

Poverty and intellectual development in childhood

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Abstract

Introduction

Childhood exposure to and duration of poverty can affect several individual characteristics related to intellectual development.

Objectives

This paper examines the implications of movement in and out of childhood poverty using a unique linkable database from the Canadian province of Manitoba. Differences in measurement of poverty and intellectual development are explored.

Methods

Almost 90,000 children were followed using two definitions of poverty – neighborhood and household poverty. The large database permitted exploring the role of another variable – maternal mental health.

Results

The association of household poverty with poorer intellectual outcomes has been shown to be stronger than the association of neighborhood poverty with such outcomes. This was true using various outcome measures appropriate across childhood (from age 5 to age 17). Comparisons with the role of maternal mental health were made and further analyses suggested.

Conclusion

The richness of the data has facilitated the study of childhood intellectual development. Household poverty appears to play an important role; neighborhood poverty and maternal mental health also seem to influence such development, but less strongly.

Keywords

poverty; child development; routinely collected data; developmental vulnerability

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Introduction

Children born into poverty face many challenges that can negatively impact their long-term social, educational, and health outcomes [1–4]. A lack of school readiness and poor academic achievement have been associated with poverty which may be influenced, in part, by factors such as atypical structural brain development, limited language development, increased out-of-home care, and a greater likelihood of experiencing food insecurity [5–11]. Furthermore, previous studies have shown that higher household family income and neighborhood socioeconomic status lead to greater school readiness in numeracy knowledge, communication, vocabulary, and attention [12, 13]. Childhood exposure to poverty has also been associated with several health outcomes including externalising mental conditions, attention-deficit/hyperactivity disorder, asthma, and injuries resulting in hospitalisations [14–20].

Although many negative outcomes have been linked to childhood poverty, less is known about the effects of exposure to and the duration of poverty. Children may be exposed to different forms of economic deprivation, and some may transition in and out of poverty throughout their developmental years. Previous studies have suggested that both household and neighborhood poverty can negatively affect childhood outcomes and that an increased duration of poverty leads to more risk factors for poor outcomes [17, 21–23]. Additionally, moving out of childhood poverty leads to better long-term outcomes; however, the specific implications of such movement are unclear [21, 24].

Measuring the timing and duration of economic deprivation facilitates the study of several individual characteristics—intellectual development, mental health, sociability, openness to new ideas—and so on [22]. The effects of the timing and duration of deprivation can be researched using a unique linkable database following almost 90,000 children born in the Canadian province of Manitoba. Poverty remains a major issue in Manitoba, which has the highest child poverty rates among all Canadian provinces. According to the Census Family Low Income After-Tax Measure, which adjusts for family size and composition, 20.68% of children in Manitoba live in poverty – 7.21 percentage points higher than the national average. Manitoba also has the highest market income child poverty rate in Canada with two of the 14 Manitoba federal electoral ridings among the country's poorest 5 ridings as to rate of poverty [25].

While poverty has been linked to developmental disparities, less is known about how intellectual differences between poor and affluent children can be measured and how these differences change throughout childhood. This paper addresses this knowledge gap by studying questions such as: How can childhood differences in intellectual development between the poor and the affluent be measured? How important are differences in measurement of poverty in assessing intellectual development? How do the differences change over childhood?

The Manitoba data allow comparison of the growth among children of different economic levels; panel data allow assessing intellectual development in children at six ages. Two definitions of poverty are used. Family or household poverty was evaluated using variables relating to receipt of Employment and Income Assistance (EIA – analogous to welfare); neighborhood poverty

was defined as living in a neighborhood with median income in the lowest income quintile [26].

Methods

Setting and data

Manitoba has previously ranked in the mid-range of a series of Canadian indicators of health status and health care expenditures [27, 28]. In 2021, the provincial population was over 1.3 million with more than half ($n = 749,607$) living in Winnipeg, Canada's eighth largest metropolitan area [29]. Manitoba has a comparatively large Indigenous population (18%) [30]. Canadian scores on the Programme for International Student Assessment (PISA), a standardised educational test administered on 15 years olds, have been above the international averages since the tests' inauguration in 2000, but scores in all three subjects (reading, mathematics, and science) declined over the 2000–2018 period [28, 31]. Analyses of the 2018 PISA scores across 79 participating countries/provinces showed students in four provinces (Prince Edward Island, New Brunswick, Manitoba, and Saskatchewan) below the Canadian average in reading [32]. Approximately 30% of Manitoba's five-year olds have been shown to be vulnerable in at least one developmental area; this exceeded the Canadian average of 26% [33]. Overall, Canada was outperformed by only three countries/regions employing the PISA test – China, Singapore, and Macao (China) [32].

We used administrative data in the Population Research Data Repository housed at the Manitoba Centre for Health Policy. A scrambled personal health number allowed linking across multiple de-identified datasets; information on linkage methods, confidentiality and privacy, and validity is reviewed elsewhere [34, 35]. Population registry data have been combined with individual-level information from: hospital discharge abstracts (containing International Classification Of Diseases [ICD] diagnosis codes; International Classification Of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] codes before April 1, 2004 and International Classification Of Diseases, 10th Revision, Canada [ICD-10-CA] codes after April 1, 2004), physician visits (ICD-9-CM codes), Families First screens (filled out during routine home visits by Public Health Nurses for most births and include information on various aspects of the mother's social circumstances), and monthly receipt of Employment and Income Assistance data - EIA (basically welfare). Canadian census data provided neighborhood-level median income.

Sample (from ages 5 through 17)

The number of children studied at each point in time varied across measures. Concentrating on those born in 2000–2002 generated a total of 7,424 children having scores on all six measures of intellectual development. Such person-specific information controlled for several known/unknown family and individual factors and extended from ages 5 through 17. Comparisons building on the very large number of cases available for less than all six time periods changed the results only minimally. Children who are home schooled or frequently

absent from school would seem less likely to have been included in the sample.

Exposure to poverty

Household poverty

The analysis of social assistance payments provides the measure of exposure to household poverty. The database was searched for monthly involvement by both the mother and child. For counting years experiencing household poverty (years on EIA), we looked for monthly involvement (i.e., receipt of EIA payment) by the mother from one year before the child's birth up to the date the child reaches a certain age, or until a particular childhood event, as well as involvement by the child from date of birth up to the same target age or event. Examples of such events would be the estimated date that the child had an assessment or test, such as the Early Development Instrument (EDI) in kindergarten or a grade-specific evaluation, or the date the child reaches a specific age (usually associated with the calendar year the child is expected to reach a specific grade) [36, 37]. Years were typically indexed at the child's date of birth, and these years were counted for every year of age the child reaches to the event date. The year was counted as experiencing household poverty (being on EIA) if an EIA payment was received in any month during that year, i.e., the involvement date fell between the two anniversary dates of the child's birthdate.

Neighborhood poverty

Using census data, neighbourhoods have been ranked from 1 (lowest median income) to 5 (highest median income); rankings were created separately for rural and urban neighbourhoods. Quintiles are based on census dissemination areas including ~400 individuals. Urban was specified as any neighborhood in Winnipeg or Brandon; rural was any other neighbourhood. Change of neighbourhood is defined in a manner parallel to the definition of change of household.

Minority and majority of years

The determination of a majority of years was based on a simple majority, i.e., a ratio of 0.5 or more. The numerator in this ratio was the count of years in poverty as described above. The denominator was the total count of years in the time period, starting from a year before the child's birth up to the event date. Using the receipt of EIA as the indicator for household poverty, the event date was the child's 18th birth date; the total denominator was 19, to count the gestational year in which the mother may have received EIA. If any EIA payment was made to the mother or child during half or more of these years, the child was placed in the group having received EIA in the majority of years to the event or assessment date. If EIA payments were received in less than half of these years, but not zero years, the child was placed in the group having received EIA in the minority of years to the target date. Lastly, if no EIA payment was received for the entire time period, the child was placed in a third group labeled "None" or "No EIA". A similar approach was used for counting the minority/majority of years in neighborhood poverty.

Measures of intellectual development

The measures were grouped together in their similarity:

1. Age 5, Early Development Instrument Index – Mean Early Development Score (MEDS)
 2. Age 8, Grade 3 Assessment Index,
 3. Age 12, Grade 7 Assessment Index,
 4. Age 13, Grade 8 Assessment Index,
 5. Age 14, Grade 9 Achievement Index,
 6. Age 17, Grade 12 Achievement Index.
- Three somewhat different grade level assessments for students in Grades 3, 7 and 8
- Two largely similar achievement indices for students in Grades 9 and 12

The measures of intellectual development described below come from largely independent assessments used for government reports and comparative studies. The mean and standard deviation of the logit scores for each measure were first calculated. Each individual score was scaled by subtracting the mean score and then dividing by the standard deviation. This yields scores with a mean of 0 and a standard deviation of 1 for the cohort year. Appendix 1 describes each measure more fully.

Early development instrument index – mean early development score (MEDS)

The Early Development Instrument Index assesses "school readiness" (i.e. a child's level of preparedness for the formal educational environment) in 5 developmental domains: physical health and well-being, social competence, emotional maturity, language and cognitive development, and communication skills and general knowledge [37, 38]. The EDI questionnaire is completed by kindergarten teachers for children in their classroom, typically in the second half of the school year. The index has acceptable interrater reliability and high internal consistency [21]. A child is considered developmentally vulnerable if scoring in the lowest 10th percentile according to national norms in 1 or more developmental domains [39, 40]. Children having all 5 EDI scores (one for each domain) are used for the Early Development Instrument Index. Mean Early Development Score scaling in a manner consistent with the measures presented below has been created from this index.

Grade level assessments (Grades 3, 7, and 8)

These grade level assessments are designed to identify individual strengths and needs as well as classroom engagement. This information helps judge the student's foundational knowledge and skills needed to support learning across the curricula.

Grade 3 assessment index

Each of two Grade 3 assessments is associated with specific competency measures. The reading assessment focuses on

goals, strategies to make sense of texts, and comprehension. The numeracy assessment emphasises repeating patterns, equalities, representing whole numbers in a variety of ways, and using mental strategies for addition and subtraction. Outcome measures relating to both assessments concerned needing help, approaching and meeting expectations, and 'out of range' due to various problems.

Grade 7 assessment index

Two types of Grade 7 assessments were based on specific competencies:

One assessment involved numeracy: ordering fractions and decimal numbers, understanding numerical representation in a variety of ways, solving problems using number patterns, and adapting a variety of strategies to calculate and explain a mental math problem.

A second assessment concerned student engagement: competencies related to demonstrating an interest in personal learning, engaging in self-assessment, awareness of learning goals, participation in lessons, and accepting responsibility for assignments.

Numeracy relevant outcome measures were centered around mid-Grade 7 performance level: "not meeting, approaching, meeting, and out of range." Measures for engagement were: "emerging, developing, establishing, inconsistent, and out of scope (mental health concerns)." The grade 7 assessment index score was based only on the set of numeracy competencies.

Grade 8 assessment index

One set of competencies associated with Grade 8 was assessed:

Reading Comprehension and Expository Writing: understanding, interpreting, and responding to texts; organising, choosing, and editing to clarify ideas; generates, selects and organises ideas to support reader understanding;

chooses languages (word choices, sentence patterns) to make an impact on the reader; and uses conventions (spelling, grammar and/or punctuation) and resources to edit and proofread to clarify meaning.

Achievement Indices (Grades 9 and 12)

Grade 9 and Grade 12 Achievement Indices were developed along parallel lines. Data come from the Manitoba Health Insurance Registry (e.g.: demographic information on age and gender) held by the Manitoba Centre for Health Policy, and from Enrollment, Marks, and Assessments information on high school (grade 9-12) class enrollment and course marks received from Manitoba Education and Training.

Results

Exposure to poverty

Tables 1 and 2 show similar standard scores and standard errors for children with no family poverty and those experiencing no neighbourhood poverty. However, major differences were found in the scores associated with exposure to the two kinds of poverty.

For example, the MEDS (Mean Early Development Score) for children with no exposure to household poverty was 0.068 (Table 1); for those with no exposure to neighborhood poverty the comparable figure was quite similar—0.059 (Table 2). The picture changes on comparing children experiencing the two types of poverty. Children with a mother receiving EIA had a MEDS score of −0.543 (Table 1) while their counterparts exposed to neighborhood poverty recorded quite a different score of −0.240 (Table 2). Household poverty is more strongly associated with lower scores on the Early Development Index than is neighbourhood poverty. Other educational indices showed parallel differences.

Table 1: Standardised indices by exposure to household poverty (Employment Income Assistance (EIA) to mother – panel data)

Composite educational index	No EIA, mean [SE]	EIA, mean [SE]	Arithmetic difference of means [SE]
Age 5 Mean Early Development Score	0.068 [0.012]	−0.543 [0.042]	0.611** [0.044]
Age 8 Grade 3 Competencies Index	0.086 [0.012]	−0.534 [0.039]	0.620** [0.041]
Age 12 Grade 7 Competencies Index	0.105 [0.012]	−0.693 [0.040]	0.798** [0.042]
Age 13 Grade 8 Competencies Index	0.085 [0.011]	−0.643 [0.041]	0.728** [0.043]
Age 14 Grade 9 Achievement Index	0.235 [0.010]	−0.559 [0.025]	0.794** [0.027]
Age 17 Grade 12 Achievement Index	0.242 [0.010]	−0.521 [0.029]	0.763** [0.031]

Standard errors [SE] are shown in brackets. ** denotes statistical significance at the 5 percent level.

7,424 children had information on all six educational indices. Of these indices, 6,711 had a mother not receiving EIA in the year before birth of her child; 713 had a mother receiving EIA.

Table 2: Standardised indices by exposure to neighbourhood poverty (residence in low-income neighbourhood – panel data)

Composite educational index	No exposure to low-income neighbourhood, mean [SE]	Exposure to low-income neighborhood, mean [SE]	Arithmetic difference of means [SE]
Age 5 Mean Early Development Score	0.059 [0.012]	−0.240 [0.031]	0.299** [0.033]
Age 8 Grade 3 Competencies Index	0.080 [0.012]	−0.241 [0.029]	0.322** [0.032]
Age 12 Grade 7 Numeracy Competencies Index	0.092 [0.012]	−0.286 [0.031]	0.378** [0.033]
Age 13 Grade 8 Reading/Writing Competencies Index	0.063 [0.012]	−0.221 [0.031]	0.284** [0.033]
Age 14 Grade 9 Achievement Index	0.216 [0.011]	−0.128 [0.025]	0.344** [0.027]
Age 17 Grade 12 Achievement Language Arts & Math Index	0.229 [0.011]	−0.132 [0.026]	0.361** [0.028]

Standard errors [SE] are shown in brackets. ** denotes statistical significance at the 5 percent level.

6,183 children had no exposure to a low-income neighbourhood in their first year of life. 1,241 resided in a low-income neighbourhood in their first year of life.

Intellectual development in the categories related to poverty was measured six times. Taking household poverty as an example (Table 1).

- 1) Differences among children with no EIA exposure and with EIA exposure (differences between Mean Early Development Scores of 0.611) are striking (by kindergarten entry – about age 5).
- 2) Differences among children with and without EIA exposure increase very slowly after age 8 when indices of development are compared. With the indices constructed differently, the findings must be interpreted cautiously.
- 3) Differences among children whose mothers received EIA and those who did not were significant at the 5 percent level for all ages. The difference between the Mean Early Development measure and the Grade 3 assessment was not significant at the 5 percent level, neither for children whose mothers received EIA nor those who did not. Differences between children aged 8 and age 12 are substantial; the increase in the difference of means between those ages is significant at the 5 percent level.

In summary, differences emerge by age 5, with administration of the Early Development Index. These differences are largely the same at age 8, even though another measure (the Grade 3 Competencies Index) is used. Such findings reinforce efforts at better understanding the early stages of childhood and call attention to facilitating development at these stages.

Comparison of Tables 1 and 2 show expected differences between children growing up in poverty and those who did not. The third column reports the average differences in

outcomes between the columns for each measure. As expected, the differences were substantially greater for those children experiencing household poverty than those experiencing neighborhood poverty.

Introducing maternal mental health problems

The administrative data facilitate introducing new variables into the research. For example, maternal mental health data highlight the importance of this variable. Chartier et al. (2018) coded maternal diagnosis of mood and anxiety disorders, substance use disorders, psychotic disorders (including schizophrenia), or personality disorders in detail in the year before birth [41].

Examining an index using the maternal mental health diagnoses generates a different picture than does analysing the family poverty data. Comparing tables with mothers receiving EIA in the year before their birth (N=713) (Table 1) with those using mothers with a mental health diagnosis in this period (N=527) (Table 3), the composite educational indices differed markedly between the two groups. The 713 children with a history of suffering from household poverty averaged lower standardised scores on the six educational indices (from −0.543 to −0.693) (Table 1) than did the 527 children whose mothers were diagnosed with mental health issues (from −0.083 to −0.237) (Table 3). The gap between Mean Early Development Scores (MEDS – measured about age 5) and the Grade 7 Numeracy Competency Index was somewhat greater for children suffering from household poverty (0.798–0.611=0.187) (Table 1).

Table 3: Standardised indices by exposures to mother with mental health diagnoses – panel data

Composite educational index	No exposure to mother with mental health diagnosis mean [SE]	Exposure to mother with mental health diagnosis mean [SE]	Arithmetic difference of means [SE]
Age 5 Mean Early Development Score	0.025 [0.012]	−0.196 [0.052]	0.221** [0.053]
Age 8 Grade 3 Competencies Index	0.045 [0.012]	−0.218 [0.044]	0.263** [0.044]
Age 12 Grade 7 Numeracy Competencies Index	0.049 [0.012]	−0.237 [0.046]	0.286** [0.048]
Age 13 Grade 8 Reading/Writing Competencies Index	0.033 [0.012]	−0.221 [0.046]	0.254** [0.048]
Age 14 Grade 9 Achievement Index	0.178 [0.010]	−0.090 [0.036]	0.268** [0.039]
Age 17 Grade 12 Achievement (Language Arts & Math Index)	0.188 [0.010]	−0.083 [0.036]	0.271** [0.039]

Standard errors [SE] are shown in brackets. ** denotes statistical significance at the 5 percent level.

6,897 children had mothers with no mental health problems in the year before birth; 527 children had mothers with mental health problems in the year before birth.

Duration of poverty

Additional analyses present the number of years a child experienced household poverty and scores on the educational indices. Table 4 puts together the “no EIA, minority of years with EIA, and majority of years with EIA” categories for each of the six measures. Table 5 highlights similar data using the large N with single index comparisons.

The duration of poverty is important. Across all six indices representing varying ages and somewhat differing data, the children with most of their years spent in household poverty showed less intellectual development than their counterparts with fewer such years. Those living

without experiencing poverty showed the greatest intellectual development.

For example, counting the number of years of assessment with the panel data (Table 4), children (age 5, 6 years of assessment) scored average values of 0.108 on the Mean Early Development Score with no years of EIA, (n=6,194). Children having a minority of years on EIA (n=499) averaged −0.430 while those spending most years on EIA (n=731) averaged −0.531. For each age-related index, the more years of poverty, the lower the educational index. Table 4 presents a fuller picture of household poverty across multiple years and all six indices. Similar trends were found for the duration of exposure to neighbourhood poverty.

Table 4: Standardised development indices by duration of household poverty (receipt of EIA to mother, in years to assessment - three categories, panel data)

Composite educational index	No EIA, mean [SE]	N	Minority of years, mean [SE]	N	Majority of years, mean [SE]	N
Age 5<6 years used > Mean Early Development Score	0.108 [0.012]	6,194	−0.430 [0.052]	499	−0.531 [0.040]	731
Grade 3 Competencies Index	0.131 [0.012]	6,140	−0.343 [0.042]	606	−0.590 [0.040]	678
Grade 7 Competencies Index	0.164 [0.012]	6,080	−0.467 [0.037]	797	−0.756 [0.046]	547
Grade 8 Competencies Index	0.139 [0.012]	6,069	−0.414 [0.036]	832	−0.733 [0.049]	523
Grade 9 Achievement Index	0.299 [0.011]	6,058	−0.349 [0.023]	852	−0.660 [0.029]	514
Grade 12 Achievement Index	0.312 [0.011]	5,995	−0.325 [0.026]	931	−0.638 [0.035]	498

Standard errors [SE] are shown in brackets. Columns 1-6 report the mean index value for no years, for a minority or for a majority of years to each assessment where Employment Income Assistance (EIA) was received, and number in each category. Means in each category differed substantially from each other at the 5 percent level, through a series of two-sample T-tests.

Correlations among developmental indices

Indices developed for the six-wave panel study ($N = 7,424$) were also created using the largest available number of cases for each comparison. The correlations in Table 5 are remarkably stable (generally within .02) when the two approaches (panel study and largest available numbers) were compared; such stability is typical when the different approaches are compared. The pairs using largest available numbers varied between 15,015 and 88,035 in size.

Table 6 presents the moderate correlations among most developmental indices, regardless of the details in their construction. The correlation between the Grade 9 and Grade 12 Achievement Indices provides one exception. These two indices were built using very similar assessment methods and scaled logit scores calculated from rank categories based primarily on high school marks; this doubtless contributed

to the higher correlation (.723) between the Grade 9 and 12 indices.

Table 6 also shows a generally slow decline in correlations as the years between measurement increase. The correlations seem remarkably strong, given the number of years involved. Such correlations suggest that the developmental indices can be used for multiple purposes without worrying unduly about measurement issues. Change in circumstances with age and, perhaps, changes in measurement would seem responsible for the observed differences.

Maternal mental health, poverty, and educational outcomes

To further explore the relationship between maternal mental health and child educational outcomes, we conducted additional linear regression analyses using the panel study subset. These models examined the independent effects of

Table 5: Standardised development indices by duration of household poverty (receipt of EIA to mother, in years to assessment - three categories, using all cases available for a single time period)

Composite educational index	No EIA, mean [SE]	N	Minority of years, mean [SE]	N	Majority of years, mean [SE]	N
Mean Early Development Score	0.113 [0.006]	24,568	-0.398 [0.025]	2,091	-0.607 [0.021]	3,201
Grade 3 Competencies Index	0.128 [0.005]	35,464	-0.431 [0.018]	3,454	-0.690 [0.016]	4,396
Grade 7 Competencies Index	0.151 [0.003]	70,576	-0.444 [0.010]	10,025	-0.837 [0.012]	7,434
Grade 8 Competencies Index	0.141 [0.003]	70,352	-0.416 [0.010]	10,386	-0.797 [0.013]	7,065
Grade 9 Achievement Index	0.165 [0.004]	77,831	-0.538 [0.007]	13,170	-0.725 [0.008]	7,894
Grade 12 Achievement Index	0.172 [0.004]	54,249	-0.510 [0.009]	10,520	-0.776 [0.012]	5,125

Standard Errors [SE] are shown in brackets. Columns 2-6 report the mean index value for no years, for a minority or for a majority of years to each assessment where Employment Income Assistance (EIA) was received, and number in each category. Means in each category differed statistically from each other at the 5 percent level through a series of two-sample T-tests.

Table 6: Correlations among standardised development indices of household poverty – panel data

Composite educational index	Age 5 mean early development score	Age 8 grade 3 competencies index	Age 12 grade 7 competencies index	Age 13 grade 8 competencies index	Age 14 grade 9 achievement index
Age 8 Grade 3 Competencies Index	0.464	—	—	—	—
Age 12 Grade 7 Competencies Index	0.432	0.518	—	—	—
Age 13 Grade 8 Competencies Index	0.459	0.510	0.578	—	—
Age 14 Grade 9 Achievement Index	0.410	0.415	0.537	—	—
Age 17 Grade 12 Achievement Index	0.385	0.408	0.505	0.527	0.723

7,424 children provided information on all six measures. Correlations among indices are significant at the .05 level.

specific maternal mental health diagnoses, poverty indicators, and sociodemographic factors on educational achievement at Grades 3 (Table 7), 9 (Table 8), and 12 (Table 9).

Both maternal mood/anxiety and substance use disorders were associated with lower educational achievement in children across all three grade levels, even after adjusting for poverty and other sociodemographic factors. Children growing up in poverty, especially those in families receiving EIA, showed poorer educational outcomes, with the effect becoming more pronounced by Grade 12 (Table 9). Being born small for gestational age may affect early achievement, but its impact diminished by adolescence. Maternal marital status remained a modest but consistent predictor across the three grade levels.

Discussion

Earlier research has shown household poverty to be associated with worse early childhood outcomes than neighbourhood poverty [17, 21]. This study extends such work across childhood up to grade 12, looking at a series of indicators of intellectual development. Specifically, this paper has introduced analyses of 1) panel information on poverty and maternal mental health within large administrative data sets and 2) measures of intellectual development made as equivalent as possible given their collection in different ways. This study is specific to Manitoba, which has unique demographic and socioeconomic characteristics along with a strong data infrastructure. While our findings may not generalise directly to other regions, they demonstrate the value of using detailed population data to understand child development and poverty. These insights can inform similar work in comparable settings.

Tables 1 and 2 illustrate the same general pattern – the children experiencing poverty show lower scores on the measures of intellectual development than do their more affluent counterparts. Furthermore, household poverty is demonstrated to be more strongly associated with lower scores on the EDI than is neighborhood poverty, aligning with previous research. A UK scoping review found that individual-level measures of economic disadvantage were more strongly linked to child health outcomes than area-level measures [42]. Similarly, another UK study found household income to be a stronger predictor of academic achievement and various health outcomes compared to neighbourhood level socioeconomic indicators [43]. A British Columbia study also observed that household poverty was more consistently associated with poorer developmental outcomes in Canada [17, 21]. Comparisons with Table 3 highlight the importance of coding decisions in deciding the importance of variables. If household poverty is taken as a definition of poverty, poverty seems much more important than maternal mental health in affecting a child's intellectual development. However, if neighbourhood poverty is used to define poverty, maternal mental health and poverty appear to have effects on childhood intellectual development which are more similar. Definition plays a critical role in interpretation.

To build on these findings, we disaggregated maternal mental health into specific diagnostic categories and found mood/anxiety disorders and substance use disorders to be consistently associated with lower educational achievement across Grades 3, 9, and 12, even after adjusting for poverty and other sociodemographic factors. These results highlight the importance of considering both the definition and the granularity of variables when interpreting their effects. It is also important to recognise that socioeconomic status may

Table 7: Maternal mental health and associated sociodemographic covariates with outcome - grade 3 competencies index

Covariates	Cases	Prevalence rate	Estimate (95% CLs)	Pr > ChiSq
Maternal ADHD in year before birth of child to 9th birthday	40	5.388	0.0000 (−0.2946, 0.2946)	0.9998
Maternal mood/anxiety disorder in year before birth of child to 9th birthday	3,033	408.54	−0.0568 (−0.1014, −0.0122)	0.0125
Maternal psychotic disorder in year before birth of child to 9th birthday	43	5.792	−0.0771 (−0.3616, 0.2073)	0.5951
Maternal substance abuse disorder in year before birth of child to 9th birthday	680	91.595	−0.1915 (−0.2679, −0.1151)	<.0001
Received EIA in majority of years to grade 3 assessment	1,962	264.278	−0.2731 (−0.3143, −0.2319)	<.0001
Low-income neighbourhood majority of years from child's birth to age 8	3,540	476.832	−0.1490 (−0.1804, −0.1176)	<.0001
Mother not married/common-law at birth of child	3,540	476.832	−0.0574 (−0.1037, −0.0111)	0.0152
Mother below age 20 at birth of child	454	61.153	−0.0176 (−0.1147, 0.0795)	0.7224
Child was Small for Gestational Age	524	70.582	−0.1123 (−0.1965, −0.0281)	0.0089

Table 8: Maternal mental health and associated sociodemographic covariates with outcome - grade 9 achievement index

Covariates	Cases	Prevalence rate	Estimate (95% CLs)	Pr > ChiSq
Maternal ADHD in year before birth of child to 15th birthday	89	11.988	−0.0890 (−0.2554, 0.0774)	0.2944
Maternal mood/anxiety disorder in year before birth of child to 15th birthday	3,822	514.817	−0.0592 (−0.0962, −0.0223)	0.0017
Maternal psychotic disorder in year before birth of child to 15th birthday	70	9.429	−0.0877 (−0.2750, 0.0995)	0.3583
Maternal substance abuse disorder in year before birth of child to 15th birthday	975	131.331	−0.2728 (−0.3284, −0.2172)	<.0001
Received EIA in majority of years to grade 9 assessment	1,880	253.233	−0.3599 (−0.3975, −0.3223)	<.0001
Low-income neighbourhood majority of years from child's birth to age 14	3,514	473.33	−0.1452 (−0.1737, −0.1167)	<.0001
Mother not married/common-law at birth of child	3,540	476.832	−0.1525 (−0.1912, −0.1138)	<.0001
Mother below age 20 at birth of child	454	61.153	−0.0299 (−0.1107, 0.0510)	0.4689
Child was Small for Gestational Age	524	70.582	−0.0053 (−0.0758, 0.0652)	0.8828

Table 9: Maternal mental health and associated sociodemographic covariates with outcome - grade 12 achievement language arts and math index

Covariates	Cases	Prevalence rate	Estimate (95% CLs)	Pr > ChiSq
Maternal ADHD in year before birth of child to 19th birthday	145	19.531	−0.0547 (−0.1884, 0.0789)	0.4223
Maternal mood/anxiety disorder in year before birth of child to 19th birthday	4,236	570.582	−0.0511 (−0.0892, −0.0131)	0.0084
Maternal psychotic disorder in year before birth of child to 19th birthday	87	11.719	0.0172 (−0.1540, 0.1885)	0.8436
Maternal substance abuse disorder in year before birth of child to 19th birthday	1,098	147.899	−0.2228 (−0.2772, −0.1683)	<.0001
Received EIA in majority of years to grade 12 assessment	1,927	259.564	−0.3722 (−0.4105, −0.3338)	<.0001
Low-income neighbourhood majority of years from child's birth to age 17	3,601	485.048	−0.1396 (−0.1686, −0.1107)	<.0001
Mother not married/common-law at birth of child	3,540	476.832	−0.1271 (−0.1666, −0.0877)	<.0001
Mother below age 20 at birth of child	454	61.153	−0.0224 (−0.1045, 0.0598)	0.5934
Child was Small for Gestational Age	524	70.582	−0.0188 (−0.0906, 0.0529)	0.6072

influence not only the prevalence of mental health conditions but also the likelihood of receiving a diagnosis and accessing treatment [44]. As a result, the observed associations may underestimate the true burden of maternal mental health challenges in lower-income populations.

Policies targeting household-level poverty appear to have a greater impact on early childhood outcomes than those aimed at neighborhood-level poverty. Direct economic support such as income supplements, housing assistance, or food programs may be particularly effective in improving children's intellectual

development [43, 45]. The variation in findings based on how poverty is defined also underscores the importance of using precise, household-level measures, in addition to neighborhood-level factors, to better identify families most in need [43]. While maternal health remains important, alleviating household poverty may be a more foundational intervention for supporting early development.

Some additional analyses are relatively simple. Dramatic differences in performance on the educational indices are seen when boys and girls are considered separately. Girls do much better than boys. But the two sexes show similar trends; experiencing poverty is consistently associated with lower index scores, no matter the age. Dividing the panel study participants into six age groups opens the door for other research on within-family influence. For example, instead of time spent in poverty, time spent with a mother having mental health issues could be studied. Alternatively, child's mental health – particularly after the first few years – might be taken as an outcome of poverty.

Population-based data suggest many analytical possibilities. Additional variables based on various behaviors and medical diagnoses are available in the data base; these include maternal drug or alcohol use and maternal smoking during pregnancy. If childhood conditions are included, the list of medical conditions which might correlate with intellectual development increases markedly. Measures of overall health and of specific conditions such as diabetes might prove as or more important than poverty. Using measures of intellectual development for the older children allows selecting health diagnoses suitable for this group.

Such longitudinal information would also allow analysing both the larger effects of the COVID-19 pandemic in school districts with different characteristics [46] and the effects of varying educational interventions [47]. The effects of traumatic childhood events – such as family breakup or death of a family member – can be studied using baseline data from the previous assessment period. Work among children under the age of five to try to better understand how these differences become established needs to be increased [48]. More broadly, being able to use population-based data in various ways, incorporating panels, siblings, and instrumental variables, can be critical in performing nonexperimental research to investigate developmental differences [49].

Conclusion

The richness of the data has facilitated the study of childhood intellectual development. Household poverty appears to play an important role in the intellectual growth of children; neighbourhood poverty and maternal mental health also seem to influence such development.

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Territory acknowledgement

The University of Manitoba campuses are located on original lands of Anishinaabeg, Ininewak, Anisininewuk, Dakota Oyate, and Dene, and on the National Homeland of the Red River Metis. We respect the Treaties that were made on these territories, we acknowledge the harms and mistakes of the past and we dedicate ourselves to move forward in partnership with indigenous communities in a spirit of reconciliation and collaboration.

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Statement on conflict of interest

The authors have no conflicts of interest or relevant financial relationships to disclose.

Ethics statement

This study was approved by the University of Manitoba Health Research Ethics Board (H2019:110) and the Health Information Privacy Commission at Manitoba Health, Seniors and Active Living (2018/2019 – 70). Using deidentified administrative data files did not require participants' informed consent.

Data availability statement

The source data used in this study were originally collected during the routine administration of health and social services in Manitoba and were provided to the Manitoba Centre for Health Policy (MCHP) for secondary use in research under specific data sharing agreements between the data trustees and MCHP. The data are approved for use at MCHP only. They are not owned by the researchers or by MCHP and cannot be deposited in a public repository. To review source data specific to this article or project, interested parties should contact the MCHP Repository Access & Use team at MCHP.Access@umanitoba.ca. The team will then facilitate data access by seeking consent of the original data holders and the required privacy and ethics review bodies.

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Supplementary appendix 1: methodology for composite educational indices

We developed new composite indices based on Early Development Instrument assessments, grade 3, 7 & 8 reading and numeracy assessments, the grade 9 index, and the grade 12 language arts and math indices. We describe here the methodology employed for these indices.

While these indices can be a useful measure of overall academic performance, composite indices can mask challenges only seen in one area of an assessment, but not strongly affecting the mean composite score. This is particularly true in the earlier years assessments such as EDI and grade 3 reading and numeracy, where a developmental vulnerability or need for ongoing help in one domain or area of assessment may not show up in the composite score but could greatly impact future educational achievement.

Mean early development score (MEDS)

The EDI assessment calculates numeric scores in the range 0-10 for five development domains: Physical Health & Well Being, Social competence, Emotional Maturity, Language and Cognitive Development, and Communication Skills & General Knowledge. For each of these scores a comparison is made to the population-level 10th percentile value as a cutoff. Scores below the cutoff for their domain indicate the child is developmentally vulnerable in that development domain [39, 50].

The five EDI assessment domain scores are used to calculate a composite score based on the methodology recommended by Eric Duku et al., at the Offord Centre. This methodology was described in an email conversation with Eric Duku, and a poster entitled *Creating and evaluating two cumulative developmental vulnerability risk measures*, by Eric Duku, Molly Pottruff & Magdalena Janus, Offord Centre for Child Studies, McMaster University, Hamilton, Ontario, Canada [51]. The technique involves normalising the numeric scores in the range 0–10 for the five development domains. While the Offord Centre normalises the domain scores at the full population level, for consistency with our other educational indices we normalise at the cohort level. However, for this first normalisation step, all cohort years are averaged together. For each of these scores, a normalised Z-score value is calculated. A mean composite score is calculated from the five Z-scores for each person in the cohort.

In our own addition to the methodology recommended by the Offord Centre, the mean composite scores are re-normalised at the cohort year level, to obtain a consistent scaling with the other indices. Without this final normalisation into a new Z-score, the SD of the mean of means would be less than 1. While far less year-to-year variation in testing methods is expected for this assessment than the others, normalising at the cohort year level correct, for any year-to-year variations. The score is only calculated if numeric scores for all five domains are available.

Compared with the educational indices based on scaled logit scores, the MEDS values tend to have a more skewed distribution, with a longer tail in the negative values.

Grade 3 reading and numeracy assessment index

The grade 3 assessments measure seven competencies, three in the area of reading, and four in numeracy [52]. When a child is assessed, one of the following codes is recorded for each competency:

- 0004 - Out of Range - below
- 0030 - Needs Ongoing Help
- 0031 - Approaching Expectations
- 0032 - Meeting Expectations

From these individual competency assessments, composite indicators are determined for reading and numeracy, for meeting all competencies in the area, and for meeting or approaching all competencies.

For the composite index, we first convert the 4 assessment result codes above to a number from 1-4, and sum up the numeric scores for the areas of reading and numeracy. To give the sums equal weight, we take of the sum for numeracy, as it is composed of four competency scores, while the reading score is composed of only three. These values are added to get a composite score in the range 6-24, which is subtracted from 25, then rounded down to an integer value (floor), to get a ranking from 1-19. This ranking is then used to calculate a scaled logit score in the same manner as for the grade 9 achievement index and the grade 12 LA & Math indices [53, 54]. The score is only calculated if valid results for all seven competencies are available.

Grade 7 numeracy assessment index

The grade 7 assessments measure several competencies in the area of number skills and number sense.[52] When a child is assessed, one of the following codes is recorded for each competency:

- 0004 - Out of Range - below
- 0016 - Not Meeting Mid-Grade 7 Level of Performance
- 0017 - Approaching Mid-Grade 7 Level of Performance
- 0018 - Meeting Mid-Grade 7 Level of Performance

From these individual competency assessments, composite indicators are determined for numeracy, for meeting all competencies in the area, and for meeting or approaching all competencies.

For the composite index, we first convert the 4 assessment result codes above to a number from 1-4, and sum up the numeric scores for the area of numeracy. These values are added to get a composite score in the range 5-20, which is subtracted from 21 to get a ranking from 1-16. This ranking is then used to calculate a scaled logit score in the same manner as for the grade 9 achievement index and the grade 12 LA & Math indices [53, 54]. The score is only calculated if valid results for all five competencies are available.

Grade 8 reading and writing assessment index

The grade 8 assessments measure six competencies in the areas of reading comprehension and expository writing [52]. When a child is assessed, one of the following codes is recorded for each competency:

- 0004 - Out of Range - below
- 0020 - Not Meeting Mid-Grade 8 Level of Performance
- 0021 - Approaching Mid-Grade 8 Level of Performance
- 0022 - Meeting Mid-Grade 8 Level of Performance

From these individual competency assessments, composite indicators are determined for reading and writing performance, for meeting all competencies in the area, and for meeting or approaching all competencies.

The composite index involves first converting the 4 assessment result codes above to a number from 1-4 and sum up the numeric scores for the areas of reading and writing. These values are added to get a composite score in the range 6-24, which is subtracted from 25 to get a ranking from 1-19. This ranking is then used to calculate a scaled logit score in the same manner as for the grade 9 achievement index and the grade 12 LA & Math indices [53, 54]. The score is only calculated if valid results for all six competencies are available.

Grade 9 achievement index

The grade 9 achievement index, also known as the grade 9 performance index, is calculated from the high school enrollment, marks and assessment data [54]. A scaled logit score, with a mean of 0 and standard deviation scaled to ± 1 , is created based on an overall ranking for each student.

This ranking takes into consideration the number of credits passed and the average grade in the expected year of grade 9 attendance. Students who earned fewer than 7 credits are assigned a lower rank category than those who earned similar marks but completed more credits. Rankings from 1-16 are determined based on the criteria detailed in the above-referenced concept. A frequency analysis on the rankings for the entire cohort year is used to calculate the logit score using a formula presented in Willms (1986), for the grade 12 LA & Math indices [53, 55]. To normalise the logit scores, we calculate the mean and standard deviation of these scores for each cohort year, scale each individual score by subtracting the mean score, and then divide by the standard deviation. This yields scores with a mean of 0 and SD of 1 for the cohort year. This produced scores comparable from year to year, despite differences over time in testing and scoring.

Grade 12 language arts and math composite index

The grade 12 LA & Math achievement indices are already calculated as scaled logit scores, with a mean of 0 and standard deviation scaled to ± 1 [53]. These two logit scores are created from ranking categories based on scores in the grade 12 language arts and mathematics standards tests. A frequency analysis of these two rankings, from 1-19, is used to calculate the two logit scores. To calculate a composite index for grade 12, we simply took the mean of the two scaled logit scores for LA and Math, giving them equal weight. As the standard deviation for the combined score differed from the mean of the previous two SDs, to maintain the same scaling, the score for each person is divided by the recalculated standard deviation of scores for all students in the same year, in the same way as the original two logit scores were scaled.

