



Parent report of child behaviour: Findings from the Flint Registry cohort

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Abstract

Background: Children in Flint, Michigan, have multiple risk factors for behavioural challenges, including exposure to lead during the Flint water crisis. However, their behavioural health status is largely unknown. Robust data from the Flint Registry can help understand the burden of behavioural outcomes and inform the allocation of resources.

Objectives: This population-level evaluation of Flint children's behavioural outcomes aims to answer the question: What is the burden of parent-reported child behaviour problems in Flint Registry enrolled children?

Methods: This cross-sectional study describes parent-reported behavioural outcomes of children 2–17 years old who enrolled in the Flint Registry between December 2018 and December 2020. Parents/guardians completed behavioural assessments including the Behavior Assessment System for Children (BASC-3) Parent Rating Scale and Behavior Rating Inventory of Executive Function (BRIEF2) Screening Parent Form. Demographics of enrollees were compared with census data. Composite BASC-3 T scores were compared with national norms. Distributions for clinically relevant categories of BASC-3 and BRIEF2 scores were examined across age and sex groups.

Results: Of the 3579 children included in this study (mean age 9.73 ± 3.96 years), about half were female and 79.7% were eligible for free or reduced-price lunch. Almost half of the children were reported to have clinically concerning scores on the BASC-3 Parent Rating Scale (44.7%) and the BRIEF2 Screening Parent Form (46.7%). Across most age and sex groupings, the reported adaptive skills were relatively low and behaviour symptoms relatively high.

Conclusions: Results reveal a substantial burden of parent-reported behavioural problems in Flint Registry children. This is clinically significant and indicates that a large number of children may require comprehensive neuropsychological evaluation and potential medical and/or educational services. Recognising the potential for long-term manifestations of childhood exposures to environmental hazards, longitudinal surveillance is critical to continue to identify and support participants.

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KEYWORDS

adolescent, behaviour, adaptive, child, executive function, human development, problem behaviour

1 | BACKGROUND

The Flint water crisis, a public health emergency, began in April 2014 when the drinking water source of Flint, Michigan, United States, was changed from Lake Huron to the Flint River without proper corrosion control treatment. Unbeknownst to the residents of Flint and for over 18 months, lead leached from the drinking water infrastructure. A potent neurotoxicant with no safe level, lead exposure is implicated in deleterious cognitive, behavioural, developmental and health consequences.¹⁻⁶

In response to the critical need to understand and mitigate the public health impact of the water crisis, the U.S. Centers for Disease Control and Prevention (CDC)-supported Flint Registry was created at Michigan State University in collaboration with many community partners. Modelled after large-scale exposure-based registries like the World Trade Center Health Registry,⁷ the Flint Registry was developed to identify and enrol individuals exposed to the Flint water crisis and connect them to services through a screening and referral process.

In addition to supporting impacted individuals, the Flint Registry seeks to provide a population-level description of community health and behavioural outcomes. While the Flint Registry serves the entire exposed population, the health and neurodevelopmental status of children is of particular concern. Children have increased vulnerability to the neurotoxic effects of lead,⁸ as well as to other toxic stresses such as childhood poverty and systemic racism;^{9,10} at the same time, there is great potential to proactively mitigate deleterious consequences. As such, the Flint Registry enrolment survey included questions and instruments designed to broadly assess child health and development. Specifically, the Behavior Assessment System for Children, Third Edition (BASC-3) Parent Rating Scale¹¹ and Behavior Rating Inventory of Executive Function, Second Edition (BRIEF2) Screening Parent Form¹² were included because of their wide age applicability, ease of administration, comparison to national norms (BASC-3 only), shared utilisation by Flint-area educators and clinicians, rigorous development and use for screening children in need of neuropsychology referral.

Studies of Flint children's behavioural and neurodevelopmental outcomes have been limited. There have been no population-level or descriptive studies. One study of 170 preschoolers exposed to the Flint water crisis found a wide range of neurodevelopmental outcomes, with half of children demonstrating low scores across all cognitive and behavioural domains;¹³ evaluating the same cohort, a study of 184 preschoolers found wide ranges of IQ scores, with the average in the low-normal range, in the presence of a wide range of adaptive skills, with the average level in the adequate range.¹⁴ These studies underscore the need for robust population-level data to understand the burden of behavioural outcomes and to appropriately allocate resources.

Synopsis

Study question

What is the burden of parent-reported child behaviour problems in Flint Registry enrolled children?

What's already known

Children in Flint, Michigan, have multiple risk factors for behavioural challenges, including lead exposure during the Flint water crisis. Earlier work indicated Flint preschoolers have average adaptive function; however, the behavioural health status of Flint children is largely unknown.

What this study adds

This study reveals a substantial burden of parent-reported behavioural problems in a large sample of Flint children. Almost 50% of children had at-risk or clinically concerning behaviour on the BASC-3 Parent Rating Scale. The BRIEF-2 Screening Parent Form found similar results. Flint parents reported relatively low levels of adaptive skills and relatively high levels of concerning behavioural symptoms in their children.

Utilising BASC-3 and BRIEF2 survey data from children enrolled in the Flint Registry, this population-level evaluation of Flint children's behavioural outcomes aims to determine the burden of parent-reported child behaviour problems.

2 | METHODS

Eligibility criteria for the Flint Registry were determined by the CDC and included individuals who reported that they lived in Flint, went to school in Flint or attended day care in Flint during the time period on Flint water, between 24 April 2014 and 15 October 2015, including those who were prenatally exposed. Enrolment launched in December 2018. Individuals were recruited to the Flint Registry via an extensive outreach and marketing campaign which included signing up at local locations, over the phone, or via the Flint Registry website. In addition, recruitment mailings were sent to lists of potentially eligible individuals, including all current Flint residents and children who lived at an address serviced by the Flint Water System during 2014–2015 and who were enrolled in a Michigan Department of Health and Human Services

program (e.g. Michigan Care Improvement Registry, Childhood Lead Poisoning Prevention Program and Medicaid). Recruitment activities included sending text messages, e-mails, and letters and making phone calls to encourage individuals to complete their enrolment survey. Enrolment in the Flint Registry is ongoing with the first follow-up survey conducted 1 year post-enrolment. The cohort remains open for enrolment.

This cross-sectional study of children enrolled in the Flint Registry examined data collected at the time of enrolment. During enrolment, participants completed eligibility, consent and a baseline survey with measures of ongoing environmental lead exposure, health status and child behaviour assessment instruments. Additionally, basic demographic information, including child age, biological sex, city of residence and race, was collected via survey. The survey allowed participants to select all that applied from the following race categories: White or Caucasian; Black or African American; Native American or Alaska Native; Asian Native Hawaiian or Other Pacific Islander; Middle Eastern or North African; and Other, please specify. For children, enrolment forms and surveys were completed by a parent or guardian. Flint Registry enrolment surveys are predominantly completed online (over 85%). Informed consent was obtained over the phone, in person, or via a web form. The Flint Registry survey and assessment data were collected using REDCap electronic data capture tools hosted at Michigan State University.^{15,16}

2.1 | Cohort selection

An estimated 21,700 children living in the City of Flint, Michigan during the Flint water crisis were under the age 18 years when enrolment launched in late 2018. Flint Registry children were included in this analysis if they completed the Flint Registry enrolment survey (i.e. enrolled) between December 2018 and December 2020; reported that they lived in Flint during the time period on Flint water or were prenatally exposed ($N = 3836$); and had at least one valid composite measure of the BASC-3 Parent Rating Scale ($N = 3579$), which required them to be aged 2–17 years at the time of enrolment. Of these children, 3191 also had BRIEF2 Screening Parent Form scores.

2.2 | Outcomes

Survey responses from two validated instruments were analysed: BASC-3 Parent Rating Scale and BRIEF2 Screening Parent Form. Both are licensed assessments that were purchased for use in this study population.

The BASC-3 Parent Rating Scale measures adaptive and problem behaviours in community and home settings. It underwent bias analyses, was age-standardised and has norms derived from a large, representative sample of children across the United States.¹¹ There are 139 items for preschoolers (aged 2–5), 175 for school-age children (aged 6–11) and 173 for adolescents (aged 12–21). The items

describe a child behaviour; parents indicate how frequently each occurs using the responses never, sometimes, often or almost always. Item scores combine to create composite age-standardised T scores for four scales: externalising problems, internalising problems, behavioural symptoms index and adaptive skills (see Table S1). Higher externalising problems, internalising problems, and behavioural symptoms index and lower adaptive skills composite T scores are associated with greater likelihood of problem behaviour. T-score categories for clinical relevance—very low, low, average, at-risk and clinically significant—are derived from the standard T-score distribution with a mean of 50 and standard deviation of 10.

The BASC-3 manual reports the reliability, Cronbach's alpha, of the composite T scores ranged from 0.93 to 0.97 for preschoolers, 0.95 to 0.97 for school-age children and 0.96 to 0.97 for adolescents.¹¹ In the current study, Cronbach's alpha ranged from 0.89 to 0.92 for preschoolers, 0.94 to 0.95 for school-age children and 0.93 to 0.95 for adolescents.

The BRIEF2 Screening Parent Form is frequently used in research as well as in medical and educational settings to help determine whether more comprehensive assessment to identify executive function deficits is appropriate. The 12-item behavioural rating scale has response options of never, sometimes and often. Raw scores range from 12 to 36; higher scores are associated with increased likelihood of executive function deficits. No T scores were calculated; percentiles were provided for raw scores based on eight age (5–7, 8–10, 11–13 and 14–18 years) and gender (male/female) groupings. Percentiles correspond to different levels of clinical relevance: average, potentially clinically elevated and clinically elevated (Table S2). Cut scores were based on standardised data from the BRIEF2 full inventory. The BRIEF2 manual reports internal consistency reliability for the BRIEF2 Screening Parent Form is $\alpha = 0.89$, and test-retest reliability, $r = 0.79$.¹² Calculated for the current study, Cronbach's alpha was 0.92.

2.3 | Statistical analysis

BASC-3 composite T-score sample means were compared with the expected means for each age by gender group outlined above. Mean differences, Cohen's d and confidence intervals were employed to explore the standardised magnitude of differences. Per convention, a Cohen's d of 0.20 indicates a small effect, a Cohen's d of 0.50 indicates a medium effect, and 0.80 was considered a large effect. In addition, the composite T scores were categorised using BASC-3 classifications into clinically relevant categories, and frequencies were calculated. BRIEF2 screening data are reported by age group and gender. IBM SPSS version 27 was used to analyse the data.

2.3.1 | Missing data

Missing item-level data for the BASC-3 Parent Rating Scale were handled as prescribed in the administration manual, which specifies

that a maximum of two unscorable (i.e. omitted or multiply marked) items is allowed per scale, and for these records, data are imputed using the developed 'PRS Adjustment Factors for Unscorable Item Response'.¹¹ Flint Registry enrollees without at least one validated BASC-3 composite score (6.7%) were excluded from the study.

The descriptive analysis of the BRIEF2 Screening Parent Form includes data from 3191 children; 361 children in the study were less than 5 years of age and did not meet the age requirement for administration of the BRIEF2 Screening Parent Form, and 27 (0.8%) children had missing item data and thus do not have a BRIEF2 score.

2.3.2 | Sensitivity analyses

To assess for potential selection bias, included and excluded groups were compared by biological sex, race and free and reduced-price lunch eligibility.

2.4 | Ethics approval

This study was conducted after the Michigan State University Institutional Review Board approved the secondary analysis of Flint Registry data and in accordance with federal, state and local regulations, university policies and ethical standards.

3 | RESULTS

3.1 | Sample size and demographics

As of 31 December 2020, 12,232 individuals have enrolled in the Flint Registry, including 3836 children aged 2–17 years who reported living in Flint during the time of the Flint water crisis. The 3579 children with BASC-3 scores included in this analysis represent approximately 16% of the estimated denominator of 21,700 Flint children

born before 2016 and who were less than 18 years of age when enrolment in the Flint Registry began at the end of 2018.¹⁷ BRIEF2 scores were available for 3191 children.

About half of the children were female (49.7%). The mean age of children at assessment was 9.73 ± 3.96 years. Most children (79.7%), as reported by their parents, were eligible for free or reduced-price lunch services. Additionally, 65.7% of the children were identified as Black only and 19.9% as white only. See [Table 1](#) for comparison with US Census data demographics based on estimates of the entire 2016 population of children under 18 years for the City of Flint.

The study children were demographically similar to the Flint population with the same percentage of children qualifying for free and reduced-price lunch but did vary in reported race, with fewer children in the Flint Registry identifying as white only. There were no discernible differences between the sample population and those cases excluded due to a lack of BASC-3 data or BRIEF2 data relative to biological sex, race, and free and reduced-price lunch eligibility.

3.2 | Child behaviour ratings

3.2.1 | BASC-3 parent rating scale

On average, the preschool boys and girls scored at or near the expected mean of 50 on most of the BASC-3 composite measures: externalising problems, internalising problems, behavioural symptoms and adaptive skills (see [Table 2](#)). One noted difference was revealed in adaptive skills of preschool boys, whose mean scale score was 3.39 points lower than the expected mean. A Cohen's *d* of -0.30 for adaptive skills implies a small to medium effect size, and that preschool boys were reported to exhibit weaker social skills, functional communication and adaptability than their peers (see [Table 3](#)).

Mean T scores for school-age girls—6 to 11 years—differed from the expected mean scores on the composite measures of behavioural symptoms and adaptive skills by 2.56 and -3.39 points respectively.

TABLE 1 Demographics of Flint Registry study participants (N = 3579) and Flint children based on the 2016 American Community Survey

Demographic	Number of Study Participants (aged 2–17) (%) ^a	2016 Flint Population Estimate (aged 0–17) (%) ^{b,c}
Sex		
Female	1777 (49.7)	11,465 (48.4)
Male	1802 (50.3)	12,204 (51.6)
Race		
Black only	2338 (65.7)	15,115 (59.1)
White only	707 (19.9)	8388 (32.8)
Other and More than One Race	514 (14.4)	2072 (8.1)
Free and Reduced-Price Lunch Eligible	2809 (79.7)	16,008 (80.8)

^aThe study included individuals who were residents of the City of Flint between 25 April 2014 and 15 October 2015. Reported race was missing for 20 (<1%) study participants, and free and reduced-price lunch eligibility was missing for 53 (1%).

^bSex and race estimates are based on the 2016 American Community Survey.^{17,18}

^cFree and reduced-price lunch eligibility is based on data from the Kids Count Data Center.¹⁹

	N	Mean (standard deviation)	Interquartile range
Preschool Females: 2–5 years			
Externalising problems	327	50.6 (11.4)	42, 56
Internalising problems	327	51.0 (12.0)	43, 56
Behavioural symptoms	327	51.2 (11.6)	43, 57
Adaptive skills	327	49.3 (10.3)	42, 57
Preschool males: 2–5 years			
Externalising problems	315	51.7 (12.8)	43, 57
Internalising problems	315	48.5 (11.1)	41, 55
Behavioural symptoms	315	51.9 (12.4)	43, 57
Adaptive skills	315	46.6 (11.1)	39, 55
School-aged females: 6–11 years			
Externalising problems	829	52.0 (13.5)	42, 59
Internalising problems	829	49.9 (12.6)	40, 57
Behavioural symptoms	829	52.6 (13.3)	42, 61
Adaptive skills	829	46.6 (11.5)	38, 56
School-aged males: 6–11 years			
Externalising problems	856	56.2 (16.5)	44, 64
Internalising problems	856	50.1 (13.1)	40, 58
Behavioural symptoms	856	56.9 (15.8)	45, 66
Adaptive skills	856	43.8 (11.6)	35, 52
Adolescent females: 12–18 years			
Externalising problems	621	50.8 (10.3)	43, 54.5
Internalising problems	621	51.7 (11.6)	43, 58
Behavioural symptoms	621	52.2 (10.2)	44, 59
Adaptive skills	621	46.3 (10.8)	38, 54.5
Adolescent Males: 12–18 years			
Externalising problems	631	53.2 (12.3)	44, 59
Internalising problems	631	49.1 (11.2)	41, 55
Behavioural symptoms	631	53.6 (11.3)	45, 61
Adaptive skills	631	43.0 (10.7)	35, 51

Note: BASC-3 = Behavior Assessment System for Children, Third Edition.

Cohen's *d* of 0.19 suggests a small effect size relative to behavioural symptoms and a Cohen's *d* of -0.29 a small-to-medium effect size relative to adaptive skills. School-age girls in this study had more behavioural symptoms and less adaptive skills than their peers.

The study's school-age boys differed from their peers on externalising problems (mean difference = 6.24), behavioural symptoms (mean difference = 6.93) and adaptive skills (mean difference = -6.25). The differences from the expected mean of 50 approached or reached a medium effect size as measured by Cohen's *d*. The school-age boys were reported to have more hyperactivity, aggression, and conduct problems, more behavioural symptoms and less adaptive skills than their peers.

Both male and female adolescents—aged 12 to 18 years—had mean T scores on the BASC-3 behavioural symptoms and adaptive skills that differed from their peers. Cohen's *d* generally showed small-to-medium effect sizes for these differences except the

TABLE 2 Flint Registry study participants' BASC-3 Parent Rating Scale scores

adaptive skills measures for adolescent males, which appear to reveal a medium-to-large effect size of -0.65 . Adolescent males also had externalising problem mean T scores that exceeded expected scores by 3.19 and a Cohen's *d* of 0.26, revealing a small effect size. In summary, male and female adolescents were reported to have more behavioural symptoms and less adaptive skills than their peers. In addition, male adolescents' T scores reveal more externalising problems such as hyperactivity, aggression and conduct problems.

The BASC-3 composite scores are presented as clinical and adaptive classifications in Figure 1. The graphic reflects the findings presented above. Overall, 44.7% of children were reported to have clinically significant or at-risk BASC-3 scores. A considerable number of school-age and adolescent children had BASC-3 adaptive skills and behavioural symptoms composite scores that categorise their behaviour as clinically significant or at-risk. In addition, a large percentage of school-age children and adolescent boys had

TABLE 3 Comparison between Flint Registry study participants' BASC-3 Parent Rating Scale scores and national norms

	N	Mean difference (95% CI)	Effect size
			Cohen's d ^a (95% CI)
Preschool females: 2–5 years			
Externalising problems	327	0.57 (–0.66, 1.81)	0.05 (–0.06, 0.16)
Internalising problems	327	0.97 (–0.33, 2.27)	0.08 (–0.03, 0.19)
Behavioural symptoms	327	1.19 (–0.07, 2.46)	0.10 (–0.01, 0.21)
Adaptive skills	327	–0.70 (–1.82, 0.41)	–0.07 (–0.18, 0.04)
Preschool males: 2–5 years			
Externalising problems	315	1.66 (0.24, 3.07)	0.13 (0.02, 0.24)
Internalising problems	315	–1.48 (–2.71, –0.26)	–0.13 (–0.25, –0.02)
Behavioural symptoms	315	1.88 (0.51, 3.25)	0.15 (0.04, 0.26)
Adaptive skills	315	–3.39 (–4.63, –2.15)	–0.30 (–0.42, –0.20)
School-aged females: 6–11 years			
Externalising problems	829	1.99 (1.07, 2.91)	0.15 (0.08, 0.22)
Internalising problems	829	–0.09 (–0.95, 0.77)	–0.01 (–0.08, 0.06)
Behavioural symptoms	829	2.56 (1.65, 3.46)	0.19 (0.12, 0.26)
Adaptive skills	829	–3.36 (–4.15, –2.58)	–0.29 (–0.36, –0.22)
School-aged males: 6–11 years			
Externalising problems	856	6.24 (5.13, 7.34)	0.38 (0.31, 0.45)
Internalising problems	856	0.06 (–0.82, 0.94)	0.01 (–0.06, 0.07)
Behavioural symptoms	856	6.93 (5.87, 7.99)	0.44 (0.37, 0.51)
Adaptive skills	856	–6.25 (–7.03, –5.47)	–0.54 (–0.61, –0.47)
Adolescent females: 12–18 years			
Externalising problems	621	0.80 (0.00, 1.61)	0.08 (0.00, 0.16)
Internalising problems	621	1.73 (0.81, 2.64)	0.15 (0.07, 0.23)
Behavioural symptoms	621	2.25 (1.44, 3.06)	0.22 (0.14, 0.30)
Adaptive skills	621	–3.66 (–4.51, –2.81)	–0.34 (–0.42, –0.26)
Adolescent males: 12–18 years			
Externalising problems	631	3.19 (2.23, 4.15)	0.26 (0.18, 0.34)
Internalising problems	631	–0.86 (–1.73, 0.01)	–0.08 (–0.16, 0.00)
Behavioural symptoms	631	3.57 (2.69, 4.46)	0.32 (0.24, 0.40)
Adaptive skills	631	–6.96 (–7.80, –6.12)	–0.65 (–0.73, –0.56)

Note: BASC-3 = Behavior Assessment System for Children, Third Edition.

^aPer convention, a Cohen's d of 0.20 indicates a small effect, a Cohen's d of 0.50 a moderate effect, and 0.80 was considered a large effect.

clinically significant or at-risk T scores on the externalising problems composite.

BASC-3: A greater per cent of males had clinically elevated or potentially clinically elevated scores.

3.2.2 | BRIEF2 screening parent form

As with the BASC-3, the BRIEF2 screening results show that Flint children exhibited clinically concerning behaviours (see Figure 2). The sample size of BRIEF2 screenings is smaller ($n = 3191$) and reflects the older age of BRIEF2 eligibility (5 years vs. 2 years in BASC-3). Clinically elevated or potentially clinically elevated BRIEF2 scores identifying deficits in executive functioning were found in 46.7% of children. The BRIEF2 data by sex revealed patterns similar to the

4 | COMMENT

4.1 | Principal findings

The results of this study revealed a substantial burden of behavioural problems in Flint Registry enrolled children as reported by their parents across three domains. For adaptive skills, with the exception of preschool girls, all age and gender groups had lower levels of reported function than their peers. For school-age and

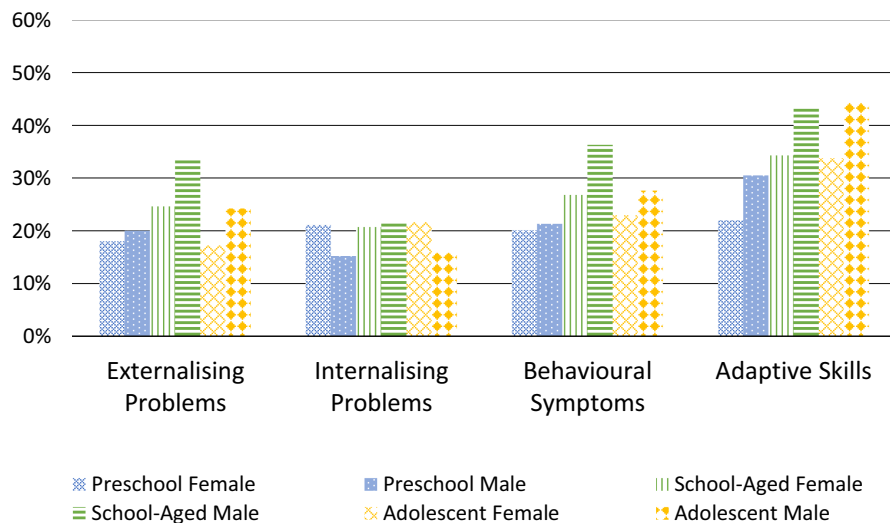


FIGURE 1 Per cent of Flint Registry study participants with at-risk or clinically significant scores on the BASC-3 Parent Rating Scale (N = 3579). Note: BASC-3 = Behavior Assessment System for Children, Third Edition

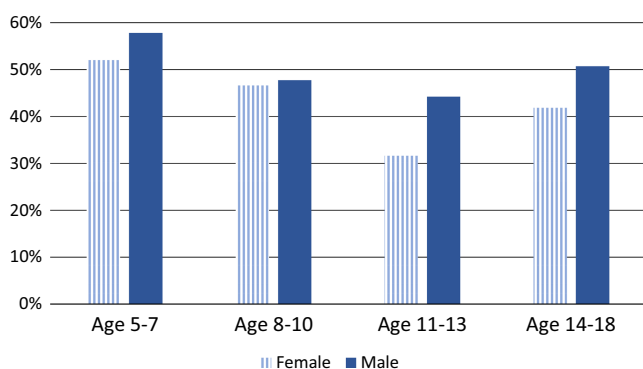


FIGURE 2 Per cent of Flint Registry study participants with potentially clinically elevated or clinically elevated scores on the BRIEF2 Screening Parent Form (N = 3191). Note: BRIEF2 = Behavior Rating Inventory of Executive Function, Second Edition

adolescent males, the effect sizes of adaptive skills difference were medium to large. For behavioural symptoms, school-age and adolescent males and females demonstrated more symptoms than their peers, with small-to-medium effect sizes. For externalising problems, school-age and adolescent males had more symptoms, with small effect sizes. The BASC-3 Parent Rating Scale and BRIEF2 Screening Parent Form each identified almost 50% of the Flint Registry children as exhibiting at-risk or clinically concerning behaviour. Consistently, preschool girls in this analysis appear to be the most resilient subgroup; they did not differ from their national peers in externalising problems, internalising problems or adaptive skills.

4.2 | Strengths of the study

The greatest strength of this study is the large sample size in an understudied population with concerning exposure to environmental toxicants. In addition, the study utilised validated assessments (BASC-3 Parent Rating Scale and BRIEF2 Screening Parent

Form) that reveal consistent findings. Each instrument identified parent-reported behaviour problems in nearly 50% of Flint Registry children.

While the results of this study identify a great number of children who are potentially at-risk for behavioural health issues, the strength of the Flint Registry is its referrals to secondary prevention services to support families with the goal of reducing the burden of health and development concerns.

4.3 | Limitations of the data

Although the current sample size is large and predominantly demographically representative of Flint, this cohort of Flint Registry enrolled children may represent a more impacted population because parents/caregivers were seeking additional resources for their children. Conversely, the children who have not enrolled may represent a harder-to-reach and more neurodevelopmentally vulnerable cohort. The differences in the sample-reported race versus census data may be related to how race was measured: The Flint Registry survey response categories for race differed from the US Census question and the US Census data from 2016 relied on population estimates.

These results were obtained from parent-reported survey tools that are being used to identify children with behavioural and mental health concerns to be referred for in-depth, in-person neuropsychological evaluation and services. Information supplied by parents is typically highly accurate.²⁰ However, parent assessments of child behaviour may be influenced by the parent's own stress or experiences.^{21,22}

4.4 | Interpretation

Study findings align with the known behavioural consequences of childhood lead exposure: externalising behaviours and relative deficits in executive function.²³⁻²⁵ In addition to lead exposure, Flint children are exposed to multiple other toxic stresses such as

poverty, food and housing insecurity, and systemic racism. Toxic stress causes specific behavioural profiles, including increased externalising behaviours, decreased executive function and emotional dysregulation.^{9,26-29}

While prior work indicated that preschool-aged Flint children have average adaptive function,^{13,14} the current study indicates most Flint children in this sample have lower levels of adaptive function than their peers. These are not contradictory findings; the current study includes a wider age range of children, is powered to detect smaller effect sizes and gender differences and is designed to define burden, not diagnoses. The preschool group in the current study had the smallest adaptive behaviour burden, which is consistent with the Zheng et al preschool cohort. Adaptive skills were most impacted in school-age and adolescent boys. The role of adaptive function, distinct from other neurocognitive functions, is understudied in relation to risk, resiliency and childhood outcomes. The work of Zheng et al points towards potential interventions that may enhance adaptive function, specifically those that promote nurturing practices among parents.¹⁴

The gender differences in our study may be partially attributed to differential impacts of risk and resilience factors.³⁰⁻³⁵ There is evidence that neurotoxicants, including lead, impact biochemistry differentially in males and females, and that these differences are associated with different neurodevelopmental profiles.³⁰⁻³² In addition, recent research has demonstrated that many early childhood interventions aimed at improving childhood outcomes are more effective for girls than boys.³³⁻³⁵ In response to the Flint water crisis, many early childhood interventions such as universal early intervention, childcare expansion, literacy programming, parenting support and home visiting programs were implemented prior to the Flint Registry.³⁶

5 | CONCLUSIONS

The Flint Registry's public health infrastructure helps identify children with potential behavioural and developmental concerns for referral to diagnostic services. This study reveals that there is a substantial population of children with parent-reported, clinically significant behavioural problems, and these children will likely benefit from further neuropsychological evaluation and medical and/or educational services. The hope is that with early identification and subsequent referral to comprehensive assessments and supportive services, Flint children will not fully experience the possible neurodevelopmental sequelae of the environmental and socioeconomic adversities they face, including the Flint water crisis, and instead will reach their full developmental potential. Future analyses hope to determine if the availability of early identification and referral services and participation in mitigating interventions reduced potential challenges, especially for the more resilient subgroups like preschool girls.

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CONFLICTS OF INTEREST

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AUTHOR CONTRIBUTIONS

NJ, LO, JL, KL, and MHA designed or contributed to the design of the Flint Registry, while NJ, JD, LO, JL, and MHA designed the analysis of this study. NJ and JD contributed to the acquisition of data. JD performed data analysis. NJ, JD, LO, and JL drafted the manuscript. All authors interpreted the data, critically revised the manuscript, approved the final version for publication, and agree to be accountable for the work.

DATA AVAILABILITY STATEMENT

Requested data may be provided after IRB approval and appropriate data use agreements have been obtained.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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