completed gestation, and birthweight coded as low birthweight of 0-2,499 grams) provided the best results, and therefore represented the final measurement model.

The better statistical performance of the dichotomous versions of the variables likely indicates that the influence of these variables are more related to threshold effects or extreme values, rather than smaller changes in the middle of each distribution. Taking birthweight as an example: the relationship between birthweight and educational outcomes appears more related to whether the baby was born below 2,499 grams, rather than between smaller differences in the normal range (e.g. between 3000 and 3500 grams).

3.9.1.3 The final measurement model

The final measurement model included the following variables:

Health Status At Birth was related to four manifest variables:

- gestational age: 0/1 indicator of preterm birth (less than 37 weeks)
- birthweight: 0/1 indicator of birthweight less than 2,500 grams
- length of stay at birth: 0/1 indicator of 'long stay' at birth (above 90th percentile)
- 3+ days in intensive care: 0/1 indicator of whether the child was admitted to an intensive or intermediate care unit for 3 or more days during their birth hospitalization episode (including transfers)

Health Status Through Childhood was related to two manifest variables:

- number of physician visits in preschool period (from birth discharge to 5th birthday)

- Minor ADG-years: 0/1 indicator of whether the child had above the 90th percentile of the number of Minor ADG-years (24), from birth discharge to 5th birthday

Major Illness was related to three manifest variables:

- Major ADG-years: 0/1 indicator of whether the child had above the 90th percentile of the number of Major ADG-years (3), from birth discharge to 5th birthday
- days in hospital: a 0/1 indicator of whether the child spent six or more days in hospital, from birth discharge to 5th birthday
- intensive care: 0/1 indicator of admission to an intensive care unit, from birth discharge to 5th birthday

The other variables in the analysis were:

- the child's sex and exact age (to the day)
- average household income of the area in which the child's family lived, on the child's 5th birthday
- mother's age at the birth of her first child
- indicator of whether breastfeeding was initiated during birth hospitalization
- family size: the number of children born to the mother, by the child's 8th birthday
- indicator of whether the mother used health services for depression at any time between the child's birth and their 8th birthday
- marital status: whether the mother was registered as 'married' or not, on the child's 5th birthday
- the number of residential moves recorded for the child's family, between the time of the child's birth and their 8th birthday

- indicator of whether the child was in a family receiving Income Assistance at any time between their 5th and 8th birthdays (data were not available for previous years)
- The outcome measure: the average of the two LOGIT-transformed values (Mathematics and Language Arts) combining progress and performance in school.

3.9.2 Step 2: The causal model

The initial causal model was adapted directly from the final measurement model, as shown in Figure 3.2. No changes to the variables involved were made in creating the causal model – they were exactly as specified in the final measurement model described above.

The causal model successfully converged to a solution, and provided good fit to the data. However, there were several large residuals, which indicated that some of the relationships among the variables were not well estimated by the model. To address this, additional terms were added to the model to specify covariances between error terms of related manifest variables (using indications provided in the output from the software). Such changes diminish the loading values, but do not indicate any weakening of the relationships involved, only that the variances are being allocated differently as a result of the new covariance term specified. Several of these additional covariance terms were sequentially added (between manifest variables in a given latent construct). Each addition reduced the residuals and significantly ($p<.01$) enhanced the overall fit of the model. Covariances added were between error terms of the following pairs of variables:

- hospital days used and ICU use during the preschool period

- hospital days and Major ADG-years
- gestational age and birthweight
- birthweight and length of ICU stay at birth
- gestational age and length of stay at birth
- birthweight and length of stay at birth

3.10 Assessing the 'fit' of the final model

The 'fit' of a model refers to the ability of the model to reproduce the variance-covariance matrix data in the empirical data. If a model does not provide good fit to the data, then there can be no meaningful interpretation of the results and relationships estimated. For the kind of structural equation model used in this study, assessing model fit is relatively straight forward. While there is no single test or indicator that can be used to make this judgment, many indicators have been developed in the statistical literature, so a number of indicators are considered together in making the final assessment. Detailed descriptions and comparisons of the various indicators, by Kenny (170), Kline (157), and Newsom (171), as well as consultation with the Biostatistical Consulting Unit at the University of Manitoba, were used to select the following list of indicators. The large number of observations involved in this study (N = 5,873) made many of the indicators, in particular, those based on the Chi-squared technique, inappropriate because the Chi-squared measure is known to be biased when large samples are involved (defined by Kenny and Newsom as more than 200 cases). The fit indexes chosen for this study were:

1. Bentler's Comparative Fit Index (CFI)
2. Bentler & Bonnet's Normed Fit Index (NFI)

3. Bentler & Bonnet's Non-Normed Fit Index (NNFI)
4. Bollen's Normed Index (Rho1)
5. Bollen's Non-Normed Index (Delta2)
6. The Root Mean Square Residual (RMR)
7. The Root Mean Square Error of Approximation (RMSEA)
8. Akaike's Information Criterion (AIC)

The first five fit indexes share the interpretation that higher values indicate better fit. Models with values above 0.90 are considered acceptable; those below are not (157;170;171). The Root Mean Square Residual (RMR) and Room Mean Square Error of Approximation (RMSEA) are measures of 'badness' of fit, so smaller values are preferred. Models with RMR and RMSEA under 0.10 are considered acceptable; those above are not (157;170;171). In addition, Akaike's Information Criterion (AIC) values were used to help decide between competing models. AIC values have no absolute cutoff, they are strictly a comparative number. Models with lower values are preferred over those with higher values (157;170;171).

3.11 Adding socio-economic variables at birth

As noted in section 3.9, the revised analysis plan called for the refinement of a full model, followed by an attempt to introduce some of the social, economic, and demographic variables measured at the time of the child's birth (in addition to the 'later' measures already included in the model).

Several of the variables were not considered for addition because they were 'static' variables; that is, they contained the same values at both times (attempting to add them again would have caused estimation errors). These included the child's sex, the mother's age at the birth of her first child, and whether breastfeeding was initiated at birth. Two other variables could not be defined at birth, as they required a period of time in order to be measured: maternal depression, and number of family moves. Data were not available for family receipt of income assistance at the time of the child's birth, so that variable could not be added either. For family size, the value measured at the child's 8^{th} birthday was considered necessarily more informative than at the child's birth, because the later measure captures all younger siblings born up to the study child's 8^{th} birthday, providing a superior measure of family size. Therefore, the only variables to be added at birth were area-level income, and mother's marital status.

The first model included both variables, but did not converge to a valid solution. A second model without mother's marital status at birth provided a valid solution, but the variable loadings and model fit were inferior to prior models without this variable.

Both models were attempted in several iterations, which differed in terms of which subsequent variables were designated as being affected by these 'birth-era' variables. Furthermore, to ensure that co-linearity of the area-level income measures at the two times was not the cause of these problems, models were also tested in which the 'later' income variable was calculated as the change in income between the two time periods. All of these models provided either invalid or inferior solutions to prior models.

Chapter 4: Results

4.1 Introduction

The objective of this study was to assess whether a child's health status, both at birth and through childhood, affects their progress and performance in school, controlling for a variety of social, economic and demographic factors. Structural Equation Modeling (SEM) was used because it allows for the estimation of latent constructs, as well as intervening variables (157-161), both of which were prominent aspects of this project.

The main findings for this study come from the final structural equation model, which was the culmination of a series of analyses described in detail in Chapter 3, based on the widely recommended two-step process developed by Anderson and Gerbing (168). The final model provided excellent fit to the data, and explained a significant proportion of the variation in the outcome. The outcome measure is called 'progress and performance in school' because it incorporates both aspects in to a single measure, depending on the child's circumstances. This was a birth cohort study, so all children born to Winnipeg mothers were followed forward in time. For most children (82%), their performance in school was assessed by marks on Standards Tests in Language Arts and Mathematics at the end of the Grade 3 year. However, not all children had reached Grade 3 by the 1998/99 school year, and of those that did, not all wrote the standards tests. For these children, progress in school was determined by their status: whether enrolled in a lower grade, or in Grade 3 but exempted from writing the tests for a number of reasons. The final outcome measure (described in Chapter 3) involved a transformation which allowed all children to be rated on a single continuous outcome scale.

This chapter is organized as follows: Section 4.2 provides descriptive results about the study group analyzed, comparing them to children lost to follow-up. Section 4.3 addresses the correlations among the predictor variables, and their univariate relationships with the final outcome. Section 4.4 shows the results of the main analyses - the structural equation model. Section 4.5 addresses the substantive findings from the analysis: the relationships between the health-related factors and the educational outcome, as well as the direct and indirect effects of the social, economic, and demographic factors. Section 4.6 describes the results of supplementary analyses performed to further explore several key issues, and Section 4.7 provides a summary of results.

4.2 Descriptive characteristics

The final analyses included 5,873 singleton births to Winnipeg mothers in 1990. There were 3,030 children lost to follow-up: 2,862 whose families moved away, 86 who died, and 82 for whom complete data were not available in health (6) or education (76) records. Table 4.1 shows the descriptive characteristics for all 4 groups.

Table 4.1: Descriptive statistics for study group and those lost to follow-up

		Study Group n=5,873	**Movers** n=2,862	**Deaths** n=86	**Missing Data** n=82
Variable	Abbrev	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)
Health Status At Birth					
Preterm birth (<37 weeks)	Preterm	5.02%	5.17%	46.5%*	24.3%*
Low Birthweight < 2,500 g	LBW	4.54%	4.75%	43.0%*	17.6%*
Long stay at birth	Longstay	5.94%	5.97%	24.4%*	9.46%
ICU 3+ days at birth	ICU 3+ days	4.44%	4.57%	18.6%*	5.41%
Health Status Through Childhood					
Number of MD Visits	MD Visits	38.27 (19.6)	na	na	na
Above 90% Minor ADG-yrs	90% Minor ADG	8.1%	na	na	na
Major Illness in Childhood					
2+ Major ADG-years	2+ Major ADGs	8.41%	na	na	na
6+ days in hospital	6+ days in hosp	4.05%	na	na	na
Admitted to ICU	ICU	1.29%	na	na	na
Control variables: Social, Economic, Demographic					
Age of child on test day	Age of child	8.92 (.28)	na	na	na
Sex of child (% male)	Sex of child	51.4%	51.9%	54.7%	44.6%*
Area-Level Average Income	Area Income	$43,614 (17,323)	$40,434* (16,251)	$39,532 (15,768)	$35,772* (15,290)
Mother's age at first birth	Mother's Age	25.3 (5.09)	23.8* (4.97)	23.3 (5.58)	22.7* (5.43)
Family has 5+ children	Family Size	3.93%	na	na	na
Mother treated for depression	Matern Depr	26.1%	na	na	na
Mother married	Married	69.6%	60.8%*	51.1%*	47.3%*
Family receive Income Assistance	Ever get IA	13.6%	na	na	na
Family moved 5+ times	# Moves	5.67%	na	na	na
Breastfeeding initiated at birth	Breastfed	75.2%	75.1%	33.7%*	56.7%*

Notes: * indicates significantly different from Study Group (p<.01). Cells with 'na' denote values which could not be calculated (e.g. health status through childhood for children who moved could not be determined, because data are not available for non-Manitobans).

Statistical testing of the differences between groups revealed the following:

4.2.1 Study group compared to movers

Children whose families moved out of Winnipeg were not statistically different on any of the variables used to assess Health Status At Birth. This is important, because it means the study is not biased because of the exclusion of this group; children whose families moved were no less healthy at birth than study children. Three of the control variables showed statistically significant differences: children from families who moved had lived in lower income areas (at birth), and had mothers who were slightly younger and less likely to have been married at the time of the child's birth.

4.2.2 Study group compared to deaths

Children who died before age eight were dramatically less healthy at birth than study group children. In fact, 45% of the deaths occurred within the first week after birth, and 73% within the first year. All of the variables in the Health Status At Birth group reflect this significantly worse health status. These children were also less likely to have been breastfed, and had mothers less likely to report being married at the child's birth. The loss of these children introduces some bias to the study, as these are clearly the least healthy of all children in the birth cohort. However, the effect of this bias would be limited, as they represent less than 1.5% of the number of children in the study group (86 of 5,873).

4.2.3 Study group compared to missing data

Children for whom incomplete data were available were different from the study group on two of the four health status at birth variables: they were more likely to have been born preterm, and at low birthweight. They were also less likely to have been breastfed, they lived in lower income areas, and they had mothers who were less likely to have been married at the time of the child's birth. As with deaths, this group could potentially bias the study results, but as above, such bias would be limited given the small size of this group (82 of 5,873).

4.3 Relationships among predictor variables, latent constructs, control variables, and outcome

4.3.1 Correlations among predictors and control variables

Table 4.2 shows the correlations among all the health-related predictor variables and the social, economic, and demographic control variables for the 5,873 children in the study group. Values shown are Pearson correlation coefficients, with p values below (in cases involving two dichotomous variables, the Pearson is equivalent to the PHI value, and the Chi-squared value is reported). Correlations significant at the $p<0.001$ level are shown in bold text.

Table 4.2: Correlations among predictor variables (N=5,873)

			Health status at birth					Hlth Stat in childhood		Major Illness			Social, economic, demographic					
	Age	Sex	Pre-term	LBW	Long stay	ICU 3+	Breast feed	MD Vis	Minor ADG	Major ADG	ICU	Hosp 6+	Inc-ome	Mum Age	IA	5+ kids	Mum depr	5+ mov
Sex	.009 .474																	
Preterm	.002 .865	.021 .115																
LBW	-.019 .134	-.020 .121	**.578** .0001															
Long-stay	.011 .406	.028 .032	**.483** .0001	**.433** .0001														
ICU 3+	.012 .341	.033 .013	**.522** .0001	**.484** .0001	**.592** .0001													
Breast-feeding	-.001 .940	.016 .374	**-.085** .0001	**-.073** .0001	**-.079** .0001	**-.067** .0001												
MD Vis	-.009 .512	.078 .001	**.069** .0001	**.062** .0001	**.079** .0001	**.079** .0001	-.037 .004											
Minor ADG	-.027 .036	**.076** .0001	**.069** .0001	**.043** .0009	**.087** .0001	**.073** .0001	-.019 .137	**.556** .0001										
Major ADG	-.007 .600	.022 .094	**.222** .0001	**.199** .0001	**.264** .0001	**.289** .0001	-.039 .003	**.164** .0001	**.117** .0001									
ICU	.000 .992	.015 .258	**.091** .0001	**.083** .0001	**.111** .0001	**.122** .0001	-.028 .029	**.097** .0001	**.093** .0001	**.161** .0001								
Hosp 6+	-.017 .190	.044 .0007	**.087** .0001	**.063** .0001	**.109** .0001	**.111** .0001	**.066** .0001	**.193** .0001	**.174** .0001	**.211** .0001	**.305** .0001							
Income	.029 .022	-.013 .330	.001 .918	-.014 .280	-.026 .045	-.011 .415	**.171** .0001	**-.073** .0001	**-.063** .0001	-.037 .005	-.021 .114	**-.062** .0001						

	Age	Sex	Pre-term	LBW	Long stay	ICU 3+	Breast feed	MD Vis	Min ADG	Maj ADG	ICU	Hosp 6+	Inc-ome	Mum Age	IA	5+ kids	Mum depr	5+ mov
Mum age	.011	-.009	-.002	.010	.014	.018	**.175**	-.039	-.033	-.012	.003	-.049	**.321**					
	.419	.497	.905	.433	.300	.158	.0001	.003	.012	.370	.810	.0002	.0001					
IA	-.011	-.012	.020	.023	.031	.004	**-.191**	**.086**	**.079**	.030	.021	**.085**	**-.273**	**-.373**				
	.417	.360	.118	.074	.018	.770	.0001	.0001	.0001	.020	.114	.0001	.0001	.0001				
5+ kids	**-.037**	.007	.029	.006	.005	.007	**-.056**	.012	.008	.002	**.047**	**.061**	**-.123**	**-.214**	**.165**			
	.001	.579	.023	.629	.718	.572	.0001	.355	.562	.890	.001	.0001	.0001	.0001	.0001			
Matern depress	-.015	.011	-.019	-.003	-.013	-.013	-.029	**.145**	**.098**	.024	.018	.031	-.074	**-.074**	**.135**	.045		
	.241	.412	.131	.842	.313	.315	.027	.0001	.0001	.065	.173	.016	.002	.0001	.0001	.001		
5+ moves	-.003	-.011	.011	-.008	.019	.007	**-.130**	**.061**	.044	.005	.005	**.069**	**-.215**	**-.287**	**.380**	**.178**	**.113**	
	.844	.407	.398	.562	.138	.956	.0001	.0001	.0008	.686	.730	.0001	.0001	.0001	.0001	.0001	.0001	
Married	.022	.012	-.015	-.027	-.024	-.014	**.116**	-.023	**-.061**	-.028	-.019	**-.067**	**.175**	**.213**	**-.446**	**-0.09**	**-.091**	**-.255**
	.095	.344	.250	.040	.069	.284	.0001	.076	.0001	.033	.142	.0001	.0001	.0001	.0001	.0001	.0001	.0001

The results in Table 4.2 show that there were many significant correlations among the predictor and control variables. Among manifest variables relating to the same latent construct, a high correlation is a positive characteristic, as the two variables are supposed to be reflecting the same underlying construct. Conversely, high correlations among other variables suggests potential for overlapping explanations, and underscores the importance of using a multivariate technique in the final analysis, to determine the independent contributions of each variable.

4.3.2 Estimating the latent variables: the three health constructs

The variables representing the constructs of health status at birth, health status through childhood and major illness were developed as latent variables, estimated using information contained in the manifest variables related to them. The table below shows the loading values for each manifest variable onto its latent construct. Loading values below 0.4 are considered low; values between 0.4 and 0.6 are considered acceptable, and values above 0.6 are considered high.

Table 4.3: loading values of manifest variables on latent constructs

	Health-related Latent Construct		
Manifest Variable	**Health Status At Birth**	**Health Status Thru Childhood**	**Major Illness**
Preterm	.7258		
Low BW	.6763		
ICU 3+ d	.7605		
Long Stay	.7075		
MD Visits		.8250	
Minor ADGs 90%+		.6731	
2+ Major ADGs			.5007
6+ Hosp days			.4834
ICU use			.4268

The results in Table 4.3 show that all of the loading values were above the cutoff value of 0.4, and many were above the preferred 0.6. The high loading values for the manifest variables relating to the health status at birth and health status through childhood constructs suggest that those constructs were well characterized by the manifest variables used. The lower loading values associated with the manifest variables for major illness suggest that this construct was not as well captured.

4.3.3 Relationships between individual predictors and outcome

The relationships between each predictor and control variable and the outcome score of progress and performance in school are shown in Table 4.4 below. The 'Coefficient' values describe the nature of the relationship, the standardized coefficients allow comparison of the relative strength of the various variables, and the p values indicate the likelihood that the relationship was due to chance. Within each group, the variables are listed in decreasing strength of association with the outcome.

Table 4.4: Univariate regressions between each predictor variable and progress and performance in school

Variable	Coefficient	Std Error	Std'd Coeff	t value	p< value	R^2 (%)
Health-related constructs:						
Major Illness	-.79334	.10231	-.10069	7.75	.0001	1.01
Health status through childhood	-.34071	.04409	-.10033	7.73	.0001	1.00
Health status at birth	-.40378	.07763	-.06773	5.20	.0001	0.46
Control variables: Social, Economic, Demographic						
Family receipt of income assistance	-.74568	.03430	-.27297	21.74	.0001	7.45
Area-level income (in $10,000 units)	.12187	.00567	.26989	21.48	.0001	7.28
Mother's age at birth of first child (yrs)	.04847	.00231	.26409	20.98	.0001	6.97
Family moved 5+ times in 8 years	-.70739	.05198	-.17487	13.61	.0001	3.06
Mother registered as married	.35963	.02643	.17485	13.61	.0001	3.06
Age of child (months)	.04240	.00357	.15300	11.86	.0001	2.34
Breastfeeding initiated at birth	.31188	.02798	.14398	11.15	.0001	2.07
Sex of child (0=female, 1=male)	-.23146	.02424	-.12365	9.55	.0001	1.53
Family had 5+ children	-.59202	.06234	-.12301	9.50	.0001	1.51
Mother depressed	-.15868	.02773	-.07446	5.72	.0001	0.55

The values in Table 4.4 show that all of the predictor and control variables used in this study were significantly related to the outcome when analyzed one at a time (reflected in the t values and p values). The 'Coefficient' values indicate the amount by which the outcome score would change, given a one unit increase in that variable. To assist with interpreting the numbers, it is helpful to know that an increase of 0.1 in the final outcome score is equivalent to about a 2% increase in the Grade 3 test scores.[11] So

[11] Note: the relationships are not linear across all values, so cannot be interpreted broadly; this example was provided to give some ability to relate outcome values to test score percentages.

for example, the coefficient for sex is -0.23, suggesting that boys, on average, scored about 5% lower on the tests than girls.

The standardized coefficients allow comparison of the relative strengths of the various predictors, and the R^2 numbers give an idea of what proportion of the variation in the outcome was explained by that variable. These values show that family receipt of income assistance and average area-level income explained the highest proportion of the outcome (7.45% and 7.28%, respectively), followed by mother's age at the birth of her first child (6.97%). However, these univariate analyses ignore the correlations among these predictors: the families receiving income assistance could also be those in which the mother was younger at the birth of her first child, and they might also live in lower-income areas. Moreover, all three of these variables were also correlated with other variables in the model as well (Table 4.2). This underscores the importance of using a multivariate approach, to determine the independent contributions of each variable, controlling for all others.

It is also interesting to note from the values in Table 4.4 that while all three of the health-related constructs were statistically significant, the Health Status Through Childhood and Major Illness factors each explained almost twice as much variation in the outcome as the Health Status At Birth construct. In the final analysis, these constructs were all entered simultaneously, and reflected the temporal ordering of the variables. This allowed for estimation of the independent effect of each construct, while accounting for the other health constructs and the control variables (the social, economic, and demographic characteristics), as described in Section 4.5.

4.3.4 Multivariate normality

The analysis in this study used the Maximum Likelihood estimation method, which is the recommended default for structural equation modeling analyses. This approach requires that the variables in the model are normally distributed, including from the multivariate perspective. The output from the analysis included the Relative Multivariate Kurtosis value, which should be below 1.96 for the data to be considered 'multivariate normal.' In the final model of this study, the value was 1.73, indicating the data in this analysis satisfied the requirement for multivariate normality.

4.4 The Final Model

4.4.1 The 'fit' of the final model

The first issue to be assessed in a structural equation modeling analysis is how well the model fits the empirical data. If a model does not provide good fit to the data, then the results are not meaningful. While there is no single test or indicator that can be used to make this judgment, many such indicators have been developed in the statistical literature, so a number of indicators are considered together in making a final assessment about model fit. Table 4.5 shows the values for the fit indicators most relevant for analyses involving a large number (>200) of observations, as in this study (discussed in Chapter 3: Methods).

Table 4.5: Values of fit indexes from the final model

Indicator	Value
Bentler's Comparative Fit Index (CFI)	.9767
Bentler & Bonnet's (1980) Non-Normed Fit Index (NNFI)	.9549
Bentler & Bonnet's (1980) Normed Fit Index (NFI)	.9717
Bollen's (1986) Normed Index (Rho 1)	.9452
Bollen's (1988) Non-normed Index (Delta 2)	.9768
Root Mean Square Residual (RMR)	.0023
Root Mean Square Error of Approximation (RMSEA)	.0274

Interpretation:

The first five fit indicators share the interpretation that higher values indicate better fit. Models with values above 0.90 are considered acceptable; those below are not. The last two indicators, Root Mean Square Residual (RMR) and Room Mean Square Error of Approximation (RMSEA), are measures of 'badness' of fit, so smaller values are preferred. Models with RMR and RMSEA under 0.10 are considered acceptable. The final model in this analysis exceeds the requirements of all these indexes, indicating an excellent fit to the data.

In addition, Akaike's Information Criterion (AIC) values were used to help decide between competing models during development. AIC values have no cutoff value – they are strictly a comparative number. Models with lower values are preferred over those with higher values. The first full causal model analyzed had an AIC value of 1,072, and the final model had an AIC value of 384.

4.4.2 'Explanatory Power' of the model

The next issue to address concerns the model's ability to predict or explain variation in the outcome variable. A model might fit the data well and its variables might be strongly related to the constructs theorized, but if it explains only a small proportion of the variation in outcome scores, then the practical utility of the model is limited. The final model in this analysis explains 18.6% of the total variation in the outcome measure, suggesting that the model includes several key variables important for predicting school performance. This would qualify as a 'medium' effect size using the classical definition by Cohen (172).

4.5 Substantive findings from the final population-based model

4.5.1 Results of the multivariate analysis

The results of the multivariate analysis show that most of the predictor and control variables entered in the analysis made important contributions to explaining the outcome. Table 4.6 below shows the relationship for each predictor and control variable with the outcome (progress and performance in school). Within each category, the variables are shown from highest to lowest strength of association with the outcome. The R^2 column in the table shows how much variation in progress and performance in school can be 'explained' by that variable alone, followed by a ranking of significant influences ('1' being the strongest predictor).

Table 4.6: Results of the final model: Relationships of each variable with progress and performance in school (N=5,873).

Variable	Coeff	Std Error	Std'd Coeff	t value	p < value	R^2 (%)	Rank
Health-related constructs:							
Major Illness	-.6275	.1743	-.1124	3.60	.0003	1.26	6
Health status through childhood	-.1132	.0419	-.0391	2.70	.01	0.15	8
Health status at birth	.1032	.1245	.0193	.828	n.s.	.005	
Control variables: Social, Economic, Demographic							
Age of child	.4777	.0393	.1438	12.14	.0001	2.07	1
Area-level average income	.6477	.0595	.1436	10.88	.0001	2.06	2
Mother's age at first birth	.2395	.0248	.1306	9.65	.0001	1.71	3
Family received income assistance	-.3285	.0406	-.1204	8.09	.0001	1.45	4
Sex of child (0=female, 1=male)	-.2173	.0225	-.1162	9.65	.0001	1.35	5
Breastfeeding initiated at birth	.1203	.0266	.0556	4.52	.0001	0.31	7
Family had 5+ children	-.1783	.0593	-.0371	3.01	.005	0.14	9
Family moved 5+ times in 8	-.1286	.0536	-.0318	2.39	.02	0.10	
Mother registered as married	.0626	.0277	.0304	2.26	.05	0.09	
Mother depressed	-.0441	.0262	-.0207	1.68	n.s.	0.04	
All variables combined						**18.6%**	

4.5.2 Effect of health-related factors on outcome

The results in Table 4.6 show clearly that health-related factors are statistically significant predictors of progress and performance in school, supporting Hypothesis 1 (see Chapter 3). Of the three health factors used (health status at birth, health status through childhood, and major illness), the major illness construct was the most strongly related to the outcome. Major illness alone explained 1.26% of the variation in the outcome. Health status through childhood was also independently related to the outcome, though considerably weaker, in that it alone explained 0.15% of the outcome. Health status at birth was not significantly related to the outcome directly, but had strong indirect effects through major illness and, to a lesser degree, health status in childhood. That is, health status at birth was significantly related to major illness and to health status through childhood, both of which, in turn, affect progress and performance in school. In statistical terms, this means that major illness and health status through childhood completely mediate the relationship between health status at birth and the educational outcome. This finding represents a new contribution to the literature in this area.

Comparing the standardized coefficients in Table 4.6 to those in Table 4.4 reveals the differences between the multivariate and the univariate analyses (in which each individual variable analyzed alone was found to predict the outcome significantly). The multivariate results reflect the mediating role of major illness and health status through childhood on the relationship between health status at birth and the outcome: its standardized coefficient dropped from -.0677 to the non-significant .0193. The standardized coefficient for health status through childhood also dropped, from -.10 to -.039, though it was still significant in the multivariate model. Conversely, the standardized coefficient for the major illness construct was higher in the multivariate (-.112) than in the univariate analysis (-.10).

4.5.3 Direct effects of social, economic, and demographic control factors

The values in Table 4.6 also show how strong the social, economic, and demographic control factors are in determining children's progress and performance in school, supporting Hypothesis 2. The five strongest individual predictors of the outcome were all among these control factors. The child's exact age and the average household income of the area where the child's family lived were the strongest factors in the final model, each (alone) explaining over 2% of the variation in the outcome variable. The mother's age at the birth of her first child explained 1.71%, and family receipt of income assistance and the sex of the child each explained 1.4% of the variance. Hypothesis 3 was supported by the finding that breastfeeding initiation was positively related to progress and performance in school, explaining 0.31% of the outcome variation. Maternal depression, marital status, and whether the family moved 5 or more times were not significantly related to the outcome directly in the multivariate analysis.

4.5.4 Indirect effects of social, economic, and demographic factors

In addition to their direct influences on the educational outcome, four of the social, economic, and demographic factors also had indirect influences, operating through the 'Health Status Through Childhood' construct. Area-level income, maternal depression, family receipt of income assistance, and the sex of the child were all significantly related to health status through childhood, which was in turn related to the outcome. There were no indirect effects of any social, economic, or demographic variables through the Major Illness construct. All of the direct and indirect associations are illustrated in Figure 4.1, including all predictor and control variables used in the analysis. The numbers in the figure are the standardized coefficients indicating the strength of each relationship. Statistically significant values are indicated by bold text.

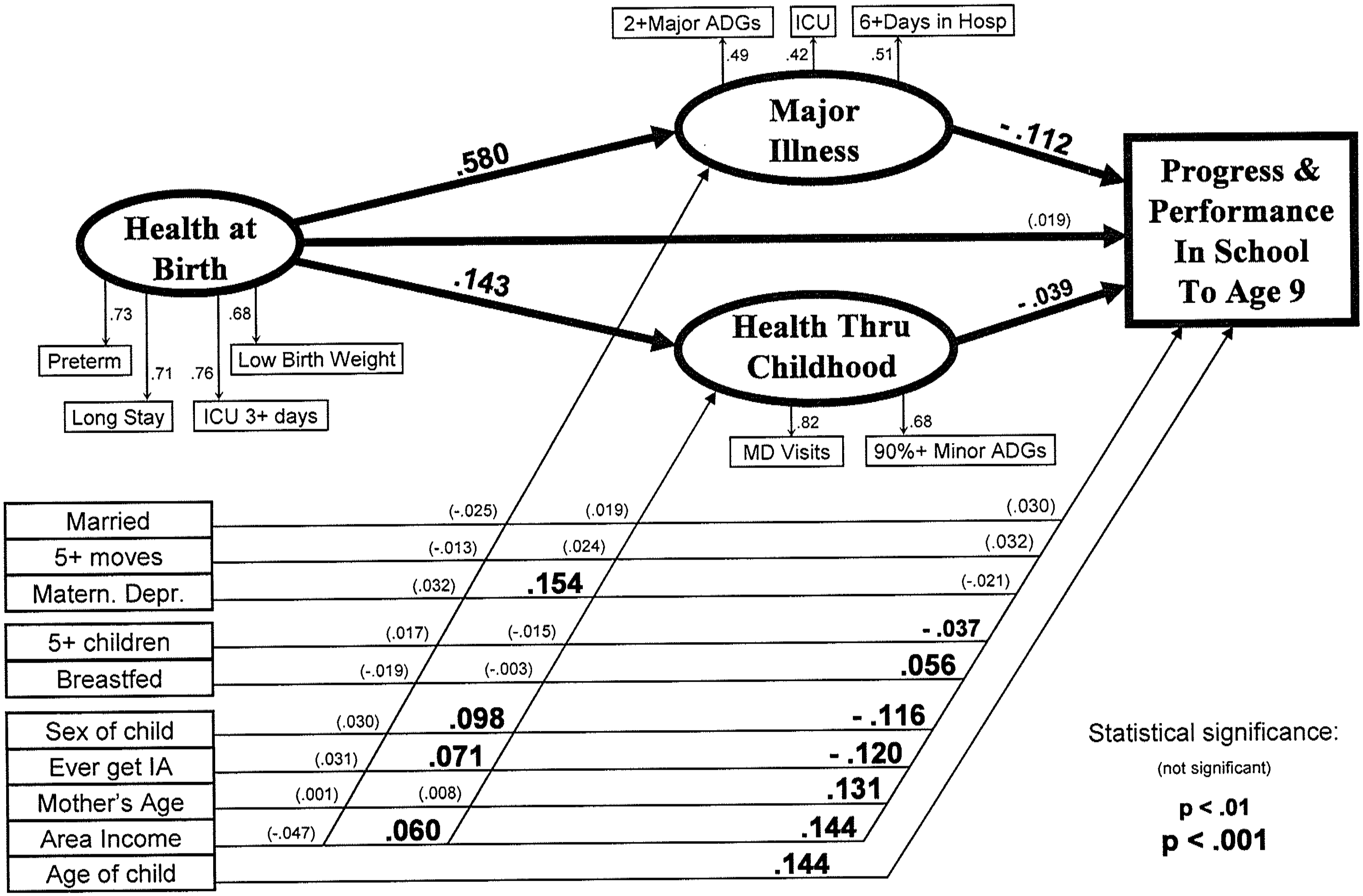
The standardized coefficients for all of the social, economic and demographic control variables were substantially lower in the multivariate analysis than the univariate analyses. This reflects the correlations among these variables, as well as the indirect influences noted above. For example, a portion of the influence of area-level income on the final outcome was through income's effect on health status through childhood. This pattern also applied to family receipt of income assistance and the sex of the child.

Maternal depression was different, in that its only connection to the outcome was indirect, through its relationship with health status through childhood.

4.5.5 Non-significant variables

The multivariate analysis also revealed that two of the control variables were not significant in the final multivariate model. The mother's marital status, and whether the family moved 5 or more times had no significant relationships in the final model. That is, once all other factors were accounted for, these two variables were not significantly related to the outcome or the mediating health constructs.

Figure 4.1: Relationships among health constructs, control factors, and progress & performance in school



4.5.6 Synthesis of findings from main analysis

The results of this study suggest that health-related factors, both at birth and through childhood, have a statistically significant but modest impact on progress and performance in school. The experience of a major illness was particularly important, and health status at birth was strongly related to major illness in childhood. However, several social, economic, and demographic factors were stronger predictors of the outcome among the entire study group. The two strongest predictors, child age and area-level income, each explained just over 2% of the variation in the outcome variable, almost twice as much as the strongest health-related factor, major illness, which explained 1.26% of the variation in outcomes for the full study group.

The results also suggest that there are two 'tiers' of influential variables. The first tier includes the variables most strongly predictive of the outcome: the child's exact age, area-level income, mother's age at the birth of her first child, family receipt of income assistance, the child's sex, and experience of a major illness. The factors in tier one each explain at least 1.25% of the variation in the outcome variable. The second tier factors, while still statistically significant, were all considerably weaker, with each explaining less than 0.31% of the outcome. These were: breastfeeding, health status through childhood, and being in a family with 5 or more children. The two remaining control variables were not significantly related to the outcome or the mediating variables: being in a family which moved 5 or more times, and whether the mother was married (though again, it needs to be noted that these variables are not necessarily insignificant for the outcome, but that their relationships may be overlapping with other variables used in the analysis).

The main results are interpreted as follows (ranked by strength of association with progress and performance in school):

1) Age of child: with each additional month of age, the average test score increased by 0.8%.
2) Area-level income: for each $10,000 increase in area-level income, the average test score increased by about 1.3%.
3) Mother's age at the birth of her first child: for each additional year of maternal age, the average test score increased by about 2%.
4) Income assistance receipt: the average for children in families that received income assistance was 6.6% lower than that for children in families that did not.
5) Sex of child: girls scored on average 5% higher than boys
6) Major illness: the average score for children with a major illness was 6% lower than those without any indication of major illness.
7) Breastfeeding: children who were breastfeeding (exclusive or partial) scored on average 2.5% higher than those who were not breastfeeding at birth hospital discharge.
8) Health status through childhood: children with a higher than average (38) number of physician visits scored 2.5% lower than those who visited less often
9) Family size: children from large families (5 or more children) scored 6% lower than children from smaller families
10) Health status at birth: children born preterm (less than 37 weeks of gestation completed) scored 3.5% lower than those born after 37 or more weeks; children born at low birthweight (0-2499 grams) scored 7% lower than those born at 2500 grams or

higher; children who stayed in hospital longer than the 90th percentile scored 3% lower than those with shorter stays; children who spent 3 or more days in intermediate or intensive care scored 5% lower than those who spent 0-2 days

11) Maternal depression: children whose mothers were depressed scored 3% lower than those whose mothers were not depressed

4.5.7 Combination of direct and indirect effects

Table 4.7 below shows the sum of the direct and indirect effects of each predictor and control variable on progress and performance in school.

Table 4.7: Combination of direct and indirect effects

Variable	Direct effect	Indirect effects	Total
Health-related constructs:			
Major Illness	-.1124	n/a	-.1124
Health status through childhood	-.0391	n/a	-.0391
Health status at birth	n.s.	-.059	-.059
Control variables: Social, Economic, Demographic			
Age of child	.1438	n/a	.1438
Area-level average income	.1436	-.0023	.1413
Mother's age at first birth	.1306	n.s.	.1306
Family received income assistance	-.1204	-.0028	-.1232
Sex of child (0=female, 1=male)	-.1162	-.0038	-.1200
Breastfeeding initiated at birth	.0556	n.s.	.0556
Family had 5+ children	-.0371	n.s.	-.0371
Family moved 5+ times in 8	n.s.	n.s.	n.s.
Mother registered as married	n.s.	n.s.	n.s.
Mother depressed	n.s.	-.006	-.006

4.6 Supplementary Analyses

The main population-based model showed that health-related factors had a statistically significant but substantively modest effect on children's progress and performance in school. However, the majority of children are in very good to excellent health, which reduces the extent to which their health status could affect their schooling outcomes. An alternative explanation of the results shown is that the impact of health status is minimal for the majority of children in good health, but larger for the minority of children who have some sort of health problem.

To test this hypothesis directly, a supplementary analysis was undertaken in which only those children with some indication of major illness were included. These analyses used the same variables as the final structural equation model, but included only a sub-sample of the original study group. Since the strongest of the health constructs in the full model was the major illness construct, that factor was chosen to sub-divide the cohort.

The distribution of values on the major illness construct showed that the majority of children have no experience with major illness. A small group, comprising 11.5% (n = 668) of all children, had higher scores on this construct, so this group was used for the supplementary analysis. Table 4.8 shows the descriptive statistics for the two groups. The objective was to determine whether the results for this less healthy sub-group would provide different coefficients relating each variable with the outcome. If so, that would suggest that the nature and strengths of the various relationships were different for the 'Major Illness' subgroup than for the rest of the study group.

Table 4.8: Descriptive statistics of Major Illness subgroup

		Major Illness n=668	**No Major Illness** N=5,205
Variable	Abbrev	Mean (S.D)	Mean (S.D)
Health Status At Birth			
Preterm birth (<37 weeks)	Preterm	21.1%	3.6%
Low Birthweight < 2,500 g	LBW	18.2%	3.3%
Long stay at birth	Longstay	26.5%	4.1%
ICU 3+ days at birth	ICU 3+ days	24.1%	2.6%
Health Status Through Childhood			
Number of MD Visits	MD Visits	48.93 (22.93)	37.29 (19.03)
Above 90% Minor ADG-yrs	90% Minor ADG	18.6%	7.1%
Major Illness in Childhood			
2+ Major ADG-years	2+ Major ADGs	100% (by defn)	0%
6+ days in hospital	6+ days in hosp	17.8%	2.8%
Admitted to ICU	ICU	7.28%	.74%
Control variables: Social, Economic, Demographic			
Age of child on test day	Age of child	8.92 (0.27)	8.92 (0.28)
Sex of child (% male)	Sex of child	55.1%	51.1%
Area-Level Average Income	Area Income	$46,997 ($20,273)	$49,726 ($20,746)
Mother's age at first birth	Mother's Age	25.09 (5.17)	25.29 (5.09)
Family has 5+ children	Family Size	4.1%	3.9%
Mother treated for depression	Matern Depr	29.6%	25.8%
Mother married	Married	65.2%	70.0%
Family Income Assistance	Ever get IA	17.0%	13.25%
Family moved 5+ times	# Moves	4.1%	3.9%
Breastfeeding initiated at birth	Breastfed	69.6%	75.7%

The results revealed that among the sub-group of children with major illness, health status at birth and health status through childhood were substantially more important than they were among the entire study group. This was shown by higher coefficient values and statistical significance ('Supp 1' column in Table 4.8). Health status at birth was highly significant in this major illness group, whereas it was not significant in the model for the entire study group. Moreover, health status through childhood was the strongest single predictor in this model – achieving the same strength as the key socioeconomic measures.

The coefficient for major illness was lower, reflecting the fact that all children in this sub-group had an elevated value for major illness (resulting in smaller range of values, and less influence on the final outcome). Most of the coefficients relating to the social, economic, and demographic control variables remained similar, except that mother's age at first birth and breastfeeding initiation were both non-significant among this sub-group with major illness.

These results support the notion that health status is a more important factor in predicting progress and performance in school among those with major illness than among the population as a whole. The key social, economic, and demographic factors were still strongly related to progress and performance in school, but health status through childhood showed the same strength of association.

The second supplementary analysis analyzed the other group: the 88.5% of children without major illness. The results of this model (Supp 2 in Table 4.8) reveal that among children without major illness, health status at birth and health status through childhood have no significant influence on progress and performance in school. The roles of the social, economic, and demographic variables were very similar to those for the entire study group.

An additional pair of supplementary analyses was performed (Supplementary models 3 & 4) to confirm the indirect influence of health status at birth, while controlling for other variables. Supplementary model 3 used only health status at birth – that is, it excluded the health status through childhood and major illness constructs. This model showed that in the absence of the later health status measures, health status at birth was strongly related to progress and performance in school. This model explained 17.5% of the variation in the outcome score. Supplementary model 4 excluded the health status at birth construct, and revealed results similar to the final model. This model explained 18.0% of the variance in the outcome, consistent with the notion that health status at birth remains an important contributor to the 'full' relationship despite not having a significant independent effect on the outcome in the full model.

Table 4.9: Results of supplementary analyses

Variable	Full Model N=5,873	Supp 1 Major Illness only n=668	Supp 2 No Major Illness n=5,205	Supp 3 Health status at birth only n=5,873	Supp 4 No Health Status at Birth n=5,873
Health-related constructs:					
Major Illness	-.112**	-.003	n/a		-.069**
Health status through childhood	-.039*	-.160**	-.012		-.038*
Health status at birth	.019	-.074**	-.007	-.051**	
Control variables: Social, Economic, Demographic					
Age of child (yrs)	.144**	.157**	.144**	.145**	.143**
Area-level income	.144**	.156**	.149**	.151**	.147**
Mother's age at first birth	.131**	.026	.144**	.130**	.130**
Family received income assistance	-.120**	-.159**	-.117**	-.127**	-.121**
Sex of child (0=female, 1=male)	-.116**	-.106**	-.122**	-.123**	-.117**
Breastfeeding initiated	.056**	.036	.058**	.058**	.057**
Family had 5+ children	-.037*	-.118**	-.024	-.038*	-.036*
Family moved 5+ times	-.032*	-.040	-.029	-.031	-.029
Mother registered as married	.030	-.042	.043*	.033	.032
Mother depressed	-.021	-.016	-.025	-.030	-.023
Total R^2	**18.6%**	**21.2%**	**17.1%**	**17.5%**	**18.0%**

Note: * p < 0.01 ** p < .001

Chapter 5. Discussion

5.1 Introduction

The influence of health status on educational outcomes of young children has not been studied extensively. Several studies have reported modest associations between birthweight and later outcomes, while others measured health status later in childhood (e.g. at school entry). However, no published studies have incorporated longitudinal measures of health status, to determine the potential for direct and indirect associations among health variables at different times in early childhood. This study addresses that gap, while controlling for several social, economic, and demographic factors known to have significant influences on educational outcomes. It also uses a novel approach to defining illness in children, combining information from disease diagnoses with measures of health service use, and also distinguishes major from minor illness.

A key challenge for research in this area is that the majority of children are in very good or excellent health (76-79). For these children, health-related factors are not likely to affect progress and performance in school. Because poor health is relatively rare among school-aged children, attempts to study the issue require extensive data on large numbers of children.

It is also difficult to measure health status in children, both at birth and in childhood, and this complicates the task of relating health status to educational outcomes. As noted in Chapter 2, some studies have assessed the impact of specific diseases or disorders, for example asthma or diabetes, but the results have been mixed. This lack of association could be due to the small sample sizes used, or confounding factors such as the severity and chronicity of the disease, the co-morbid conditions the child is also experiencing, and the socioeconomic environment of the child's family.

This study examined how health status at birth and through childhood affects progress and performance in school using broad measures of health status, and distinguishing major from minor illness. The availability of population-based health and education data provided information on an entire birth cohort, allowing a large and robust analytic model to be developed. This study represents the first known population-based analysis of the impact of health status at birth and through childhood on progress and performance in school.

5.2 Findings from the final population-based model

The final model in this study provided excellent fit to the data and explained 18.6% of the variation in the outcome measure, suggesting that the factors used in this analysis make a significant contribution to explaining children's progress and performance in school. This is comparable to other studies (223, 388, 226}, including the extensive multilevel model developed by Tremblay et al (31) analyzing Grade 3 performance in Ontario. Their model incorporated student, classroom, teacher, and school-level influences, and explained 21% of the variation in the outcome. These modest figures indicate that all these studies were missing important variables affecting student outcomes (notably the student's cognitive ability). In Cohen's categorization of effect sizes, these results would qualify as a 'medium' effect (172).

5.2.1 Direct and indirect effects of health status factors

The results of the final population-based model show that health status measures have a statistically significant but substantively modest influence on children's progress and performance in school. This is broadly consistent with the findings of previous studies, using either health status at birth (35;42-44;46-49;51;52;56;105;133;138;139;141;145) or health status later in childhood (30;97;106;107;109-114;116;152-154). These studies showed that the independent contribution of health status is modest compared with the contribution of family background factors, as was found in this analysis.

In the final model, the 'top tier' of variables most strongly related to the outcome were: the child's exact age, the average income of the area where the child's family lived, the mother's age at the birth of her first child, family receipt of income assistance, the sex of the child, and whether the child experienced major illness.

In this study, three latent constructs of child health were used; one to represent health status at birth, and two to represent health status through the preschool period: one for the experience of major illness, and the other for 'general' health status through childhood. Of the three, the major illness construct had the strongest direct relationship with the outcome measure, followed by health status through childhood. Health status at birth was not directly related to progress and performance in school. The major illness construct was the only health-related factor in the 'top tier' of most influential variables in the final model. This finding is consistent with previous studies suggesting that children with disabilities or neurological disorders often have the poorest outcomes in terms of later cognitive and educational performance (42;44;51;105;133;138;138;139;146;147;151;153).

The modest strength of the health constructs in predicting progress and performance in school for the entire study group may have been influenced by the fact that most children are in very good or excellent health. Therefore, supplementary analyses were performed to determine whether the results were different for children with major illness (11.5%), compared to those without (88.5%). The first supplementary analysis confirmed that among children with major illness, health status at birth and through childhood were more strongly related to progress and performance in school than they were for the entire study group. For children without major illness, health status at birth and through childhood were not significantly related to progress and performance in school (supplementary analysis 2). That is, it was only in the presence of a major illness that health status at birth and through childhood affected progress and performance in school. Furthermore, among these children, health status through childhood was the strongest predictor of progress and performance in school, showing a slightly stronger relationship than any other variable in the model. These results are similar to early reports suggesting that children with major abnormalities have poorer cognitive outcomes, but those with only minor health issues show no problems (28).

In the main population-based model, health status at birth was not significantly related to the outcome directly, but had strong indirect effects through both major illness and health status in childhood. In fact, major illness and health status through childhood completely mediated the relationship between health status at birth and the educational outcome. This finding constitutes a new contribution to the literature in this area.

Previously published studies used only measures of health status at one point in time: either at birth or later in childhood. In both groups of studies, the health measures were found to be related to later outcomes, leaving the question of whether an analysis including both would show independent effects of each. The results of this study show that the role of health status at birth was completely mediated by the health status measures later in childhood.

Supplementary analyses were also conducted to further explore these relationships. Supplementary analysis 3 kept the health status at birth construct, but excluded the measures of major illness and health status through childhood. In this model, health status at birth was a strong predictor of progress and performance in school. The model explained 17.5% of the variation in the outcome, compared to 18.6% for the 'full' model. This suggests that while the full model was better at predicting the outcome, using health status at birth alone goes a long way toward predicting progress and performance in school. Whether the increase in explanatory power justifies the added complexity of the larger model thus becomes an important issue for future analyses. For some kinds of projects, it may well suffice to use birth health measures only, thus simplifying the analysis, and sacrificing relatively little explanatory power. This prospect also offers an advantage in terms of more widespread application: the measures used in the health status at birth construct (gestational age, birth weight, length of stay, and ICU use) are readily available in many jurisdictions, whereas the measures used in the later health constructs may not be (for example, Major and Minor ADGs; total hospital days in preschool period, etc).

In supplementary analysis 4, major illness and health status through childhood were used, but health status at birth was excluded. The results of this model were in between those of the final model and supplementary analysis 3 which used health status at birth alone. This model explained 18% of the variation, showing that major illness and health status through childhood together are more strongly related to progress and performance in school than health status at birth alone, but not as strong as the full model.

Throughout all of the analyses, the key social, economic, and demographic variables remained strongly related to progress and performance in school. They remained the top 5 predictors in all models except for the model on only children with major illness: in that model, health status through childhood was the strongest predictor. However, it was only marginally stronger than the social, economic and demographic factors, which made up the next 5 strongest variables in that model.

Having longitudinal individual-level data on health status, linkable to education outcomes, for a large group of children, was the key to sorting out these relationships.

5.2.2 Direct effects of social, economic, and demographic factors

The results of this study are consistent with the universal finding that characteristics of the family environment in which a child is reared have strong effects on the child's progress and performance in school (see Chapter 2). In this analysis, the child's exact age and the area-level average income were virtually tied as the strongest predictors of the outcome. They each explained almost twice the amount of variation in the outcome (2.1%) as the strongest health measure, the major illness construct (1.25%). Of the six predictors in the 'top tier' of influential variables, the first 5 were among the social, economic, and demographic characteristics. Moreover, the fact that an area-based (rather than family or household-level) measure was used to represent income likely means the true impact of family income was under-estimated in this analysis.

The child's age and the average household income of the area where the child's family lived were the strongest predictors in this analysis, with almost identical strength of association (see Table 4.6). Children born earlier in the year, who were therefore older than their peers, had better outcomes than younger children: all other things being equal, a child that was one month older than another would score just under 1% higher on the standards tests. This is consistent with the results of some previous studies (28;58;62;63;65), but not all (66). Moreover, in the studies that found age-related effects, the differences were small, whereas in this study, child age was the strongest predictor of progress and performance in school. The majority of research in this area considers only whether the child is at the appropriate grade for their age; very little research compares 'within-year' differences among children. Thus, the unusually high strength of child age found in this study may be partly attributable to precision in the measurement of age (to the day). It was also noted that younger children were over-represented among those in the 'Grade 2 or lower' group (though not in any other of the groups), and therefore a series of sensitivity analyses were performed, excluding children with low outcome scores (at various levels). These analyses confirmed that child age remained among the top three predictors even when retained students were excluded from the analysis.

The average household income of the area where the child's family lived was also a very strong predictor in this study, consistent with much previous research (23;24;28-31). The underlying causes and consequences of this relationship have received much attention (see Chapter 2). In 1982, White described the effect as the most enduring finding in sociological research (24). However, it is likely that income is not the direct or only cause of this association: much of this difference is attributable to differences on other variables, mostly relating to the quality of the environment in which the child is reared, particularly parenting practices and behaviours (173-178).

The finding that the mother's age at the birth of her first child was the third strongest predictor of outcomes is consistent with, and also extends, previous findings. Many studies have shown risks related to adolescent parenting: in many cases, both the mothers and the children experience significant consequences (see review by (179)). This analysis used the age of the mother at the birth of her first child, not necessarily the study child, because previous studies have shown that the risks relating to young parenthood are determined by the mother's age when she begins childbearing (54;55;180). That is, a child's mother may be 25 years old when that child is born, but if the mother had her first child very young, then all her children face higher risks. In this study, the relationship was not a simple threshold effect, but a continuous gradient. That is, the results did not show that the children of teen mothers displayed poor results, and all other children performed well. Rather, the association was continuous: children of mothers who were older when they started childbearing had better outcomes.[12]

The fourth strongest predictor of progress and performance in school was the variable indicating whether the family received Income Assistance.[13] This kind of association has also been reported by other studies (27;30;35-40). In this study, only

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[12] With the possible exception that results for children of mothers who had their first child after age 40 appeared slightly worse. However, there were too few observations at this age to justify any strong conclusions.

[13] Income Assistance is the provincial program which provides financial support to individuals and families who have no other means of supporting themselves. For this analysis, receipt of income assistance indicates that for at least one month between the child's 5th and 8th birthdays, the family received support. The limitation in the time period used was driven by the unavailability of data for preceding years.

13.6% of families had received income assistance, and yet its effect on the outcome was strong enough to rank it fourth among the predictors in this study. Since area-level household income was also in the model, this finding suggests there is particularly high risk among children in families receiving income assistance, independent of the characteristics of the area in which they live. Furthermore, the measure used in this analysis captured 'any' receipt of income assistance over a three-year period. That is, it did not differentiate short-term versus long-term receipt of income assistance. Long-term dependence has been associated with particularly poor outcomes for children (27;37). These results underscore the high needs of this most disadvantaged group.

The sex of the child was also important in this analysis. Girls had better outcomes than boys, consistent with recent studies (31;67;181). In this study, the average for girls was approximately 5% higher than that for boys.

The role of breastfeeding in contributing to schooling outcomes is also interesting to consider. This analysis suggests that, controlling for all other factors in the model, the initiation of breastfeeding has a significant positive influence on progress and performance in school. This is consistent with previous studies reporting a positive association between breastfeeding and later cognitive or educational outcomes (28;69-72;182). This finding is impressive, given the nature and limitations of the data used. First, the data indicate only what is known about the baby's feeding at the time of discharge from hospital – not at any point later on. Some of these children would have been breastfed for only a short time, and others for much longer. Secondly, even when breastfeeding was indicated, it could have been exclusive or partial – meaning some of these children were given artificial milk in addition to breast milk. So the benefits of breastfeeding appear to be evident even at low dose, or short duration, or both. However, it remains possible that breastfeeding is not the direct or only cause of this difference: it could be that mothers who breastfed their children were different form those who don't in ways unmeasured in this study, and which influence the later cognitive performance of their children.

Family size was also important in this study, as in others (183). The predominant theory in this area is called 'resource dilution', meaning that when parents have to divide their resources and energy among more children, each child benefits slightly less. It is important to bear in mind that this analysis controlled for other characteristics of socio-economic status, so the impact of a large family is not confounded by other factors (e.g. lower incomes). However, this variable was the weakest of the significant influences in this study, so results should be interpreted with caution.

The remaining social, economic, and demographic factors did not have significant direct relationships with the outcome. Indeed, in the multivariate analysis, the variables for whether the family moved 5 or more times, and whether the mother was married, had no significant relationships with progress and performance in school or either of the mediating health factors. The finding that both were significantly related to the outcome in univariate analyses but not in the multivariate analysis suggests that co-linearity with other variables may account for the difference, as has been shown before (184). The results do not indicate that these factors are not related to the outcome, but that they are strongly related to other factors used in this study.

A possible alternative explanation for the non-significance of the variable for mother's marital status could be that the data used in this study was not a perfect indicator of the mother's marital status. It indicates whether the mother was registered as married with the Manitoba Department of Health, and was taken at the time of the child's fifth birthday. Some women who are married (legally married or common-law) do not register their marriage, so appear as single mothers in the data. Furthermore, marital status changes over time for many women. However, the issue marriage non-registration in the administrative data has been shown to be quite small among families with young children in Manitoba: Roos and Walld found that 96% of women who reported being married in a large national survey (the National Population Health Survey) were also registered as married in the administrative database (185). Therefore, it remains possible that the influence of this variable was slightly under-estimated in this model by the presence of some married women who were classified as single, but the effect would likely be very small, given the 96% matching rate reported.

Maternal depression was different from the other variables in this study; it did not have a significant direct influence on the outcome, but an indirect effect, operating through health status in childhood, which has been previously reported (59). This differs from other studies which have found a direct effect of maternal depression on cognitive outcomes for young children (see (60) for a review). The reason for this difference in findings is not clear, though may be at least partially related to correlations with other social, economic, and demographic variables used in this study. Another possible explanation may be related to the measure of maternal depression used in this study: it was derived from administrative claims data (physician, hospital, and pharmaceutical use), and may not have had adequate sensitivity and specificity for this kind of study. The definition was adapted from that used in a report which found it to be adequate for the purposes of estimating the prevalence of depression in the population (165), but which was not highly sensitive or specific. This means that while the definition provided acceptable estimates of population prevalence, the inaccuracies in categorizing individuals were significant, and may have affected the ability to find a significant relationship in this analysis.

5.2.3 Indirect effects of social, economic, and demographic factors

The indirect effects of the social, economic, and demographic factors through the constructs of major illness and health status through childhood among the entire study group are also interesting to explore. The fact that none were significant predictors of major illness is consistent with other work showing that serious disabilities and neurological problems are distributed across all socio-economic groups (99). That is, children from disadvantaged backgrounds are no more likely to experience major illness than those from advantaged backgrounds. There is some evidence to the contrary (186), but that study included children of all ages, which may explain some of the difference.

Conversely, four of the social, economic, and demographic factors were significantly related to health status in childhood, which in turn was modestly related to progress and performance in school. Maternal depression was related to poorer health status in childhood, a finding which has been reported before (59). The sex of the child, family receipt of income assistance and area-level income also had indirect effects. The influences were all in the expected direction: maternal depression was related to poorer health status in childhood, as was male sex, receipt of income assistance, and lower area-level income. The influence of area-level income on health status in childhood, while significant, was weaker than expected given previous findings (187;188).

5.2.4 Interpreting the differences between univariate and multivariate analyses

The differences in standardized coefficients for each predictor and control variable between the univariate and multivariate analyses (Tables 4.4 and 4.6, respectively) provide some insight into the relationships among the variables used in this study, and their net influence on the outcome.

The dramatic difference in coefficients for health status at birth, from a highly significant -.067 in the univariate analysis to the non-significant .0193, reflects that the impact of health status at birth on later outcomes was indirect, operating through major illness, and, to a lesser extent, through health status through childhood. This result represents a new finding in this area, and could only have been detected using longitudinal measures of health status, as in this study.

The coefficient for health status through childhood was also considerably lower in the multivariate analysis (-.0391) than in the univariate analysis (-.10), but remained statistically significant. This difference reflects the overlap between this construct and the major illness construct: children with higher values on the major illness construct also had higher values on the health status through childhood construct. Finally, the coefficient for the major illness construct was actually higher in the multivariate (-.112) than the univariate analysis (-.10), reflecting the fact that additional outcome variance was being explained because of its strong connection with health status at birth.

Among the social, economic, and demographic control variables, the coefficients for all but two of the variables were much lower in the multivariate than the univariate analyses, reflecting the significant correlations among many of those variables. Indeed, two variables: the mother's marital status, and the number of times the family moved, were non-significant in the multivariate analysis, despite being significant in the univariate analyses. The exceptions were the age and sex of the child, which reflects that they were not highly correlated with the other control variables. A portion of the small reduction in the coefficient for sex was attributable to the indirect influence of sex on health status through childhood.

5.3 Strengths of this study

The comparative strengths of this study derive primarily from the size and nature of the group analyzed, the incorporation of longitudinal measures of health status, the separation of major from minor illness, and the development of the health status measures used.

This analysis was based on 5,873 children: all singleton children born to mothers in Winnipeg and continuously resident in the city for nine years. No exclusion criteria were used to remove children from the sample; the only children not in the final analysis were those who moved or died, or for whom complete data were not available. This is different from many other studies, which either used smaller samples, or which excluded children for a number of reasons: not being enrolled in regular schools, not in the expected grade, or for other social or medical reasons. For example, the large birth cohort studies from the United Kingdom could not include children born to unwed mothers (about 20% of births), as data were not collected at their birth. Other studies excluded children deemed 'mentally subnormal', or those born at very low birthweights. These exclusions cause the study groups to be less representative of the full spectrum of children in the society, as they are systematically different; higher-risk children were often excluded.

Loss to follow up in this study included 2,862 children who moved out of Winnipeg, 82 children who died, and 76 children for whom complete health and education data were not available. The 'movers' represented 95% of those lost to follow-up. The descriptive analyses revealed that the children who moved were statistically similar, on the health status at birth measures, to those who remained in the study. This suggests that their absence from the study does not bias the results substantially, though the possibility cannot be ruled out altogether. Children who died were significantly less healthy at birth than the study group, as expected. Children with missing health or education data were slightly less healthy at birth than study group children. All three groups had lived in somewhat lower-income areas, had mothers who were slightly younger at the birth of their first children, and were less likely to be married, though not all of these differences were statistically significant.

Another key strength of this study is that the cohort analyzed was defined by birth in 1990, rather than being in Grade 3 in the 1998/99 school year (the age-appropriate level). As Brownell et al (50) reported, a significant portion of children do not reach Grade 3 'on time' with their birth cohort, especially among children living in disadvantaged areas. The use of the birth cohort approach allowed this study to incorporate those children in the analysis, such that if health-related factors were part of why those children did not reach Grade 3 on time, it was reflected in the results of the analysis. This represents a major advantage over the alternative approach of assessing 'just' those who wrote the Grade 3 tests as expected, which would have missed the significant influences of grade retention, absence, and exemption from test writing; see (50;189). This study included all children by creating an outcome score which allowed those without test scores (for whatever reason) to be incorporated.

The incorporation of longitudinal measures of health status at birth and through the preschool years constitutes a unique strength of this project. Previous studies of the relationship between health status and later cognitive or educational outcomes used only health measures at one point in time: either at birth, or later in childhood. Both groups of studies found modest but significant associations, but because none included longitudinal measures of health status, they could not assess whether health status at birth and health status later in childhood have independent or overlapping effects. This design turned out to be of major importance, as the results showed that the often-reported influence of health status at birth on later outcomes is in fact completely mediated by health status later in childhood.

The analysis also separated major from minor illness, which turned out to be critical: it revealed that the most important issue was whether or not the child had a major illness. Among children without major illness, health status at birth and through childhood were not significantly related to progress and performance in school. Children with major illness (11.5%) had significantly poorer outcomes. Moreover, health status at birth and through childhood were much stronger influences among this group, with health status through childhood becoming the strongest single predictor, though the key social, economic, and demographic factors remain strong predictors as well.

Measurement of health status is always challenging, especially among children, who are predominantly healthy as a group. To address this issue, the health status measures used in this study were operationalized as latent constructs, each created through the combination of information from multiple variables. These constructs were specifically designed to incorporate aspects of severity of illness, co-morbidity with other illnesses, and chronicity of ill-health. This was accomplished by using a combination of measures including health service use and the Adjusted Diagnostic Groups of the Johns Hopkins ACG system. This approach was devised to address the lack of association found among studies of specific illnesses and educational outcomes, and was successful in that respect. The measures created to capture major illness and health status through childhood were particularly important in the final results, and represent another new contribution to the literature in this area. This study effectively used the rich data system available in Manitoba, showing that administrative data can provide insights which are difficult to capture using data sources that are not universal.

5.4 Limitations of this study

The key limitations of this study are related to the issues of omitted variables, the nature of administrative data, and the uncertainty of statistical modeling.

This study focused on measuring the influence of health factors on progress and performance in school, while controlling for available social, economic, and demographic factors. However, many variables known to influence educational outcomes could not be incorporated, due to the lack of availability of such data for all children. These include the multitude of factors measured in educational, psychological, and sociological studies.

Key among these are the student's cognitive ability (or 'intelligence'), motivation to participate and perform in school, and parental factors. The omission of important predictor variables often makes it difficult to achieve models which predict a significant proportion of variation in the outcome measure, and provide high 'goodness of fit' statistics. The final model in this study had excellent fit to the data, but explained a modest 18.6% of the outcome variation. This is related to the absence of important variables noted in Chapter 2.

The data sources used in this study also present limitations. Administrative data often lack the depth and nuance desired to fully characterize the factors being studied. As noted above, health status is notoriously difficult to assess, particularly with administrative data alone. However, the use of latent variables to combine several related measures clearly helped, as this study found significant relationships that were not identified using disease-specific approaches.

There is also a limitation related to the income measures used in this study. Area-level data on average household income were used, rather than individual or family-level data (unavailable). This means that conclusions relating to family income cannot be made. However, previous research in Manitoba and elsewhere has shown that individual and area-level income measures can provide similar results in terms of their relationship with health variables (190-194). There is now a large and growing body of evidence that family- and area-level factors have independent influences (36;195) but that family-level data are usually more strongly related to child outcomes than area-level measures (32;36;192). The understanding of the actual causes of area-level influences is becoming more sophisticated over time, but some issues remain unclear (196;197). The potential for confounding of variables is also a potential issue for this analysis, as in almost all studies. That is, the relationships presented in the results may not actually be caused by the measures used (for example, the influence of income, as discussed above).

Finally, no statistical model can ever definitively provide the 'best' answer possible in any given situation. While the program's output provides indications of how well the variables are contributing to the model, this kind of analysis is as much art as science. It is likely that other similar models, employing slightly different variables and/or different relationships among the variables, would provide an equally satisfactory solution given the data provided. That said, it was encouraging to note that the several series of models run in the course of this research project all led to similar results.

5.5 Summary

This study is the first known population-based analysis of how health status at birth and through childhood affects progress and performance in school. The results are consistent with those of many previous studies, and provide two new contributions to the literature in this area.

First, the final population-based model showed that the well-established relationship between health status at birth and later outcomes was completely mediated by major illness and health status through childhood. This strong indirect association explains and synthesizes previous results showing that health status measured either at birth or later in childhood were each individually related to schooling outcomes. This clarification was revealed by the use of longitudinal measures of health status, a unique aspect of the design of this study.

Second, and perhaps more importantly, the findings revealed that the key issue in the relationship between health status and educational outcomes is whether the child experienced a major illness or not. Among those with major illness (approximately 11.5% of the population), health status at birth and through childhood strongly affect progress and performance in school, and the poorer their health status, the larger the impact on the outcome. For children without major illness (the vast majority), health status at birth and through childhood were not significantly related to progress and performance in school.

In this study, as in most other studies of educational outcomes, the social, economic, and demographic characteristics of the environment in which the child was reared were significantly related to the outcome. In almost all models, they comprised the five strongest predictors of progress and performance in school. The exception was the analysis of children with major illness, among whom health status through childhood was the strongest factor, but was closely followed by the same five social, economic, and demographic variables.

In the population health field, education is considered a key driver of health status, in that individuals and groups with higher educational attainment live longer, healthier lives than those with less. An ongoing debate in this literature regards the role of 'reverse causality', referring to the fact that some people's compromised health status interferes with their ability to achieve occupational and economic success, which in turn affects their health status. This study suggests that, at least in early childhood, the role of 'reverse causality' is limited to the minority of children who experience major illness. Among children without major illness, health status does not appear to influence progress and performance in school.

Chapter 6: Implications

The main objective of this study was to determine whether health status at birth and through childhood affects progress and performance in school. The results showed that there is a significant influence, but only for children who experience some form of major illness. For the majority of children without such challenges, health status was not a significant predictor of schooling outcomes. Moreover, several social, economic, and demographic factors were shown to be strongly related to schooling outcomes for all children, with and without major illness.

These findings have implications for program and policy development in the areas of health, education, and social services. Several of these are not 'new' ideas, but familiar ones which gain strength and relevance from the evidence provided by this population-based analysis. There are also suggestions for further research. The most important implications are in the realm of broad social policy, but the implications for health and education-related issues will be discussed first, as this study was focused on those areas.

6.1 Implications for the health care system

Manitoba, like all provinces in Canada, operates a comprehensive, universal health care system based on the principles of the Canada Health Act. The key characteristics are that services are provided based on medical need, and that care is provided without direct payment for service by the patient. Previous studies have shown that the system appears to be largely meeting these goals, as significantly more services are provided to residents of low income areas (198) who are known to be in worse health. However, there remains the issue of 'unmet need' – that is, even frequent users of the health system may be experiencing problems which are not being addressed, for any number of reasons.

The results of this study showed that children with major illness are more likely to experience problems in school. The strong linkage between major illness and health status at birth suggests that some of these children might be identified very early. The measures used in the health status at birth factor point to easily identifiable target groups: children born at low birthweight (less than 2,500 grams), those born preterm (before 37 weeks completed gestation), those with exceptionally long hospital stays at birth (longer than 5 days for vaginal deliveries; 8 days for cesarean sections), or those using higher-level care (intensive or intermediate care services) represent the children at highest risk. Of course, not all children with one or more of these risk factors will have a major illness, but they represent the sub-group among whom surveillance would best be targeted to identify children with major illness. Children with such problems would likely benefit from extra supports in both health and educational realms. Therefore, parents, health care providers, and educators should work together to manage the child's health issues and limit their implications for the child's learning.

Another implication of this research comes from the significant influence of several social factors on children's health status in childhood, which is in turn related to their schooling outcomes. The results showed that four of the social, economic, and demographic factors had significant relationships with health status in childhood: area-level income, maternal depression, family receipt of Income Assistance, and the sex of the child. The influence of these factors is relevant for health care providers, who need to bear in mind the relationships between social factors and child health and developmental outcomes. For example, health professionals serving mothers of young children should be aware that if the mother is depressed, her children may be at risk of poorer health and educational outcomes; these women should be offered counseling and other psychological/psychiatric services to treat their depression. The influence of social factors on health and educational outcomes might also deserve more emphasis in training programs for doctors, nurses, and other health care professionals.

The results also showed that boys are in poorer health than girls, only marginally at birth, but significantly during childhood. This is not likely related to the health care they receive, and is consistent with long-standing observations that slightly more boys than girls are born, but fewer males than females survive into adulthood (199;200).

The positive impact of breastfeeding also warrants mention. Efforts aimed at increasing the rate of breastfeeding should be enhanced. As noted earlier, the frequent finding that breastfed children do better than those not breastfed may not be driven exclusively by biological factors relating to breast milk itself; mothers who choose not to breastfeed are likely different from those who do in other ways which also affect child outcomes. Nonetheless, there is a solid case regarding the risks for poor health and cognitive outcomes among children who are not breastfed, or breastfed for only a short time (69;73;201). A first step for the health care system might be to encourage all hospitals to consider implementing the Baby Friendly Hospital Initiative, which, among other things, effectively fosters higher rates of breastfeeding (201-204). There are also programs like the Canadian Perinatal Nutrition Program, which target prenatal health and nutrition of the mother, as well as best practices for infant care, including breastfeeding (205).

Preterm birth and low birthweight were also significant components of the health status at birth measure, and programs to reduce these would also be helpful. There is some uncertainty in the literature about how much these rates can be lowered through prenatal care (206), though reductions in cigarette smoking would lower the preterm birth rate (104), and provide other benefits to mother and child. Since preterm birth and low birthweight are both more common among lower socioeconomic groups, efforts aimed at addressing that issue (discussed in more detail below) would also be helpful.

Finally, health professionals may need to be more involved in helping to develop education plans for the children with major illnesses as they enter the school system. For some children, this may include delayed entry, or development of individualized education plans, taking into account each child's specific needs.

6.2 Implications for the education system

Given the significant relationship between major illness and schooling outcomes, the education system might consider further exploration of this issue. The existing system for assessing children with 'Special Needs' may already be capturing children whose major illnesses impact on their education. However, the system focuses on behavioural, cognitive, and learning issues, not health issues directly, so might be enhanced by adding specific consideration of health problems. This is an area in which the health and education systems should work together. Further research will likely be required to develop a list of conditions which frequently lead to educational problems.

The education system can also help to address the findings of the strong relationships between the social, economic, and demographic factors and schooling outcomes. (There are larger-scale implications of these relationships as well, which will be further addressed below.) For the education system, the results of this study reinforce the findings of much previous work showing that children from disadvantaged backgrounds are at much higher risk for poor performance in school (23;24;27). Educators need to be engaged in the development of effective means of overcoming these problems. These might include involvement in services to families in disadvantaged areas, and programs for children in the pre-school years. Readily-available measures such as the proportion of families in the school catchment area that are receiving Income Assistance, or living below the 'Low Income Cut-Off' might trigger additional funding and resource supports for that school and children in that neighbourhood, in conjunction with preschool programs discussed below.

6.3 Implications for other social services

The strong influences of several social, economic, and demographic factors in this study provide the grounds for the most important implications of this study. The fact that these influences were consistently ranking among the strongest predictors of schooling outcomes for all children (with and without major illness), provides compelling motivation to act on these findings.

There are two basic approaches to addressing these kinds of issues: the first is to address the identified factors directly (i.e. reducing social inequities), and the second is to intervene to mitigate the deleterious impact of these factors on children's outcomes. A combination of both approaches will likely be required, because some do not lend themselves to one or the other approach.

6.3.1 Interventions focused on the social, economic, and demographic factors

Addressing the direct approach first, a number of factors can be immediately removed from the list because they are simply beyond the bounds of policy influence, including: the child's age and sex, whether the child's mother is married, and the size of the family. The remaining factors are ones which cannot be mandated or directly changed by public policies or programs, but which can be influenced by them, including: breastfeeding, the age at which the mother has her first child, whether the mother experiences depression, the child's health status (at birth and beyond), and family income. Thus, a wide range of programs can be supported: programs that encourage breastfeeding, that support maternal and infant health, and taxation and social support policies to improve the life circumstances of the most disadvantaged residents.

Such programs already exist in Canada and Manitoba. For example: the Canadian Perinatal Nutrition Program noted above, and the Canadian Child Tax Benefit (CCTB) program. The CCTB program is a joint initiative of the federal, provincial, and territorial governments. Its goals are to prevent and reduce the depth of child poverty, and to promote attachment to the workforce. Of particular relevance to the findings of this study, the program also offers a tax-free benefit for families who care for a child with a severe physical or mental functional impairment. Ongoing evaluations of these programs should be used to ensure optimal program operation and outcomes.

Finally, the importance of the income assistance variable, above and beyond the influence of area-level average household income, suggests that this group may require separate interventions to improve outcomes for these children and their families.

6.3.2 Interventions to mitigate the consequences of disadvantage

Even among the factors discussed above which are to some degree amenable to policy interventions, many can be difficult to change in practice. This, combined with the influence of factors beyond policy influence, suggest a 'secondary' approach. These initiatives are aimed not at the causal factors or social inequities themselves, but instead focus on interventions to improve the outcomes for high-risk children and families, to prevent the risk factors from manifesting their effects.

The most promising area in this respect is in early childhood interventions. A large number of initiatives have been undertaken and extensively researched over the last forty years, mostly in the United States. The ground-breaking study in this area was the Perry Preschool program, which started in 1962 in Ypsilanti, Michigan (207;208). It randomly assigned preschoolers from disadvantaged backgrounds to a program or control group. Early evaluations of the program suggested no effect, as school performance was not different for the program and control groups. However, as the children entered the teen years, schooling differences started to emerge. With time, even larger benefits accrued: higher graduation rates, fewer arrests, higher earned incomes, less welfare dependency, more home ownership, and more stable marriages (209). Interestingly, the control group actually contained sub-groups, to simultaneously examine differences in program design. Results showed that the approach that was most open-ended and responsive to children's interests provided superior results to a more 'no-nonsense' approach stressing academic skills.

Thereafter came many other programs: Head Start (210) (and later, Early Head Start), the Carolina Abecedarian project (211) the Chicago Child-Parent-Centre program (212), the Infant Health and Development Program (213), and Early Head Start (210), among many others. Most of these were small intervention programs or pilot studies, with the exception of Head Start and Early Head start. All of these programs showed that high quality, intensive programs which begin early in a child's life can effectively counteract major disadvantages in a child's family environment (214-233). Furthermore, economic evaluations of these programs suggest large returns on investment, ranging from \$2 to \$7 saved for every \$1 invested (209;234;235).

The key characteristics of high quality early childhood environments relate to the intensity and quality of the interactions with the child (236), most notably verbal interactions. Studies have shown that the number and variety of words that children hear in the early years are directly and strongly related to the growth of their own vocabularies (173;174;176). Children's early verbal abilities are in turn strongly correlated with verbal and cognitive ability later in childhood (173;174;176). There are social gradients in how parents interact with their children, and children from disadvantaged backgrounds are at much higher risk of not being exposed to stimulating environments in the early years (34;173;175-178;237). Therefore, these children are likely the most in need of high quality early learning opportunities, and should be the first group to be targeted with policies and programs focused on providing all children what they need for optimal development.

Along these lines, governments and community organizations in Manitoba could work together to create a solution. Indeed, progress is being made under the leadership of the Healthy Child Manitoba Office (HCMO). This undertaking is a joint initiative of eight provincial government departments that have major interests in child health and development, with support from the federal government as well. The HCMO has developed a comprehensive approach to these issues, and has initiated programs in several areas including healthy pregnancies and perinatal development, special supports for families facing severe problems, and recent initiatives at improving parenting practices (238). Ongoing evaluations of these programs will be important for adapting programs and services, and for securing additional funding so that successful programs can be expanded to serve all families in need.

The ultimate goal might be a comprehensive network of programs to enhance early learning and child development. This could include a broad range of services from full-time programs for preschool children, to part-day recreational programs, to parent support services. Ideally, key program components could be offered to all families, but with strategic mechanisms to target extra resources and supports to the families in highest need. This and other studies show that there are a number of ways to define such families using existing data, so individual family-level assessment would not be required to operate the program. Families receiving income assistance would likely make a good initial target group, as their children face the highest risks of poor outcomes. The program could then be extended to more families as needed.

6.4 Implications for future research

This study showed that for the majority of kids – those without major illness – health status does not affect progress and performance in school. Therefore, future studies should focus on children with major illness, to further understand the details of this relationship, and the specific characteristics of the children included in this category.

For more general studies of cognitive or educational outcomes that attempt to control for health status, the results of this study suggest that measures of health status at birth alone might provide adequate control: while the full model which included health status through childhood provided more explanatory power, the model using health status at birth alone performed almost as well. This offers the advantage of not having to gather longitudinal measures of health status, which should facilitate broader uptake, as the measures used in health status at birth are available in many jurisdictions.

Future research should also attempt to include some of the other major factors known to affect educational outcomes – most prominently the cognitive ability of the child. Interactions among variables would also be worthy of exploration, particularly among children with major illness. Such work could help answer follow-up questions like: Are the effects of major illness similar or different for children from different backgrounds?

Longer-term outcomes should also be monitored. This study used the end of the Grade 3 year as the point at which outcomes were measured. It is likely that in subsequent years, trajectories for some children will change, so it would be helpful to know which factors have consistently strong connections with longer-term outcomes. This could lead to an enhanced understanding of the relative importance of key factors at each stage of child and adolescent development, and into adulthood.

Finally, ongoing monitoring and evaluation of programs is recommended. The government of Manitoba, primarily through the Healthy Child Manitoba Office, has recently introduced a number of programs and services designed to enhance maternal and child health, and foster early child development in a number of ways. These programs are now starting to be evaluated to understand their impacts. Future evaluations might also incorporate the kinds of issues dealt with in this study, including child health status and schooling outcomes, and extend through to high school completion and beyond.

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Appendix 1: Copies of letters of approval for research project

UNIVERSITY OF MANITOBA

BANNATYNE CAMPUS
Research Ethics Boards

P126-770 Bannatyne Avenue
Winnipeg, Manitoba
Canada R3E 0W3
Tel: (204) 789-3255
Fax: (204) 789-3414

APPROVAL FORM

Principal Investigator: Mr. Randall Fransoo
Supervisor: Dr. N. Roos

Protocol Reference Number: H2005:113
Date of REB Meeting: May 30, 2005
Date of Approval: May 30, 2005
Date of Expiry: May 30, 2006

Protocol Title: **How health status at birth and through childhood affects children's performance in school"**

The Health Research Ethics Board at the Bannatyne Campus, University of Manitoba, which is organized and operates according to Health Canada/ICH Good Clinical Practices, Tri-Council Policy Statement, and the applicable laws and regulations of Manitoba reviewed the above mentioned study at the REB meeting held on May 30, 2005. The membership of this Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the *Food and Drug Regulations*. The research was approved as submitted.

The following is/are approved for use:

- **Proposal (submitted May 16, 2005)**

The approval is valid for one year from the date of the meeting at which it was reviewed. A study status report must be submitted annually and must accompany your request for re-approval. Any significant changes of the protocol and informed consent form should be reported to the Chair for consideration in advance of implementation of such changes. The REB must be notified regarding discontinuation or study closure.

This approval is for the ethics of human use only. For the logistics of performing the study, approval should be sought form the relevant institution, if required.

Sincerely yours,

Ken Brown, MD, MBA
Chair, Health Research Ethics Board
Bannatyne Campus

KB/bz

Please quote the above protocol reference number on all correspondence.
Inquiries should be directed to the REB Secretary
Telephone: (204) 789-3255/ **Fax:** (204) 789-3414

Manitoba

Health

300 Carlton Street
Winnipeg, MB R3B 3M9

HEALTH INFORMATION PRIVACY COMMITTEE

14 July 2005

HIPC #: 2005/2006 - 11

Mr Randall Fransoo
Manitoba Centre for Health Policy
Department of Community Health Sciences
Faculty of Medicine, University of Manitoba
4th Floor, 727 McDermot Ave
Winnipeg, Manitoba R3E 3P5

Dear Mr Fransoo:

Re: How does health status at birth and throughout childhood affect children's performance in school?

The Health Information Privacy Committee has ***conditionally approved*** this study pending (a) clarification that data is not required beyond 1 year after the anticipated age of a child in grade 3 for either the child or the mother, (b) clarification that the types of data requested are limited to those in the attached proposal summary, and (c) letters of support to access the non-health databases for this project.

As this study has been conditionally approved, it will not have to go back to the Committee once a response has been received.

If you have any questions or concerns, please do not hesitate to contact Leonie Stranc at

Yours truly,

Dr R. Walker
Chair

Please quote the file number on all correspondence

c.c. L. Barre

July 6, 2005

Dr. Gerald Farthing
Acting Deputy Minister
Manitoba Education, Citizenship and Youth
Room 156 Legislative Building
450 Broadway Avenue
Winnipeg, Manitoba R3C 0V8

Dear Dr. Farthing,

Manitoba Centre for Health Policy

Dept. of Community Health Sciences, Faculty of Medicine, University of Manitoba

4th Floor, Room 408
727 McDermot Ave.
Winnipeg, Manitoba
Canada R3E 3P5
Ph (204) 789 3819
Fax (204) 789 3910

RE: **How Health Status at Birth and Through Childhood affects Children's Performance in School – Doctoral Dissertation Proposal**

Mr. Randy Fransoo, a doctoral student at MCHP, has formulated the above stated dissertation proposal. The purpose of this research proposal is to determine whether health status at birth and in early life affects progress and performance in school through age eight, for an entire population cohort, using administrative data from health, education and social systems.

As part of doing this research we would like to use the data files for enrollment, Grade 3 provincial exam and Special Needs indicators from the Department of Education

He has submitted this project both to the University of Manitoba Research Ethics Board (HREB) and to the Manitoba Health Information and Privacy Committee (HIPC). At this time, we seek your permission for the use of the data. If it is of interest, we will be happy to provide you with briefings on the outcomes prior to public release.

This project, as most projects undertaken by university researchers, assumes the right to publish results obtained as part of the research, subject to established safeguards for the protection of privacy or confidentiality of personal data.

In compliance with PHIA section 24(4) - we agree:

- not to publish the personal health information requested in a form that could reasonably be expected to identify the individuals concerned;

August 2, 2005

Mr. Milton Sussman
Deputy Minister
Manitoba Family Services and Housing
Room 351, Legislative Building
450 Broadway Avenue
Winnipeg, MB R3C 0V8

Dear Mr. Sussman,

RE: **How Health Status at Birth and Through Childhood affects Children's Performance in School – Doctoral Dissertation Research Proposal**

Manitoba Centre for Health Policy

Dept. of Community Health Sciences, Faculty of Medicine, University of Manitoba

4th Floor, Room 408
727 McDermot Ave.
Winnipeg, Manitoba
Canada R3E 3P5
Ph (204) 789 3819
Fax (204) 789 3910

Mr. Randy Fransoo, a MCHP researcher and a Department of Community Health Sciences doctoral student, has developed the above dissertation research proposal. The purpose of this research proposal is to determine whether health status at birth and in early life affects progress and performance in school through age eight, for an entire population cohort, using administrative data from health, education and social systems.

This study may provide new insights into the influence of health on children's progress and performance in school. Adding health and other social influences to the list of factors already studied may reveal 'policy sensitive' influences in the health, education, and social systems which might be used to improve educational outcomes. This study will also provide a population perspective to understanding the nature and timing of health problems and their effect on educational success. Knowing more about how and when a child's health and social environments affect their educational outcomes could be helpful in planning health and educational interventions.

As part of doing this research he would like to use the income assistance data files from the Department of Family Services. He has submitted this research proposal both to the University of Manitoba Research Ethics Board (HREB) and to the Manitoba Health Information and Privacy Committee (HIPC). At this time, we seek your permission for the use of the data.

If it is of interest, he will be happy to provide you with briefings on the outcomes prior to public release.

This project, as most projects undertaken by university researchers, assumes the right to publish results obtained as part of the research, subject to established safeguards for the protection of privacy or confidentiality of personal data.

In compliance with PHIA section 24(4) - we agree:

- not to publish the personal health information requested in a form that could reasonably be expected to identify the individuals concerned;
- to use the personal health information requested solely for the purposes of the approved research project; and

- to use the personal health information requested solely for the purposes of the approved research project; and
- to ensure that the research project contains reasonable safeguards to protect the confidentiality and security of the personal health information and procedures to remove all identifying information at the earliest opportunity consistent with the purposes of the project.

As stated in our data sharing agreement (copy attached), access to data will only be permitted upon approval of the specific project from you or your appointee. John VanWalleghem has reviewed and approved this project and we now officially seek your approval for use of these data for the project "How health status at birth and through childhood affects children's performance in school?" (doctoral dissertation proposal attached).

We look forward to working with you and providing you with important policy relevant research.

Yours sincerely

Patricia J. Martens, PhD
Associate Professor, Department of Community Health Sciences
Senior Researcher and Director
Manitoba Centre for Health Policy

cc: John VanWalleghem, Director, Research and Planning, Manitoba Education, Citizenship and Youth
Louis Barre, Director, Health Information Management, Manitoba Health

encls: Doctoral dissertation proposal and Data Sharing Agreement

I approve the access of the Education, Citizenship and Youth Data housed in the Manitoba Population Health Research Data Repository at MCHP, for use in "How health status at birth and through childhood affects children's performance in school.".

July 11/05

Gerald Farthing, Acting Deputy Minister
Manitoba Education, Citizenship and Youth

Date

- to ensure that the research project contains reasonable safeguards to protect the confidentiality and security of the personal health information and procedures to remove all identifying information at the earliest opportunity consistent with the purposes of the project.

As stated in our data sharing agreement (copy attached), access to data will only be permitted upon approval of the specific project from you or your appointee. Charlene Paquin has reviewed and approved this project and we now officially seek your approval for use of these data for the project "How health status at birth and through childhood affects children's performance in school?" (doctoral dissertation proposal attached).

We look forward to working with you and providing you with important policy relevant research.

Yours sincerely

Patricia J. Martens, PhD
Associate Professor, Department of Community Health Sciences
Senior Researcher and Director
Manitoba Centre for Health Policy

cc: Charlene Paquin, Acting Director, Policy and Planning Branch, Manitoba Family Services and Housing
Louis Barre, Director, Health Information Management, Manitoba Health

encls: Doctoral dissertation research proposal and Data Sharing Agreement

I approve the access of the Family Services and Housing Data housed in the Manitoba Population Health Research Data Repository at MCHP, for use in "How health status at birth and through childhood affects children's performance in school".

AUG 10 2005

Milton Sussman, Deputy Minister
Manitoba Family Services and Housing

Date

Appendix 2: MCHP's Pledge of Privacy

The Manitoba Centre for Health Policy strictly adheres to its Privacy Code and Principles. In fact, we've taken them further, with our own Pledge of Privacy. Our top priority is to respect the privacy of users and providers of the health care system, and furthermore, to protect data against loss, destruction or unauthorized use.

We promise to:

Respect Privacy: MCHP through the University of Manitoba is a public trustee of sensitive de-identified information. We are bound by legislation, professional ethical standards and moral responsibility to never share, sell under any circumstance or use the data for purposes other than approved research. We ensure that all data under our management are anonymized, and that their use adheres to strict procedures, practices and policies.

Safeguard Confidentiality: We respect the confidentiality of sensitive and private information. All staff and collaborating researchers must sign an oath of confidentiality; anyone who breeches this oath faces immediate loss of access to data and possible dismissal. All records are anonymized before we receive them. Before findings are released, all MCHP publications are reviewed by Manitoba Health and/or appropriate data providing agency and our own management to further ensure individual privacy.

Provide Security: The environment in which research is conducted is tightly controlled. We restrict access to our workplace with additional levels of security for access to data spaces. The security of data is further protected through state-of-the-art technology, including but not limited to firewalls, encryption, password access and monitoring of users. The databases are housed on computers that are isolated to prevent access by unauthorized persons.

Appendix 3: Listing of the 32 Adjusted Diagnostic Groups of the Johns Hopkins ACG Case-Mix System, Version 6.0

The listing below provides the names of the 34 Adjusted Diagnostic Groups (ADGs) of the Johns Hopkins ACG System, along with sample diagnoses included in each (using ICD-9-CM codes). Two of the groups (# 15 and #19) are no longer in use.

ADGs 3, 9, 11, 12, 13, 18, 25, and 32 are the 'Major' ADGs for children, and are shown in bold below; all others are 'Minor'. ADGs 31 (Prevention / Administration), 33 (Pregnancy) and 34 (Dental) were not used in this study (shown in italics).

1. Time Limited: Minor
   - 558.9 Noninfectious Gastroenteritis
   - 691.0 Diaper or Napkin Rash
2. Time Limited: Minor – Primary Infections
   - 079.9 Unspecified Viral Infection
   - 464.4 Croup
3. **Time Limited: Major**
   - 451.2 Phlebitis of Lower Extremities
   - 560.3 Impaction of Intestine
4. Time Limited: Major – Primary Infections
   - 573.3 Hepatitis, Unspecified
   - 711.0 Pyogenic Arthritis
5. Allergies
   - 477.9 Allergic Rhinitis, Cause Unspecified
   - 708.9 Unspecified urticaria
6. Asthma
   - 493.0 Extrinsic Asthma
   - 493.1 Intrinsic Asthma
7. Likely to Recur: Discrete
   - 274.9 Gout, unspecified
   - 724.5 Backache, unspecified
8. Likely to Recur: Discrete – Infections
   - 474.0 Tonsillitus
   - 599.0 Urinary tract infection
9. **Likely to Recur: Progressive**
   - 250.10 Adult Onset Type II Diabetes with ketoacidosis
   - 434.0 Cerebral Thrombosis

10. Chronic Medical: Stable
    250.00 Adult-onset Type I Diabetes
    401.9 Essential hypertension
11. Chronic Medical: Unstable
    282.6 Sickle-Cell Anemia
    277.0 Cystic Fibrosis
12. Chronic Specialty: Stable – Orthopedic
    721.0 Cervical sponsylosis without myelopathy
    718.8 Other joint derangement
13. Chronic Specialty: Stable – Ear, Nose, Throat
    389.14 Central Hearing Loss
    385.3 Cholesteatoma
14. Chronic Specialty: Stable – Eye
    367.1 Myopia
    372.9 Unspecified disorder of conjunctiva
15. no longer in use
16. Chronic Specialty: Unstable – Orthopedic
    724.02 Spinal Stenosis of Lumbar Region
    732.7 Osteochondritis Dissecans
17. Chronic Specialty: Unstable – Ear, Nose, Throat
    383.1 Chronic Mastoiditis
    386.0 Meniere's Disease
18. Chronic Specialty: Unstable – Eye
    365.9 Unspecified Glaucoma
    379.0 Scleritis / Episcleritis
19. no longer in use
20. Dermatologic
    078.1 Viral Warts
    448.1 Nevus, Non-Neoplastic
21. Injuries / Adverse Events: Minor
    847.0 Neck Sprain
    959.1 Injury to Trunk
22. Injuries / Adverse Events: Major
    854.0 Intracranial Injury
    972.1 Poisoning by Cardiotonic Glycosides and Similar Drugs
23. Psychosocial: Time Limited, Minor
    305.2 Cannabis Abuse, Unspecified
    309.0 Brief Depressive Reaction
24. Psychosocial: Recurrent or Persistent, Stable
    300.01 Panic Disorder
    307.51 Builimia
25. Psychosocial: Recurrent or Persistent, Unstable
    295.2 Catatonic Schizophrenia
    291.0 Alcohol Withdrawal with Delerium Tremens

26. Signs / Symptoms: Minor
    784.0 Headache
    729.5 Pain in Limb
27. Signs / Symptoms: Uncertain
    719.06 Effusion of Lower Leg Joint
    780.7 Malaise and Fatigue
28. Signs / Symptoms: Major
    429.3 Cardiomegaly
    780.2 Syncope and Collapse
29. Discretionary
    550.9 Inguinal Hernia NOS
    706.2 Sebaceous Cyst
30. See and Reassure
    611.1 Hypertrophy of Breast
    278.1 Localized Adiposity
31. Prevention / Administration (not used in this study)
    V20.2 Routine Infant of Child Health Check
    V72.3 Gynecological Examination
32. Malignancy (Cancer)
    174.9 Malignant Neoplasm of Breast NOS
    201.9 Hodgkin's Disease, Unspecified
33. Pregnancy (not used in this study)
    V22.2 Pregnant State
    650.0 Delivery in a Completely Normal Case
34. Dental (not used in this study)
    521.0 Dental Caries
    523.1 Chronic Gingivitis

Appendix 4: Listing of programs and log files from SAS analyses

1) The final measurement model

2) The final structural equation model

1) The final measurement model

Program for final measurement model:

```
* ModelMM728, based on MM317b: back to LBW to lower mardia's;

libname thesis '/project/randyf/data';

data thesis.semvars (keep = phin v1-v17 v19-v20 V25);
 set thesis.finalandfactors;
 by phin;
 V1 = avg;
 V2 = inc_pre/100000;
 V3 = magefbirth/10;
 V4 = fam5plus;
 V5 = deprmum;
 V6 = MARRIED5;
 V7 = EVERONIA;
 V8 = mov5plus;
 V9 = psicu;
 V10 = psdays6;
 V11 = totvisitsps/50;
 V12 = minor90;
 V13 = maj2plus;
 V14 = bfeed;
 V15 = n_sex;
 v16 = premie;
 V17 = lbw;
 V19 = lbstay;
 V20 = bicu3;
 V25 = c_TESTAGE;
run;



proc calis covariance corr residual all modification tech=newrap g4=100
data=thesis.semvars ;
  lineqs
    V11 = LV11F2 F2 + E11,
    V12 = LV12F2 F2 + E12,

    V16 = LV16F3 F3 + E16,
    V17 = LV17F3 F3 + E17,
    V19 = LV19F3 F3 + E19,
    V20 = LV20F3 F3 + E20,

    V9 =  LV9F1 F1  + E9,
    V10 = LV10F1 F1 + E10,
    V13 = LV13F1 F1 + E13 ;


  STD
    V1-V8 = VARV1-VARV8,
    V14 = VARV14,
    V15 = VARV15,
    V25 = VARV25,
    F1 = 1,
    F2 = 1,
    F3 = 1,
    E9-E13 = VARE9-VARE13,
    E16-E17 = vare16-vare17,
    E19-e20 = VARE19-VARE20 ;
```

```
COV

  V25 V1 = CV25V1,
  V25 V2 = CV25V2,
  V25 V3 = CV25V3,
  V25 V4 = CV25V4,
  V25 V5 = CV25V5,
  V25 V6 = CV25V6,

  V25 V7 = CV25V7,
  V25 V8 = CV25V8,
  V25 V14 = CV25V14,
  V25 V15 = CV25V15,
  V25 F2 = CV25F2,
  V25 F3 = CV25F3,

  V14 V1 = CV14V1,
  V14 V2 = CV14V2,
  V14 V3 = CV14V3,
  V14 V4 = CV14V4,
  V14 V5 = CV14V5,
  V14 V6 = CV14V6,
  V14 V7 = CV14V7,
  V14 V8 = CV14V8,
  V14 F2 = CV14F2,
  V14 F3 = CV14F3,

  V15 V1 = CV15V1,
  V15 V2 = CV15V2,
  V15 V3 = CV15V3,
  V15 V4 = CV15V4,
  V15 V5 = CV15V5,
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  V15 V7 = CV15V7,
  V15 V8 = CV15V8,
  V15 V14 = CV15V14,
  V15 F2 = CV15F2,
  V15 F3 = CV15F3,

  V8 V1 = CV8V1,
  V8 V2 = CV8V2,
  V8 V3 = CV8V3,
  V8 V4 = CV8V4,
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  V8 V6 = CV8V6,
  V8 V7 = CV8V7,
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  V7 V1 = CV7V1,
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  V7 V6 = CV7V6,
  V7 V14 = CV7V14,
  V7 V15 = CV7V15,
  V7 V25 = CV7V25,
  V7 F2 = CV7F2,
  V7 F3 = CV7F3,

  V6 V1 = CV6V1,
```

```
    V6 V7 = CV6V7,
    V6 V8 = CV6V8,

    V5 V4 = CV5V4,
    V5 V3 = CV5V3,
    V5 V2 = CV5V2,
    V5 V1 = CV5V1,
    V5 V6 = CV5V6,
    V5 V7 = CV5V7,
    V5 V8 = CV5V8,

    V4 V3 = CV4V3,
    V4 V2 = CV4V2,
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    V4 V6 = CV4V6,
    V4 V7 = CV4V7,
    V4 V8 = CV4V8,

    V3 V2 = CV3V2,
    V3 V1 = CV3V1,
    V3 V6 = CV3V6,
    V3 V7 = CV3V7,
    V3 V8 = CV3V8,

    V2 V6 = CV2V6,
    V2 V7 = CV2V7,
    V2 V8 = CV2V8,
    V2 V1 = CV2V1,

    F2 V1 = CF2V1,
    F2 V2 = CF2V2,
    F2 V3 = CF2V3,
    F2 V4 = CF2V4,
    F2 V5 = CF2V5,
    F2 V6 = CF2V6,

    F3 V1 = CF3V1,
    F3 V2 = CF3V2,
    F3 V3 = CF3V3,
    F3 V4 = CF3V4,
    F3 V5 = CF3V5,
    F3 V6 = CF3V6,
    F3 F2 = CF3F2,

    F1 V1 = CF1V1,
    F1 V2 = CF1V2,
    F1 V3 = CF1V3,
    F1 V4 = CF1V4,
    F1 V5 = CF1V5,
    F1 V6 = CF1V6,
    F1 V7 = CF1V7,
    F1 V8 = CF1V8,
    F1 V14 = CF1V14,
    F1 V15 = CF1V15,
    F1 V25 = CF1V25,
    F1 F2 = CF1F2,
    F1 F3 = CF1F3 ;

  VAR v1-v17 v19-v20 V25;
RUN;
```

Log file for final measurement model:

```
1                                                           The SAS System
10:36 Friday, June 1, 2007

NOTE: Copyright (c) 2002-2003 by SAS Institute Inc., Cary, NC, USA.
NOTE: SAS (r) 9.1 (TS1M3)
      Licensed to UNIVERSITY OF MANITOBA, Site 0002246003.
NOTE: This session is executing on the SunOS 5.9 platform.



$Id: /project/randyf/prog/ModelMM728FINAL.sas Apr 20 19:15 randyf randyf $


NOTE: SAS initialization used:
      real time           0.10 seconds
      cpu time            0.09 seconds


NOTE: AUTOEXEC processing beginning; file is /home/rfransoo/autoexec.sas.

Release 9.1 - SAS 9 Format Library in use
NOTE: Libref LIBRARY9 was successfully assigned as follows:
      Engine:        V9

      Physical Name: /cpe/fmtlib

Program ModelMM728FINAL.sas
$Id: /project/randyf/prog/ModelMM728FINAL.sas       June 1, 2007 randyf $
NOTE: Libref CPE8 was successfully assigned as follows:
      Levels:            12
      Engine(1):         V9

      Physical Name(1): /cpe/db/hosp
      Engine(2):         V9
      Physical Name(2): /cpe/db/ltc
      Engine(3):         V9
      Physical Name(3): /cpe/db/med
      Engine(4):         V9
      Physical Name(4): /cpe/db/mims
      Engine(5):         V9
      Physical Name(5): /cpe/db/mis
      Engine(6):         V9
      Physical Name(6): /cpe/db/pmf
      Engine(7):         V9
      Physical Name(7): /cpe/db/pop
      Engine(8):         V9
      Physical Name(8): /cpe/db/vs
      Engine(9):         V9
      Physical Name(9): /cpe/db/dpin/v8
      Engine(10):         V9
      Physical Name(10): /cpe/db/mssp
      Engine(11):         V9
      Physical Name(11): /cpe/db/eusl
      Engine(12):         V9
      Physical Name(12): /cpe/db/pccf

NOTE: AUTOEXEC processing completed.

1          * ModelMM728, based on MM317b: back to LBW to lower mardia's;
2
```

```
        libname thesis '/project/randyf/data';
NOTE: Libref THESIS was successfully assigned as follows:
      Engine:        V9
      Physical Name: /project/randyf/data

        data thesis.semvars (keep = phin v1-v17 v19-v20 V25);
         set thesis.finalandfactors;
         by phin;
         V1 = avg;
         V2 = inc_pre/100000;
         V3 = magefbirth/10;
         V4 = fam5plus;
         V5 = deprmum;
         V6 = MARRIED5;
         V7 = EVERONIA;
         V8 = mov5plus;
         V9 = psicu;
         V10 = psdays6;
         V11 = totvisitsps/50;
         V12 = minor90;
         V13 = maj2plus;
         V14 = bfeed;
         V15 = n_sex;
         v16 = premie;
         V17 = lbw;
         V19 = lbstay;
         V20 = bicu3;
         V25 = c_TESTAGE;
        run;

NOTE: There were 5873 observations read from the data set
THESIS.FINALANDFACTORS.
NOTE: The data set THESIS.SEMVARS has 5873 observations and 21 variables.
NOTE: DATA statement used (Total process time):
      real time           0.10 seconds
      cpu time            0.08 seconds




        proc calis covariance corr residual all modification tech=newrap
g4=100
     ! data=thesis.semvars ;
          lineqs
            V11 = LV11F2 F2 + E11,
            V12 = LV12F2 F2 + E12,

            V16 = LV16F3 F3 + E16,
            V17 = LV17F3 F3 + E17,
            V19 = LV19F3 F3 + E19,
            V20 = LV20F3 F3 + E20,

            V9 =  LV9F1 F1  + E9,
            V10 = LV10F1 F1 + E10,
            V13 = LV13F1 F1 + E13 ;


          STD
            V1-V8 = VARV1-VARV8,
            V14 = VARV14,
            V15 = VARV15,
            V25 = VARV25,
            F1 = 1,
```

```
      F2 = 1,
      F3 = 1,
      E9-E13 = VARE9-VARE13,
      E16-E17 = vare16-vare17,
      E19-e20 = VARE19-VARE20 ;

    COV

      V25 V1 = CV25V1,
      V25 V2 = CV25V2,
      V25 V3 = CV25V3,
      V25 V4 = CV25V4,
      V25 V5 = CV25V5,
      V25 V6 = CV25V6,
      V25 V7 = CV25V7,
      V25 V8 = CV25V8,
      V25 V14 = CV25V14,
      V25 V15 = CV25V15,
      V25 F2 = CV25F2,
      V25 F3 = CV25F3,

      V14 V1 = CV14V1,
      V14 V2 = CV14V2,
      V14 V3 = CV14V3,
      V14 V4 = CV14V4,
      V14 V5 = CV14V5,
      V14 V6 = CV14V6,
      V14 V7 = CV14V7,
      V14 V8 = CV14V8,
      V14 F2 = CV14F2,
      V14 F3 = CV14F3,

      V15 V1 = CV15V1,
      V15 V2 = CV15V2,
      V15 V3 = CV15V3,
      V15 V4 = CV15V4,
      V15 V5 = CV15V5,
      V15 V6 = CV15V6,
      V15 V7 = CV15V7,
      V15 V8 = CV15V8,
      V15 V14 = CV15V14,
      V15 F2 = CV15F2,
      V15 F3 = CV15F3,

      V8 V1 = CV8V1,
      V8 V2 = CV8V2,
      V8 V3 = CV8V3,
      V8 V4 = CV8V4,
      V8 V5 = CV8V5,
      V8 V6 = CV8V6,
      V8 V7 = CV8V7,
      V8 F2 = CV8F2,
      V8 F3 = CV8F3,

      V7 V1 = CV7V1,
      V7 V2 = CV7V2,
      V7 V3 = CV7V3,
      V7 V4 = CV7V4,
      V7 V5 = CV7V5,
      V7 V6 = CV7V6,
      V7 V14 = CV7V14,
      V7 V15 = CV7V15,
      V7 V25 = CV7V25,
```

```
V7 F2 = CV7F2,
V7 F3 = CV7F3,

V6 V1 = CV6V1,
V6 V7 = CV6V7,
V6 V8 = CV6V8,

V5 V4 = CV5V4,
V5 V3 = CV5V3,
V5 V2 = CV5V2,
V5 V1 = CV5V1,
V5 V6 = CV5V6,
V5 V7 = CV5V7,
V5 V8 = CV5V8,

V4 V3 = CV4V3,
V4 V2 = CV4V2,
V4 V1 = CV4V1,
V4 V6 = CV4V6,
V4 V7 = CV4V7,
V4 V8 = CV4V8,

V3 V2 = CV3V2,
V3 V1 = CV3V1,
V3 V6 = CV3V6,
V3 V7 = CV3V7,
V3 V8 = CV3V8,

V2 V6 = CV2V6,
V2 V7 = CV2V7,

V2 V8 = CV2V8,
V2 V1 = CV2V1,

F2 V1 = CF2V1,
F2 V2 = CF2V2,
F2 V3 = CF2V3,
F2 V4 = CF2V4,
F2 V5 = CF2V5,
F2 V6 = CF2V6,

F3 V1 = CF3V1,
F3 V2 = CF3V2,
F3 V3 = CF3V3,
F3 V4 = CF3V4,
F3 V5 = CF3V5,
F3 V6 = CF3V6,
F3 F2 = CF3F2,

F1 V1 = CF1V1,
F1 V2 = CF1V2,
F1 V3 = CF1V3,
F1 V4 = CF1V4,
F1 V5 = CF1V5,
F1 V6 = CF1V6,
F1 V7 = CF1V7,
F1 V8 = CF1V8,
F1 V14 = CF1V14,
F1 V15 = CF1V15,
F1 V25 = CF1V25,
F1 F2 = CF1F2,
```

```
          F1 F3 = CF1F3 ;

        VAR v1-v17 v19-v20 V25;
      RUN;

NOTE: Type of model matrix _BETA_ changed to: Identity Matrix.
NOTE: Due to a sparse Jacobian the Hessian algorithm 11 will be used.
NOTE: Using the BFGS minimization technique would save you much memory and
probably computation
      time too.
NOTE: GCONV convergence criterion satisfied.
NOTE: There were 5873 observations read from the data set THESIS.SEMVARS.
NOTE: The PROCEDURE CALIS printed pages 1-70.
NOTE: PROCEDURE CALIS used (Total process time):
      real time           0.86 seconds
      cpu time            0.83 seconds


NOTE: SAS Institute Inc., SAS Campus Drive, Cary, NC USA 27513-2414
NOTE: The SAS System used:
      real time           1.12 seconds
      cpu time            1.05 seconds
```

2) The final structural equation model

Program for final model:

```
* SEM730: this is the FINAL FINAL model!!;

libname thesis '/project/randyf/data';

data thesis.semvars (keep = phin v1-v17 v19-v20 V25);
 set thesis.finalandfactors;
 by phin;
 V1 = avg;
 V2 = inc_pre/100000;
 V3 = magefbirth/10;
 V4 = fam5plus;
 V5 = deprmum;
 V6 = MARRIED5;
 V7 = EVERONIA;
 V8 = mov5plus;
 V9 = psicu;
 V10 = psdays6;
 V11 = totvisitsps/50;
 V12 = minor90;
 V13 = maj2PLUS;
 V14 = bfeed;
 V15 = n_sex;
 v16 = premie;
 V17 = lbw;
 V19 = lbstay;
 V20 = bicu3;
 V25 = TESTAGE;
run;

proc calis covariance corr residual all tech=newrap g4=100 all platcov
outstat=thesis.latentcoeffs data=thesis.semvars ;
  lineqs
    V11 =        F2 + E11,
    V12 = LV12F2 F2 + E12,

    V16 = LV16F3 F3 + E16,
    V17 = LV17F3 F3 + E17,
    V19 =        F3 + E19,
    V20 = LV20F3 F3 + E20,

    V9 =  LV9F1 F1  + E9,
    V10 = LV10F1 F1 + E10,
    V13 =        F1 + E13,

    V1 = PV1V2 V2+PV1V3 V3+PV1V4 V4+PV1V5 V5+PV1V6 V6+PV1V7 V7+PV1V8 V8+PV1V25
V25+PV1V15 V15+
         PV1V14 V14+PV1F1 F1+PV1F2 F2+PV1F3 F3+E1,
    F2 = PF2V2 V2+PF2V3 V3+PF2V4 V4+PF2V5 V5+PF2V6 V6+PF2V7 V7+PF2V8 V8+PF2V14
V14+PF2V15 V15+
         PF2F3 F3 + D2,
    F1 = PF1V2 V2+PF1V3 V3+PF1V4 V4+PF1V5 V5+PF1V6 V6+PF1V7 V7+PF1V8 V8+PF1V14
V14+PF1V15 V15+
         PF1F3 F3 + D1,
    F3 = PF3V15 V15 + D3 ;


  STD
    V2-V8 = VARV2-VARV8,
```

```
  V14 = VARV14,
  V15 = VARV15,
  V25 = VARV25,
  D1-D3 = VARD1-VARD3,
  E1 = VARE1,
  E9-E13 = VARE9-VARE13,
  E16-E17 = vare16-vare17,
  E19-e20 = VARE19-VARE20 ;

COV

  V25 V2 = CV25V2,
  V25 V3 = CV25V3,
  V25 V4 = CV25V4,
  V25 V5 = CV25V5,
  V25 V6 = CV25V6,
  V25 V7 = CV25V7,
  V25 V8 = CV25V8,
  V25 V14 = CV25V14,
  V25 V15 = CV25V15,

  V14 V2 = CV14V2,
  V14 V3 = CV14V3,
  V14 V4 = CV14V4,
  V14 V5 = CV14V5,
  V14 V6 = CV14V6,
  V14 V7 = CV14V7,
  V14 V8 = CV14V8,

  V15 V2 = CV15V2,
  V15 V3 = CV15V3,
  V15 V4 = CV15V4,
  V15 V5 = CV15V5,
  V15 V6 = CV15V6,
  V15 V7 = CV15V7,
  V15 V8 = CV15V8,
  V15 V14 = CV15V14,

  V8 V2 = CV8V2,
  V8 V3 = CV8V3,
  V8 V4 = CV8V4,
  V8 V5 = CV8V5,
  V8 V6 = CV8V6,
  V8 V7 = CV8V7,

  V7 V2 = CV7V2,
  V7 V3 = CV7V3,
  V7 V4 = CV7V4,
  V7 V5 = CV7V5,
  V7 V6 = CV7V6,
  V7 V14 = CV7V14,
  V7 V15 = CV7V15,
  V7 V25 = CV7V25,

  V6 V7 = CV6V7,
  V6 V8 = CV6V8,

  V5 V4 = CV5V4,
  V5 V3 = CV5V3,
  V5 V2 = CV5V2,
  V5 V6 = CV5V6,
  V5 V7 = CV5V7,
  V5 V8 = CV5V8,
```

```
    V4 V3 = CV4V3,
    V4 V2 = CV4V2,
    V4 V6 = CV4V6,
    V4 V7 = CV4V7,
    V4 V8 = CV4V8,

    V3 V2 = CV3V2,
    V3 V6 = CV3V6,
    V3 V7 = CV3V7,
    V3 V8 = CV3V8,

    V2 V6 = CV2V6,
    V2 V7 = CV2V7,
    V2 V8 = CV2V8,

    E16 E17 = CE16E17,
    E17 E20 = CE17E20,
    E9 E10 = CE9E10,
    E10 E13 = CE10E13;

  VAR v1-v17 v19-v20 V25;
RUN;

* now a bit of work to save out the values of the latent variables;

proc score data=thesis.semvars score=thesis.latentcoeffs
out=thesis.semvarsandlatentsf1 (drop=f2 f3);
 var v9 v10 v13;
run;

proc score data=thesis.semvars score=thesis.latentcoeffs
out=thesis.semvarsandlatentsf2 (drop=f1 f3);
 var v11 v12;
run;

proc score data=thesis.semvars score=thesis.latentcoeffs
out=thesis.semvarsandlatentsf3 (drop=f2 f1);
 var v16 v17 v19 v20;
run;

data thesis.semvarsandlatents;
 merge thesis.semvarsandlatentsf1 thesis.semvarsandlatentsf2
thesis.semvarsandlatentsf3;
 by phin;
run;
```

Log file for final structural equation model:

```
1                                                      The SAS System
10:36 Friday, June 1, 2007

NOTE: Copyright (c) 2002-2003 by SAS Institute Inc., Cary, NC, USA.
NOTE: SAS (r) 9.1 (TS1M3)
      Licensed to UNIVERSITY OF MANITOBA, Site 0002246003.
NOTE: This session is executing on the SunOS 5.9 platform.



$Id: /project/randyf/prog/ModelSEM730FINAL.sas May 29 10:15 randyf randyf $


NOTE: SAS initialization used:
      real time           0.11 seconds
      cpu time            0.10 seconds


NOTE: AUTOEXEC processing beginning; file is /home/rfransoo/autoexec.sas.

Release 9.1 - SAS 9 Format Library in use
NOTE: Libref LIBRARY9 was successfully assigned as follows:
      Engine:        V9
      Physical Name: /cpe/fmtlib

Program ModelSEM730FINAL.sas
$Id: /project/randyf/prog/ModelSEM730FINAL.sas       June 1, 2007 randyf $
NOTE: Libref CPE8 was successfully assigned as follows:
      Levels:            12
      Engine(1):         V9
      Physical Name(1): /cpe/db/hosp
      Engine(2):         V9
      Physical Name(2): /cpe/db/ltc
      Engine(3):         V9
      Physical Name(3): /cpe/db/med
      Engine(4):         V9
      Physical Name(4): /cpe/db/mims
      Engine(5):         V9
      Physical Name(5): /cpe/db/mis
      Engine(6):         V9
      Physical Name(6): /cpe/db/pmf
      Engine(7):         V9
      Physical Name(7): /cpe/db/pop
      Engine(8):         V9
      Physical Name(8): /cpe/db/vs
      Engine(9):         V9
      Physical Name(9): /cpe/db/dpin/v8
      Engine(10):         V9
      Physical Name(10): /cpe/db/mssp
      Engine(11):         V9
      Physical Name(11): /cpe/db/eusl
      Engine(12):         V9
      Physical Name(12): /cpe/db/pccf

NOTE: AUTOEXEC processing completed.

1          * SEM730: this is the FINAL FINAL model!!;
2
3          libname thesis '/project/randyf/data';
NOTE: Libref THESIS was successfully assigned as follows:
```

```
      Engine:        V9
      Physical Name: /project/randyf/data

           data thesis.semvars (keep = phin v1-v17 v19-v20 V25);
            set thesis.finalandfactors;
            by phin;
            V1 = avg;
            V2 = inc_pre/100000;
            V3 = magefbirth/10;
            V4 = fam5plus;
            V5 = deprmum;
            V6 = MARRIED5;
            V7 = EVERONIA;
            V8 = mov5plus;
            V9 = psicu;
            V10 = psdays6;
            V11 = totvisitsps/50;
            V12 = minor90;
            V13 = maj2PLUS;
            V14 = bfeed;
            V15 = n_sex;
            v16 = premie;
            V17 = lbw;
            V19 = lbstay;
            V20 = bicu3;
            V25 = TESTAGE;
           run;

NOTE: There were 5873 observations read from the data set
THESIS.FINALANDFACTORS.
NOTE: The data set THESIS.SEMVARS has 5873 observations and 21 variables.
NOTE: DATA statement used (Total process time):
      real time           0.08 seconds
      cpu time            0.07 seconds



           proc calis covariance corr residual all tech=newrap g4=100 all
platcov
         ! outstat=thesis.latentcoeffs data=thesis.semvars ;
             lineqs
               V11 =         F2 + E11,
               V12 = LV12F2 F2 + E12,

               V16 = LV16F3 F3 + E16,
               V17 = LV17F3 F3 + E17,
               V19 =         F3 + E19,
               V20 = LV20F3 F3 + E20,

               V9 =  LV9F1 F1  + E9,
               V10 = LV10F1 F1 + E10,
               V13 =         F1 + E13,

               V1 = PV1V2 V2+PV1V3 V3+PV1V4 V4+PV1V5 V5+PV1V6 V6+PV1V7 V7+PV1V8
V8+PV1V25 V25+PV1V15
         !  V15+
                    PV1V14 V14+PV1F1 F1+PV1F2 F2+PV1F3 F3+E1,
               F2 = PF2V2 V2+PF2V3 V3+PF2V4 V4+PF2V5 V5+PF2V6 V6+PF2V7 V7+PF2V8
V8+PF2V14 V14+PF2V15
         !  V15+
                    PF2F3 F3 + D2,
               F1 = PF1V2 V2+PF1V3 V3+PF1V4 V4+PF1V5 V5+PF1V6 V6+PF1V7 V7+PF1V8
V8+PF1V14 V14+PF1V15
```

```
        !  V15+
                PF1F3 F3 + D1,
           F3 = PF3V15 V15 + D3 ;


         STD
           V2-V8 = VARV2-VARV8,

           V14 = VARV14,
           V15 = VARV15,
           V25 = VARV25,
           D1-D3 = VARD1-VARD3,
           E1 = VARE1,
           E9-E13 = VARE9-VARE13,
           E16-E17 = vare16-vare17,
           E19-e20 = VARE19-VARE20 ;

         COV

           V25 V2 = CV25V2,
           V25 V3 = CV25V3,
           V25 V4 = CV25V4,
           V25 V5 = CV25V5,
           V25 V6 = CV25V6,
           V25 V7 = CV25V7,
           V25 V8 = CV25V8,
           V25 V14 = CV25V14,
           V25 V15 = CV25V15,

           V14 V2 = CV14V2,
           V14 V3 = CV14V3,
           V14 V4 = CV14V4,
           V14 V5 = CV14V5,
           V14 V6 = CV14V6,
           V14 V7 = CV14V7,
           V14 V8 = CV14V8,

           V15 V2 = CV15V2,
           V15 V3 = CV15V3,
           V15 V4 = CV15V4,
           V15 V5 = CV15V5,
           V15 V6 = CV15V6,
           V15 V7 = CV15V7,
           V15 V8 = CV15V8,
           V15 V14 = CV15V14,

           V8 V2 = CV8V2,
           V8 V3 = CV8V3,
           V8 V4 = CV8V4,
           V8 V5 = CV8V5,
           V8 V6 = CV8V6,
           V8 V7 = CV8V7,

           V7 V2 = CV7V2,
           V7 V3 = CV7V3,
           V7 V4 = CV7V4,
           V7 V5 = CV7V5,
           V7 V6 = CV7V6,
           V7 V14 = CV7V14,
           V7 V15 = CV7V15,
           V7 V25 = CV7V25,

           V6 V7 = CV6V7,
```

```
            V6 V8 = CV6V8,

            V5 V4 = CV5V4,
            V5 V3 = CV5V3,
            V5 V2 = CV5V2,
            V5 V6 = CV5V6,
            V5 V7 = CV5V7,
            V5 V8 = CV5V8,

            V4 V3 = CV4V3,
            V4 V2 = CV4V2,
            V4 V6 = CV4V6,
            V4 V7 = CV4V7,
            V4 V8 = CV4V8,

            V3 V2 = CV3V2,
            V3 V6 = CV3V6,
            V3 V7 = CV3V7,
            V3 V8 = CV3V8,

            V2 V6 = CV2V6,
            V2 V7 = CV2V7,
            V2 V8 = CV2V8,

            E16 E17 = CE16E17,
            E17 E20 = CE17E20,
            E9 E10 = CE9E10,
            E10 E13 = CE10E13;

          VAR v1-v17 v19-v20 V25;
        RUN;

NOTE: Due to a sparse Jacobian the Hessian algorithm 11 will be used.
NOTE: Using the BFGS minimization technique would save you much memory and
probably computation
      time too.
NOTE: GCONV convergence criterion satisfied.
NOTE: There were 5873 observations read from the data set THESIS.SEMVARS.
NOTE: The data set THESIS.LATENTCOEFFS has 70 observations and 22 variables.
NOTE: The PROCEDURE CALIS printed pages 1-85.
NOTE: PROCEDURE CALIS used (Total process time):
      real time           1.71 seconds
      cpu time            1.64 seconds



        * now a bit of work to save out the values of the latent variables;

        proc score data=thesis.semvars score=thesis.latentcoeffs
out=thesis.semvarsandlatentsf1
      ! (drop=f2 f3);
          var v9 v10 v13;
        run;

NOTE: There were 5873 observations read from the data set THESIS.SEMVARS.
NOTE: There were 70 observations read from the data set THESIS.LATENTCOEFFS.
NOTE: The data set THESIS.SEMVARSANDLATENTSF1 has 5873 observations and 22
variables.
NOTE: PROCEDURE SCORE used (Total process time):
      real time           0.03 seconds
      cpu time            0.03 seconds

```

```
148         proc score data=thesis.semvars score=thesis.latentcoeffs
out=thesis.semvarsandlatentsf2
148       ! (drop=f1 f3);
149          var v11 v12;
150         run;

NOTE: There were 5873 observations read from the data set THESIS.SEMVARS.
NOTE: There were 70 observations read from the data set THESIS.LATENTCOEFFS.
NOTE: The data set THESIS.SEMVARSANDLATENTSF2 has 5873 observations and 22
variables.
NOTE: PROCEDURE SCORE used (Total process time):
      real time           0.03 seconds
      cpu time            0.02 seconds


151
152         proc score data=thesis.semvars score=thesis.latentcoeffs
out=thesis.semvarsandlatentsf3
152       ! (drop=f2 f1);
153          var v16 v17 v19 v20;
154         run;

NOTE: There were 5873 observations read from the data set THESIS.SEMVARS.
NOTE: There were 70 observations read from the data set THESIS.LATENTCOEFFS.
NOTE: The data set THESIS.SEMVARSANDLATENTSF3 has 5873 observations and 22
variables.
NOTE: PROCEDURE SCORE used (Total process time):
      real time           0.03 seconds
      cpu time            0.02 seconds


155
156         data thesis.semvarsandlatents;
157          merge thesis.semvarsandlatentsf1 thesis.semvarsandlatentsf2
thesis.semvarsandlatentsf3;
158          by phin;
159         run;

NOTE: There were 5873 observations read from the data set
THESIS.SEMVARSANDLATENTSF1.
NOTE: There were 5873 observations read from the data set
THESIS.SEMVARSANDLATENTSF2.
NOTE: There were 5873 observations read from the data set
THESIS.SEMVARSANDLATENTSF3.
NOTE: The data set THESIS.SEMVARSANDLATENTS has 5873 observations and 24
variables.
NOTE: DATA statement used (Total process time):
      real time           0.05 seconds
      cpu time            0.06 seconds

NOTE: SAS Institute Inc., SAS Campus Drive, Cary, NC USA 27513-2414
NOTE: The SAS System used:
      real time           2.13 seconds
      cpu time            1.99 seconds
```