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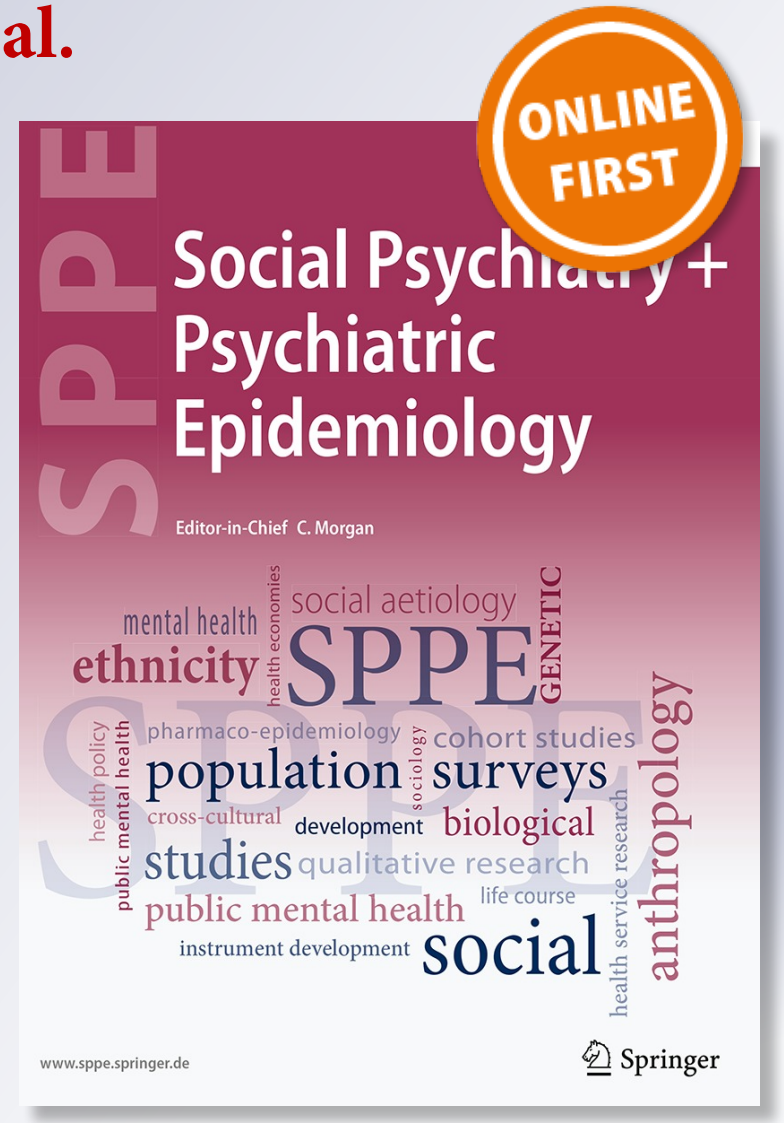

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ORIGINAL PAPER

Poverty and behavior problems trajectories from 1.5 to 8 years of age: Is the gap widening between poor and non-poor children?

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Abstract
Purpose Poverty has been associated with high levels of behavior problems across childhood, yet patterns of associations over time remain understudied. This study aims: (a) to examine whether poverty predicts changes in behavior problems between 1.5 and 8 years of age; (b) to estimate potential selection bias for the observed associations.
Methods We used the 1998–2006 waves of the Quebec Longitudinal Study of Child Development ($N = 2120$). Main outcomes were maternal ratings of hyperactivity, opposition and physical aggression from 1.5 to 8 years of age. Linear mixed-effects models were used to assess the longitudinal association between poverty and behavior problems. Models were re-estimated adjusting for wave nonresponse and using multiple imputation to account for attrition.
Results Poverty predicted higher levels of behavior problems between 1.5 and 8 years of age. Poverty predicted hyperactivity and opposition in a time dependent manner. Hyperactivity [Bpoverty*age = 0.052; CI 95 % (0.002; 0.101)] and opposition [Bpoverty*age = 0.049; CI 95 % (0.018; 0.079)] increased at a faster rate up to age 5 years, and then decreased at a slower rate for poor than non-poor children. Physical aggression decreased at a steady rate over time for all children [Bpoverty*age = −0.030; $p = 0.064$). Estimates remained similar when accounting for attrition.
Conclusion Poverty predicted higher levels of behavior problems between 1.5 and 8 years of age. The difference between poor and non-poor children was stable over time for physical aggression, but increased with age for hyperactivity and opposition. Attrition among poor children did not compromise the validity of results.

Keywords Hyperactivity · Opposition · Physical aggression · Poverty · Attrition

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Introduction

Poverty is a well establish risk factor for children's behavior problems [1]. This association is robust across several high-income countries with different health care and social policy contexts [2, 3]. However, little is known about how early in life this association starts operating, leading to differences in behavior problems levels between poor and non-poor children, and whether these putative difference increases with age. A life course framework

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[4, 5] to cumulative disadvantage posits that persistent adversity accumulates over time leading to increased heterogeneity in health trajectories with development [6, 7]. Grounded on this framework, this study examined whether poverty between 1.5 and 8 years of age is associated with developmental changes in three prevalent behavior problems during childhood [8, 9]: hyperactivity, opposition, and physical aggression. Behavior problems are of concern because they may persist across development in the form of a wide range of adverse psychosocial outcomes [10, 11].

Studies from The United States suggest that changes in family income predict changes in behavior problems from early-to-middle childhood (2–5 and 4–14 years), particularly for poor and low income families [12–15]. Specifically, one study showed that differences in behavior problems (4–14 years) between high- and low-income families increased over time [14]. Another study showed that the number of years living in poverty was associated with higher trajectories of behavior problems during those years between ages 5–9 years [15]. Similarly, studies from the United Kingdom suggest that associations between low income and behavior problems increased with age (3–7 years) [16, 17]. A Norwegian study have also shown that income gains was associated with diminished behavior problems, especially for low income children from 1.5 to 3 years of age [18]. Studies were based on global measures of behavior problems capturing specific aggressive and delinquent behaviors. Overall, findings indicate that variations in family income, as well as the time spent in poverty are associated with changes in behavior problems over time.

Previous studies essentially focused on early or middle childhood (i.e., before and after age 5 years), but did not provide information about changes in behavior problems across developmental periods. Nor did they examine whether poverty predicts increasing disparities in behavior problems from early-to-middle childhood, as previous studies were mostly based on income gains. Another limitation of previous studies is that they were not based on annual measurements, which constrains the analysis of developmental change in behavior problems. Regular, annual assessments in the early years can provide valuable information on early onset of behavior problems and their patterns of change. Further, few studies have considered different subtypes of behavior problems in relation to poverty. Poverty heightens the risk of children's behavior problems, but whether this association is magnified with age across different subtypes remains unclear. It is important to distinguish subtypes of behavior problems because they have different developmental trajectories [19]. Finally, few studies, if any, have addressed selection bias regarding differential attrition affecting the poorest and children displaying high levels of behavior problems.

This study addressed these issues using a birth cohort in which data was available between 1.5 and 8 years of age. There were two primary objectives to the study. First, we wanted to examine whether poverty predicts changes in behavior problems between 1.5 and 8 years of age. The goal was to extend previous research by estimating potential variations in the link between poverty and three subtypes of behavior problems. The distinct contribution of the study resides in examining whether the poverty gap that is initiated early and whether it is widening over time. We hypothesized that poverty would increase behavior problems with age. The second objective was to estimate potential selection bias on the association between poverty, behavior problems, and age. When testing for selection bias, we also hypothesized that predicted poverty estimates would be smaller due to retention of the healthier and wealthier participants in the study.

Methods

Data

We used the 1998–2006 waves of the Quebec Longitudinal Study of Child Development (QLSCD). Ethics approval was obtained from the Quebec Institute of Statistics and Sainte-Justine Hospital. The target population was singleton infants born in 1997–1998 and whose mothers reside in Quebec, Canada [20]. The initial sample comprised of 2120 children aged 3–8 months (mean age 5 months). Data were collected yearly until 2005 when the interview schedule shifted to a biennial design. Interviews were conducted by trained research assistants through home interviews and directed to the person most knowledgeable about the child (mothers in 98 % of cases). Written informed consent was obtained from all respondents. We used seven assessments points in which information on maternal ratings of children's behavior problems were available. Assessments were conducted at: 1.5, 2.5, 3.5, 4.5, 5, 6 and 8 years. When children were 8 years of age, 1451 participants from the initial sample remained in the study (i.e., 69 % of retention rate). Our analytic sample ($N = 2045$) included study participants with at least one score for either behavior problems.

Attrition and non-participation

Attrition between baseline and follow-up at 4 years of age was low (8.8 %). Attrition increased for assessments conducted at 5, 6 and 8 years of age (i.e., 17, 29.6 and 29.4 %,

Table 1 Distribution of behavior problems and poverty from baseline to 8 years of age

Age	Hyperactivity	Physical aggression	Opposition	Poverty	
	N (mean ± SD)	*N* (mean ± SD)	*N* (mean ± SD)	Poor *N* (%)	Non-poor *N* (%)
0.5	–	–	–	511 (24.1)	1571 (74.1)
1.5	2045 (3.92 ± 2.40)	2045 (1.33 ± 1.53)	2045 (3.41 ± 2.14)	416 (19.6)	1599 (75.4)
2.5	1997 (3.91 ± 2.38)	1997 (1.88 ± 1.72)	1997 (3.60 ± 2.29)	398 (17.4)	1598 (75.4)
3.5	1948 (4.22 ± 2.15)	1949 (2.29 ± 2.26)	1950 (3.88 ± 2.29)	319 (15.0)	1594 (75.2)
4.5	1942 (3.88 ± 2.15)	1942 (1.82 ± 2.08)	1942 (3.58 ± 2.15)	–	–
5	1759 (3.99 ± 2.09)	1759 (1.77 ± 2.10)	1759 (3.50 ± 2.11)	298 (14.1)	1438 (67.8)
6	1492 (3.79 ± 2.20)	1492 (1.63 ± 2.05)	1492 (3.47 ± 2.00)	245 (11.6)	1235 (58.3)
8	1450 (3.18 ± 2.25)	1267 (1.53 ± 2.08)	1450 (3.03 ± 2.08)	218 (10.3)	1220 (84.8)

Behavior problems were not available at 0.5 years of age. Poverty status was not available at 4.5 years of age

Table 2 Frequency of participants according to the number of wave nonresponse in the QLSCD from 1.5 to 8 years of age

Number of times participants missed a wave	*N* (%)
0	1287 (60.7)
1	280 (13.2)
2	251 (11.8)
3	132 (6.2)
4	42 (2.0)
5	20 (0.9)
6	45 (2.1)
7	63 (3.0)

respectively). Specifically, poor children, mothers who were not sufficiently fluent in either French and English, one-parent families, mothers who had less than a high school diploma, and mothers younger than 25 years of age were more likely to be lost to follow-up [20]. Table 1 shows the distribution of behavior problems and poverty over sampling period and how sample declines with age. Table 2 shows the number of time participants missed a wave (i.e., wave nonresponse) from 1.5 to 8 years of age. Respondents were defined as participating if they completed all or part of the Interviewer Completed Computerized Questionnaire (ICCQ).

Measures

Outcome variables: hyperactivity, opposition and physical aggression

Mothers rated their child's behavior problems between 1.5 and 8 years of age using the early childhood behavior scale from the Canadian National Longitudinal Study of Children and Youth [21]. Mothers rated the frequency scale of their child's behavior problems, namely whether the child never (0), sometimes (1), or often (2) exhibited hyperactivity, physical aggression and opposition. Hyperactivity items were: (1) "cannot sit still", (2) "is restless or hyperactive", (3) "is impulsive, acts without thinking", (4) "has difficulty waiting his/her turn", and (5) "cannot settle down to do anything for more than a few moments". Higher scores indicated higher levels of hyperactivity (range 0–10). Cronbach's alphas ranged from 0.67 to 0.77 across assessments. Opposition items were: (1) "is defiant or refuses to comply with adults request or rules?", (2) "does not seem to feel guilty after misbehaving?", and (3) "punishment doesn't change his/her behavior?". Higher scores indicated higher levels of opposition (range 0–6). Alpha levels were ranged between 0.46 and 0.65 across assessments. Physical aggression items were: (1) "gets into fights?", (2) "physically attacks others", and (3) "hits, bites, kicks other children". Higher scores indicated higher levels of physical aggression (range 0–6). Alpha levels ranged between 0.63 and 0.76 across assessments.

Exposure to poverty

First, mothers reported their best estimate of the total income before taxes and deductions of all household members when the child aged between 1.5 to 8 years. Poverty was defined according to the Canadian Low Income Cut-Offs (LICOs) calculated by Statistic Canada. LICOs were available yearly in the QLSCD, with the exception of the 4.5 years of age assessment. The calculation is based on family income, the number of people in the household, and the level of urbanisation of the place of residence in the past 12-months [22]. A family was considered poor (i.e., household income below the LICOs) when attributing 20 % or more of their household income than the average Canadian family to food, shelter, and clothing. For example, in 2012 LICOs were $ 30 250, $ 34 414, $ 37 610, and $ 43 942 (CAD) for a family of four

living in rural areas, towns (<30,000 inhabitants), towns between 30,000 and 99,999 inhabitants, or large cities (>500,000 inhabitants) respectively [23]. Poverty status was coded as (1) when children lived in household whose income was below the LICOs and (0) otherwise.

Baseline and time-varying confounders

Baseline confounders included: (a) immigration status (1 = immigrant mother; 0 = otherwise); (b) maternal history of antisocial behavior assessed when children aged 5 months (range 0–5 and Mean = 0.82; SD = 0.94), where higher scores indicate higher levels of antisocial behavior (e.g., "Before the end of high school, did you more than once get into fights that you had started?"); and (c) child's sex (1 = boys and 50.2 % of the sample; 0 = girls). Time-varying confounders assessed seven times over sampling period included: (a) maternal education (1 = mothers who did not complete high-school; 0 = otherwise); (b) family structure (1 = children whose parents were separated or single; 0 = otherwise). These confounders were selected based on their reported association in the literature [24–26] as well as to their association with behavior problems and poverty in bivariate analyses. For a Directed Acyclic Graph (DAG) illustrating the hypothesized causal structure and underlying confounding bias of our research question, see Appendix (Figure S1).

Statistical analysis

We conducted two sets of analyses: (a) Testing whether poverty predicted changes in behavior problems between 1.5 and 8 years of age; and (b) Estimating potential selection bias on the association between poverty, behavior problems, and age. Analyses were conducted with SPSS v.22.0. We used a threshold for significance at $p < 0.05$.

In the first set of analyses, we used linear mixed models (LMMs) with random intercept and trend (random effects models) to estimate individual growth curves for behavior problems over time in relation to poverty. Models are described using a two-level structure under which measurements were observations in time (Level 1) nested in children (Level 2). The following equation describes the simplest model (Model 1) using a random intercept and linear trend LMM where the quadratic age effect was considered in the fixed effects:

$$Y_{ij} = \left[\beta_0 + \beta_1 t_{ij} + \beta_2 t_{ij}^2\right] + \left[b_{0i+} b_{1i} t_{ij} + \varepsilon_{it}\right]$$

where the first bracket contains the fixed effects and the second bracket contains the random effects. Y_{ij} is the outcome variable for a child i at time j. Among the fixed effects, β_0, β_1 and β_2 are the population intercept, the linear trend and the quadratic trend. Among the random effects, b_{0i} and b_{1i} are the individual intercepts and trends, and ε_{ij} are the errors. Model 2 added the exposure variable and its interaction with age. Model 3 added baseline confounders. Model 4 introduced time-varying confounders. Finally, Model 5 represented the best fit and most parsimonious model built using the log-likelihood ratio test, employing a backward approach to retain variables below the threshold for significance. Table 3 presents full sequence of models. Further, simple t tests were performed at each age to identify when age-related changes began to appear due to poverty and its interaction term with age.

Table 3 Sequence of models summary

Model	Variables
1 (Time effects)	Age + Age^2
2 (Exposure)	Model 1 + poverty + poverty*age
3 (Baseline confounders)	Model 2 + immigration status + maternal antisocial behavior + child's sex
4 (Time-varying confounders)	Model 3 + maternal education + family structure
5 (Best fit and most parsimonious)	Model 4

In the second set of analyses, we estimated potential selection bias in a three-staged analysis: (1) re-estimating models accounting for the number times participants missed a wave (Table 2); (2) re-estimating models using Multiple Imputation (MI) [27, 28]. The explanatory variables used in the imputation process are: behavior problems (1.5–8 years), poverty (1.5–8 years) and both baseline and time-varying confounders. The motivation behind this decision was that individual missing values are likely dependent on observed data (i.e., missing at random, MAR). A total of five imputed datasets were produced. Finally, we restricted the analyses to a sub-sample of the cohort with complete data. Then, we compared coefficients across this three-staged analysis to those from the initial analysis. Variations in the poverty predictive estimates from these models were taken to analyse the nature and magnitude of selection bias.

Results

Table 4 displays the longitudinal associations between poverty and behavior problems. For all outcomes, results indicate that a quadratic trend with age best represented patterns of change between 1.5 and 8 years of age. Negative values indicate that behavior problems declined with age. However, the interpretation of the overall variation

Table 4 Longitudinal associations of poverty predicting behavior problems between 1.5 and 8 years of age

	Hyperactivity			Opposition			Physical aggression		
	Coef.	*p* value	95 % CI	Coef.	*p* value	95 % CI	Coef.	*p* value	95 % CI
Fixed effects									
Intercept	2.97	<0.001	2.77, 3.17	1.47	<0.001	1.35, 1.59	1.25	<0.001	1.12, 1.38
Age	0.316	<0.001	0.246, 0.387	0.288	<0.001	0.242, 0.335	−0.055	0.025	−0.103, −0.007
Age^2	−0.046	<0.001	−0.054, −0.039	−0.038	<0.001	−0.042, −0.033	−0.006	0.016	−0.011, −0.001
Poverty	0.002	0.986	−0.236, 0.241	−0.149	0.047	−0.297, −0.002	0.212	<0.001	0.127, 0.298
Poverty*age	0.052	0.042	0.002, 0.101	0.049	0.002	0.018, 0.079	–	–	–
Child's sex	0.638	<0.001	0.493, 0.783	0.152	<0.001	0.072, 0.231	0.418	<0.001	0.333, 0.502
Immigration status	−0.423	0.001	−0.672, −0.175	−0.320	<0.001	−0.459, −0.182	–	–	–
Antisocial behavior	0.186	<0.001	0.107, 0.265	0.122	<0.001	0.080, 0.166	0.087	<0.001	0.040, 0.133
Education	0.149	0.012	0.033, 0.264	–	–	–	0.160	<0.001	0.087, 0.234
Family structure	0.253	0.001	0.108, 0.399	0.133	0.003	0.045, 0.221	0.101	0.028	0.011, 0.191
Random effects									
Residual variance	2.23	<0.001	2.15, 2.31	1.04	<0.001	1.01, 1.08	1.15	<0.001	1.11, 1.19
Intercept variance	3.87	<0.001	3.50, 4.28	0.969	<0.001	0.850, 0.1.11	1.65	<0.001	1.48, 1.83
Covariance (b_{0i}, b_{1i})	−0.381	<0.001	−0.443, −0.319	−0.090	<0.001	−0.112, −0.069	−0.162	<0.001	−0.189, −0.136
Trend variance	0.086	<0.001	0.074, 0.099	0.022	<0.001	0.018, 0.027	0.024	<0.001	0.020, 0.030
−2 log likelihood	41262.45			32754.65			33669.22		

Best fit and most parsimonious model (Model 5 in Table 3); $N = 2045$ participants and $N2 = 14840$ observations

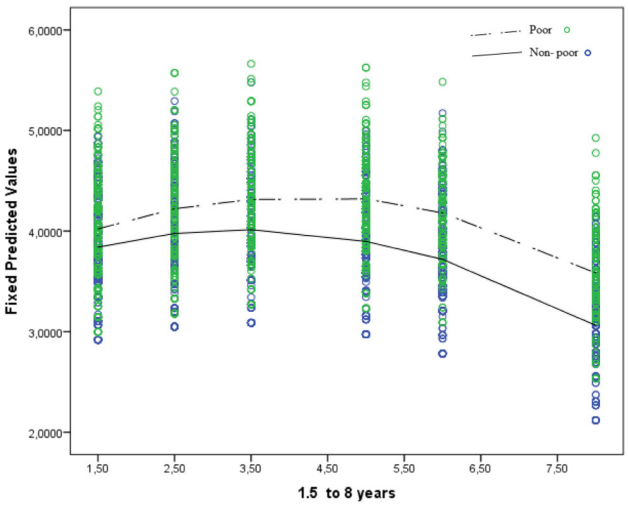
with age must take into account its linear and quadratic effects together. The same type of interpretation must be applied to poverty due to its interaction with age. Further, given that models relied on cross-sectional associations between poverty and behavior problems at each time point, the difference in the proportion of change between poor and non-poor children could not be estimated at age 4.5 years. Rather, it reflects individual differences in behavior problems between the ages of 1.5–4.5 years. Results are as follow:

Testing whether poverty predicts changes in behavior problems over time

For hyperactivity, a simple *t* test indicated that initial levels at 1.5 years of age were significantly higher for poor than non-poor children ($\Delta = -0.056$ units; $p = 0.034$). Figure 1 illustrates the predicted average change for hyperactivity between 1.5 and 8 years of age. The main contribution of poverty to hyperactivity was time dependent. Models revealed that the gap between hyperactivity trajectories of poor and non-poor children widened over time at a rate of 0.052 units (see also Table 4). The linear and quadratic terms for age show that hyperactivity trajectories peaked at age 5 years and started declining afterwards with poverty producing greater divergence with age. Specifically, poor children exhibited an increase in hyperactive behavior at a faster rate until age 5 years and later showed slower declines than non-poor children. All confounders were retained in the final model.

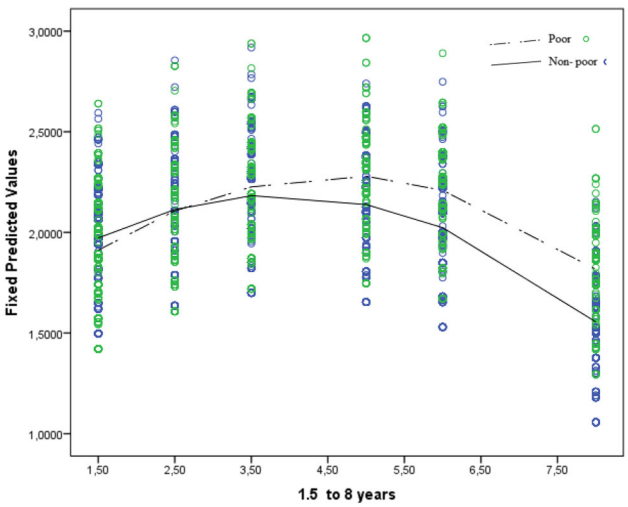
For opposition, a simple *t* test showed that initial levels at 1.5 years of age did not differ significantly between poor and non-poor children ($\Delta = -0.012$ units; $p = 0.671$). Figure 2 illustrates the predicted average change for opposition among poor and non-poor children between 1.5 and 8 years of age. As for hyperactivity, the main contribution of poverty to opposition was time dependent. Opposition trajectories peaked at age 5 years, and then declined, but with increased divergence as a function of poverty (i.e., rate of 0.049 units with age; see also Table 4). Compared to non-poor children, poor children exhibited an accelerated increase in oppositional behavior until age 5 years, and then a slower decline. All confounders were retained in the final model, with the exception of education.

For physical aggression, a simple *t* test indicated that initial levels at 1.5 years of age were significantly higher for poor than non-poor children ($\Delta = -0.097$ units; $p < 0.001$). Figure 3 illustrates the predicted average change for physical aggression between 1.5 and 8 years of age. Compared to non-poor children, poor children showed higher levels of physical aggression by about 0.212 units (see also Table 4). This difference remained constant across age ($B_{\text{Poverty*Age}} = -0.030$; $p = 0.064$). Hence, the decline with age in physical aggression was uniform regardless of poverty. All confounders were retained in the



Note. Dots represent individual values.

Fig. 1 Hyperactivity average trajectories based on random intercept and random trend models for poor and non-poor children between 1.5 and 8 years of age. *Dots* represent individual values



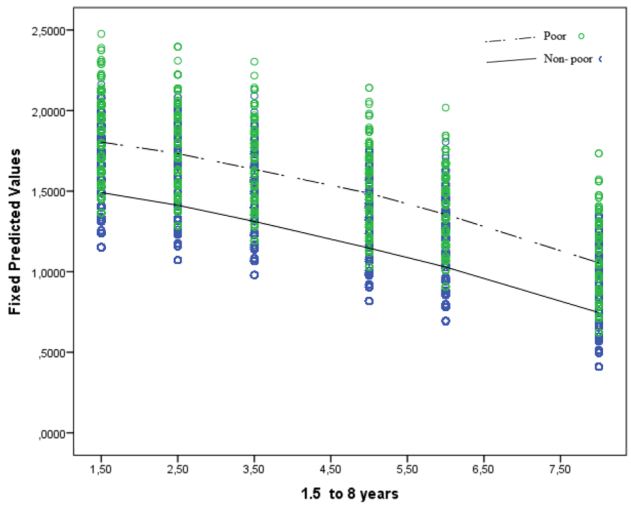
Note. Dots represent individual values.

Fig. 2 Opposition average trajectories based on random intercept and random trend models for poor and non-poor children between 1.5 and 8 years of age. *Dots* represent individual values

final model, with the exception of family structure and immigration.

Estimating selection bias on the behavior problems trajectories

Table 5 presents re-estimated LMMs accounting for wave nonresponse (Model 2), using MI (Model 3) and restricting analysis to a sub-sample with complete data (Model 4) to estimate potential selection bias in observed associations. Model 1 represent LMMs as presented in Table 4.



Note. Dots represent individual values.

Fig. 3 Physical aggression average trajectories based on random intercept and random trend models for poor and non-poor children between 1.5 and 8 years of age. *Dots* represent individual values

For hyperactivity, Models 1–3 were nearly identical but Model 4 showed slightly higher *p*-values. Specifically, Model 4 showed that the poverty interaction term was no longer significant, and revealed instead that the gap between trajectories was maintained with age. Changes in the interaction coefficient were consistently small in magnitude across all models.

For opposition, changes in poverty main contribution and its interaction coefficients remained similar in Models 1–3. Model 4 generated the lowest estimate for poverty main contribution and the highest coefficient for its interaction term. This suggests that when considering only a sub-sample with complete data, the gap between opposition trajectories widened at a faster rate for children exposed to poverty.

For physical aggression, Models 1–3 showed similar results. Model 4 generated the lowest estimate for poverty main contribution, suggesting that the gap between trajectories was narrower than in Models 1–3. This suggests that when considering only a sub-sample with complete data, the quadratic term for age disappeared from results in Model 4.

Overall, results from Models 1–3 comparing findings accounting for attrition were, by and large, similar for all outcomes. Therefore, wave nonresponse, as unit nonresponse is relatively unimportant to our findings. Further, poverty main contribution decreased across all outcomes when restricting analysis to a sub-sample with complete data. Indeed, results deviated substantially from Model 1 suggesting a less accurate model due to severe loss of observations. Particularly, poverty was no longer a significant predictor of hyperactivity trajectories. Results from

Table 5 Estimating selection bias in longitudinal associations between behavior problems and poverty between 1.5 and 8 years of age

	Model 1		Model 2		Model 3		Model 4	
	Coef.	*p* value	Coef.	*p* value	Coef.	*p* value	Coef.	*p* value
Hyperactivity								
Intercept	2.97	<0.001	3.01	<0.001	3.18	<0.001	2.95	<0.001
Age	0.316	<0.001	0.314	<0.001	0.260	<0.001	0.307	<0.001
Age^2	−0.046	<0.001	−0.046	<0.001	−0.015	<0.001	−0.045	<0.001
Poverty	0.002	0.986	0.016	0.894	0.015	0.900	−0.051	0.739
Poverty*Age	0.052	0.042	0.049	0.050	0.052	0.054	0.052	0.085
−2 log likelihood	41262.45		41265.00		–		29832.63	
Opposition								
Intercept	1.47	<0.001	1.50	<0.001	1.54	<0.001	1.50	<0.001
Age	0.288	<0.001	0.285	<0.001	0.260	<0.001	0.281	<0.001
Age^2	−0.038	<0.001	−0.037	<0.001	−0.032	<0.001	−0.037	<0.001
Poverty	−0.149	0.047	−0.134	0.074	−0.121	0.073	−0.223	0.019
Poverty*Age	0.049	0.002	0.047	0.003	0.042	0.004	0.061	0.001
−2 log likelihood	32754.65		32754.94		–	–	23668.75	
Physical agression								
Intercept	1.25	<0.001	1.27	<0.001	1.44	<0.001	1.30	<0.001
Age	−0.055	0.025	−0.57	0.021	−0.123	<0.001	−0.065	0.021
Age^2	−0.006	0.016	-0.006	0.016	0.005	0.057	−0.005	0.092
Poverty	0.212	<0.001	0.217	<0.001	0.194	<0.001	0.148	0.005
−2 log likelihood	33669.22		33673.47			–	24325.69	

Models are as follow: Model 1: Best fit model as provided in Table 4; Model 2: Model accounting for the number of wave nonresponse; Model 3: Model using imputed data. The −2 log likelihood was not available for MI with SPSS; and Model 4: Model using a sub-sample with complete data ($N = 1287$ and $N2 = 9009$ observations)

Model 4 suggest that restricting analyses to a sub-sample with complete data without any adjustments to deal with missingness will lead to biased estimates due to attrition.

Discussion

The aim of this study was to examine whether poverty predicted changes in hyperactivity, opposition and physical aggression between 1.5 and 8 years of age, and then examine the potential impact of selection bias on the pattern of results. Findings revealed that poverty predicted higher trajectories of behavior problems over time, and that patterns of poverty-age interactions differed according to subtypes of behavior problems. Specifically, children who remained poor at all 7 years exhibited increasing levels of hyperactivity and opposition at a faster rate up to 5 years and decreasing levels at a slower rate afterwards. In contrast, physical aggression levels decrease overtime at a stable rate for both poor and non-poor children. Findings are consistent with prior research showing there is a general tendency for behavior problems to decrease or stabilize with age [29–31]. Further, selection bias did not appear to compromise the validity of results as estimates remained similar when accounting for attrition. Differences between hyperactivity/opposition and physical aggression trajectories and the effect of time of poverty point to the importance of distinguishing between different types of behavior problems in future studies.

The finding that the association between poverty and hyperactivity/opposition varied by age is consistent with previous studies on the association between economic deprivation and changes in behavior problems [13, 15, 31]. The results from this study extend previous findings by showing that the gap in hyperactivity/opposition between poor and non-poor children increases from early-to-middle childhood. Thus, it seems that hyperactivity/opposition disparities between poor children and others increases over the length of time spent in poverty. Further, the acceleration of hyperactivity/opposition over time for persistently poor children not only mirrors what was suggested by a previous study, but now extends poverty-time association over a longer period.

Importantly, the gap in physical aggression trajectories between poor and non-poor children can be observed as early as age 1.5 years. However, the association between poverty and physical aggression, rather than increasing with age, remained constant from early-to-middle

childhood. This could be due to the early and time-varying interplay of genetic and environmental factors [32–34]. Twin studies and other genetically informed studies have shown the importance of Gene x Environment interactions in the aetiology of aggressive behavior [35]. Taken together, studies suggest that individual differences in physical aggression may be linked to genetic influence and moderated by prenatal and post-natal environmental risk. It is possible that children are born with biological susceptibilities to physical aggression, and that these susceptibilities develop as a function of environmental adversities, including poverty.

Selection bias is an important issue in poverty research because of nonrandom exclusion of the most disadvantaged participants due to lack of resources, illness and other factors that might influence attrition. We have considered a number of rival models to adjust for selection bias and found similar results in models accounting for attrition. For the majority of outcomes, estimates of the attrition-adjusted models were slightly smaller than corresponding estimates of non-adjusted models. Our results demonstrate that the gap between behavior problems trajectories linked to poverty disappear when restricting analyses to a subsample of children that were present at all assessments points in the study. Thus, the gap between behavior problems trajectories linked to poverty disappear when restricting analyses to a sub-sample of children that were present at all assessments points in the study. This suggests that excluding participants with incomplete data or those lost to follow-up may lead to an underestimation of the true growth in behavior problems linked to poverty.

Strengths and limitations

This study has several strengths, including high quality prospective data and repeated and robust measures of exposure to poverty using national thresholds (i.e., LICOs). To our knowledge, LICOs are the most widely accepted measure of economic deprivation in Canada [36]. Second, we used validated behavior problems scales assessed yearly during early childhood and starting as early as age 1.5 years. Third, we minimized selection bias by taking advantage of individuals with incomplete data with LMMs as our analytical approach. Fourth, the examination of three subtypes of behavior problems suggesting that poverty is an important and a common risk factor which is age-dependent only to certain behavior problems. However, this study is not without limitations. Changes in sample demographics over the years may compromise the generalizability of our results. Mothers who did not speak French or English were excluded in the QLSCD and results cannot be inferred to any minority groups who cannot speak French or English. We relied only on maternal ratings of behavior problems. Ideally, children's behavior problems should be assessed by multiple informants (e.g., teacher and parent reports). The use of mother ratings is justified by her being the person who is the most knowledgeable about the child from early-to-middle childhood; teacher's ratings can only be used after age 5 years. Also, because our objective was to model normal variations of changes in behavior problems in a population-based sample, we could not rely on clinical ratings. Finally, although we were careful in controlling for confounders our capacity to make causal inferences is limited due to the correlational design of the study.

Conclusion

This study supports that poverty is a key factor in differentiating behavior problems among poor and non-poor children from early-to-middle childhood. The difference between poor and non-poor children is stable over time for physical aggression, and it increases as children age for hyperactivity and opposition. Findings highlight that compared to hyperactivity and opposition, the poverty gap in physical aggression does not increase with age. Attrition overtime among the poor and those with higher levels of behavior problems should be addressed in future longitudinal studies when replicating our results.

Policies directed at reducing child poverty will help decreasing the poverty gap in behavior problems at least through age 8 years. Such policies may be particularly important in the current economic context given that 2008 crisis and the global recession have harmed children's health, and disproportionately affected the most disadvantaged groups [37]. Policies may be in the form of financial benefits to increase family income or in the form of service delivery including child care and parental interventions [38–40].

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Compliance with ethical standards

Conflict of interest None.

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