How Health Status Affects Progress and Performance in School
A Population-based Study

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ABSTRACT

Objective: To assess the effects of health status at birth and health status in the preschool years on educational outcomes to age 9 in a population-based birth cohort.

Methods: Administrative data were used to follow all children born to Winnipeg mothers in 1990, and remaining in Manitoba until September 2004 (N=5,873). A structural equation model was used, incorporating latent variables to represent Health Status at Birth, Major Illness and Minor Illness during the preschool years. The model also included the child’s sex and exact age, along with a number of social, economic, and demographic characteristics of the child’s family. The outcome was a combination of marks on Grade 3 Standards Tests and enrolment in the appropriate grade for age.

Results: Major Illness in the preschool years had a significant influence on progress and performance in school (p=0.0003), predicting 1.26% of the variation in the outcome. Minor Illness was weaker but still significant (p<0.01). Health Status at Birth was not directly related to the outcome; its effect was mediated by Major and Minor Illness in childhood. Overall, the strongest predictors were the child’s age and the area-level income, followed by the mother’s age, family receipt of income assistance, the sex of the child, breastfeeding initiation (all p<0.0001), and Major Illness.

Conclusions: Health status plays a statistically significant but substantively small role in explaining progress and performance in school among a population-based cohort. Major Illness was more important than Minor Illness, and these two factors completely mediated the influence of Health Status at Birth on the outcome. The strength of the social, economic, and demographic variables underscores the importance of the broader factors that affect both health and educational outcomes.

Key words: Child health; health status; health services; social determinants; health policy

La traduction du résumé se trouve à la fin de l’article.
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Population-based study group
All singletons born to Winnipeg mothers in 1990 (N=8,903) were followed to June 1999 for outcomes at the end of the Grade 3 year, along with progression to Grade 9 entry in September 2004. The only exclusions were children who died (n=86), moved out of the city (n=2,862), or had missing data (n=82). The final analysis was based on 5,873 children.

Explanatory variables
Three health constructs were developed as latent variables, each derived from several related measures. Health Status at Birth was comprised of birthweight, gestational age, length of hospital stay at birth, and use of intensive care during birth hospitalization. Major Illness included the number of days in hospital between birth discharge and the child’s fifth birthday, use of Intensive Care Units in that period, and the sum of annual assignments to Major Adjusted Diagnostic Groups (ADGs; using the Johns Hopkins grouper on each child’s physician visit and hospitalization records). Minor Illness combined the number of physician visits from birth discharge to fifth birthday and the sum of annual assignments to Minor ADGs. Details regarding these constructs (loadings, etc.) are contained in the Technical Appendix.

Both Major Illness and Minor Illness were conceptualized as constructs which could have direct effects on the outcome, and possibly mediate the relationship between Health Status at Birth and the outcome.

Each child’s sex and exact age (to the day) were also entered into the model, along with the following social, economic and demographic characteristics: the number of children in the family as of the study child’s 8th birthday; the mother’s age at the birth of her first child; whether breastfeeding was initiated before discharge from hospital; whether there was any indication that the child’s mother experienced depression during the child’s preschool years (as recorded in physician claims or hospital abstract diagnoses); whether the family ever received Income Assistance; the number of times the family moved by the child’s 8th birthday; the mother’s marital status as of the child’s 5th birthday; and the average household income of the Census Enumeration Area where the child’s family lived on the child’s 5th birthday.

### Outcome variable: Progress and performance in school
The outcome variable combined marks on mandatory Standards Tests in Grade 3 Mathematics and Language Arts with information from school enrolment records, because not all children were in Grade 3 and completed the tests. To keep all children in the analysis, a LOGIT transformation was used to generate an outcome score for each child on a single, continuous scale. Details of this transformation are provided in the Appendix.

### Statistical analysis
Structural equation modeling (SEM) was used, to allow incorporation of the latent variables and the longitudinal design. All of the social, economic and demographic factors (except child age) were also tested for mediation effects acting through the Major and Minor Illness constructs. The analysis was performed in SAS Version 9, using PROC CALIS. Details of the final model are contained in the Appendix.

### Results
Table 1 shows the descriptive characteristics for the study group and the excluded groups. Children whose families moved before complete data could be obtained were not statistically different from study children on Health Status at Birth. Children who died or had missing data were less healthy at birth than the study group, but represent less than 1.9% of the birth cohort.

#### Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Study Group</th>
<th>Movers</th>
<th>Deaths</th>
<th>Missing Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of children</td>
<td>N = 5873</td>
<td>n = 2862</td>
<td>n = 86</td>
<td>n = 82</td>
</tr>
<tr>
<td>Maternal depression (%)</td>
<td>26.1</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Family has 5+ children (%)</td>
<td>3.93</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Breastfeeding initiated at birth (%)</td>
<td>75.2</td>
<td>75.1</td>
<td>33.7*</td>
<td>56.7*</td>
</tr>
<tr>
<td>Area-level average household income</td>
<td>$34,614*</td>
<td>$40,434*</td>
<td>$39,532</td>
<td>$35,772*</td>
</tr>
<tr>
<td>Mother’s age at first birth (%)</td>
<td>25.3</td>
<td>23.8*</td>
<td>23.3</td>
<td>22.7*</td>
</tr>
<tr>
<td>Family received Income Assistance (%)</td>
<td>13.6</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Sex of child (%)</td>
<td>51.4</td>
<td>51.9</td>
<td>54.7</td>
<td>44.6*</td>
</tr>
<tr>
<td>Breastfeeding initiated at birth (%)</td>
<td>75.2</td>
<td>75.1</td>
<td>33.7*</td>
<td>56.7*</td>
</tr>
<tr>
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<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Maternal depression (%)</td>
<td>26.1</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

* indicates different from Study Group (p<0.01)

N/A = data not available

### Influence of health-related factors
The Major Illness construct alone explained 1.26% of the variation in progress and performance in school (p=0.0003). Minor Illness was also independently related to the outcome, though weaker, explaining 0.15% of the outcome.
Health Status at Birth was not directly related to the outcome; its influence was completely mediated by Major Illness and Minor Illness in the preschool years.

Influence of social, economic and demographic factors
Almost all of the social, economic and demographic factors were significant predictors of progress and performance in school, and most were more strongly related to the outcome than were the health factors. Better outcomes were related to the following characteristics, in order of importance: children who were older (born earlier in the year); those living in higher income areas; children born to older mothers; those in families which never received income assistance; girls; children breastfed at birth (all p<0.0001); and those in smaller families (p<0.01). Conversely, residential mobility, mother’s marital status and maternal depression were not significantly related to the outcome directly.

Maternal depression, the sex of the child, family receipt of income assistance and area-level income also had influences on the outcome mediated through Minor Illness (see Figure 1).

DISCUSSION
The results of this study suggest that early health status, particularly experience with a Major Illness, is significantly associated with progress and performance in school. This is consistent with the findings of previous studies using either health status at birth or health status later in childhood. However, the results show that the role of Health Status at Birth is completely mediated by Major Illness and Minor Illness. This means that poor Health Status at Birth is related to later cognitive outcomes only because of its association with Major and Minor Illness later in childhood, rather than having a direct relationship with the outcome, as implied by previous research. This finding underscores the importance of incorporating longitudinal measures of health status in the analysis.

The 18.6% of outcome variance explained by the final model is comparable to the 21% explained by the multilevel model developed by Tremblay et al. analyzing Grade 3 performance in Ontario, which incorporated student, classroom, teacher and school-level influences. These relatively modest figures suggest that both studies were missing important variables affecting student outcomes (for example, each student’s cognitive ability). Other investigators have reported similar effect sizes, which in Cohen’s categorization would qualify as a ‘medium’ effect. In our results, older children (those born earlier in the year) had better outcomes than younger children, which is consistent with previous research. The importance of household income is also consistent with previous reports, though this may be more related to characteristics of the environment in which the child is reared, particularly parenting practices and behaviours, rather than an effect of income per se. The significance of the mother’s age is also consistent with previous findings (see review by Elfenbein & Felice), as is family receipt of Income Assistance benefits. In this study, as
in most studies of early child development, girls had slightly better outcomes than boys. Finally, the importance of Major Illness is consistent with findings from smaller and clinical studies suggesting that children with disabilities or neurocognitive disorders have the poorest outcomes in terms of later cognitive and educational performance. The results of this study extend these findings to a large, population-based study group.

Rather than defining the analysis group as children with Standards Test scores, this study used a birth cohort with few exclusion criteria. As Brownell et al. reported, a significant portion of children do not reach Grade 3 ‘on time’, especially among those living in disadvantaged areas. The inclusion of all births strengthens the analysis because it incorporates the likelihood that a child’s absence, exemption from the test, or failure to progress to Grade 3 on time might have been related to their health status.

**Limitations**

There are several limitations of this study. The use of administrative data provides population coverage, but limits the availability of relevant variables; for example, each child’s cognitive ability and motivation. Recording bias in health service records may also be present, potentially affecting several measures (e.g., mother’s use of health services for Depression may not always be recorded as such). The use of area-level instead of household-specific income level is a weaker limitation, because the relationships have been shown to be similar, and the Income Assistance variable was family-specific. Furthermore, the aggregate measure may be capturing true area-level influences. Confounding always remains a potential threat, as variables not included in the analysis may be responsible for the reported relationships. Finally, because this study was limited to singleton births, the relationships may differ for children of multiple births.

**Conclusions**

Health status in the preschool years has a statistically significant but substantively small effect on progress and performance in school, except that children experiencing Major Illness are at significantly higher risk. The strong linkage between Major Illness and Health Status at Birth suggests that many of these children could be identified early. The overwhelming strength of the social, economic and demographic factors underscores the continuing need to address the broader social determinants of health and educational outcomes, including the development of a comprehensive program for early child health and development.

**References**

39. Linver MR, Brooks-Gunn J, Kohmen DE. Family processes as pathways from income to young child... continues on page 349
Technical Appendix

Preliminary analyses
Before the main structural equation modeling was initiated, a number of preliminary analyses were performed on several of the explanatory variables.

Latent Variables for Health Status
The initial conceptual model for this study contained only one latent variable representing health status in the preschool period, which was related to all five manifest variables listed below. These measures of health service use were used as indicators of health status, in accordance with previous research.22,52-54 and based on their demonstrated validity in the data repository at MCHP.21

Manifest Variables
• the number of physician visits from birth discharge until the child’s 5th birthday,*
• the number of hospital days from birth discharge through 5th birthday,
• use of intermediate or intensive care units (at any time)
• the number of Minor ADG-years for that child, from birth through 5th birthday*
• the number of Major ADG-years for that child, from birth through 5th birthday.

However, a preliminary factor analysis revealed that these five measures loaded onto two distinct factors, one labelled Minor Illness, and the other Major Illness. The loading values for these constructs and the ‘Health Status at Birth’ construct were all above the recommended value of 0.4, and most were above 0.6, as shown in Table A1.

Table A1: Loading Values of Manifest Variables on Latent Constructs

<table>
<thead>
<tr>
<th>Manifest Variable</th>
<th>Health Status at Birth</th>
<th>Minor Illness</th>
<th>Major Illness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm birth</td>
<td>.7258</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low birthweight</td>
<td>.6763</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICU use (birth)</td>
<td>.7605</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long hospital stay at birth</td>
<td>.7075</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physician visits</td>
<td>.8250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor ADGs</td>
<td>.6731</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major ADGs</td>
<td>.5007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital days</td>
<td>.4834</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICU use (preschool)</td>
<td>.4268</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Social, Economic, and Demographic Variables
A number of variables were available to describe the environment within which each child was being reared. For several variables, values could be specified at any time during childhood. Therefore, those for which it made sense to measure total cumulative exposure from birth were measured as of the child’s 5th birthday: the number of children born to the child’s mother; the number of residential moves recorded for the child’s family; and whether the mother was diagnosed with depression during any physician visits or hospitalizations. Those for which effects were hypothesized to require a period of time to have an effect on educational outcomes were measured as of the child’s 5th through his or her 8th birthday. Mother’s age at the birth of her first child was a constant. A factor analysis was performed to reduce the number of variables required in the final model, but revealed inadequate correlations among the variables to create a small number of strong factors. Therefore, all these variables were entered into the final models as separate variables.

Outcome measurement
The main outcome variable combined information from school enrollment records and results from mandatory Standards Tests in Grade 3 Mathematics and Language Arts. Most of the children (4,821/5,873) completed the standards tests, and their outcome value was the average of their two test scores (after transformation as described below). The remaining children were either exempt from writing (n=391 children, primarily with cognitive disabilities), enrolled in Grade 2 or lower (n=275), or started but did not complete the tests (n=186). It was important to include these children in the analysis, to determine whether their school performance was related to health problems. A single outcome score was generated for each child using a LOGIT transformation.22,54

The LOGIT transformation provided a valid method to combine students who had test scores with students who did not. Groupings of students were created based on the subcategories of the groups listed above (e.g., there were several subcategories of exemptions), and using decile groupings for those with test scores (e.g., 0-10%, 11-20%, etc.). The groups were then ranked according to the proportion of students in each group who enrolled in Grade 9 by September 2004 as expected (except those exempted for cognitive disabilities, who were designated as the lowest outcome group). All groups were then ‘placed’ into a bell curve in proportion to their size, thus filling in the area under the curve which represented all 5,873 children in the analysis. This distribution then provided standardized scores for each child. For example, children exempted due to cognitive disabilities were all assigned the z score of -2.27; children in Grade 2 received a score of -1.42; those who averaged 70% on the tests received a score of +1.81, and those who averaged 100% received a score of +2.79.

Relationships among explanatory variables and outcome
Table A2 shows the results of regression models between each explanatory variable and the final outcome. Virtually all explanatory variables demonstrated significant correlations, emphasizing the need for multivariate analysis to sort out the independent and overlapping effects of these variables.

Table A2: Univariate Regressions Between Each Predictor Variable and Progress and Performance in School

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std Error</th>
<th>Standardized Coefficient</th>
<th>R2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health-related constructs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major Illness</td>
<td>-79343</td>
<td>.02773</td>
<td>-0.79334</td>
<td>1.01</td>
</tr>
<tr>
<td>Minor Illness</td>
<td>-34071</td>
<td>.00449</td>
<td>-0.31188</td>
<td>1.00</td>
</tr>
<tr>
<td>Health Status at Birth</td>
<td>-40378</td>
<td>.07763</td>
<td>-0.40378</td>
<td>0.46</td>
</tr>
<tr>
<td>Social, economic, and demographic variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family receipt of income assistance</td>
<td>-74568</td>
<td>.03430</td>
<td>-0.74568</td>
<td>7.45</td>
</tr>
<tr>
<td>Area-level income (in $10,000 units)</td>
<td>.12187</td>
<td>.00567</td>
<td>0.12187</td>
<td>7.28</td>
</tr>
<tr>
<td>Mother’s age at birth of first child (yrs)</td>
<td>0.04847</td>
<td>.00231</td>
<td>0.04847</td>
<td>6.97</td>
</tr>
<tr>
<td>Family moved 5+ times in 8 years</td>
<td>-70739</td>
<td>.05198</td>
<td>-0.70739</td>
<td>3.06</td>
</tr>
<tr>
<td>Mother registered as married</td>
<td>.35963</td>
<td>.02643</td>
<td>0.35963</td>
<td>3.06</td>
</tr>
<tr>
<td>Age of child (months)</td>
<td>.04240</td>
<td>.00357</td>
<td>0.04240</td>
<td>2.34</td>
</tr>
<tr>
<td>Breastfeeding initiated at birth</td>
<td>.31188</td>
<td>.02798</td>
<td>0.31188</td>
<td>2.07</td>
</tr>
<tr>
<td>Sex of child (0=female, 1=male)</td>
<td>-.23146</td>
<td>.04242</td>
<td>-0.23146</td>
<td>1.53</td>
</tr>
<tr>
<td>Family had 5+ children</td>
<td>-.59202</td>
<td>.06234</td>
<td>-0.59202</td>
<td>1.51</td>
</tr>
<tr>
<td>Mother depressed</td>
<td>-.15868</td>
<td>.02773</td>
<td>-0.15868</td>
<td>0.55</td>
</tr>
</tbody>
</table>

p<0.0001

The final structural equation model
The final model was created using the widely recommended two-step process developed by Anderson and Gerbing,25 which involves creation and refinement of a measurement model, followed by the final causal model. The maximum likelihood estimation was used, and the requirement for multivariate normality was satisfied (value = 1.73). Covariances were specified among several pairs of variables to address large residuals. The final model provided excellent fit to the data: Bentler’s Comparative Fit Index value was 0.9767 (above recommended minimum 0.95, as were all other fit index values); the Root Mean Square Residual was 0.0023, and the Root Mean Square Error of Approximation was 0.0274 (both recommended to be under 0.10). The model explained 18.6% of the total variation in the outcome measure, thus qualifying as a ‘Medium’ effect in Cohen’s classical definition.28

Mediation test
The mediating role of Major and Minor Illness is confirmed by the result for Health Status at Birth in Table A2. That is, without the Major and Minor Illness variables in the model, Health Status at Birth displayed a highly significant direct association with the outcome (p<0.0001). However, in the full model, which included Major and Minor Illness, the direct association between Health Status at Birth and the outcome was not significant (p=0.75). The relationships between Health Status at Birth and both Major and Minor Illness were significant (p=0.0001), and those variables were both significantly related to the outcome, indicating that the relationship between Health Status at Birth and progress and performance in school is completely mediated by Major and Minor Illness in the preschool years.

* For the ADG measures, each child was assigned to Major and Minor ADGs for each of the first five years of life. The sum of these assignments was used to calculate the number of Minor ADG-years and the number of Major ADG-years for each child from birth through 5th birthday.
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RÉSUMÉ

Objectif : Évaluer les effets de l’état de santé à la naissance et au cours des années préscolaires sur les résultats pédagogiques jusqu’à 9 ans au sein d’une cohorte de naissance représentative.


Résultats : Les maladies graves contractées au cours des années préscolaires avaient une influence significative sur le cheminement et le rendement scolaires (p=0,0003), en prédisant 1,26 % de l’écart dans le résultat final. L’influence des maladies bénignes était plus faible, mais encore significative (p<0,01). L’état de santé à la naissance n’était pas directement lié au résultat; son effet était atténué par les maladies graves et bénignes durant l’enfance. Globalement, les prédicteurs les plus forts étaient l’âge de l’enfant et le revenu dans la région, suivis de l’âge de la mère, du fait que la famille toucha une aide au revenu, du sexe de l’enfant, de l’allaitement maternel (tous ces facteurs, p<0,0001) et de l’existence d’une maladie grave.

Conclusion : L’état de santé jouait un rôle significatif, mais tout de même assez faible, dans le cheminement et le rendement scolaires au sein d’une cohorte représentative. L’influence des maladies graves était plus important que celui des maladies bénignes, et ces deux facteurs comprenaient entièrement l’influence de l’état de santé à la naissance sur le résultat. La force des variables sociales, économiques et démographiques souligne l’importance des facteurs généraux qui touchent à la fois la santé et les résultats pédagogiques.

Mots clés : santé de l’enfant; état de santé; services de santé; déterminants sociaux; politiques de santé.