Child Health and Young Adult Outcomes

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October 2008

We are grateful to Randy Fransoo for sharing his expertise about the data and to Paul Newacheck, Louise Sequin and participants in seminars at Brown University, the Wharton School, Peking National University and the Chinese University of Hong Kong for helpful comments. We also thank the following people from the Manitoba Ministry of Education, Citizenship, and Youth--Heather Hunter and Shirley McLellan; from the Ministry of Family Services and Housing--Harvey Stevens and Jan Forster; and from the Ministry of Health and Healthy Living--Louis Barre. Funding was provided by the Partnership for America's Economic Success, the Social Science and Humanities Research Council of Canada, and the Canadian Institute for Advanced Research and the RBC Financial group. The results and conclusions presented are those of the authors. No official endorsement by Manitoba Health and Healthy Living, the Partnership for America's Economic Success or other funding agencies is intended or should be inferred.

Abstract

Previous research has shown a strong connection between birth weight and future child outcomes. But this research has not asked how insults to child health after birth affect long-term outcomes, whether health at birth matters primarily because it predicts future health or through some other mechanism, or whether health insults matter more at some key ages than at others? We address these questions using a unique data set based on public health insurance records for 50,000 children born between 1979 and 1987 in the Canadian province of Manitoba. These children are followed until 2006, and their records are linked to provincial registries with outcomes data. We compare children with health conditions to their own siblings born at most 9 years apart, and control for health at birth. We find that health problems in early childhood are significant determinants of outcomes linked to adult socioeconomic status.

Introduction

A large literature has established that low birth weight babies (those under 2500 grams) are more likely to suffer various deficits, including lower average educational attainment. But previous research has not asked how poor child health after birth affects long-term outcomes, whether health at birth matters primarily because it predicts future health or through some other mechanism, and whether health problems matter more at some key ages than at other times?

This study provides a first look at these questions using a unique administrative data set based on public health insurance records from the Canadian province of Manitoba. The data combines information from birth records, hospitalizations, and ambulatory physician visits with information from other provincial registers about educational outcomes and use of social assistance. These outcomes include: achievement on a standardized test of grade 12 language arts, whether children took college-preparatory math courses in high school, whether they were in grade 12 by age 17, and welfare participation in the months immediately after becoming eligible at age 18. This health and outcome information is much more complete, and in many ways more accurate, than what is typically available in survey data. And because Canada has universal public health insurance, this study sheds light on the consequences of disparities in child health in a setting that abstracts from differences in access to insurance coverage.

We follow 50,000 children born in the Canadian province of Manitoba between 1979 and 1987, until 2006, when they are young adults. We are able to compare siblings with different health problems, to control for health at birth (including the presence of congenital anomalies and perinatal problems), and to compare the effects of health problems at different ages.

A growing body of research suggests that adverse conditions in early childhood may have particularly negative long term effects. Cunha and Heckman (2007) hypothesize that this is because health human capital is complementary to skills and "skill begets skill," so that children who suffer early disadvantages may fall behind and never catch up. On the other hand, to the extent that children are resilient and recover, one might expect more recent health conditions to have greater effects on current outcomes. If both mechanisms are at work, then one might expect to find that both health insults in early childhood and recent health problems have particularly negative effects on young adult outcomes.

We show that early health problems have significant effects on future adult outcomes. For schooling outcomes, this is largely due to effects on future health outcomes. However, early health conditions have lingering effects on social assistance use net of effects of future health conditions. Mental health conditions are an exception: we find that diagnoses of Attention Deficit Hyperactivity Disorder or Conduct disorder at school entry are significant predictors of future outcomes whether or not future diagnoses are controlled. We also find that controlling for early health problems reduces, but does not eliminate the effect of low birth weight, confirming the importance of fetal conditions for future outcomes. We conclude that differences in health in childhood may be a significant source of socioeconomic disparities in adulthood.

2. Background

There is a large literature linking low birth weight to lower average scores on a variety of tests of intellectual and social development (see for example, Breslau et al. 1994, Brooks-Gunn, Klebanov, and Duncan, 1996). Currie and Hyson (1999) show that low birth weight children from the 1958 British birth cohort study (all of the children born in Great Britain in one week in 1958) have lower test scores, educational attainments, wages, and probabilities of being employed as of age 33, even conditional on many measures of family background and circumstances. Case, Fertig, and Paxson (2005) extend this research by showing that the same is true at age 42, and for adults who suffered chronic conditions as children.

Several studies have used sibling designs and/or large-scale administrative data sets to examine the relationship between low birth weight and future outcomes in models that control more fully for family background characteristics by comparing siblings or twins. In these studies the "control" for the low birth weight child is the child's non-low birth weight sibling. Using data from the Panel Study of Income Dynamics, Conley and Bennett (2000) find that low birth weight reduces the probability of high school graduation, while Johnson and Schoeni (2007) find that low birth weight is strongly related to poorer adult health and lowers adult annual earnings by 17.5%.

Lawlor et al. (2006) examine the birth weights of Scottish siblings born between 1950 and 1956 and find that lower birth weight siblings had lower scores on a test of intelligence at age 7. Black, Devereux, and Salvanes (2005) examine a large sample of Norwegian twins and find, using twin fixed effects, that a 10% increase in birth weight leads to a one percentage point increase in the probability of graduating from high school and a one percent increase in earnings. Moreover, these effects are surprisingly linear between about 1,500 grams and 3,500 grams, suggesting that an exclusive focus on the 2,500 gram cutoff for low birth weight is unwarranted.

Royer (2005) and Currie and Moretti (2007) use linked mother-child birth certificate data for California. Royer examines mothers who were twins, and finds that each 1,000 gram increase in birth weight is associated with a gain of 0.16 years of education at the time the mother gives birth to her own child. Currie and Moretti (2007) compare mothers who are sisters by conditioning on grandmother fixed effects, and find that a sister who was low birth weight is 3% more likely to live in a poor area at the time she delivers her own child, and 3% less likely to be married when she gives birth. The low birth weight sister also has about a tenth of a year less education on average.

Oreopoulos, Stabile, Roos, and Walld (2007) examine the Manitoba data used in this study and find results consistent with those discussed above: children with birth weight between 1,500 to 2,500 grams were 8.2 % less likely to reach grade 12 by age 17 than siblings who weighed over 3,500 grams and these children also spent longer on welfare than their siblings who weighed over 3,500 grams.

In one of the very few studies to look at other child health measures, Luo and Waite (2005) use data from the Health and Retirement Survey, a national survey of older adults, and find that the effect of a retrospective self-reported measure of childhood SES on future health, education, and income is attenuated by the inclusion of child health measures, suggesting that child health may explain some of the impact of low childhood SES on future outcomes. But there are issues with self-reported health data, and it is possible that these correlations are due to other characteristics of households that are associated both with poor child health and poorer outcomes.

Smith (2007) examines the long-term effects of child health using a similar retrospective health measure using data from the Panel Study of Income Dynamics. In 1999, the 25 to 47 year old adult children of PSID respondents were asked a retrospective question about the state of their health when they were less than or equal to 16 years old: Whether it was excellent, very good, good, fair or poor? In models with sibling fixed effects, Smith finds significant negative effects of poor overall health status in childhood on earnings.

Case and Paxson (2006) treat adult height as an indicator of childhood health, and show that much of the wage premium associated with adult height can be explained by children's cognitive test scores. They interpret their results as evidence that early child health affects cognition, which in turn affects earnings.

As Currie (forthcoming) documents, there has been little research examining the long-term effects of other specific health conditions besides low birth weight, with the result that we know little about how other conditions affect children's prospects. Salm and Schunk (2008) use data from an administrative data set in a German city to show that 6 year old children with health problems also have lower test scores, but they are not able to track the children over time.

Moreover, we do not know whether low birth weight and other childhood health conditions matter primarily because they are linked to future health conditions or through other channels. Elo and Preston (1992) show that cohorts who suffered high death rates in childhood also tend to show high death rates in adulthood, presumably at least in part because of the direct effects of childhood health conditions on future morbidity. For example, Linnet et al., 2006 show in a large cohort of Danish children that low birth weight is linked to Attention Deficit Hyper Activity Disorder. Hence, it is possible that the effects of low birth weight on future outcomes could be eliminated by including controls for future health status.

3. Data

Our main source of data is records that are routinely collected through the administration of Manitoba's public health insurance system. These records include enrollment files, physician claims, and hospital claims for every person in Manitoba. These data are matched to administrative records on educational attainment and social-assistance (welfare) take-up and use.

The registry contains information on 96% of all children born in Manitoba over the sample period and tracks 99% of the original sample conditional on remaining in the province until June of their 18th year.[1] We restrict our sample to families with more than one child born between 1979 and 1987 (excluding 1983 as we are unable to match this cohort to educational information). We track outcomes for these children through to 2006. We restrict our sample to children with siblings also born in the period of interest as our identification strategy (discussed in more detail below) relies on sibling comparisons. Previous work using these data (Oreopoulos et al, 2008) has shown that the sibling cohort and entire cohort of Manitoba births over this period are quite similar. We also exclude children who ever have a diagnosis of mental retardation. Further details on the construction of the data set are available in the data appendix.

Because the data set includes all hospitalizations and ambulatory visits, there are a very large number of potential health measures. Birth weight, congenital anomalies and perinatal problems are obtained from hospital records. These measures are important conceptually as summary measures of health at birth: We wish to investigate the effects of health problems after birth, so it is necessary to control for the continuing effects of health at birth.[2] It is also of interest to ask whether the documented effects of health at birth matter primarily because they affect future health, or through some other mechanism.

In order to collapse the available health measures in an objective and arms-length way, we use Adjusted Clinical Group (ACG) software developed by researchers at Johns Hopkins University (The Johns Hopkins University, 2003). The ACG is designed to measure morbidity by creating constellations of diagnoses. Medical providers indicate diagnoses using what are

[1] The registry data do suffer from attrition when families move out of the province and can no longer be tracked. Approximately 20% of the sample leaves the province between the birth of the child and their 18th year. Previous studies (Oreopoulos, Stabile, Roos and Walld) find that there does not appear to be a correlation between children being in poor health and the families leaving the province. There is also a small amount of attrition from children who die, but children who died before age eight were much less healthy at birth and most of these deaths (~3/4) occur within the first year of life.

[2] Congenital problems may continue to generate diagnoses, or may even be discovered as the child ages. For example, we code a 10 year old's visit related to a congenital heart defect as a congenital problem, and control for it.

called International Classification of Disease codes (ICD9 or ICD10 codes depending on the year). The ACG software groups 14,000 ICD codes into 32 groups (called Aggregated Diagnostic Groups or ADGs) on the basis of 5 criterion: 1) Duration of the Condition (acute, recurrent, or chronic), 2) severity of the condition (e.g. minor and stable versus major and unstable), 3) diagnostic certainty (symptoms focusing on diagnostic evaluation versus documented disease focusing on treatment), 4) etiology of the condition (infectious, injury, or other), and 5) specialty care involved (medical, surgical, obstetric, etc.) Individuals are assigned an ADG code if they have been diagnosed with any of the ICD codes in the group in either an outpatient or hospital visit over the past year.

The ADG system has been extensively validated in the U.S. (Weiner, Starfield, Steinwachs et al., 1991; Weiner, Starfield, and Lieberman, 1992; Powe, Weiner, Starfield et al., 1998; Wiener, Dobson, Maxwell et al., 1996). The Manitoba Center for Health Policy has also evaluated the application of the ACG software to the Manitoba administrative data (Reid et al., 1999). See the data appendix for further details.

We use the ADG codes to construct several health measures. First, the Johns Hopkins software classifies some ADGs as major and some as minor for each age group, and we start by looking at their definition of major diagnoses for children. However, this definition excludes several diagnoses that are highly prevalent among children, and which are thought to have important effects: While the Johns Hopkins definition includes acute, unstable mental health conditions such as psychosis, it excludes "stable" mental health conditions such as Attention Deficit Hyper Activity Disorder (ADHD) and Conduct disorders, two of the most common mental health conditions among children. Also excluded are asthma and major injuries.[3]

[3] "Major injuries" are not included as a major ADG for 0 to 17 year olds, but they are included for 18 year olds. In order to construct a more consistent measure, we use the same definition of a major

These are potentially significant exclusions. Using retrospective questions about onset, Kessler et al. (1995) find that those with early onset psychiatric problems were less likely to have graduated from high school. Using large-scale national surveys of children from both the U.S. and Canada, Currie and Stabile (2006, 2007) show that mental health conditions in childhood are associated with lower future test scores and schooling attainments in both countries. Externalizing disorders such as ADHD and conduct disorders were found to have the largest effects on future outcomes. Duncan et al. (2006) report similar findings.

Injuries are the leading cause of death among children over one year of age in developed countries, notwithstanding a dramatic reduction in deaths due to injuries in the past 30 years (Glied, 2001). Yet we have little information about the burden of morbidity caused by injuries among surviving children (Bonnie et al, 1999).

Asthma is the leading cause of school absence and pediatric hospitalizations in children, and one of the most common chronic conditions of childhood (U.S. Environmental Protection Agency, 2006). The available evidence suggests however, that when properly managed asthma may have little impact on children's functioning or academic achievements so it is not clear that asthma in childhood should be expected to have consistent effects on young adult outcomes (Annett et al. 2000; Gutstadt et al., 1989).

In view of these literatures, we examine the effects of asthma, major injuries, two specific stable mental health problems (ADHD and conduct disorders), as well as the number of other major health conditions as classified by the ADG software. In each case the measure is constructed to cover a specific age range starting from the date of birth of the child. So, for example, we define a child as having a major injury between ages 0 and 3 if the child has a diagnosis of a major injury at any point between birth and their 4th birthday. We construct

conditions for 18 year olds as we do for younger children. Further details are in the data appendix.

similar measures for the age ranges 4 to 8, 9 to 13, and 14 to 18. We chose these age ranges to correspond to important stages of childhood: The preschool years, early elementary school, early adolescence, and the late teen years.

The data appendix shows the mapping between our measures and the most common ICD9 codes in each category (the rankings are much the same for ICD10 codes). For example, Appendix Table 3 shows that open wounds of the head are one of the most important major injuries at all ages.

Of course, given that we are using administrative data, what we observe is whether a child had any interaction with the health care system for a specific ADG over a four year interval. However, it is reasonable to expect that over a four year period a fully insured child who is experiencing a severe health condition, or being treated for that condition, would need to interact with the health care system at least once. For example, a child who was on medication for asthma would need to see a physician periodically to have his or her prescription renewed, even in the absence of acute asthma attacks. Moreover, our measure is not affected by the number of visits for a particular condition, only by whether there is at least one visit. Hence, we believe that our measure, while imperfect, offers a reasonable proxy for whether or not a child had a particular condition in a given age range, and for the number of major conditions a child had.

Table 1 shows the means of our measures for each age range. Because the first age range is one year smaller than the others, the estimates are pro-rated so that they all apply to a 5 year interval. The fraction of children with a medical contact for asthma ranges from 8% among 0 to 3 year olds, to 14.4% among 9 to 13 year olds. These numbers compare very closely with the best available evidence of asthma prevalence for the U.S., which suggest that 13.1% of 0 to

17 year old children have ever been told by a doctor that they have asthma (Bloom and Cohen, 2007).

Major injuries are clearly the most common reason for seeking medical attention, with around 40% of children having at least one visit for major injury over each age interval. U.S. data suggest that in 2000, 11.9% of children less than 10 and 17.9% of children 10 to 19 received medical attention for an injury, which suggests that over a 4 or 5 year period, a rate of 40% is not unreasonable.

In comparison, contacts for externalizing mental health problems are not nearly as prevalent: 3 to 4% of children receive a medical contact for ADHD or conduct disorders over each period. U.S. rates of ADHD prevalence are higher than this. For example, Froehlich et al. (2007) report that 8.7% of 8 to 15 year old children in the National Health Interview Survey have been told by a doctor that they have ADHD. But there is evidence that Canadian rates of mental health diagnosis are lower than in the U.S. Currie and Stabile (forthcoming) found that 9.3% of children in the U.S. National Longitudinal Survey of Youth were being treated for mental health conditions compared to 4.5% in a similar Canadian survey. This disparity in the rates suggests that Canadian children who are diagnosed may display more severe behavior problems than treated children in the U.S., a comparison which should be born in mind when interpreting the results below.[4]

Congenital and perinatal (pertaining to the period from 22 weeks gestation to one week after birth) problems are common among 0 to 3 year olds. We retain only those problems that are considered "major" health conditions by the ADG system. Appendix Table 3 lists these conditions and shows that they include problems such as birth asphyxia and neonatal jaundice

[4] We have repeated our analyses with a broader measure of mental health conditions as discussed further below.

accompanying preterm delivery. A small number of older children have contacts for congenital problems such as heart defects. Though these contacts occur later, they result from health conditions present at birth, so we control for them in our examination of the effects of health after birth.

About 15% of children 0 to 13 have other major conditions. Appendix Table 2 provides a breakdown of the ICD9 codes represented by this variable. This table demonstrates that although it is relatively common to have a medical contact for a major health problem, most individual types of problems have low prevalence. For example, the 629 children who had a medical contact related to hearing lost when they were 0 to 3 represent only 1.2% of the sample. This is the main reason that we group these other major health conditions together. The average number of major health conditions is a little over .2 for children 0 to 13 (vs. .335 for 14 to 18 year olds) which suggests that most children with a major health condition have only one such condition. There are however a small number of children who have multiple conditions, with the maximum being 10 to 12 for 0 to 13 year olds (14 for 14 to 18 year olds). Finally, the table shows the effects of limiting our attention to major conditions. While the average number of major conditions identified is far less than 1, the average child has an average of 5 different major *and* minor conditions diagnosed over a five year period.

Table 2 explores the temporal pattern of health problems for the children in our sample. For example, a child is assigned the pattern 0000 if he or she did not have a diagnosis for a particular health condition in any age range. The fractions ever diagnosed with asthma, ADHD/conduct disorder or major injuries are 28.31, 10.18, and 82.06 respectively, while 47.36% ever have another major condition. Relatively small numbers of children have a diagnosis related to the same condition in each period. However, 5.58% of sample children have a major injury in every period.

There is clearly state dependence in diagnoses. For asthma, a child who is diagnosed with asthma has about a 50% chance of being diagnosed with asthma in the next period, whereas a child with no diagnosis has about a 10 to 20% probability of having a diagnosis in the next period. For ADHD/conduct disorder, children diagnosed in the first period have a 20% chance of having a medical contact for this diagnosis in the second period; and children with a previous diagnosis become more likely to be diagnosed in the current period as they age. Even for major injuries, a child who has a major injury in the current period has about a 50% chance of having a diagnosis for major injury in the next period, while a child without a diagnosis this period, has only a 30 to 40% probability of such a diagnosis in the next period.

Still, the variation in our data over time periods suggests that in each period, some children without initial health conditions develop them, and other children with health conditions recover from them. Such variation is the key if we are to be able to use the data to examine the impact of health conditions at different ages.

The outcome variables we examine are created by linking the health care registry information to administrative data on education, and social assistance.[5] We link education enrollment records with the provincial registry to determine whether a student has attained Grade 12 by age 17. This measure is available for all birth cohorts. Overall, about 70% of children are in grade 12 by age 17. Not attaining grade 12 by this age could indicate that a student entered school late, has been held back in a grade at least once, or has dropped out. Hence, we also

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[5] These data are available only for Manitoba residents. The analysis of the effects of health on these longer-term outcomes, therefore, is conditional on both survival and on remaining a resident in the province. This issue is discussed further in the data appendix.

looked at whether the child was in school at age 17, but did not find significant effects of early health on this measure. Therefore, it seems that "grade 12 by age 17" mostly captures the effect of starting school late or of being delayed.

We also have information from provincial language arts standards tests taken in grade 12. These tests contribute 30% to the students' final course grade. Individuals pass the language arts test by scoring 50% or more on a comprehensive exam.[6] The score on the test is normalized to have a mean of zero and a standard deviation of one for the entire population of students in Manitoba. Within each birth cohort, some test scores are missing and we have imputed scores for these children based on the reasons for the failure to write the test, as discussed further in the data appendix.

Students in the province can select into one of several math tracks. While the courses offered differ by year and school, they always include courses that would prepare the student for college level mathematics. In each year we classify high school courses into college versus non-college preparatory mathematics based on the difficulty of the course and the course material. The number of college preparatory math courses available increased over our sample period, and as a result the number of students in college preparatory courses also increased. In our empirical analysis, year fixed-effects will help to account for this trend.[7] We calculate that 22% of the sample took college-preparatory math courses.

Finally, the sample of Manitoba residents is matched to monthly social assistance records (the provincial welfare program). Residents become age-eligible to participate in welfare in

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[6] The test focuses on reading comprehension, exploring and expanding on ideas from texts, the management of ideas and information, and writing and editing skills.

[7] To further ensure that our results are not overly sensitive to the fact that the number of courses increases, we estimated alternative models using information on the grade obtained in the course and assign students with a grade of 80% or better to college-level math. Results using this specification are quite similar to the results using just the course assignment and we present our results using only the course assignment here.

their own right (rather than as a dependent child) on their 18th birthday. Our youngest birth cohort can only be followed for 1.25 years after the age of 18. While the older cohorts can be tracked for longer, we define our social assistance exposure window to be a consistent 1.25 years for each cohort (or 70 weeks). Using this exposure window, 6% of our sample went on social assistance in the 70 weeks after they became eligible on their 18th birthday.

Note that our last age group, 14 to 18, encompasses the ages when some of our outcomes are measured. This, combined with the fact that some people might delay seeking treatment for conditions first noted at say age 16, leads us to consider the health measures for 14 to 18 as roughly contemporaneous with the outcomes we are examining. Hence, we have measures of early health, health in middle childhood, and measures that are roughly contemporaneous with the outcomes examined.

Appendix Table 1 shows the means of the other variables that we control for in our models. The administrative and registry records provide information on the characteristics of the mother at the birth of the child, and on the number of children in the family. We use 2004 as the fixed point to determine family size and the birth order of the child. This year, many years after the final birth cohort used in the analysis (1987), was chosen in order to try to ensure that families were past the childbearing phase.

4. Conceptual Framework

The simplest model that captures key elements of our approach is:

(1) $Y_t = aH_t^{\alpha}C_t^{\beta}$

(2) $c_t = b_0 + b_1 c_{t-1} + b_2 h_{t-1}$

(3) $h_t = \gamma h_{t-1} + u_t$

where Y_t is a young adult outcome, H_t is contemporaneous health, C_t is contemporaneous cognitive ability, and h_t and c_t are log health and log cognitive ability, respectively. We assume that outcomes are produced using inputs of health and cognitive ability, and that cognitive ability depends on ability last period and also on health last period. Finally, health depends on health last period, and is subject to random problems, u_t. Solving the model recursively yields an equation of the form:

(4) $\log(Y_t) = \delta + \delta_1 c_{t-4} + \delta_2 h_{t-4} + \delta_3 u_t + \delta_4 u_{t-1} + \delta_5 u_{t-2} + \delta_6 u_{t-3}$

where, in our context, $(\delta_1 c_{t-4} + \delta_2 h_{t-4})$ represent endowments at birth, u_t is a contemporaneous health problem, and u_{t-3} is a health problem in the first 3 years of life. The coefficients δ_3 to δ_6 are given by:

$\delta_3 = \alpha$

$\delta_4 = \alpha\gamma + \beta\, b_2$

$\delta_5 = \gamma\delta_4 + \beta\, b_2\, b_1$

$\delta_6 = \gamma\delta_5 + \beta\, b_2\, b_1^2$.

We can consider several interesting special cases:

Case 1. $b_2 = 0$ so that cognition does not depend on health. If it is also true that $\gamma=1$ then all health problems have the same effect. If $\gamma < 1$ then health depreciates, and the effects of health problems die out over time. In this case, more recent health problems always have a larger effect. In order for early health problems to have a large effect in this model, it must be the case that $b_2 > 0$.

Case 2: $b_2 > 0$ and $\gamma=1$. Now early health problems matter more than later health problems. The reason is that early health problems affect the development of cognitive ability through multiple periods.

Case 3. if $b_2 > 0$ and $\gamma < 1$ then it is possible to generate many interesting patterns in the data, even with this simple model. For example, if $\alpha=\beta=.5$; $b_1=1.5$; $b_2=.2$; $\gamma=.7$, then $\delta_3= .5$, $\delta_4 = .45$, $\delta_5= .47$, $\delta_6= .56$ then health problems in the first year of life and contemporaneous health problems matter most. In other words, the pattern of coefficients is U-shaped rather than monotonically increasing or decreasing.

The intuition is that there are two different mechanisms at work. On the one hand, early health problems affect early cognitive ability, which affects future cognitive ability. Hence, the effects of these early problems cumulate. Second, people tend to recover from health problems over time, so that the main effect of the health problem per se diminishes with time.

The empirical analogue of (4) is given by:

(5) $OUTCOME = a + b_1X + b_2HEALTH_0 + b_3HEALTH_{0\text{-}3} + b_4HEALTH_{4\text{-}8} + b_5HEALTH_{9\text{-}13} + b_6HEALTH_{14\text{-}18} + e$,

where OUTCOME is one of the young adult outcomes described above, X is a vector of controls including marital status, sex of the child, and mother's age at birth, dummy variables for birth order of the child, and year of birth indicators, $HEALTH_0$ are measures of health at birth and $\{HEALTH_{0\text{-}3}, HEALTH_{4\text{-}8}, HEALTH_{9\text{-}13}, HEALTH_{14\text{-}18}\}$ is a vector of age specific health problems. We use a number of different measures of health, as described above.

These models show the correlations between young adult outcomes and an individual's health history, but they may be biased by omitted characteristics of families, including characteristics that affect young adult outcomes, the health of children in the family and the propensity of the family to seek medical care.

Hence, our main focus is on models of the following form:

(6) $OUTCOME_{ya} = a + b_1X + b_2HEALTH_0 + b_3HEALTH_{0\text{-}3} + b_4HEALTH_{4\text{-}8} + b_5HEALTH_{9\text{-}13} + b_6HEALTH_{14\text{-}18} + MOTHER + e$,

where MOTHER is an indicator for each mother in the data. The inclusion of mother fixed effects will help us to control for many unobserved family background characteristics that may be correlated with the propensity to use medical care, true health status, and with young adult outcomes. The fact that we observe families over a relatively short period of time is also helpful, as siblings will be less likely to be exposed to different environments over a short time than over a long time. We estimate all of our models using linear probability models for dichotomous outcomes both for ease of interpretation, and for ease of including fixed effects.

This model will allow us to interpret the time pattern of health insults. For example, if children largely recover from initial health problems over time, then one would expect measures taken in the teen years to be more highly related to young adult outcomes than measures taken in early childhood. On the other hand, if “skill begets skill” then it may be the case that problems at early ages cause children to stay on a lower trajectory than they would otherwise have obtained. If there is some truth to both arguments, then problems at both older and younger ages will be important.

5. Estimation Results

In order for models that include family fixed effects to be informative there must be variation within families in both the health problems children experience and the outcomes observed later in life. To explore the extent of this variation we report the average difference in each outcome for families with children who have different health measures in each age group.

The results are reported in Table 3, and the mean differences for each health measure are plotted in Figures 1 to 4.

The first column of Table 3 reports the number of siblings with different health measures at each age. So, for example, there were 3177 pairs of siblings with differences in whether they were ever treated for asthma between age 0 to 3. The remaining columns report the average difference in outcomes for these pairs. In each case the difference is reported as the outcome for the child with the worse health measure minus the outcome for the child with the better health outcome.

Many of the mean differences reported in Table 3 are significantly different than zero. They are all of the anticipated sign except for the case of asthma at age 0 to 3. Although siblings with an asthma diagnosis are more likely that those without to lag behind in school and they score lower on literacy tests, they are less likely to be on welfare in young adulthood. As shown in Figure 1, sibling differences for asthma show inconsistent patterns across outcomes. Asthma in early childhood seems to have a large effect on the literacy score, with the effect on literacy declining with age.

Figure 2 shows that sibling differences in major injuries have surprisingly little effect on welfare use, but quite consistent negative effects on school outcomes which grow larger with child age. Consistent with what we will show below, Figure 3 indicates that sibling differences in externalizing mental health conditions have large effects of the anticipated sign on all our outcomes, and that these effects grow larger as children age.

Children with other major conditions have consistently worse outcomes than their siblings, as shown in Figure 4. Table 3 shows that most of the mean differences are statistically significant. These effects show a variety of age patterns – the effects of major conditions on welfare use increase with age, while the effect on school progression is constant from age 4 on. The effects on college preparatory math are greatest for older children, while the mean differences for literacy follow an inverse U.

Finally, Table 3 indicates that children with congenital or perinatal problems do worse than their siblings in terms of both welfare use and the schooling measures. The estimates are generally much larger for children with medical contacts at older ages, which probably reflects selection: Only the most serious congenital or perinatal problems require follow up at older ages.

We next turn to estimation of models of the effects of birth weight which show that we can replicate the results of earlier studies that focused exclusively on this measure. We will then use these estimates as a baseline to see how the inclusion of health measured at later ages changes inferences about the about the effect of birth weight.

The first panel of Table 4 presents Ordinary Least Squares estimates of the effects of birth weight. These models include all of the controls listed in Appendix Table 1. The estimates suggest that lower birth weight has negative effects on all of our outcomes. Moreover, the effects are monotonic: The lower the birth weight of the surviving infant, the more likely the young adult is to be on social assistance, the less likely they are to have been in grade 12 by age 17, the lower the probability that they take college preparatory math, and the lower their literacy score.

The second panel shows that including mother fixed effects (so that lower birth weight siblings are compared to their own siblings of higher birth weight) reduces, but does not entirely eliminate these effects. It becomes difficult to identify the effects of birth weight less than 1000 grams, probably because there are relatively few surviving children in this birth weight category, though birth weight in this category is estimated to have large negative effects on the probability of being in grade 12 by age 17 and on the literacy score.

For welfare use and grade 12 by age 17, there are however significant effects of birth weight between 1000 and 1500 grams which are larger in absolute value that the effects of birth weight between 1500 and 2500 grams. These estimates suggest that children of lower birth weight are indeed more likely to end up on welfare, and are less likely to have reached grade 12 by age 17. The estimated effects on literacy scores are monotonic, and suggest increasing scores with birth weight.

The contrast between the two panels of Table 5 shows the importance of adequately controlling for family background when examining the effects of ill health. In the remaining tables, we focus on models that include mother fixed effects.

Table 5 shows estimates of a model similar to (6) except that we include only measures of health at 0 to 3. There has been a good deal of popular discussion of the idea that the earliest ages are a uniquely vulnerable period, so it is of interest to see if health conditions at these ages have long term effects.

When we control for all of these health conditions (in contrast to Table 3) we find no significant effects for asthma. For major injuries, there is a significant negative effect on grade 12 by age 17. ADHD/conduct disorder has much stronger effects which are significant for every outcome except college preparatory math. The estimates indicate that children with an early diagnosis of one of these conditions are 1.6 percentage points more likely to end up on welfare immediately after becoming eligible (on a baseline of 5.5%). They are also 4.4% less likely to be in grade 12 by age 17, and obtain scores that are .06 of a standard deviation less on the literacy test.

The number of other major conditions has a strong effect, which is significant across the board. An additional major condition increases the probability of being on welfare by 18%. The probability of being in grade 12 by age 17 is reduced by about 1%, the probability of taking college preparatory math is reduced by 3%, and the literacy score is reduced by .15 of a standard deviation. Finally, congenital and perinatal problems are important determinants of future outcomes, with significant effects on 3 out of the 4 outcomes.

The addition of these controls reduces but does not eliminate the effect of low birth weight. Indeed, the pattern of significant effects is much the same as it was in Table 4. Hence, on the one hand, low birth weight continues to exhibit negative effects on future outcomes net of the effects of health at early ages. On the other hand, a reduction in the magnitude of the estimated effects suggests that some of the long term effect of low birth weight comes about because low birth weight is predictive of future conditions such as ADHD or conduct disorder, and/or other major health conditions.

But this observation raises the question of how much of the effect of early health conditions is due to the fact that they are predictive of later health conditions? Table 6 takes up this question by adding all but the contemporaneous health measures to the model. There are some small negative effects of asthma in this table: A diagnosis at age 4 to 8 is estimated to increase the probability of welfare use, and a diagnosis at age 9 to 13 is estimated to reduce the probability of taking college preparatory math. Major injuries at 0 to 3 no longer have any significant effect, while a major injury at age 9 to 13 has a significant negative effect on all of the schooling variables: A major injury at this age is estimated to reduce the probability of being in grade 12 by age 17 or of taking college preparatory math by 2%, and to reduce the literacy test score by .035 of a standard deviation.

The estimated effects of ADHD/conduct disorder at 0 to 3 are reduced and remain significant only for the probability of being in grade 12 by 17. However, a diagnosis of this type at school entry (ages 4 to 8) has large negative effects, and a diagnosis at age 9 to 13 has effects which are even larger. The estimates suggest that a child who was seen for one of these disorders at both ages would be 6.8 percentage points more likely to be on welfare after age 18, 35% less likely to be in grade 12 by age 17, and 50% less likely to take college preparatory math, and that these children also have scores on the literacy test that are half a standard deviation lower than others on average.

The addition of controls for health at later ages also reduces the estimated effects of the number of major conditions from 0 to 3, though a significant effect on welfare use, and the probability of taking college preparatory math remains. The probability of welfare use appears to be impacted similarly by the number of major conditions at each age, while the number of conditions has an increasingly negative effect on the probability that a child is in grade 12 by age 17. Only major conditions at 9 to 13 are estimated to significantly impact the literacy score.

Finally, Table 7 shows estimates from a model of the form (6) which includes both childhood health conditions, and conditions for those 14 to 18. When asthma in the oldest age group is controlled, the estimated effect of asthma at 4 to 8 on welfare use, and the estimated effect of asthma from 9 to 13 on college preparatory math become slightly smaller and are significant only at the 90% level of confidence.

A major injury at age 9 to 13 remains a significant determinant of schooling outcomes, and the coefficients are little changed by the addition of a measure of major injuries at 14 to 18. Moreover, injuries at the two ages have fairly similar effects on these outcomes.

ADHD/conduct disorders at school entry and at age 9 to 13 also continue to have large effects on all outcomes, even when additional diagnoses at age 14 to 18 are controlled for.

Turning to other major conditions, the number of major conditions at age 0 to 3 and at age 4 to 8 continues to be a significant predictor of eventual welfare use in young adulthood. But the number of health conditions during childhood has no effect on the schooling outcomes when the number of conditions at age 14 to 18 is controlled.

The models shown in Tables 6 and 7 also included controls for birth weight categories, but the estimated coefficients were almost identical to those shown in Table 5. That is, adding additional controls for health at older ages did not alter the size or significance of the birth weight coefficients.

These estimates suggest that while childhood health conditions do affect outcomes through their effects on future health, some conditions have additional effects on outcomes independent of future health. In particular, early diagnoses of mental health conditions have strong effects independent of future diagnoses of these and other conditions, and other early major health conditions impact the probability of being on social assistance after age 18.

6. Extensions

While the ADG system is a well established way to construct health measures from underlying ICD9/ICD10 codes, some arbitrariness in grouping diagnoses and in classifying diagnoses as major or minor is inevitable. The fact that the software was written by a third party with no vested interest in our study is a significant advantage. Still, it is tempting to try to look at a greater number of individual diagnoses.

It is especially tempting to try to break down the injury category, since it is so large. We have tried to estimate the effect of serious head injuries (skull fractures and intracranial injuries including concussion) since there is a literature positing long term effects of such injuries (Hawley et al, 2008). However, although 4 to 7% of children have such injuries in each age group, we did not find any statistically significant effects. It is possible that to do so may require larger samples.

Our findings with regard to ADHD/conduct disorders are provocative and beg the question of how other mental illnesses affect child outcomes. We have repeated our analyses with a somewhat broader measure of mental health conditions defined using all of the conditions included in ADG 24 "Recurrent or Persistent, Stable Psychosocial conditions" the ADG category that includes both ADHD and conduct disorder. This exercise produced similar though somewhat larger estimates of the effects of mental health conditions.

Reliance on administrative data entails some limitations on our analysis. For example, we have no information about measures of socioeconomic status (SES) such as parent's income or education. SES-related gaps in maternal reports of child health status tend to grow with child age in both the United States and Canada (Case, Lubotsky and Paxson, 2002; Currie and Stabile, 2003). And poor children receive more insults to their health than richer children, including more injuries, chronic conditions and acute conditions (see for example, Newacheck, 1994; Newacheck and Halfon, 1998; Currie and Lin, 2007; Case, Lubotsky and Paxson, 2002). Hence, it would be of great interest to break down our results by SES.

We constructed a measure of socioeconomic status (SES) using income measured at the enumeration area level (an area similar to a U.S. Census tract with 400 to 700 people) from the1986 Canadian Census. We used the area in which the child's family resided as of Dec. 31, 1987 (see the data appendix for further discussion) and ranked enumeration areas by their median incomes. We then used residence in the bottom two quintiles of enumeration areas as an indicator of "lower SES" (the results were similar if we focus on residence in the lowest quintile as our measure). Other work using these data suggests that the correlation between individual-level income and median income in the enumeration area is about .44 (Roos et al, 2005).

Our outcome measures show a clear gradient by this measure which suggests that it is capturing real differences between groups. For the entire sample of siblings, 5.5% of the full sample are on social assistance compared to 9.5% of the low SES sample. The comparable figures for reaching grade 12 by age 17 are 69% vs. 53%, while for college preparatory math and the normalized literacy score they are 21.4% vs. 14.8% and 0 vs. -.34.

When we attempt to estimate separate models for the lower SES group, some of the point estimates are higher for the low SES than for the full sample. However, the standard errors are also higher so that it is difficult to draw any firm conclusions about whether the long term effects of health conditions in childhood are greater for those of low SES from these data.

The outcomes that can be tracked are also limited by the availability of administrative data sets that can be merged to the health records. It would be very interesting to be able to measure adult earnings or employment status, but this information is currently unavailable.

6. Discussion and Conclusions

The strengths of our study include: a large sample; virtually complete coverage of the population from birth to follow-up; a long follow up period; and the use of objective health measures rather than self-reports or retrospective measures. The fact that we observe multiple children from the same family is an additional strength because sibling comparisons enable us to control statistically for many unobserved characteristics of families that could be related to health and propensity to seek care.

Large numbers of children suffer from health problems in childhood. Previous research across a number of countries has shown that there is a strong link between socioeconomic status and poor health (see Adler and Ostrove (1999), Marmot and Wilkinson (1999), and Cutler and Lleras-Muney (2006) for reviews) and that low socioeconomic status in childhood is related to poorer future adult health. But it has not been clear whether health problems in early childhood had any effect on determinants of SES over and above their effects on future health. The paucity of data on health in early childhood has severely limited research in this area.

Our research offers several striking conclusions. First, low birth weight continues to be predictive of long term negative effects even after measures of subsequent health conditions are included in the models. Moreover, the estimates are remarkably similar to those obtained in models without such measures. The main exception is that the effects of birth weight between 1500 and 2500 grams (higher birth weight low birth weight babies) are no longer significant when future health measures are controlled. Birth weight less than 1500 grams has pronounced effects on future outcomes apart from its effects on future health.

Turning to health conditions at age 0 to 3, the measures that are most predictive of negative future outcomes are the number of "other" major conditions and whether the child has a diagnosis related to ADHD/conduct disorders. A child with two other major diagnosis over this interval is predicted to be 3% more likely to end up on social assistance after age 18, 1.6% less likely to be in grade 12 by age 17, 2% less likely to take college preparatory mathematics courses in high school, and has a literacy score that is .03 of a standard deviation lower than their own sibling. A diagnosis related to ADHD or conduct disorders has a similar effect on the probability of social assistance use, but a much larger negative effect on being in grade 12 by age 17 (a 6% reduction relative to baseline) and on the literacy score (a reduction of .06 of a standard deviation).

Conditional on health at later ages the number of major conditions at 0 to 3 continues to be an important predictor of social assistance use. But its effects on schooling attainment disappear when future health measures are added to the model suggesting that many early child health conditions affect schooling attainments mainly through their effects on later health.

In contrast, the estimated effects of diagnoses related to ADHD or conduct disorders at school entry (age 4 to 8) are large and largely unaffected by controlling for later diagnoses of these or other health conditions. Children with a stable diagnosis of ADHD or conduct disorder from 4 to 18 are more than 10 percentage points more likely to end up on social assistance, more than 30 percentage points less likely to be in grade 12 by age 17, over 15 percentage points less likely to take college preparatory mathematics courses, and also have literacy scores more than a half a standard deviation lower than unaffected siblings. Major injuries sustained at ages 9 to 13 have significant effects on our measures of academic achievement, which are robust to the inclusion of health measures at age 14 to 18.

In sum, our results suggest considerable heterogeneity in the long term effects of specific early child health conditions. Birth weight less than 1500 grams has long term effects regardless of future health. Many other early health conditions affect future schooling outcomes mainly through their effects on future health, though they remain predictive of future use of social assistance programs. This may in some sense be good news in that it suggests that better treatment of medical conditions as late as high school can help some children to succeed in school.

However, mental health problems at early ages have large and robustly estimated effects on future schooling and social assistance outcomes, regardless of whether they go on to lead to mental health diagnoses at later ages. This result suggests that better screening and treatment of young children with mental health problems, and/or education geared to these children might have a significant effect on eventual schooling attainments.

Our overall conclusion is that health problems in early childhood may be significant determinants of adult socioeconomic status, even in a country like Canada where all children have access to health insurance.

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Table 1: Means of Health Variables at Various Ages

Diagnoses related to:	0 to 3	4 to 8	9 to 13	14 to 18
Asthma	0.081	0.125	0.144	0.120
Major Injury	0.412	0.412	0.386	0.404
ADHD/Conduct disorder	0.033	0.037	0.038	0.030
Congenital/Perinatal Problem	0.156	0.016	0.012	0.013
Any other major condition	0.154	0.148	0.153	0.219
Any of the above	0.599	0.563	0.544	0.642
Number of Major diagnoses	0.208	0.228	0.216	0.335
	[0.580]	[0.691]	[0.628]	[0.806]
Maximum # major diagnoses	11	12	10	14
Number Total diagnoses major and	10.500	10.320	9.45	10.01
minor	[5.28]	[5.72]	[5.76]	[6.48]
Number of Observations	50404			

Notes: Standard deviations of continuous variables in brackets.

Table 2: Pattern of Health Conditions Across Age Groups

Age Pattern	Asthma	Major Injury	ADHD/ Conduct Disorder	Other Major Condition
0000	71.69	17.94	89.82	52.64
0001	4.29	7.97	1.37	12.02
0010	4.70	6.47	1.67	6.28
0011	2.46	5.00	0.70	2.99
0100	4.03	7.62	1.99	6.46
0101	0.54	4.70	0.12	1.72
0110	1.95	4.47	0.50	1.54
0111	2.26	4.59	0.51	0.97
1000	3.45	8.73	2.46	7.45
1001	0.30	4.52	0.07	2.05
1010	0.35	4.31	0.12	1.15
1011	0.30	3.85	0.06	0.6
1100	1.07	5.70	0.35	1.77
1101	0.27	4.23	0.02	0.63
1110	0.79	4.32	0.10	0.79
1111	1.55	5.58	0.13	0.93

Notes: Reported numbers are percentages. N=50404.
Patterns reflect whether the child had a diagnostic code for a particular condition in each of the age categories 0-3, 4-8, 9-13, and 14-18.
E.g. 0000 denotes have no diagnoses for any of the 4 age categories, while 0001 denotes having a diagnosis between ages 14-18 only

Table 3: Mean Differences Between Sibling Pairs with Divergent Health Measures

	# Sib pairs w diff	Diff in on SA	Diff in grade 12 by 17	Diff College Math	Diff in Literacy
Asthma 0-3	3177	-0.010	-0.016	0.005	-0.088
		[0.005]	[0.008]	[0.008]	[0.017]
4 to 8	4427	0.000	-0.004	0.003	-0.041
		[0.004]	[0.007]	[0.007]	[0.015]
9 to 13	5217	-0.005	-0.004	-0.015	-0.028
		[0.004]	[0.006]	[0.007]	[0.014]
14-18	4675	0.010	-0.010	-0.018	-0.017
		[0.004]	[0.007]	[0.007]	[0.014]
Major Injury 0-3	10789	0.002	-0.016	-0.005	-0.041
		[0.002]	[0.004]	[0.004]	[0.010]
4 to 8	10928	-0.003	-0.016	-0.006	-0.045
		[0.003]	[0.004]	[0.004]	[0.009]
9 to 13	10798	-0.001	-0.025	-0.021	-0.077
		[0.003]	[0.004]	[0.004]	[0.009]
14-18	11055	0.004	-0.033	-0.026	-0.082
		[0.003]	[0.004]	[0.004]	[0.009]
ADHD/Conduct Disorder	1438	0.011	-0.052	-0.018	-0.084
		[0.008]	[0.013]	[0.012]	[0.026]
4 to 8	1619	0.029	-0.144	-0.062	-0.322
		[.009]	[0.013]	[0.011]	[0.025]
9 to 13	1650	0.038	-0.208	-0.094	-0.463
		[0.008]	[0.013]	[0.010]	[0.024]
14-18	1332	0.070	-0.215	-0.117	-0.468
		[0.011]	[0.015]	[0.011]	[0.026]
Other Major Conditions 0-3	6103	0.011	-0.005	-0.012	-0.021
		[0.004]	[0.006]	[0.006]	[0.012]
4 to 8	5986	0.014	-0.020	-0.015	-0.035
		[0.004]	[0.006]	[0.006]	[0.012]
9 to 13	6147	0.011	-0.019	-0.009	-0.038
		[0.004]	[0.006]	[0.006]	[0.012]
14-18	8103	0.035	-0.020	-0.023	-0.029
		[0.003]	[0.005]	[0.005]	[0.011]
Congenital Anomalies	5868	0.004	-0.009	-0.014	-0.031
& Perinatal Problems 0-3		[0.004]	[0.006]	0.006]	[0.012]
4 to 8	755	0.033	-0.058	-0.01	-0.091
		[0.011]	[0.016]	[0.016]	[0.033]
9 to 13	585	0.042	-0.045	0.003	-0.113
		[0.012]	[0.019]	[0.018]	[0.040]
14-18	606	0.033	-0.032	-0.01	-0.093
		[0.013]	[0.018]	[0.017]	[0.039]
Mean of Outcome:		0.055	0.691	0.214	-0.014

Notes: Standard Errors in brackets. Table shows the average over the differences between sibs with a health condition and sibs without a health condition, for all sibling pairs where there is a difference in the specified health condition.

Table 4: Effects of Birth Weight on Future Outcomes

	On Social Assistance	Grade 12 by 17	College Math	Literacy Score
Ordinary Least Squares Estimates				
Birth weight<=1000 grams	0.095	-0.268	-0.148	-0.334
	[0.037]	[0.067]	[0.066]	[0.148]
1000<Birth weight<=1500	0.064	-0.063	-0.062	-0.171
	[0.017]	[0.031]	[0.031]	[0.069]
1500<Birth weight<=2500	0.025	-0.610	-0.028	-0.118
	[0.05]	[0.009]	[0.009]	[0.020]
2500<Birth weight<=3500	0.005	-0.019	0.016	-0.054
	[0.002]	[0.004]	[0.004]	[0.008]
R-squared	0.075	0.237	0.079	0.232
Sibling Fixed Effects Estimates				
Birth weight<=1000 grams	-0.001	-0.280	-0.125	-0.395
	[0.047]	[0.079]	[0.080]	[0.166]
1000<Birth weight<=1500	0.055	-0.074	0.019	-0.068
	[0.023]	[0.038]	[0.039]	[0.080]
1500<Birth weight<=2500	0.016	-0.052	-0.015	-0.039
	[0.007]	[0.012]	[0.012]	[0.025]
2500<Birth weight<=3500	0.000	-0.018	-0.015	-0.022
	[0.003]	[0.005]	[0.012]	[0.010]
R-squared	0.609	0.731	0.648	0.752
Mean of Outcome:	0.055	0.691	0.214	-0.014
# Observations	50404			

Notes: Models include all of the controls listed in Appendix Table 1. Standard errors in brackets.

Table 5: Sibling Fixed Effects Regressions of Outcomes on Early Health Conditions

	On Social Assistance	Grade 12 by Age 17	College Math	Literacy Score
Asthma 0-3	-0.004	-0.003	0.005	-0.019
	[0.005]	[0.008]	[0.008]	[0.017]
Major Injury 0-3	0.004	-0.008	-0.002	-0.010
	[0.003]	[0.004]	[0.004]	[0.009]
ADHD/Conduct 0-3	0.016	-0.044	-0.011	-0.058
	[0.007]	[0.012]	[0.012]	[0.025]
# Other Major	0.010	-0.006	-0.007	-0.015
Conditions 0-3	[0.002]	[0.003]	[0.003]	[0.006]
Birth weight<=1000 grams	-0.026	-0.263	-0.099	-0.348
	[0.047]	[0.079]	[0.080]	[0.167]
1000<Birth weight<=1500	0.038	-0.061	0.038	-0.035
	[0.023]	[0.038]	[0.039]	[0.081]
1500<Birth weight<=2500	0.011	-0.046	-0.007	-0.025
	[0.007]	[0.012]	[0.012]	[0.025]
2500<Birth weight<=3500	-0.001	-0.018	-0.007	-0.021
	[0.003]	[0.005]	[0.005]	[0.010]
# Congenital/Perinatal	0.004	-0.006	-0.011	-0.015
0-3	[0.002]	[0.004]	[0.004]	[0.007]
R-squared	0.609	0.731	0.648	0.752
Mean of Outcome:	0.055	0.691	0.214	-0.014
# fixed effects	22692			
# Obs.	50404			

Notes: Standard errors in brackets. Models also control for mother fixed effects and the control variables listed in Appendix Table 1.

Table 6: Sibling Fixed Effects Regressions of Outcomes on all Childhood Health Conditions

	On Social Assistance	Grade 12 by Age 17	College Math	Literacy Score
Asthma 0-3	-0.005	-0.004	0.007	-0.022
	[0.005]	[0.008]	[0.008]	[0.017]
Asthma 4-8	0.008	0.005	0.006	0.014
	[0.004]	[0.007]	[0.007]	[0.015]
Asthma 9-13	-0.004	0.004	-0.017	0.001
	[0.004]	[0.006]	[0.006]	[0.014]
Major Injury 0-3	0.004	-0.006	-0.002	-0.006
	[0.002]	[0.004]	[0.004]	[0.009]
Major Injury 4-8	0.001	-0.003	-0.002	0.000
	[0.002]	[0.004]	[0.004]	[0.009]
Major Injury 9-13	0.002	-0.012	-0.014	-0.035
	[0.003]	[0.004]	[0.004]	[0.009]
ADHD/Conduct 0-3	0.012	-0.031	-0.005	-0.032
	[0.007]	[0.012]	[0.012]	[0.025]
ADHD/Conduct 4-8	0.026	-0.081	-0.030	-0.166
	[0.007]	[0.011]	[0.012]	[0.024]
ADHD/Conduct 9-13	0.042	-0.161	-0.076	-0.314
	[0.007]	[0.011]	[0.011]	[0.024]
# Other Major	0.007	-0.002	-0.005	-0.006
Conditions 0-3	[0.002]	[0.003]	[0.003]	[0.006]
# Other Major	0.006	-0.006	-0.004	-0.009
Conditions 4-8	[0.002]	[0.003]	[0.003]	[0.007]
# Other Major	0.006	-0.008	-0.005	-0.015
Conditions 9-13	[0.002]	[0.003]	[0.004]	[0.007]
R-squared	0.611	0.734	0.649	0.755
Mean of Outcome:	0.055	0.691	0.214	-0.014
# fixed effects	22692			
# Obs.	50404			

Notes: Standard errors in brackets. Models also control for mother fixed effects and the birth weight categories, diagnoses related to congenital and perinatal problems at each age and the other control variables listed in Appendix Table 1.

Table 7: Sibling Fixed Effects Regressions of Outcomes on Childhood Health Conditions Conditional on Current Health

	On Social Assistance	Grade 12 by Age 17	College Math	Literacy Score
Asthma 0-3	-0.005	-0.004	0.007	-0.021
	[.005]	[0.008]	[0.008]	[0.017]
Asthma 4-8	0.007	0.007	0.007	0.018
	[0.004]	[0.007]	[0.007]	[0.015]
Asthma 9-13	-0.007	0.008	-0.013	0.011
	[0.004]	[0.007]	[0.007]	[0.014]
Asthma 14-18	0.008	-0.012	-0.011	-0.028
	[0.004]	[0.007]	[0.007]	[0.015]
Major Injury 0-3	0.004	-0.006	-0.002	-0.006
	[0.002]	[0.004]	[0.004]	[0.009]
Major Injury 4-8	0.000	-0.002	-0.001	0.002
	[0.002]	[0.004]	[0.004]	[0.009]
Major Injury 9-13	0.001	-0.011	-0.013	-0.033
	[0.003]	[0.004]	[0.004]	[0.009]
Major Injury 14-18	0.005	-0.015	-0.018	-0.027
	[0.002]	[0.004]	[.004]	[0.009]
ADHD/Conduct 0-3	0.010	-0.028	-0.002	-0.025
	[.007]	[0.012]	[0.012]	[0.024]
ADHD/Conduct 4-8	0.021	-0.071	-0.024	-0.145
	[0.007]	[0.011]	[0.012]	[0.024]
ADHD/Conduct 9-13	0.024	-0.121	-0.053	-0.234
	[0.007]	[0.012]	[0.012]	[0.025]
ADHD/Conduct 14-18	0.060	-0.132	-0.075	-0.268
	[0.008]	[0.013]	[0.013]	[0.027]
# Other Major	0.006	-0.001	-0.004	-0.004
Conditions 0-3	[.002]	[0.003]	[0.003]	[0.006]
# Other Major	0.005	-0.005	-0.004	-0.009
Conditions 4-8	[.002]	[0.003]	[0.003]	[0.007]
# Other Major	0.000	-0.004	0.001	-0.005
Conditions 9-13	[.002]	[0.004]	[0.004]	[0.008]
# Other Major	0.017	-0.012	-0.010	-0.025
Conditions 14-18	[.002]	[0.003]	[0.003]	[0.006]
R-squared	0.614	0.736	0.650	0.756
Mean of Outcome:	0.055	0.691	0.214	-0.014
# fixed effects	22692			
# Obs.	50404			

Notes: Standard errors in brackets. Models also control for mother fixed effects and the birth weight categories, diagnoses related to congenital and perinatal problems at each age and the other control variables listed in Appendix Table 1.

Figure 1: Mean Sibling Difference in Outcomes with Difference in Asthma at each age

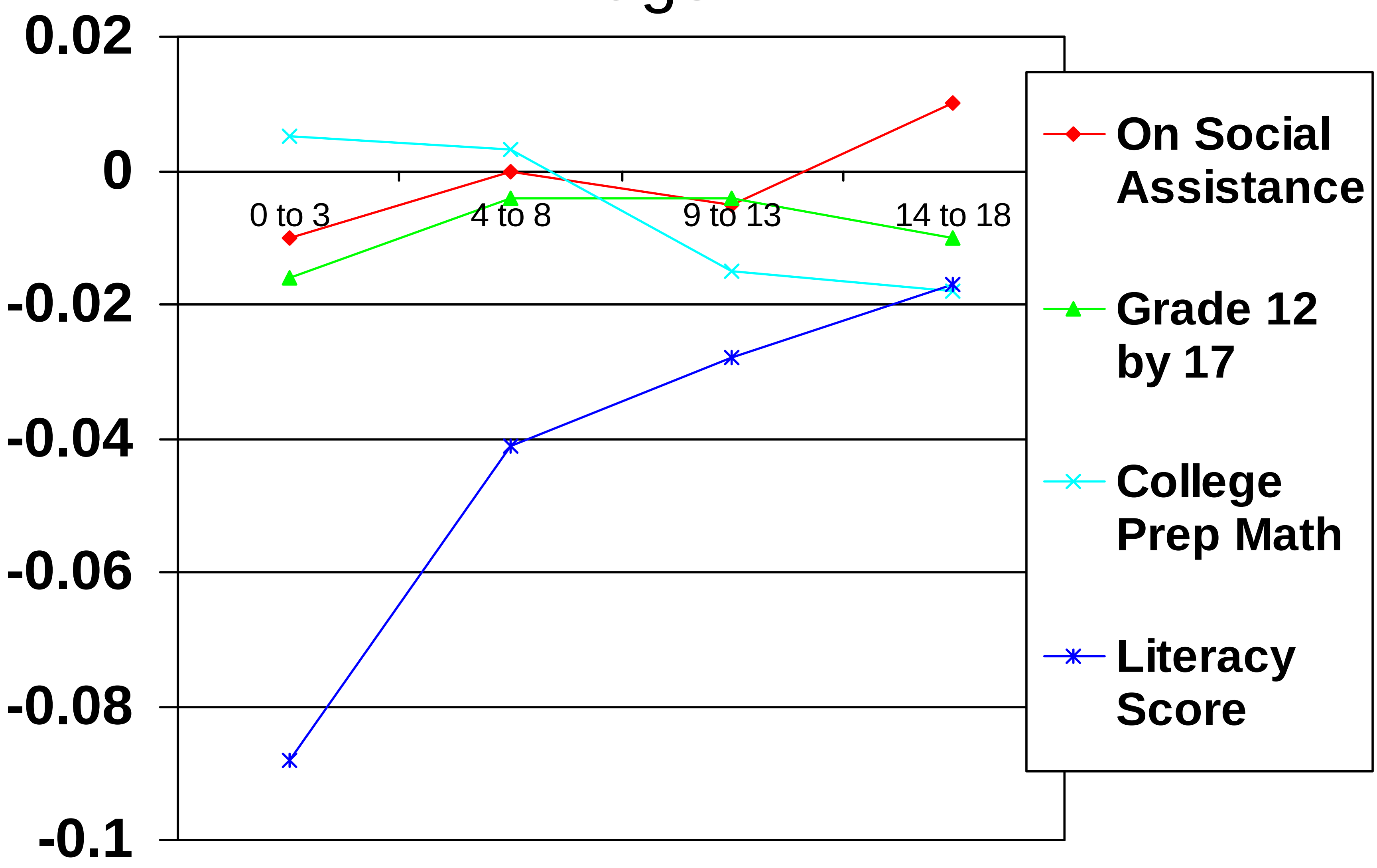


Figure 2: Mean Sibling Difference in Outcomes with Difference in Major Injury at each age

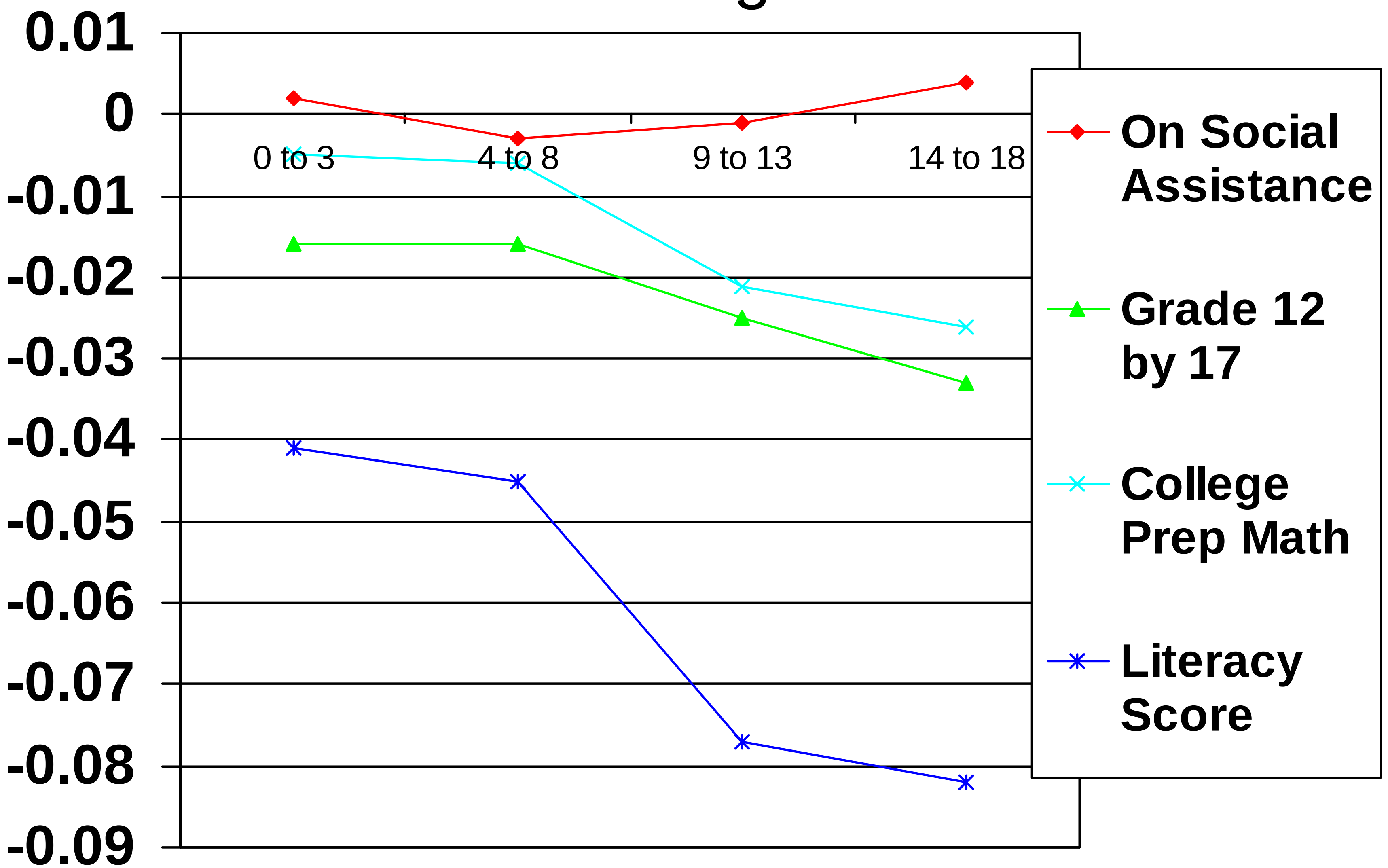


Figure 3: Mean Sibling Difference in Outcomes with Difference in ADHD/Conduct Disorder at each age

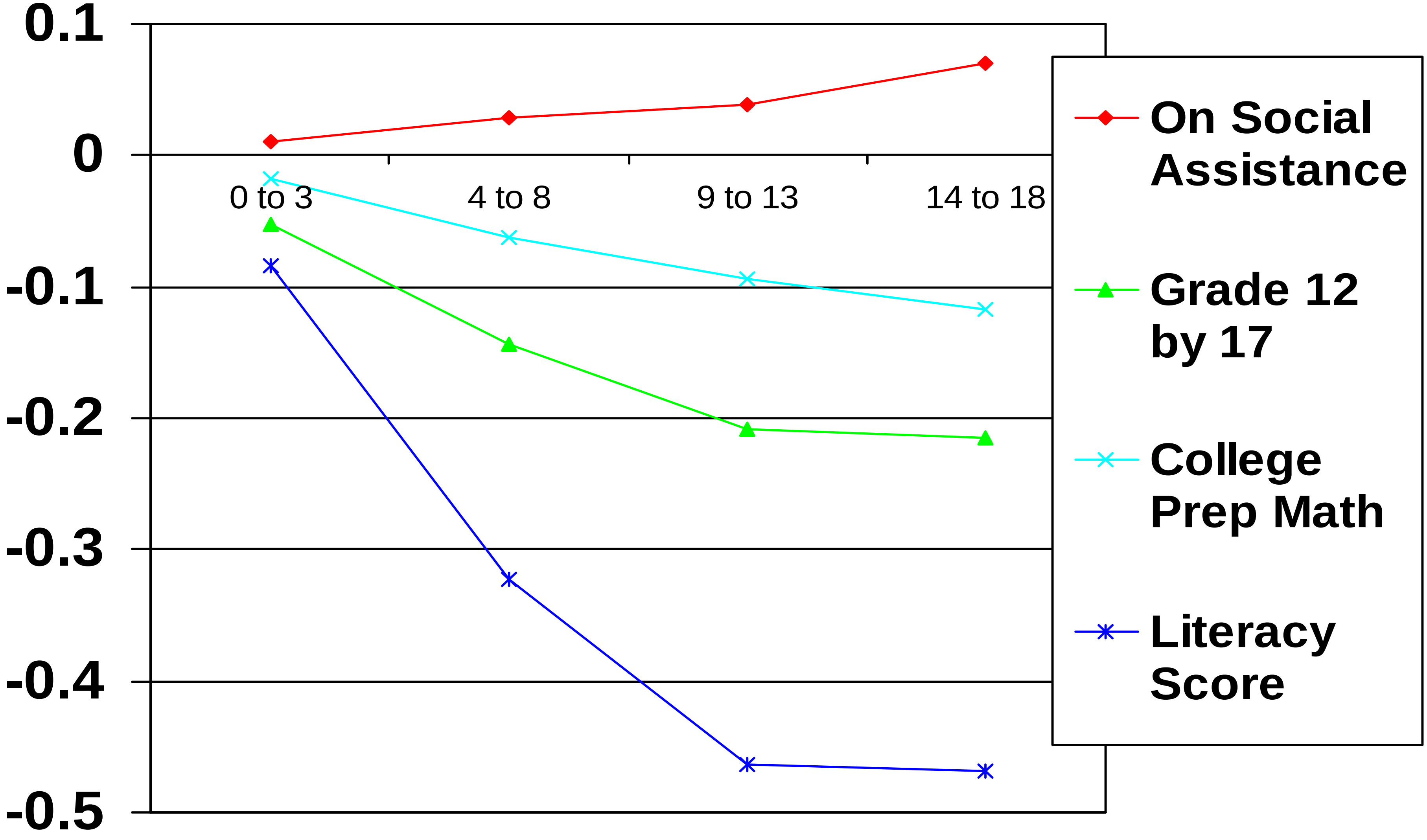
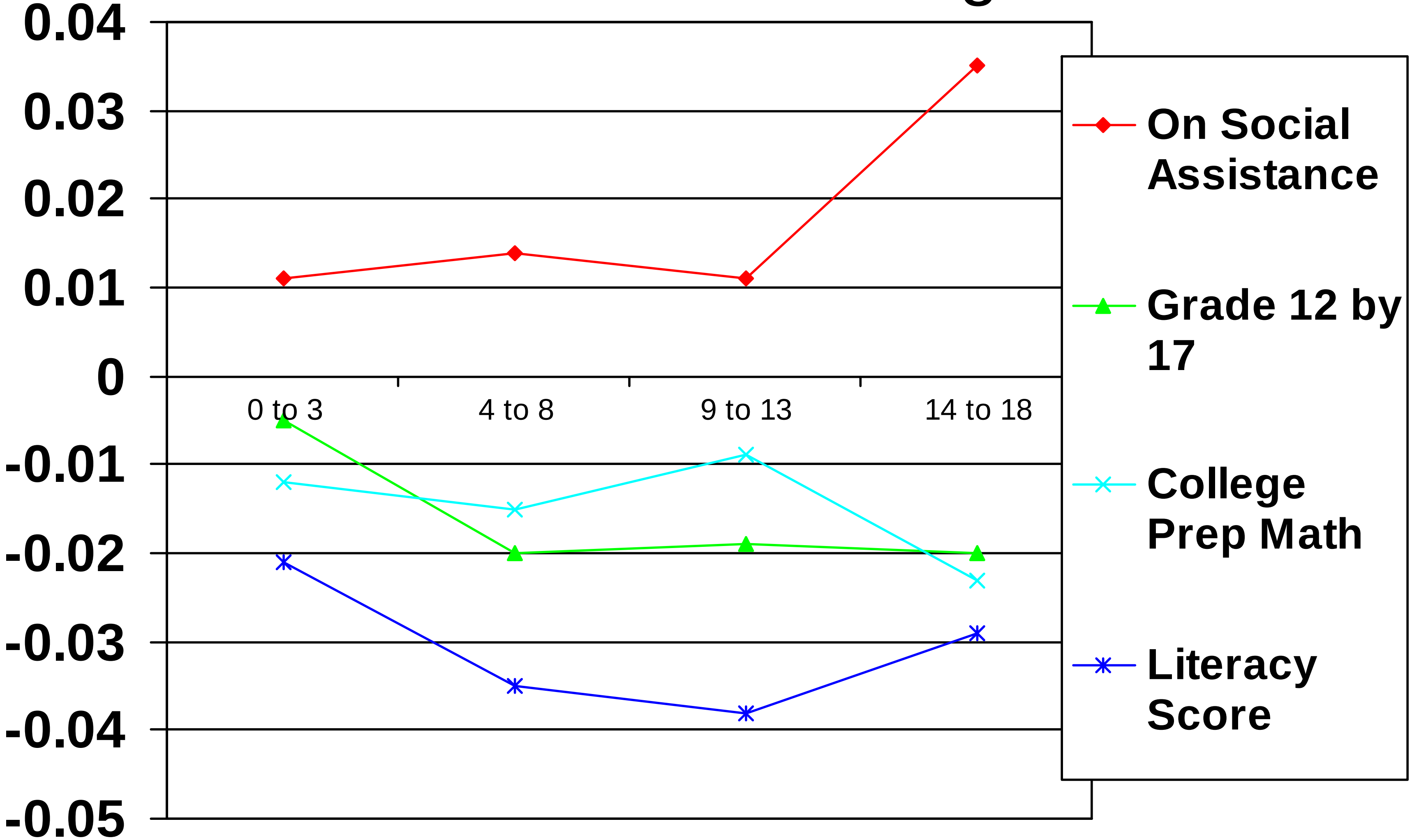


Figure 4: Mean Sibling Difference in Outcomes with Difference in #Other Major Conditions at each age



DATA APPENDIX:

The province of Manitoba was chosen for this study because of the unique ability to link the sources of data used in this paper. With a population of 1.17 million, Manitoba has the 5th largest population among Canada's provinces and territories. Within Canada, Manitoba has generally ranked in the mid-range of a series of indicators of health status, socioeconomics, and health care expenditures.

The data used in this study come from a number of sources. The birth data originate from Manitoba Health hospital records. The registry contains information on all births in Manitoba since 1970. Siblings are linked to mothers using hospital birth record information. The registry data allow us to specify the mother in all cases. Fathers are specified in 85 percent of cases. When an individual turns eighteen years old, he or she receives his or her own family identification number. On marriage, a female receives the identification number of her husband. Both the mother's identification number (an encrypted Personal Health Identification Number) and the family identification number are used to define siblings[1]. Several checks on this algorithm as applied to the nine years of birth cohorts (looking at missing data, the number of children designated as having the same mother and father, and complicated blended families) have indicated it to be highly accurate.

Information on the provincial language arts test is taken from education enrollment records and linked to the provincial registry. Taken in grade 12, these tests

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1 Siblings are noted as "full siblings" if they are children of the same mother (as noted on the birth record) and the same man is noted on the research registry (using the child's family identification number) as 'family head' at the time of the child's birth. Slightly over 85 percent of those identified as siblings (from having the same mother) meet the criterion set out above.

contribute 30 percent to the students' final course grade. Individuals pass the language arts test by scoring 50 percent or more on a comprehensive exam. The test focuses on reading comprehension, exploring and expanding on ideas from texts, the management of ideas and information, and writing and editing skills. For each birth cohort, we record the test score in 5 percentage point categories (13 in total, with a residual 14^{th} for students scoring between 0 and 35 percent) in the year that most students write the test. Within each birth cohort, approximately 40% of test scores are missing. We impute scores for missing students based on the reason for missing information (ranking them below the lowest scoring category among those who wrote the test).

The missing data categories, listed from highest to lowest rank are: absent (about 1 percent of each birth cohort sample); In grade 12 but not tested (about 8 percent); In grade 11 or lower (about 19 percent), Not enrolled (about 2 percent), and Withdrawn from School (about 10 percent). For the entire sample, we therefore have 19 test score categories. Following methods discussed by Mosteller and Tukey (1977) and Willms (1986), we compute a standardized score for each individual by assuming an underlying logit distribution, which is divided into pieces according to the percentage of cohort members in each category. Scores are calculated separately for each birth cohort because of small changes in the categories available and in the percentage distribution each year. In a typical year, the highest scorers are given an index score of 2.96, while those withdrawn from school are given a score of -1.84. The logit transform produces an index with an overall mean of zero and a standard deviation of one. The ordering on this index is closely correlated with the student's eventual graduation status.

We remove children who ever had a diagnosis of mental retardation from the sample. This includes ICD9's 317 to 319 and ICD10's F70-F79.

Appendix Table 1 shows means of the "control variables" that are available in our administrative data. Note that while we start with approximately the same number of children in each birth cohort, the focus on comparing siblings means that in our sibling sample, children in the middle cohorts are more likely to be retained in the sample (because they are more likely to have a sibling in the sample).

In order to collapse the number of health measures to a manageable number in an objective and arms-length way, we use Adjusted Clinical Group (ACG) software developed by researchers at Johns Hopkins University (The Johns Hopkins University, 2003). The ACG is designed to measure morbidity by clustering individuals by their age, gender, and constellations of diagnoses. Medical providers indicate diagnoses using what are called International Classification of Disease 9th or 10thedition (ICD9 or ICD10) codes. This software groups 14,000 ICD9 codes into 32 groups (called Aggregated Diagnostic Groups or ADGs) on the basis of 5 criteria: 1) duration of the condition (acute, recurrent, or chronic), 2) severity of the condition (e.g. minor and stable versus major and unstable), 3) diagnostic certainty (symptoms focusing on diagnostic evaluation versus documented disease focusing on treatment), 4) etiology of the condition (infectious, injury, or other), and 5) specialty care involved (medical, surgical, obstetric, etc.) Individuals are assigned an ADG code if they have been diagnosed with any of the ICD9/10 codes in the group in either a physician or hospital visit over the past year. A person can have from zero to 32 ADGs. The system further classifies diagnoses as "major" or "minor", a distinction we take advantage of in our study.

The ADG system has been extensively validated in the U.S. (Weiner, Starfield, Steinwachs et al., 1991; Weiner, Starfield, and Lieberman, 1992; Powe, Weiner, Starfield et al., 1998; Wiener, Dobson, Maxwell et al., 1996). The Manitoba Center for Health Policy has also evaluated the application of the ACG software to the Manitoba administrative data (Reid et al., 1999). They found, for example, that the diagnostic codes used in Manitoba worked well with the ACG software, and that the fraction of people with no valid code in a given year (18%) was similar to that expected on the basis of previous analyses of Manitoba data. (People have no valid code if they did not see a doctor at all during the reference period). About 16% of the population had 4 or more ADG codes in a year. The system also generated a distribution of relative expenditures similar to that seen in other data sets (Minnesota Medicaid recipients, and a large U.S. HMO), suggesting that relative expenditures for different types of illness are not very different in Canada and the United States. Finally, the MCHP study verified that areas with high rates of premature mortality also had higher morbidity as measured by the ACG system.

We use the ADG codes to construct the health measures used in the analysis. In each case the measure is constructed to cover a specific age range for the child defined by the date of birth for the child (rather than by calendar years). So, for example, we sum the number of major condition codes recorded in each year between ages 0 and 3 to get a measure of the number of major conditions in that age range. We construct this measure for the age ranges 0-3, 4-8, 9-13 and 14-18.

Major conditions are defined using ADG codes 3, 9, 11, 12, 13, 18, 25 and 32. These codes capture most of the chronic and acute major illnesses faced by children including orthopedic, ear, nose throat and eye problems, cancers, and a variety of other acute major illnesses.

The definition of a "major ADG" comes directly from the John Hopkins software and depends on the age of the child. For children ages 0-17 it includes ADGs 3,9,11,12,13,18, 25 and 32 and for children ages 18 and older it includes 3, 4, 9, 11, 16, 22, 25, 32. For the sake of defining a consistent measure across age groups, we re-define the major ADG group using the 0-17 definition for all ages in the sample.

ICD9 codes have been used for both physician claims and hospital separation abstracts through March 31, 2004. These will have generated the ADG scores for all nine birth cohorts up through age 14. Beginning April 1, 2005, ICD10 coding was adopted for hospital separation abstracts. Because of this, a relatively small number of ICD10 diagnoses (N=447) on abstracts from the 1985-1987 birth cohorts were also used in categorizing major conditions.

Appendix Table 2 shows the most prevalent ICD9 codes generating major conditions for each age group. While the most common serious conditions change as children age, hearing and vision problems are important in each age group. Appendix Table 3 shows the most prevalent ICD9 codes generating major injuries. While the most common serious conditions change as children age, "open wound of the head" and "certain adverse conditions, not elsewhere classified" are important categories at all ages.

Appendix Table 4 shows the most prevalent ICD9 codes for congenital problems and perinatal problems (ICD9 740 to 779). By definition, these conditions occur at birth or slightly thereafter. However, children with serious congenital/perinatal problems continue to have contacts with the medical system that are related to these diagnoses.

Hence, one can sum the number of contacts having to do with congenital/perinatal problems at each age. In our regression models, we control for the number of contacts related to congenital/perinatal problems at each age group.

The health measures are generated from physician visits and hospital separation abstracts. Emergency department and hospital outpatient visits are not uniformly included in the data sets. Some of these visits are captured as (physician) ambulatory visits. An earlier analysis using 1 year of Winnipeg data found that 4.9 percent of ambulatory care was provided by emergency departments and outpatient clinics and that residents of lower income neighborhoods were disproportionately likely to receive such care.[i ii] In our records, 2.5 percent of physician claims are for emergency room visits, and 1.6 percent of hospital claims over the period 1979-2004 are for outpatient visits. This comparison suggests that about 1 percent of visits could be missing.

Our analysis is based on ADGs and numbers of ADGs rather than on numbers of visits. Hence, if a child with a missing visit had another contact for a diagnosis in the same ADG within a four year period (e.g. a follow up visit), that child's condition would be included in our analysis. Nevertheless, in order to gauge the potential importance of missing visit records, we conducted the comparison shown in Appendix Table 5. This table shows the number of ADGs for each age group calculated first using the entire sample of visits available, and then excluding the ER and outpatient records that we do have. Clearly, this exclusion makes very little difference to the average number of ADGs. It also had no effect on the maximum number of ADGs observed, so we have chosen to conduct our analysis using the entire sample of visit records.

Appendix Table 1: Control Variables Used in Analysis

	Mean	Standard Deviation
Birth weight 0-999 grams	.001	
Birth weight 1000-1499 grams	.003	
Birth weight 1500-2499 grams	.043	
Birth weight 2500-3499 grams	.476	
Congenital/Perinatal 0-3	.156	
# Congenital/Perinatal 0-3	.222	.587
Congenital/Perinatal 4-8	.016	
# Congenital/Perinatal 4-8	.027	.263
Congenital/Perinatal 9-13	.012	
# Congenital/Perinatal 9-13	.019	.209
Congenital/Perinatal 14-18	.013	
# Congenital/Perinatal 14-18	.019	.208
Mother married at birth	.843	
Mother<20 at birth	.073	
Mother>=20, <25 at birth	.298	
Mother>=25,<35 at birth	.581	
Mother 35+ at birth	.048	
Child Male	.514	
Child first born	.308	
Child 2nd born	.377	
Child 3rd born	.191	
Child 4th born	.072	
Child 5th born or higher	.052	
# children in family=2	.294	
# children in family=3	.342	
# children in family=4	.180	
# children in family=5	.184	
Birth year 1979	.076	
Birth year 1980	.100	
Birth year 1981	.119	
Birth year 1982	.154	
Birth year 1984	.171	
Birth year 1985	.139	
Birth year 1986	.118	
Birth year 1987	.123	
# Observations	50404	

Appendix Table 2: Top 10 ICD9 Codes for Children with Other Major Conditions, by Age Group

	0-3 Year Olds (Total Number of Diagnoses=10061)		
ICD9	Description of condition	#Cases	%Cases
378	Strabismus, Other disorder binocular eye	1647	15.57
373	Inflammation of eyelids	1219	12.12
389	Hearing Loss	1060	10.54
579	Intestinal malabsorption	454	4.51
530	Diseases of esophagus	341	3.39
385	Other disorder middle ear and mastoid	233	2.32
560	Intestinal obstruction w/o hernia	232	2.31
518	Other diseases of lung	194	1.47
514	Pulmonary congestion - hypostasis	142	1.41
707	Chronic ulcers of skin	142	1.43
	4-8 Year Olds (Total Number of Diagnoses=9429)		
389	Hearing loss	2334	24.75
378	Strabismus, other disorder binocular eye	1323	14.03
373	Inflammation of eyelids	1216	12.90
385	Other disorder middle ear and mastoid	266	2.82
541	Acute appendicitis	217	2.30
540	Appendicitis, unqualified	182	1.93
707	Chronic ulcer of skin	146	1.55
259	Other endocrine disorder	117	1.24
540.9	Acute appendicitis w/o peritonitis	115	1.22
448	Disease of capillaries	112	1.19
	9-13 year olds (Total Number of Diagnoses= 10084)		
373	Inflammation of eyelids	1431	14.09
389	Hearing loss	872	8.65
378	Strabismus, other disorder binocular eye	791	7.84
717	Internal derangement of knee	736	7.30
540	Acute appendicitis	476	4.72
718	Other derangement of joint	430	4.26
541	Appendicitis, unqualified	338	3.35
5409	Acute appendicitis w/o peritonitis	279	2.77
259	Other endocrine disorders	265	2.63
905	Late effect musculoskeletal & connective tissue injury	186	1.84
	14-18 year olds (Total Number of Diagnoses=16646)		
717	Internal derangement of knee	1557	9.35
373	Inflammation of eyelids	1548	9.30
718	Other derangement of joint	839	5.04
296	Affective psychoses	776	4.66
530	Diseases of esophagus	639	3.84
540	Acute appendicitis	535	3.21
389	Hearing loss	486	2.92
541	Appendicitis, unqualified	421	2.53
303	Alcohol dependence syndrome	393	2.36
370	Keratitis	356	2.14

Appendix Table 3: Top 10 ICD9 Codes for Children with Major Injuries, by Age Group

	0-3 Year Olds (Total Number of Diagnoses=31583)		
ICD9	Description of condition	#Cases	%Cases
873	Other open wound of head	8483	26.86
995	Certain adverse effects, not elsewhere classified	3184	10.08
854	Intracranial injury other unspecified nature	2814	8.91
883	Open wound of finger(s)	1478	4.68
977	Poison-other/unspecified drugs/medicinal	1134	3.59
879	Open wound other unspecified site except limbs	936	2.96
892	Open wound foot except toe(s) alone	799	2.53
850	Concussion	659	2.09
882	Open wound of hand except finger(s)	575	1.82
360	Disorders of the globe-eye, adnexa	535	1.69
	4-8 Year Olds (Total Number of Diagnoses= 31508)		
873	Other open wound of head	8103	25.72
995	Certain adverse effects, not elsewhere classified	3199	10.15
854	Intracranial injury other unspecified nature	1886	5.99
892	Open wound foot except toe(s) alone	1639	5.20
883	Open wound of finger(s)	1580	5.01
891	Open wound knee, lower leg and ankle	1315	4.17
879	Open wound other unspecified site except limbs	1213	3.85
882	Open wound of hand except finger(s)	868	2.75
930	Foreign body on external eye	6.43	2.04
850	Concussion	653	2.07
	9-13 year olds (Total Number of Diagnoses=30384)		
873	Other open wound of head	3419	11.25
995	Certain adverse effects, not elsewhere classified	2642	8.70
844	Sprains and strains of knee and leg	1978	6.51
883	Open wound of finger(s)	1875	6.17
891	Open wound knee, lower leg and ankle	1861	6.12
892	Open wound foot except toe(s) alone	1311	4.31
854	Intracranial injury other unspecified nature	1208	3.98
814	Fracture of carpal bones	1106	3.64
815	Fracture of metacarpal bones	1014	3.34
882	Open wound of hand except finger(s)	977	3.22
	14-18 year olds (Total Number of Diagnoses=35232)		
844	Sprains and strains of knee and leg	2915	8.27
995	Certain adverse effects, not elsewhere classified	2721	7.72
873	Other open wound of head	2708	7.69
883	Open wound of finger(s)	2513	7.13
882	Open wound of hand except finger(s)	1452	4.12
815	Fracture of metacarpal bones	1335	3.79
850	Concussion	1145	3.25
814	Fracture of carpal bones	915	2.60
891	Open wound knee, lower leg and ankle	907	2.57
824	Fracture of ankle	891	2.53

Appendix Table 4: Top 10 ICD9 Codes for Congenital Anomalies at Each Age
(includes only congenital/perinatal anomalies that are also major pediatric ADGs)

	0-3 Year Olds (Total Number of Diagnoses=11469)		
ICD9	Description of condition	#Cases	%Cases
7686	Mild/moderate birth asphyxia	1724	15.03
7742	Neonatal Jaundice-preterm delivery	980	8.54
770.6	Transitory tachypnea newborn-wet lung	965	8.41
770.1	Meconium aspiration syndrome	770	6.71
769	Respiratory distress syndrome	694	6.05
7756	Neonatal hypoglycemia	571	4.98
7685	Severe birth asphyxia	504	4.39
746	Other congenital anomalies of heart	459	4.00
745	Bulbus cordis and other anomalies of cardiac septum closure	391	3.41
775	Endocrine/metabolic disorder fetus/newborn	383	3.34
	4-8 Year Olds (Total Number of Diagnoses=1071)		
746	Other congenital anomalies of heart	420	39.22
745	Bulbus cordis and other anomalies of cardiac septum closure	179	16.71
747	Other congenital anomalies of circulatory systems	90	8.40
749	Cleft palate and cleft lip	79	7.38
751	Other congenital anomaly of digestive system	55	5.14
7455	Ostium secundum type atrial septal defect	27	2.52
741	Spina bifida	19	1.77
75689	Other congenital musculoskelatal anomalies	11	1.03
	** cells with fewer than 10 people not reported **		
	9-13 year olds (Total Number of Diagnoses=730)		
746	Other congenital anomalies of heart	386	52.88
745	Bulbus cordis and other anomalies of cardiac septum closure	104	14.25
749	Cleft palate and cleft lip	47	6.44
747	Other congenital anomalies of circulatory systems	45	6.16
741	Spina bifida	23	3.15
751	Other congenital anomaly of digestive system	15	2.05
7455	Ostium secundum type atrial septal defect	11	1.51
	** cells with fewer than 10 people not reported **		
	14-18 year olds (Total Number of Diagnoses=724)		
746	Other congenital anomalies of heart	395	54.56
745	Bulbus cordis and other anomalies of cardiac septum closure	87	12.02
747	Other congenital anomalies of circulatory systems	57	7.87
749	Cleft palate and cleft lip	44	6.08
741	Spina bifida	25	3.45
751	Other congenital anomaly of digestive system	19	2.62
	** cells with fewer than 10 people not reported **		

Table 5: Comparison of Frequencies/Counts With/Without Emergency Room Visits

	With	Without
# Major ADGs 0-3	0.260	0.260
	[0.726]	[0.726]
# Major ADGs 4-8	0.228	0.227
	[0.691]	[0.691]
# Major ADGs 9-13	0.216	0.213
	[0.628]	[0.625]
# Major ADGs 14-18	0.335	0.322
	[0.806]	[0.791]

Notes: Standard errors in brackets.

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