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Creating a Community Resource for Neuropsychological Assessments After a Lead Exposure: Process and Findings

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Abstract

The Flint water crisis was a lead-in-water disaster that occurred in Flint, Michigan. The Center for Children's Integrated Services Assessment Center (CISAC) was established to provide neuropsychological assessments and recommendations for exposed children. Our objective was to describe the implementation of the CISAC and report the clinical diagnoses of the first cohort of children who received comprehensive assessments. The CISAC's eligibility criteria were broad and allowed referrals from physicians, schools, community organizations, and parents. A cross-sectional, descriptive analysis was conducted for 376 children who received initial neurodevelopmental assessments. About 60% of assessed children (ages 3-18) were diagnosed with ADHD, and 70% were diagnosed with ≥2 conditions. Most (96.8%) children received recommendations for new or continued educational, medical, and mental health services. Recognizing the implications of lead exposure and community-wide trauma on neuropsychological trajectories, the CISAC provides longitudinal assessments, secondary prevention efforts to mitigate potential sequelae, and trauma-informed treatment.

Introduction

Between April 2014 and October 2015, 100,000 residents of the City of Flint, Michigan, experienced a manmade environmental disaster known as the Flint water crisis (FWC). Leading to the crisis, the City of Flint was experiencing loss of revenue and significant financial distress and was placed under emergency financial management by the State of Michigan under the controversial Local Financial Stability and Choice Act.[1] In order to save costs, the emergency manager switched the City of Flint water source from pretreated Great Lakes water to locally treated Flint River water.[2] The local treatment facility was ill-prepared and failed to include adequate corrosion control, resulting in the leaching of lead into residents' tap water.[3] After a demonstration of an increase in blood lead levels in children,[4] a state of emergency was declared first by the city of Flint (December 2015), then by the State of Michigan (January 2016), and then by the federal government.[5] The FWC, a population-wide lead-in-water public health emergency and community-level trauma, occurred atop long-standing socioeconomic and racial inequities that also implicated the health and development of Flint children. A 2016 task force report categorized the FWC as an environmental injustice which was prolonged due to a disregard for evidence of water quality problems and a repeated failure to respond to citizen concerns.[1]

Flint is a city with notable economic challenges, including an estimated poverty rate of 34.4% and a shrinking population.[6] In addition to these challenges, the FWC can be characterized as a prolonged, collective traumatic disaster for Flint,[7] and it exposed children to lead, a known neurotoxicant.[4] Both lead and trauma exposures are associated with neuropsychological and cognitive challenges in children. The Agency for Toxic Substances and Disease Registry's 2020 monograph on lead includes a comprehensive literature review on the health effects of lead exposure with a particular focus on child development,[8] and the National Toxicology Program has found sufficient evidence to implicate lead exposure in problems with child development, especially for cognition, attention, and behavior.[9] The Human Early-Life Exposome project, comprised of 6 European population-based birth cohorts, identified lead as an early childhood exposure associated with attention-deficit/hyperactivity disorder (ADHD).[10] Exposure to adversity and traumatic experiences during childhood are associated with deficits in children's executive function[11] as well as low academic achievement and mental health problems in

school-aged children.[12] Disasters that result in trauma are associated with long-term neuropsychological consequences for children. Human-made disasters, such as the fireworks explosion in Enschede, Netherlands, and the Boston Marathon bombings, have been associated with developmental challenges including hyperactivity and inattention[13] and conduct problems.[14] In Flint, post-water-switch education data identified declines in math achievement and increases in special education needs for the children, regardless of water service line type, which suggests that the mechanisms of injury caused by the FWC extend beyond the lead exposure.[15] The necessity of community-based resources for mental health after a disaster is well established;[16] however, disasters like the FWC give rise to a need for community-accessible neuropsychological evaluation and follow-up for children exposed to a crisis.

Limitations in the capacity for the Flint Community School District to accommodate children with special education needs prior to the FWC and concerns the Flint Community Schools and Michigan Department of Education had not expanded screening and services for FWC-exposed children[17] prompted the development of a local, no-cost assessment resource to provide early identification of potential neuropsychological and behavioral problems for children exposed to the FWC. Our objective was to describe the community resource created to administer neuropsychological assessment to FWC-exposed children and to report clinical findings from the first cohort of assessed children.

Methods

Setting

The Genesee Health System Center for Children's Integrated Services Assessment Center

In 2018, Genesee Health System (GHS)—the county mental health agency—received start-up funds from the State of Michigan as part of an American Civil Liberties Union lawsuit settlement agreement (civil action known as "D.R., et al. v. Michigan Department of Education" for systemically failing to provide ongoing screening and timely referrals for evaluations to identify students eligible for special education services pursuant to Individuals with Disabilities Education Act's child find mandate) to rectify the insufficiency of the current neuropsychological assessment capacity and enhance it to support the children exposed to the FWC.[18] Located in Flint, Michigan, and primarily funded through Medicaid, GHS is the public community mental health entity responsible for providing specialized, intensive behavioral health services for residents of Flint and Genesee County. The existing GHS neuropsychological assessment center had historically provided autism and fetal alcohol spectrum disorder evaluations. These services were expanded through the settlement funding, and by January 2019, nearly 5 years after the onset of the FWC, the GHS Center for Children's Integrated Services Assessment Center (CISAC; formerly known as The Neurodevelopmental Center of Excellence) was operational as a comprehensive clinical neuropsychological assessment center for children exposed to the FWC.

Eligibility criteria for CISAC services, determined by the settlement, included children ages 3 to 21 years of age who lived, attended school or day care, or worked in any geographical area serviced by the Flint water supply between April 2014 and September 2021, and who had not yet graduated from high school. Children who met these criteria but had subsequently moved out of the area were also eligible through a waiver process. Between 5 and 12% of blood lead tests among young Flint children exceeded the United States Centers for Disease Control and Prevention blood lead reference level during the water switch;[4,19,20] however, the extent of lead exposure in Flint that resulted from the FWC was unclear.[1] With no established threshold of safe exposure to lead[8] and the community-wide traumatic experience of the water crisis,[7] the CISAC determined their services should be made widely available and estimated that about 10,000 children were potentially eligible for assessment. Patients were referred to the CISAC through multiple channels, including other GHS health services, primary care physicians and specialists, behavioral health professionals, schools, and family self-referral; families could receive referrals from more than one source. Community outreach and media-facilitated communications promoted the availability of this no-cost community resource. Hundreds of referrals were also received from the Centers for Disease Control and Prevention–supported Flint Registry as part of its public health surveillance and support process in response to the FWC.[5] The variety of referral sources and efforts to directly engage families through community outreach resulted in a large, community-referred sample of children assessed by the CISAC in the first 3 years of operation.

All referrals were responded to by phone or mail contact to confirm parent interest in proceeding with an evaluation and to determine eligibility. Children who met CISAC eligibility criteria were scheduled in the order their eligibility was determined. As Medicaid was the primary funding source for evaluations, active Medicaid verification took place, and for those without Medicaid, application support was provided if needed. School, medical, and mental health records were requested from each institution (e.g., schools, medical providers, and GHS).

Working with clinical, education, public health, and community partners while minimizing family and child assessment burden, the CISAC developed a flexible, comprehensive neuropsychological evaluation battery, with particular emphasis on assessing cognitive and neuropsychological functions known to be impacted by lead exposure, as well as academic achievement, adaptive skills and behaviors, and psychopathology. The assessment battery was administered in a structured and standardized manner and used standardized scoring methods. Overall, the battery was completed during one face-to-face session of 4 to 6 hours, with a feedback session scheduled following report writing. Simultaneous testing sessions were scheduled with multichild families when requested, and testing sessions were broken into multiple shorter sessions when needed to accommodate individual child tolerance challenges and parent schedules.

Although the expansion goal was to provide comprehensive neuropsychological evaluations within the shortest period of time possible to an estimated 10,000 children, it was not known how many children would present to complete the evaluation nor the extent of needed resources to meet the unknown demand. The CISAC relied on expansion staffing models which utilized both neuropsychologists and neuropsychologist-supervised technicians to complete assessments and connect families to services, thereby maximizing limited professional resources.[21] All evaluations were completed in full or in part by licensed, doctoral-level psychologists with specialized training in pediatric neuropsychology. Neuropsychologist-supervised trained technicians completed administration of testing batteries when necessary. Community health workers were deployed to assist in navigating families to CISAC services and the educational, mental health, and medical resources recommended post-evaluation.

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Assessment Battery

Neuropsychological assessments, which informed diagnoses and recommendations made by neuropsychologists, included both clinician-administered and, depending on patient age, parent- or child-reported measures covering five main constructs: global intellectual function, neuropsychological function, academic achievement, adaptive skills and behaviors, and psychopathology. Within each construct, selected tests measured relevant domains (see Table 1). Test instrument selection was clinically driven based on the child's age and abilities.

Children's intellectual or neurodevelopmental functioning was assessed using one of the following standardized measures: Differential Abilities Scale-II-Early Years or DAS-II-School Age,[22] Wechsler Preschool and Primary Scale of Intelligence-IV,[23] Mullen Scales of Early Learning,[24] Wechsler Intelligence Scale for Children-V,[25] or Wechsler Adult Intelligence Scale-IV.[26] Children's executive function and attention, language, and memory and learning were assessed using both the clinician-administered Developmental Neuropsychological Assessment-II[27] and parent-report Behavior Rating Inventory of Executive Function-2 (BRIEF-2) or BRIEF-Preschool (P),[28,29] depending on the child's age. BRIEF-2 domains include a global composite executive function score and 3 subscales: behavioral regulation, emotional regulation, and cognitive regulation. The BRIEF-P includes a global composite executive function scale and 3 subscales: inhibitory self-control, flexibility, and emergent metacognition. Wechsler Individual Achievement Test-III/IV[30] was administered to gather broad-stroke evaluations of academic performances of school-aged children. Adaptive behaviors were measured using the Behavior Assessment System for Children, Third Edition (BASC-III)[31] Adaptive Skills subscale or the Adaptive Behavior Assessment System, Third Edition,[32] which includes a global composite value of adaptive behavior and 3 subscales that measure conceptual, practical, and social adaptive behaviors. Psychopathology was measured using the BASC-III,[31] which has subscales for externalizing symptoms, internalizing symptoms, and behavioral symptoms.

Child Demographics and History Variables

Child history and demographic data were extracted from the CISAC's comprehensive neuropsychological reports, which included age at testing; child sex; history of special education or individualized education plan (IEP); history of one or more medical diagnoses or conditions which required hospitalization, surgery, or other substantial ongoing treatment; history of one or more mental health diagnoses and/or current or past involvement in behavioral or mental health treatment; and history of delays in one or more early developmental milestones. History variables were categorical and defined as yes, no, or unknown, and we reported frequencies of "yes" answers.

Clinical Diagnoses and Recommendations

Diagnoses were made by pediatric neuropsychologists according to criteria set by the Diagnostic and Statistical Manual of Mental Disorders – Version 5.[33] Clinical diagnoses were coded as *International Classification of Diseases*, tenth revision (ICD-10) diagnoses and organized into clinical categories and dichotomized into present or absent for each category (Table 2). Evaluation-based recommendations and instructions for accessing supports and services were detailed in the written report. Assessment results and recommendations were reviewed in a family feedback session and with consent, written reports are shared with educators and health care providers for purposes of postevaluation follow-up. Additionally, case management or navigator services were provided to coordinate access to recommended resources. The CISAC

Table 1. Constructs assessed by Center for Children's Integrated Services Assessment Center (CISAC) test battery, associated measures, and source of information for each measure

Constructs	Measures	Informant
Demographic Information		Parent Report
Global Intellectual Function	Differential Abilities Scale-II Early Years and School Age	Clinician Administered
	Wechsler Preschool and Primary Scale of Intelligence-IV	Clinician Administered
	Mullen Scales of Early Learning	Clinician Administered
	Wechsler Intelligence Scale for Children-V	Clinician Administered
	Wechsler Adult Intelligence Scale-IV	Clinician Administered
Neuropsychology: Executive Functioning/Attention	NEPSY-II	Clinician Administered
	Behavior Rating Inventory of Executive Function-2 Behavior Rating Inventory of Executive Function-Preschool	Parent Report
Neuropsychology: Language	NEPSY-II	Clinician Administered
Neuropsychology: Memory/Learning	NEPSY-II	Clinician Administered
Academic Achievement	Wechsler Individual Achievement Test-III and IV	Clinician Administered
Adaptive Skills and Behaviors	Adaptive Behavior Assessment System-III	Parent Report
	Behavior Assessment System for Children-III Adaptive Skills Scale	Parent Report
Psychopathology	Behavior Assessment System for Children-III	Parent Report
Clinical Diagnosis	ICD–10 Diagnosis	Clinician Administered

Abbreviations: NEPSY, A Developmental NEuroPSYchological Assessment; ICD-10, International Classification of Diseases, Tenth Revision.

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Table 2. ICD-10 Codes used to classify diagnoses made by the Center for Children's Integrated Services Assessment Center (CISAC) neuropsychologists

Diagnosis Categories	ICD-10 Codes Used
Intellectual Disabilities	F70, F71, F72, F73, F88, F79
Communication Disorders	F80.9, F80.0, F80.89, F80.9
Autism Spectrum Disorder	F84.0
Attention-Deficit/Hyperactivity Disorder	F90.x
Specific Learning Disorder	F81.0, F81.81, F81.2
Other Neurodevelopmental Disorders	F88, F89
Depressive Disorders	F32.x, F33.x, F34.8, F34.1
Anxiety Disorders	F40.10, F41.1, F41.8, F41.9, F93.0
Trauma- and Stressor-Related Disorders	F94.1, F94.2, F43.10, F43.2x
Disruptive, Impulse-Control, Conduct Disorders	F91.3, F91.x, F91.8, F91.9
Up to 3 Diagnoses Not Included in the Categories Above	No specific codes

Abbreviation: ICD-10, International Classification of Diseases, Tenth Revision.

contacts families directly for continued neuropsychological follow-up. Recommendations for educational interventions, medical treatment, and mental health support were categorized as made, not made, and unknown.

Sample

To highlight some of the efforts of the CISAC, we performed a cross-sectional, descriptive analysis of diagnoses and recommendations made for the first 376 children who were assessed by the CISAC in Flint, Michigan, from January 2019 through July 2021. Though children who were enrolled in school through the age of 21 were eligible for assessment, the initial cohort's age range was 3-18 years old.

Statistical Analysis

We calculated frequencies (percentage) of diagnoses and recommendations made for evaluated children. Number of diagnoses made for each child was assessed by summing across the individual diagnoses and categorizing each child as having 0, 1, 2, or 3 or more diagnoses. We calculated median age (interquartile range) for each diagnosis, count of diagnoses, and recommendations. We analyzed data with SAS 9.4 (SAS Institute, Cary, NC) PROC MEANS and PROC FREQ.

Informed consent for CISAC clinical assessment data to be used for research was obtained during the GHS intake process. Michigan State University Institutional Review Board determined this analysis did not include human subjects because of the use of deidentified data.

Results

By October 2018, the CISAC started to evaluate a few children as part of a "soft opening" of GHS's expanded services, and the CISAC was fully operational by January 2019. Initial referral volume was extremely heavy and by January 2022, 4,800 referrals had been received, of which approximately 9% had been completed. With a significant waitlist and a no-show rate of 44%, managing the valuable and limited assessment resources was a primary concern and resulted in increased phone, mail, and media-based outreach methods. As referrals were processed and outreach efforts proceeded, it was determined that a significant number of individuals were not interested in pursuing services or were unable to be reached. By 2023, assessment capacity was well aligned with service demand and wait times no longer presented a challenge.

By July of 2021, data shared by the CISAC but not available for analysis (L. Tompkins, personal communication) indicated that 54.4% of children had a reported race of Black and 72.2% of children were residing in Flint ZIP codes at the time of assessment, with 33.5% living in 2 ZIP codes that had notable overlap with the parts of Flint that experienced the highest probability of elevated blood lead levels during the switch.[4,34]

Analysis of the Initial Cohort (Assessed January 2019 through July 2021)

The median age of the 376 children assessed was 8.3 years (IQR: 5.8, 11.6), and 205 (54.5%) were male. Prior to CISAC assessment, 156 (41.5%) children had a history of early developmental milestone delay, 216 (57.4%) had historical educational recommendations, 111 (29.5%) had historical medical involvement, and 230 (61.2%) had existing mental health needs or support use.

Diagnoses

The most common diagnosis made after evaluation was ADHD (n = 220, 58.5%; Table 3). The median age of the children diagnosed with the specific conditions ranged from 6.1 years (IQR: 4.8, 8.0) for communication disorders to 11.9 years (IQR: 9.9, 14.4) for depression (Table 3). The most frequent mental health diagnoses were depression (n = 73, 19.4%) and post-traumatic stress disorder (n = 69, 18.4%). The majority of children were given 2 or more diagnoses (n = 262, 69.7%), and ADHD was a comorbid diagnosis for 201 (76.7%) of the children who had 2 or more diagnoses (Table 4).

Treatment Recommendations

The majority of children received recommendations to obtain or continue using educational services (n = 337, 89.6%), medical services (n = 302, 80.3%), and mental health services (n = 315, 83.8%; Table 3). Many of the children who received recommendations for educational, medical, and mental health services had a history of using these services, though many children received recommendations for new services. For example, 131 (38.9%) received a new recommendation for educational services (Table 5).

Discussion

These findings highlight how the Flint community was able to respond to an environmental disaster by expanding infrastructure to provide critical neuropsychological assessments for children. Recognizing the complex histories with which many of these children presented, CISAC evaluation outcomes emphasized a multifactor contribution (including developmental, trauma, social, and other factors) and did not make conclusions about specific causality in relation to outcomes. While other large-scale lead-in-drinking-water crises are occurring across the United States,[35-37] the establishment of this type of community-based, city-wide resource after a water crisis

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Table 3. Frequencies of diagnoses and recommendations made to children evaluated by the Center for Children's Integrated Services Assessment Center (CISAC) from January 2019-July 2021 (N = 376)

Diagnoses	Freq (%)	Median Age of Diagnosed Children (q1,q3)
Disorders		
Attention-Deficit/ Hyperactivity Disorder	220 (58.5)	8.5 (6.3, 11.6)
Other Neurodevelopmental Disorders	104 (27.7)	7.8 (5.6, 11.4)
Communication Disorder	61 (16.2)	6.1 (4.8, 8.0)
Specific Learning Disorder: Reading	55 (14.6)	8.6 (7.3, 11.4)
Oppositional Defiant Disorder	47 (12.5)	9.0 (5.7, 11.5)
Intellectual Disability	45 (12.0)	9.5 (5.9, 11.7)
Autism Spectrum Disorder	44 (11.7)	8.3 (5.3, 11.3)
Specific Learning Disorder: Math	36 (9.6)	11.8 (8.5, 14.7)
Specific Learning Disorder: Writing	14 (3.7)	9.9 (8.4, 11.4)
Mental Health		
Depression	73 (19.4)	11.9 (9.9, 14.4)
Post-Traumatic Stress Disorder	69 (18.4)	7.1 (5.4, 10.1)
Anxiety	38 (10.1)	8.4 (6.8, 11.8)
Count of Diagnoses	**Freq (%)**	**Median Age of Diagnosed Children (q1,q3)**
0	46 (12.2)	8.3 (5.7, 13.2)
1	68 (18.1)	6.6 (5.5, 10.0)
2	118 (31.4)	7.7 (5.2, 11.6)
3 or More	144 (38.3)	8.9 (6.8, 12.0)
Recommendations Made	**Freq (%)**	**Median Age for Recommendations (q1,q3)**
Educational	337 (89.6%)	8.3 (5.7, 11.6)
Mental Health Services	315 (83.8%)	8.4 (5.9, 11.8)
Medical Services	302 (80.3%)	8.1 (5.7, 11.5)
Count of Recommendations Made[a]	**Freq (%)**	**Median Age for Recommendations (q1,q3)**
At Least 1	364 (96.8%)	8.2 (5.8, 11.6)
All 3	257 (68.4%)	8.2 (5.9, 11.7)
No Services Recommended	10 (2.7%)	11.4 (5.4, 14.3)

Abbreviation: Freq, frequency; q, quartile.
[a]There were 2 children whose recommendation status was unknown.

Table 4. Frequency of each diagnosis occurring as a diagnosis for children who had 2 or more diagnoses made during their assessment in the Center for Children's Integrated Services Assessment Center (CISAC) (n = 262)

Diagnosis	Frequency (%)
Attention-Deficit/Hyperactivity Disorder	201 (76.7)
Other Neurodevelopmental Disorders	100 (38.2)
Depression	70 (26.7)
Post-Traumatic Stress Disorder	59 (22.5)
Communication Disorder	53 (20.2)
Specific Learning Disorder: Reading	53 (20.2)
Oppositional Defiant Disorder	44 (16.8)
Autism Spectrum Disorder	38 (14.5)
Specific Learning Disorder: Math	36 (13.7)
Anxiety	35 (13.4)
Intellectual Disability	35 (13.4)
Specific Learning Disorder: Writing	14 (5.3)

is unique. Some of the challenges that had to be addressed included funding, sustainability, outreach and referral processes, developing an assessment battery, securing specially trained professional staffing resources, and partnering with community. In this case, initial start-up funding was established through a lawsuit on behalf of Flint children which relied upon educational law and funding from the State of Michigan. After the initial start-up, the center's activities have been sustained through carve-out mental health Medicaid billing for assessment services. Additionally, a Centers for Medicare & Medicaid Services–approved Medicaid waiver for Flint greatly expanded income requirements and provided coverage to the majority of Flint's children.[38] Long-standing partnerships with other agencies, establishment and deployment of a robust Flint-based outreach team, and multiple media and community partner educational presentations allowed an extensive number of referrals to come from community and expanded the population of children served. A significant amount of time was invested in developing a comprehensive assessment battery which was flexible across the full age span of impacted children. The sufficient and rapid securing of child-trained neuropsychology professionals presented one of the most significant challenges. Aggressive local and national recruitment efforts were made, and the use of an extender staffing model was implemented where supervised assistant-level staff were trained to conduct a portion of the testing. Still, initial service demand greatly exceeded available professional resources and because of the labor- and time-intensive training needed for extenders, this staffing model was considered to have been only partially successful in helping to meet the high and variable initial service demand.

Using cross-sectional data, we described diagnostic results from the first cohort of children. Notably, nearly 60% of children were diagnosed with ADHD and 70% were diagnosed with 2 or more conditions, demonstrating a high frequency of co-occurring conditions. Only 12% of children received no diagnoses. Recommendations were made to continue or initiate use of educational resources for about 90% of children, medical resources for 80% of children, and mental health resources for 84% of children. These results indicate that the CISAC evaluation services were reaching the children who most needed assessment for neuropsychological development in order to access educational, medical, and mental health services.

Interpretation

Among Flint children assessed by the CISAC, the frequency of ADHD diagnosis was 58.5%. Lead-exposed children have higher odds of hyperactivity[39] and of ADHD,[40,41] although it is worth

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Table 5. Cross-tabulations of historical recommendations and recommendations made after the Center for Children's Integrated Services Assessment Center (CISAC) assessment

Recommendations by History of Recommendations				
Education	CISAC Educational Recommendation			
Educational Recommendation History	No	Unknown	Yes	Total
No	21 (66%)	0	131 (38.9%)	152
Unknown	2 (6%)	2 (29%)	4 (1.2%)	7
Yes	9 (28%)	5 (71%)	202 (59.9%)	216
Total	32	7	337	376
Medical	CISAC Medical Recommendation			
Medical Recommendation History	No	Unknown	Yes	Total
No	54 (81%)	7 (100%)	201 (66.6%)	262
Unknown	0	0	3 (1.0%)	3
Yes	13 (19%)	0	98 (32.5%)	111
Total	67	7	302	376
Mental Health	CISAC Mental Health Recommendation			
Mental Health Recommendation History	No	Unknown	Yes	Total
No	35 (61%)	1 (25%)	89 (28.3%)	125
Unknown	0	0	21 (6.7%)	21
Yes	22 (39%)	3 (75%)	205 (65.1%)	230
Total	57	4	315	376

noting that the rate of 58.5% we observed in this sample is higher than other studies of lead-exposed children,[41,42] possibly indicating the impact of lead exposure compounded by trauma and the multiple socioeconomic adversities faced by CISAC-evaluated Flint children. Especially because of the period of time after the water switch and the availability of start-up funding for the CISAC (3 years), our findings could indicate our sample represents children who were exhibiting challenges, were receiving school, medical, or mental health services that prompted referral for evaluation, or had parents and caregivers with ADHD that may have experienced more concern about their children's behavior after the water switch and been more likely to seek evaluation for their children than parents and caregivers without.[43] However, in the 2021-2022 school year, 23% of the Flint Community School District's student population had documented disabilities, a full 10 percentage point higher frequency than the State of Michigan's frequency,[44] indicating that the Flint schools' children need expanded support with fewer resources as enrollment in the Flint Community School District declines.[44] Though we cannot evaluate the degree to which lead exposure or FWC-related trauma has impacted the children evaluated by the CISAC, our study demonstrates the importance of investing in the community-based center, as evidenced by the substantial need for school-based, medical, and mental health resources.

In our sample of children, about 19% were diagnosed with depression, 10% with anxiety, and 18% with post-traumatic stress disorder, which are higher than the prevalence of these conditions in the general population. In the United States, 3.8% of children had a diagnosis of depression and 8.5% had a diagnosis of anxiety in the 2018-2019 National Survey of Children's Health.[45] Life-time prevalence of post-traumatic stress disorder among 9- and 10-year-olds in the United States was estimated to be about 2.8%.[46] Estimates of post-traumatic stress disorder among children by age 18 were estimated to be around 7.8% in an English and Welsh cohort.[47] Lead exposure has been associated with depression and anxiety in children.[48] Moreover, exposure to stress and trauma in childhood is associated with a decreased ability to regulate emotion, a focus on negative thoughts,[49-52] as well as mental health disorders, including depression, anxiety, and post-traumatic stress disorder.[12] Evidence from FWC-exposed adults shows that the Flint population exposed to the FWC has persistent mental health challenges and unmet mental health treatment needs,[53] and our findings support the need for long-term follow-up of mental health for FWC-exposed children especially.

Limitations

There were some challenges with the CISAC protocol. Staffing resources and initially high and variable service demands resulted in long wait times between referral and service delivery. While wait time no longer presents as a challenge, it is considered to have been a barrier for children and families seeking these services. The comprehensive testing battery was long and required a substantial time commitment which may have limited completion of assessment for some children. To mitigate the long testing times, the CISAC offered flexible testing options when necessary. The validity of responses to the adult-reported questionnaires was evaluated by the testing psychologist and when reading comprehension was considered a potential problem, it was addressed by the CISAC staff. The assessment period presented herein was also complicated by the emergence of the COVID-19 pandemic, which required the CISAC to suspend assessment for about 6 months. Despite this disruption, the CISAC was able to evaluate almost 400 children during the first 3 years of operation.

When considering the diagnostic data, this study is not intended to be inclusive of the entire population of children exposed to the FWC and the results reflect a single instance of neuropsychological assessment. Ongoing monitoring is necessary to characterize the long-term neuropsychological consequences of the lead and trauma exposures resulting from the FWC and to capture potentially emerging sequelae.[54,55] Although this sample was drawn from many referral sources, including parent and public health registry referrals, we are unable to determine the representativeness of the sample to the broader population of children due to privacy and data sharing restrictions. We were not able to abstract referral source, race and ethnicity, socioeconomic position, or place of residency for the children included in this study, and so we cannot evaluate the representativeness of this sample of children exposed to the FWC, and we lack a comparison group of unexposed children with comprehensive neuropsychological assessments.

FWC exposure was an eligibility criterion for CISAC assessment; however, the CISAC did not have access to individual water line type, drinking water consumption, or water or blood lead levels. Through August 2021, many of the children evaluated by the CISAC lived in Flint ZIP codes and especially 2 that had the highest risk of elevated blood levels,[4,34] suggesting that recruitment

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strategies were reaching children most in need; however, this analysis cannot explain if or how lead or trauma exposure during the FWC and/or preexisting adversities impacted the evaluated children. It is important to note that ZIP codes represent the place children lived at the time of assessment, not the water switch, and that Flint ZIP codes do not align perfectly with the Flint municipal water system.[34] The CISAC was one of many community services launched to respond to the FWC and we cannot tease apart the potentially mitigating impact of other robust secondary prevention interventions launched in Flint which may have limited deleterious developmental outcomes. These resources included trauma-informed services, nutrition assistance, Medicaid waivers, and the Flint Registry. We do not expect the children in this sample to be representative of the broader population exposed to the FWC, but this study demonstrates the implementation and utility of a community-accessible neuropsychological evaluation resource.

Conclusion

The FWC was a devastating environmental and public health disaster, exposing a population of predominantly poor and minority residents to a neurotoxin, as well as to the trauma of governmental indifference and negative national attention. While the deleterious impact of lead exposure is well known, community-accessible resources for robust clinical neuropsychological assessments of lead-exposed children are uncommon. This study highlights the necessity of free community-based neuropsychological and behavioral assessment after a public health crisis to support community recovery and underscores the critical need for investment in proactive community resources that support children's educational, medical, and mental health needs. Current resources available to FWC-exposed individuals include the CISAC, expanded Medicaid eligibility,[38] the Flint Registry,[5] and improvements in the food network, childcare, and playgrounds. Ongoing and expanded secondary prevention resources to continue to prevent, identify, and support children with deficits are urgently needed.

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