METHODS ARTICLE

An algorithm using administrative data to measure adverse childhood experiences (ADM-ACE)

Laura E. Henkhaus PhD[1,2] | Gilbert Gonzales PhD, MHA[2,3] | Melinda B. Buntin PhD[2]

[1]Data Science Institute, Vanderbilt University, Nashville, Tennessee, USA

[2]Department of Health Policy, Vanderbilt University Medical Center, Nashville, Tennessee, USA

[3]Department of Medicine, Health, and Society, Vanderbilt University, Nashville, Tennessee, USA

Correspondence
Laura E. Henkhaus, Data Science Institute, Vanderbilt University, 2301 Vanderbilt Place, PMB #407791, Nashville, TN 37240, USA.
Email: laura.henkhaus@vanderbilt.edu

Abstract

Objective: To develop an algorithm using administrative data to measure adverse childhood experiences (ADM-ACE) within routinely collected health insurance claims and enrollment data.

Data Sources: We used claims and enrollment data from Tennessee's Medicaid program (TennCare) in 2018.

Study Design: We studied five types of ACEs: maltreatment and peer violence, foster care and family disruption, maternal mental illness, maternal substance use disorder, and abuse of the mother. We used diagnosis and procedure codes, prescription drug fills, and enrollment files to develop the ADM-ACE, which we applied to measure the prevalence of ACEs and to examine prevalence by demographic characteristics among our sample of children in TennCare. We compared ADM-ACE prevalence to child welfare records and survey results from Tennessee.

Data Collection/Extraction Methods: Our study sample included children aged 0–17 years who were linked to their mothers if also enrolled in TennCare in 2018 ($N = 763{,}836$ children).

Principal Findings: Approximately 19.2% of children in TennCare had indicators for ADM-ACEs. The prevalence of ACEs was higher among children who were younger ($p < 0.001$), non-Hispanic white or black (compared to Hispanic) ($p < 0.001$), and children residing in rural versus urban counties ($p < 0.001$). The prevalence of maltreatment identified through the ADM-ACE (1.6%) falls between the percent of children in Tennessee who were reported to child welfare authorities and the percent for whom reports of maltreatment were substantiated. Comparison with survey reports from Tennessee parents suggests an advantage in measuring maternal mental illness with the ADM-ACE using health insurance claims data.

Conclusions: The ADM-ACE can be applied to health encounter data to study and monitor the prevalence of certain ACEs, their association with health conditions, and the effects of policies on reducing exposure to ACEs or improving health outcomes for children with ACEs.

What is known on this topic

- Adverse childhood experiences (ACEs) are prevalent.
- ACEs are important to monitor because they can have short-term implications for children's health and are associated with worse health, social, and economic well-being in adulthood.

What this study adds

- ACEs can be identified through routinely collected administrative data.
- The algorithm using administrative data to measure ACEs (ADM-ACE) developed here can enable surveillance and new research opportunities to inform care practices, programs, and policies for children.

1 | INTRODUCTION

In a large and growing body of literature, researchers have identified, constructed measures of, and recorded adverse childhood experiences (ACEs) among children and adolescents.[1,2] According to the 2019 National Survey of Children's Health (NSCH), approximately 40% of children had been exposed to at least one ACE in their childhood; these ACEs include dimensions of income insecurity, loss of or separation from a parent, living with someone with behavioral health needs, and witnessing violence in the home or neighborhood. Almost one in five children had been exposed to multiple ACEs.[3]

ACEs are important to monitor because they can have short-term implications for children's health, learning, and development and are associated with worse health, social, and economic well-being in adulthood.[4] Prior research demonstrates that children exposed to ACEs are more likely to experience worse mental and emotional health outcomes,[5] be involved in teen pregnancy,[6] and develop physical health conditions.[7] An even larger body of literature demonstrates links between ACEs and poor outcomes in adulthood: increased likelihoods of mental[8,9] and physical health conditions, including several leading causes of death,[10–13] substance use,[14,15] arrest,[16] lower educational attainment, and reduced earnings.[17] Importantly, the probability of adverse health outcomes increases as the number of ACEs increases.[18] Thus, having granular surveillance data to monitor ACEs can inform locally tailored policies and programs to prevent and treat the sequelae of ACEs.

ACEs are difficult to measure and to study in tandem with child health metrics. At present, the most common methods for identifying ACEs include the use of population-based cross-sectional surveys with parent-reported questions on child maltreatment[19] and household exposures[20] or administrative data from child welfare records of official reports of maltreatment.[21] Some states have undergone years-long efforts to develop linked administrative databases across state agencies to enable identification of child and family ACEs,[22,23] and other researchers have used diagnosis codes from administrative health encounter data to identify child maltreatment but no other ACEs,[24] which we seek to build on here. While surveys are important

tools for understanding population-level health, including the prevalence of ACE exposure, they are subject to social desirability and recall bias, are expensive to administer, and it is infeasible to administer surveys over the entire populations of interest.[25] Further, neither surveys nor official reports of maltreatment typically allow the longitudinal study of ACEs and child health outcomes.

In this paper, we use routinely collected health encounter data to develop an algorithm of Administrative Data to Measure Adverse Childhood Experiences (abbreviated as "the ADM-ACE," pronounced "admin ace," when referring to the algorithm and "ADM-ACEs" when referring to ACEs measured using the algorithm). This approach facilitates the surveillance of ACE prevalence and the examination of ACEs and subsequent changes in child health as responses to exposures, health care interventions, or policy. Claims data are frequently used in health services research and have previously been used to develop algorithms to identify children with special health care needs[25] and individuals with chronic conditions,[26] for example.

A few states have developed administrative data infrastructures to examine social determinants of health and health care costs by engaging in multiyear efforts to link child welfare records and several other state administrative databases with Medicaid data. For example, Washington and Oregon each have developed integrated client databases, including data from state health services (to identify parental mental illness and substance use disorder), departments of corrections (to identify parental involvement in the criminal punishment system), and departments of health (to identify parental death through death certificates) along with child welfare records (to identify maltreatment and foster care), and Medicaid records (to correlate these ACEs with medical complexity).[22,23] These integrated client databases contain rich information on children's circumstances and health and have provided important insights such as the prevalence of ACEs by age groups within Oregon[23] and showing that child maltreatment and instability in foster care placements were most predictive of higher health care costs for children in Washington, compared to ACEs from parent risk factors.[22] However, the development of these state-level linked administrative databases required years of interagency coordination to share and link data; thus, measures developed with these

databases are not replicable in other states which have no linked data or by health services researchers with access to claims data but no state interagency datasets. Meanwhile, other new studies have used a similar approach to the ADM-ACE by using diagnosis codes for injuries or illnesses to identify maltreatment, including work by the Centers for Disease Control and Prevention to identify child maltreatment from emergency department visits reported to the National Syndromic Surveillance Program[24] and research by Rosen et al. to identify elder mistreatment with diagnosis codes in claims data.[27]

The primary objective of this study was to develop an algorithm of Administrative Data to Measure Adverse Childhood Experiences (ADM-ACE) for use in surveillance of trends in ACE prevalence at granular levels, health services research, epidemiology studies, and policy evaluation.

2 | METHODS

2.1 | Study sample and data

We used administrative data from children and mothers enrolled in Tennessee's Medicaid program (called TennCare) in 2018. TennCare covers about 50% of children in Tennessee.[28] In 2018, children and pregnant women in households with incomes up to 255% of the federal poverty level and other parents with incomes up to 98% of the federal poverty level were eligible for TennCare coverage.[29,30] Our cohort included all enrolled children aged 0–17 years who could be linked to their mothers' TennCare enrollment records in 2018. We followed the mother–child linkage algorithm described in prior research using Tennessee administrative data[31,32] and applied it to study child health.[33,34] The algorithm requires that children were enrolled in TennCare by age one and had birth records from the Tennessee Department of Health. TennCare enrollment files contain demographic information, and TennCare claims data include diagnoses and procedure codes from inpatient, outpatient, and physician visits in addition to outpatient pharmacy claims for filled prescriptions. Among the population of children aged 0–17 years and enrolled in TennCare in 2018 ($N = 1,110,109$), 69% ($N = 763,836$) had mothers who were also enrolled in TennCare in 2018 and were linked to their mothers' records—this is our study sample. While the study sample was enrolled in Medicaid for the full year, individuals would not have insurance claims during the study period if they did not receive any health care (doctor office visits, hospital visits, prescription drug fills) reimbursed by Medicaid insurance during the year. Among this sample of children with linked mothers in TennCare, 66% had any medical or pharmacy claims in 2018, 52% had mothers with medical or pharmacy claims in 2018, and 44% had medical or pharmacy claims for both themselves and their mothers. The percentage of children who had any medical or pharmacy claims filed on their behalf and who had mothers with claims filed varied by demographic subgroups. Most notably, only 13% of Hispanic children had claims for themselves and their mothers (Supplement A, eTable 1). Across the linked sample, the average number of medical claims per child from doctor's office or hospital visits was 15, and the average number of medical claims for mothers was 22.

2.2 | Measures

2.2.1 | Adverse childhood experiences

We considered all types of maltreatment and household adversity that were identifiable in Medicaid administrative data and thus studied the following five ACEs: childhood maltreatment and peer violence (neglect, abuse, and assault whether by a caregiver or other person), foster care and family disruption, maternal mental illness, maternal substance use disorder, and abuse of the mother. These ACEs were surveyed in the original ACE Study in the 1990s,[18] with the exception of foster care, which is now commonly considered an ACE[22,35] and is included in the ACE questionnaire approved for reimbursement when administered by Medicaid providers in California.[36] In addition, our childhood maltreatment and peer violence measure is more inclusive than the California ACE Study measure restricted to maltreatment by a caregiver. Importantly, peer violence during childhood has been recognized as an ACE and remains a significant predictor of childhood trauma symptoms.[19,36,37] To identify these ACEs, we leveraged an algorithm of diagnosis codes for probable maltreatment by Schnitzer et al., which was informed by medical chart reviews,[38] in addition to diagnostic definitions for maternal health conditions from the Chronic Conditions Data Warehouse (CCW) developed by the Centers for Medicare and Medicaid Services (CMS).[26] We extended these algorithms as described below to broaden the ability to capture ACEs, for example, by incorporating procedure codes for exams to identify sexually transmitted infections or sexual trauma and prescription drug use to identify maternal health conditions.

Childhood maltreatment and peer violence

We defined childhood maltreatment and peer violence as physical or supervisory neglect by a caregiver, emotional abuse by a caregiver, and physical or sexual abuse—whether perpetrated by a caregiver or not. Claims data generally do not identify the perpetrator. We identified childhood maltreatment and peer violence by the presence of at least one claim within inpatient, outpatient, or physician office visits with corresponding diagnosis or procedure codes. In Supplement B, see e-Table 4 for an overview of the algorithm for each ADM-ACE. Diagnosis of child abuse is challenging, and diagnostic protocols may vary across countries[39]; thus, the ADM-ACE maltreatment measure largely represents "probable maltreatment" through illnesses or injuries suggestive of maltreatment, as identified by prior chart reviews,[38] or exams for sexually transmitted infections or sexual abuse administered to children of prepubescent ages. We used diagnosis codes from the *International Classification of Diseases, Tenth Revision* (*ICD-10-CM*) to identify childhood maltreatment and peer violence both through codes explicitly indicating maltreatment[40] and through injuries or illnesses suggestive of abuse or neglect, identified as probable maltreatment from medical chart reviews by Schnitzer et al.[38] We adapted the maltreatment algorithm by Schnitzer et al. using *ICD-9-CM* data to *ICD-10-CM* codes by using the general equivalence mapping for the fiscal year 2018 from CMS[41] and searching the long description field for any codes not mapped through this system. We modified the Schnitzer et al. algorithm by including a more expansive set of assault codes and dropping the

age restriction of age under 10 years, which was their study sample, to include both childhood maltreatment and peer violence. See Supplement B, eTables 5–8 for diagnosis codes and restrictions. We further expanded upon the Schnitzer et al. algorithm of diagnosis codes by adding procedure codes from the Health care Common Procedure Coding System (HCPCS). We designated child sexual abuse for children under age 10 who had HCPCS codes for screenings for sexually transmitted infections,[42,43] colposcopies,[44,45] or pregnancy tests.[45] See Supplement B, eTable 9 for procedure codes used to identify childhood maltreatment and peer violence along with other ACEs.

Foster care and family disruption

We identified children in foster care using eligibility codes in the TennCare enrollment files. All children in foster care in the United States are eligible for their state Medicaid programs. We grouped foster care and family disruption together because separation from parents may be due to foster care placement. We identified this broader measure of family disruption using "Z codes" in the *ICD-10-CM*, which are used to record circumstances other than injuries or illnesses that result in the health care encounter or influence care. We identified children experiencing family disruption who had at least one claim of any service type with *ICD-10-CM* codes indicating changes in the composition of household members due to separation (including due to parental divorce or separation), extended absence from family members, family member return from military deployment, or death of a family member. See Supplement B, eTable 5 for diagnosis codes.

Maternal mental illness

To identify maternal mental illness, we used diagnosis codes on the mother's inpatient, outpatient, or physician claims submitted to TennCare, as well as prescription drug codes for treatment of mental illness on the mother's outpatient prescription drug file. Building off of algorithms for mental health conditions from the CCW, we identified maternal mental illness when mothers met the criteria of one inpatient claim with a diagnosis or two nondrug claims with diagnoses, and additionally searched pharmacy claims to identify mental illness for mothers with at least two pharmacy fills for medications to treat mental illness.[26] We used diagnosis codes for health conditions from the CCW in addition to codes for suicidal ideation, suicide attempt, and intentional self-harm. From the CCW, we adopted the algorithm of codes for anxiety disorders (including post-traumatic stress disorder), bipolar disorder, depression and depressive disorders, personality disorders, schizophrenia, and other psychotic conditions.[26] Drugs included treatments for depression, anxiety, other mood disorders, schizophrenia, and other psychoses. In Supplement B, see eTable 5 for diagnosis codes and eTable 10 for included drugs. We flagged visits to the emergency department as a more severe mental illness in sensitivity analyses.

Maternal substance use disorder

We identified maternal substance use disorder with diagnosis codes and procedure codes on mothers' inpatient, outpatient, or physician claims submitted to TennCare, as well as with prescription drug fills for substance use disorder treatment. Adopting the CCW algorithm for drug use disorders,[26] we identified children exposed to maternal substance use disorder whose mothers had one inpatient claim with a diagnosis, two nondrug outpatient claims with diagnoses, one encounter of any service type with a procedure code, or, extending the CCW algorithm, two pharmacy fills for medications to treat substance use disorder. We added procedure codes from the HCPCS, as well as diagnosis codes for alcohol use disorder. We included drugs for emergency treatment of overdose, such as naloxone, as well as medications used to prevent relapse, such as naltrexone. In Supplement B, see eTable 5 for diagnosis codes, eTable 9 for procedure codes, and eTable 10 for included drugs. We flagged visits to the emergency department as more severe substance use disorders for sensitivity analyses.

Abuse of the mother

We identified children exposed to adult abuse of their mothers through at least one claim for their mother for any service type with a diagnosis code or procedure code for abuse. The diagnosis codes identified adult physical, emotional, or sexual abuse. The HCPCS codes included here were for anogenital exams in adults suspected of trauma. In Supplement B, see eTable 5 for diagnosis codes and eTable 9 for procedure codes.

2.2.2 | Demographic characteristics

We used information from the TennCare enrollment file on children's age, sex, and race/ethnicity. When self-reported race/ethnicity was missing from the enrollment file, we imputed race from the child's linked hospital discharge records or mother's race as self-reported on the birth certificate when available, both from the Tennessee Department of Health. In addition, we classified the places where children lived as urban or rural by using their residential addresses from the TennCare enrollment file and rural–urban continuum codes from the US Department of Agriculture.[46]

2.3 | Statistical analysis

Using the ADM-ACE, we measured the 1-year prevalence of these ACEs in 2018. We measured the prevalence of any ACEs and each ACE type by demographic subgroups, using chi-square tests for differences by demographic characteristics. We examined the prevalence of ACEs by race/ethnicity to consider how social and cultural factors might be protective against ACE exposure; how impacts of discrimination and marginalization might be passed on to children through maternal mental and behavioral health conditions, family disruption, or intergenerational transmission of stress and violence; and whether there is differential detection of ACE exposure by race/ethnicity in our administrative data approach. All analyses were conducted in Stata (StataCorp. 2021. Stata Statistical Software: Release 17. StataCorp LLC, College Station, TX). This study was approved by the institutional review boards at Vanderbilt University Medical Center and the Tennessee Department of Health.

3 | RESULTS

3.1 | Prevalence of ACEs

Figure 1 displays the prevalence of ADM-ACEs among the study cohort of 763,836 children who, along with their mothers, were enrolled in TennCare in 2018. The 1-year prevalence of any ACEs was 19.2%, and 4.1% of children experienced multiple types of ACEs. The most commonly recorded exposure from the ADM-ACE was maternal mental illness (15.1%). See Supplement A, eTable 2 for demographic characteristics of the cohort.
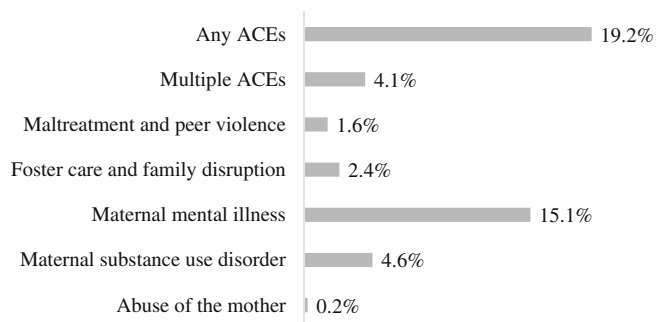

FIGURE 1 Prevalence from the algorithm of Administrative Data to Measure Adverse Childhood Experiences (ADM-ACE): Children aged 0–17 years in TennCare with linked mothers, 2018 (N = 763,836). This figure displays the prevalence of ACEs as measured with the ADM-ACE among the study cohort of children aged 0–17 enrolled in TennCare in 2018, linked with mothers also enrolled in TennCare in the year

Table 1 presents the prevalence of any ADM-ACEs by demographic characteristics. The prevalence of any ACEs was higher among children who were younger, lived in rural counties, and were non-Hispanic white (compared to other races/ethnicities). There was no difference in the prevalence of any ACEs by sex. The largest disparities, by both absolute and proportional differences, were by race/ethnicity: ADM-ACEs were identified for 3.8% of Hispanic children, which was lower compared to 24.2% of non-Hispanic white children. Table 2 presents the prevalence of the five distinct ADM-ACE types by demographic characteristics, demonstrating that differences by age in the prevalence of any ACEs were driven by a higher prevalence of maltreatment, maternal mental illness, and maternal substance use disorder among children aged 0–5, compared to older children. Rural–urban disparities were largest for maternal mental illness, which was recorded for 19.3% of children in rural counties and 13.7% of children in urban counties. As for the summary measure of any ADM-ACEs (Table 1), and for each of the five ADM-ACE subtypes (Table 2), the prevalence was highest among non-Hispanic white children and lowest among Hispanic children. Females were slightly more likely to have records of maltreatment, while males were more likely to have records of foster care and family disruption (Table 2).

3.2 | Sensitivity analyses

Potential bias from differential health care-seeking behaviors could lead families who are more likely to seek health care to be more likely to have ACEs captured through the ADM-ACE (prevalence estimates from ADM-ACE would be higher than population level); at the same

TABLE 1 Prevalence of any ADM-ACEs by demographic characteristics: Children aged 0–17 years in TennCare with linked mothers, 2018 (N = 763,836)

	Denominator for demographic group	Any ACEs		
	No.	No.	(%)	p
Age				<0.001
0–5	212,829	49,017	(23.0%)	
6–11	286,985	52,811	(18.4%)	
12–17	264,022	45,104	(17.1%)	
Sex				0.357
Female	371,929	71,386	(19.2%)	
Male	391,907	75,546	(19.3%)	
Urbanicity				<0.001
Rural	190,931	45,577	(23.9%)	
Urban	572,905	101,355	(17.7%)	
Race/ethnicity				<0.001
Hispanic	49,003	1869	(3.8%)	
Non-Hispanic black	224,459	32,499	(14.5%)	
Non-Hispanic white	443,791	107,462	(24.2%)	
Not listed or unknown	46,583	5102	(11.0%)	

Note: Urbanicity was defined using RUCC from the US Department of Agriculture (version 2013). RUCC 1–3 were classified as "urban;" RUCC 4–9 were classified as "rural." *p* Values are reported from chi-square tests.
Abbreviation: RUCC, Rural–Urban Continuum Codes.

TABLE 2 Prevalence of ADM-ACEs by type and demographic characteristics: Children aged 0–17 years in TennCare with linked mothers, 2018 (N = 763,836)

	Maltreatment and peer violence			Foster care and family disruption			Maternal mental Illness			Maternal substance use disorder			Abuse of the mother		
	No.	(%)	p	No.	(%)	p	No.	(%)	p	No.	(%)	p	No.	(%)	p
Age			<0.001			0.001			<0.001			<0.001			<0.001
0–5	5732	(2.7%)		5086	(2.4%)		37,745	(17.7%)		11,976	(5.6%)		693	(0.3%)	
6–11	4456	(1.6%)		6568	(2.3%)		41,231	(14.4%)		13,091	(4.6%)		703	(0.2%)	
12–17	1894	(0.7%)		6434	(2.4%)		36,653	(13.9%)		9939	(3.8%)		485	(0.2%)	
Sex			0.002			<0.001			0.533			0.413			0.290
Female	6082	(1.6%)		8475	(2.3%)		56,400	(15.2%)		17,120	(4.6%)		893	(0.2%)	
Male	6000	(1.5%)		9613	(2.5%)		59,229	(15.1%)		17,886	(4.6%)		988	(0.3%)	
Urbanicity			<0.001			<0.001			<0.001			<0.001			0.013
Rural	3168	(1.7%)		5428	(2.8%)		36,889	(19.3%)		10,534	(5.5%)		517	(0.3%)	
Urban	8914	(1.6%)		12,660	(2.2%)		78,740	(13.7%)		24,472	(4.3%)		1364	(0.2%)	
Race/ethnicity			<0.001			<0.001			<0.001			<0.001			<0.001
Hispanic	403	(0.8%)		260	(0.5%)		1206	(2.5%)		230	(0.5%)		33	(0.1%)	
Non-Hispanic black	3204	(1.4%)		4030	(1.8%)		24,453	(10.9%)		6759	(3.0%)		553	(0.2%)	
Non-Hispanic white	8027	(1.8%)		13,376	(3.0%)		85,818	(19.3%)		27,101	(6.1%)		1222	(0.3%)	
Not listed or unknown	448	(1.0%)		422	(0.9%)		4152	(8.9%)		916	(2.0%)		73	(0.2%)	

Note: Denominators for demographic groups are reported in Table 1. p Values are reported from chi-square tests.

time, families who are more likely to seek health care may be those in which children have greater support and are less likely to experience ACEs (prevalence estimates from ADM-ACE would be lower than population level). To address possible bias from families' different health care-seeking behaviors, in sensitivity analyses, we used the modified ADM-ACE measures to eliminate or reduce the role of choice in health care utilization. Here we focused on three modified ADM-ACEs: (1) foster care from the TennCare enrollment file, (2) maternal mental illness presented in emergency departments, and (3) substance use disorders presented in emergency departments. Results were qualitatively similar: sensitivity analyses indicated that the prevalence of ADM-ACEs was significantly higher among non-Hispanic white children compared to Hispanic children (Supplement A, eTable 3).

4 | DISCUSSION

In this study, we present a novel measure of ACEs using administrative data from health insurance claims for children and their mothers. The ADM-ACE utilizes standard codes for diagnoses and procedures received by the child or mother along with information on prescription medications received by the mother. Almost one in five children in our sample of Medicaid-enrolled children in Tennessee had at least one ADM-ACE in 2018, reflecting maltreatment and peer violence, foster care and family disruption, maternal mental illness, maternal substance use disorder, or abuse of the mother. By using demographic information from the Medicaid enrollment file, we found that the prevalence of ACEs was highest among children aged 0–5 years compared to older children, children in rural versus urban counties, and children from non-Hispanic races/ethnicities. Our findings are consistent with survey-based research that documents a much lower prevalence of traditionally studied ACEs among Hispanic children compared to non-Hispanic white and black children,[47] including in other Medicaid-eligible populations.[48] Studies using the NSCH show that the lower observed rates of ACEs among Hispanic children were driven by lower rates reported for children who are immigrants,[47,49] while the measured prevalence of ACEs among third or higher generation Hispanic children was similar to the prevalence for third or higher generation non-Hispanic white and non-Hispanic black children.[47] For childhood maltreatment and peer violence, part of the difference by age is mechanical, as the algorithm for diagnoses suggestive of child maltreatment contains age restrictions because it may be ambiguous whether the injuries or illnesses included, when observed in older children, are due to maltreatment or accident while in young children would at a minimum be considered physical or supervisory neglect (and possibly abuse).

Our study builds upon previous surveillance research on ACEs by defining children's exposures with administrative health data, including information from mothers' records. We leverage a data system routinely available to study children's health outcomes that are not subject to the same reporting bias or burden as survey data or any bias in reports to child welfare services. In our sample of all children in Tennessee's Medicaid program who could be linked to mothers also enrolled in 2018, the ADM-ACE yielded the prevalence of

maltreatment (1.6%) falling between the percent of all children in Tennessee who were investigated as victims of child maltreatment by the Department of Children's Services (2.3%), and the percentage of children whose cases were substantiated with available evidence (0.6%) in 2018.[50] The ADM-ACE captured much higher levels of maternal mental illness in a 1-year period than measured from the NSCH parent survey reports of children's exposure to *any household member* having had mental illness *ever* (from the subset of Tennessee children with public insurance in 2018–2019 NSCH) (15.1% vs. 9.5% [95% CI: 6.1%–14.6%]). Other survey reports of depression, specifically in the perinatal period, show that, in 2019, 15.1% (14.5–15.7) of pregnant people in Tennessee reported depression in the 3 months before pregnancy, as collected by the Pregnancy Risk Assessment Monitoring System (PRAMS).[51] The 1-year prevalence of maternal substance use disorder measured with the ADM-ACE was more than a third of that reported for exposure through *any household member ever* at the time of survey (4.6% vs. 12.2% [8.4%–17.4%]).[52] Abuse of the mother identified by medical claims with the ADM-ACE was only a small fraction of the prevalence of children ever witnessing domestic violence, as reported by Tennessee parents in the NSCH (0.2% vs. 11.4% [7.4%–17.3%]).[52] From PRAMS in Tennessee, 3.0% (2.8–3.3) of pregnant people reported intimate partner violence in the 12 months before pregnancy.[51] These discrepancies highlight the tradeoffs of using data from health care encounters to define maternal health and domestic violence instead of relying on survey reports. Our results suggest an advantage in using the ADM-ACE to identify children's exposure to maternal mental and behavioral health conditions, as individuals living with mental illness may not be aware of their diagnoses or may decline to self-report this information in telephone or in-person surveys due to mental health stigma. While the ADM-ACE would miss maternal mental illnesses and substance use disorders among mothers who did not have any health care encounters related to these health conditions, our approach overcomes false-negative reporting in surveys, which may be substantial for behavioral health conditions.

The ADM-ACE can be used to measure and monitor changes in the prevalence of ACEs over time and in response to programs and policies. For example, researchers could apply the ADM-ACE to measure the impacts of maternal depression screenings and follow-up on child maltreatment among young children. The ADM-ACE is also a useful tool for researchers to study the effects of interventions on children with ACEs. While the ADM-ACE does not have the sensitivity to capture all ACE events, the algorithm can be used to identify a high-priority subset of children with ACEs to include in research. For example, the ADM-ACE could be used to investigate the effects of family resource centers or statewide policy interventions on the health outcomes of children with ACEs. Researchers using the ADM-ACE to study ACEs and health measures or disparities in ACE prevalence should exercise caution due to potential bias by varying individual and group levels of engagement with the health care system. Cohort requirements for observation of any health care claims or some volume of claims can reduce this bias. While the ADM-ACE was developed as a tool for researchers to

identify children with ACEs, it could also be implemented in health care systems and public health programs to flag ACEs within children's electronic health records for consideration by their health care providers.

4.1 | Limitations

There are several limitations to measuring ACEs using health encounter data. While the ADM-ACE is valuable for examining ACEs within child health data, other approaches are needed to examine community, neighborhood, and systemic burdens on children, such as community violence, school suicides, and racial discrimination.[53,54] Among exposures identified through the ADM-ACE, we capture only those documented in health care claims data (or other health data recording diagnosis codes). The ADM-ACE will not capture child maltreatment and abuse of the mother when not recorded in medical encounters; thus, ADM-ACE measures of child maltreatment and abuse of the mother likely represent exposures among the most severe occurrences. While the ADM-ACE measure of foster care and family disruption includes family disruption where recorded, the relevant "Z codes" are inconsistently used across health systems; thus, this measure largely represents foster care as identified through the eligibility field in the TennCare enrollment file. Unfortunately, the ADM-ACE measure may undercount family disruptions due to divorce, separation, and the loss of a family member. Further, while in our application to Tennessee Medicaid data, we observe enrollment codes for foster care status, as all children in foster care are eligible for Medicaid, these codes may not be available in other types of health encounter data or may not be updated within state Medicaid administrative data as soon as children leave foster care, in which case, the measure captures current placement or history of foster care placement, which is identified in research and practice as an ACE.[22,35,36] We limited the set of drugs used to identify maternal mental illness to drugs with approved indications for mental illness and most often used for the treatment of mental illness. However, we acknowledge the possibility for some of these drugs to be prescribed for other reasons, including in off-label use. Finally, we linked children with mothers but, in our application to Medicaid data, are not able to observe mental illness, substance use disorders, or domestic violence experienced by other household members (such as other parents or siblings) consistently due to Medicaid coverage rules. The ADM-ACE, however, can be applied to other data sets with diagnoses from health encounters, including commercial health insurance claims data, which commonly contain household identifiers that would allow the consideration of other members of a child's household.

5 | CONCLUSION

Prevention, detection, and support for children with ACEs remain public health priorities. The ADM-ACE, developed here, can facilitate much-needed research and surveillance data to identify best practices in each of these areas, utilizing routinely recorded health encounter data rather than relying on the collection of survey reports. Diagnoses, procedures, and pharmacy fills captured with the ADM-ACE allow identification of children who have experienced ACEs, thereby enabling allocations of support or targeted policy interventions. The algorithm can also be used to evaluate the short- and long-term impacts of programs and policies aimed to mitigate the negative outcomes for children. By identifying ACEs during childhood, the ADM-ACE can enable much needed progress to advance care practices, programs, and policies for children.

ORCID

Laura E. Henkhaus https://orcid.org/0000-0001-6663-4549
Gilbert Gonzales https://orcid.org/0000-0002-4054-6564

REFERENCES

1. Kalmakis KA, Chandler GE. Health consequences of adverse childhood experiences: a systematic review. *J Am Assoc Nurse Pract*. 2015; 27(8):457-465.
2. Hughes K, Bellis MA, Hardcastle KA, et al. The effect of multiple adverse childhood experiences on health: a systematic review and meta-analysis. *Lancet Public Health*. 2017;2(8):e356-e366.
3. Child and Adolescent Health Measurement Initiative. National Survey of Children's Health (NSCH) data query. Data Resource Center for Child and Adolescent Health supported by the U.S. Department of Health and Human Services, Health Resources and Services Administration (HRSA), Maternal and Child Health Bureau (MCHB). 2019. Accessed December 02, 2021. http://www.childhealthdata.org/
4. Bucci M, Marques SS, Oh D, Harris NB. Toxic stress in children and adolescents. *Adv Pediatr*. 2016;63(1):403-428.
5. Vachon DD, Krueger RF, Rogosch FA, Cicchetti D. Assessment of the harmful psychiatric and behavioral effects of different forms of child maltreatment. *JAMA Psychiatry*. 2015;72(11):1135-1142.
6. Anda RF, Felitti VJ, Chapman DP, et al. Abused boys, battered mothers, and male involvement in teen pregnancy. *Pediatrics*. 2001; 107(2):E19.
7. Oh DL, Jerman P, Silverio Marques S, et al. Systematic review of pediatric health outcomes associated with childhood adversity. *BMC Pediatr*. 2018;18(1):83.

8. Fletcher JM. Childhood mistreatment and adolescent and young adult depression. *Soc Sci Med*. 2009;68:799-806.

9. Sachs-Ericsson N, Gayman MD, Kendall-Tackett K, et al. The long-term impact of childhood abuse on internalizing disorders among older adults: the moderating role of self-esteem. *Aging Ment Health*. 2010;14(4):489-501.

10. Rich-Edwards JW, Spiegelman D, Lividoti Hibert EN, et al. Abuse in childhood and adolescence as a predictor of type 2 diabetes in adult women. *Am J Prev Med*. 2010;39(6):529-536.

11. Duncan AE, Auslander WF, Bucholz KK, Hudson DL, Stein RI, White NH. Relationship between abuse and neglect in childhood and diabetes in adulthood: differential effects by sex, national longitudinal study of adolescent health. *Prev Chronic Dis*. 2015a;12:E70.

12. Ford JL, Browning CR. Effects of exposure to violence with a weapon during adolescence on adult hypertension. *Ann Epidemiol*. 2014;24: 193-198.

13. Lee C, Tsenkova V, Carr D. Childhood trauma and metabolic syndrome in men and women. *Soc Sci Med*. 2014;105:122-130.

14. Exner-Cortens D, Eckenrode J, Rothman E. Longitudinal associations between teen dating violence victimization and adverse health outcomes. *Pediatrics*. 2013;131:71-78.

15. Jonson-Reid M, Kohl PL, Drake B. Child and adult outcomes of chronic child maltreatment. *Pediatrics*. 2012;129(5):839-845.

16. Currie J, Tekin E. Understanding the cycle: childhood maltreatment and future crime. *J Hum Resour*. 2012;47(2):509-549.

17. Currie J, Widom CS. Long-term consequences of child abuse and neglect on adult economic well-being. *Child Maltreat*. 2010;15(2):111-120.

18. Felitti VJ, Anda RF, Nordenberg D, et al. Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults. The Adverse Childhood Experiences (ACE) Study. *Am J Prev Med*. 1998;14(4):245-258.

19. Finkelhor D, Turner HA, Shattuck A, Hamby SL. Prevalence of childhood exposure to violence, crime, and abuse: results from the National Survey of Children's Exposure to Violence. *JAMA Pediatr*. 2015;169(8):746-754.

20. Bramlett MD, Blumberg SJ, Zablotsky B, et al. Design and operation of the National Survey of Children's Health, 2011–2012. *Vital Health Stat 1*. 2017;(59):1-256.

21. Wildeman C, Emanuel N, Leventhal JM, Putnam-Hornstein E, Waldfogel J, Lee H. The prevalence of confirmed maltreatment among US children, 2004 to 2011. *JAMA Pediatr*. 2014;168(8): 706-713.

22. Patton DA, Liu Q, Adelson JD, Lucenko BA. Assessing the social determinants of health care costs for Medicaid-enrolled adolescents in Washington State using administrative data. *Health Serv Res*. 2019; 54(1):52-63.

23. Reuland CP, Collins J, Chiang L, et al. Oregon's approach to leveraging system-level data to guide a social determinants of health-informed approach to children's healthcare. *BMJ Innov*. 2021;7(1):18-25.

24. Swedo E. Trends in U.S. emergency department visits related to suspected or confirmed child abuse and neglect among children and adolescents aged 18 years before and during the COVID-19 pandemic—United States, January 2019–September 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69:1841-1847.

25. Miller LS, Wu M, Schettine AM, Cogan LW. Identifying children with special health care needs using Medicaid data in New York State Medicaid Managed Care. *Health Serv Res*. 2018;53(6):4157-4177.

26. Centers for Medicare & Medicaid Services. Chronic conditions data warehouse. 2019. Accessed August 27, 2020. www2.ccwdata.org

27. Rosen T, Wen K, Makaroun LK, et al. Diagnostic coding of elder mistreatment: results from a national database of Medicare advantage and private insurance patients, 2011–2017. *J Appl Gerontol*. 2021;0: 07334648211018530.

28. Tennessee Division of TennCare. *TennCare's Fiscal Year 18–19 Annual Report*. State of Tennessee; 2019.

29. Kaiser Family Foundation. Trends in Medicaid income eligibility limits. Published 2021. Accessed August 13, 2021. https://www.kff.org/state-category/medicaid-chip/trends-in-medicaid-income-eligibility-limits/

30. Tennessee Division of TennCare. Eligibility reference guide. Published 2021. Accessed August 19, 2021. https://www.tn.gov/content/dam/tn/tenncare/documents/eligibilityrefguide.pdf

31. Piper JM, Mitchel EF Jr, Snowden M, Hall C, Adams M, Taylor P. Validation of 1989 Tennessee birth certificates using maternal and newborn hospital records. *Am J Epidemiol*. 1993;137(7): 758-768.

32. Piper JM, Ray WA, Griffin MR, Fought R, Daughtery JR, Mitchel E Jr. Methodological issues in evaluating expanded Medicaid coverage for pregnant women. *Am J Epidemiol*. 1990;132(3):561-571.

33. Sanlorenzo LA, Cooper WO, Dudley JA, Stratton S, Maalouf FI, Patrick SW. Increased severity of neonatal abstinence syndrome associated with concomitant antenatal opioid and benzodiazepine exposure. *Hosp Pediatr*. 2019;9(8):569-575.

34. Maalouf FI, Cooper WO, Stratton SM, et al. Positive predictive value of administrative data for neonatal abstinence syndrome. *Pediatrics*. 2019;143(1):e20174183.

35. Barboza Solís C, Kelly-Irving M, Fantin R, et al. Adverse childhood experiences and physiological wear-and-tear in midlife: findings from the 1958 British birth cohort. *Proc Natl Acad Sci U S A*. 2015;112(7): E738-E746.

36. California Department of Health Care Services. Trauma screenings and trauma-informed care provider trainings. Published 2021. Accessed December 1, 2021. https://www.dhcs.ca.gov/provgovpart/Pages/TraumaCare.aspx

37. Turner HA, Finkelhor D, Mitchell KJ, Jones LM, Henly M. Strengthening the predictive power of screening for adverse childhood experiences (ACEs) in younger and older children. *Child Abuse Negl*. 2020; 107:104522.

38. Schnitzer PG, Slusher PL, Kruse RL, Tarleton MM. Identification of ICD codes suggestive of child maltreatment. *Child Abuse Negl*. 2011; 35(1):3-17.

39. Blangis F, Allali S, Cohen JF, et al. Variations in guidelines for diagnosis of child physical abuse in high-income countries: a systematic review. *JAMA Netw Open*. 2021;4(11):e2129068.

40. Schnitzer PG, Slusher P, Van Tuinen M. Child maltreatment in Missouri: combining data for public health surveillance. *Am J Prev Med*. 2004;27(5):379-384.

41. Centers for Medicare & Medicaid Services. *General Equivalence Mappings*. CMS.gov; 2018.

42. STD-Related Reproductive Health Training and Technical Assistance Center. List of ACA preventive services and CPT codes. 2016. Accessed August 18, 2020. http://stdtac.org/wp-content/uploads/2014/06/List-of-ACA-Preventative-Services-and-CPT-Codes-_STDTAC.pdf

43. Campbell LL. *Coding & Billing for HIV & STI Testing and Preventive Services*. Illinois Public Health Association; 2018.

44. Hansen LA, Mikkelsen SJ, Sabroe S, Charles AV. Medical findings and legal outcomes in sexually abused children. *J Forensic Sci*. 2010;55(1): 104-109.

45. *List of Services Provided for Sexual Assault Examination*. Texas Department of Public Safety Crime Laboratory; 2016.

46. U.S. Department of Agriculture Economic Research Service. Documentation. Published 2020. Accessed August 10, 2021. https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/documentation/#referencedate

47. Loria H, Caughy M. Prevalence of adverse childhood experiences in low-income Latino immigrant and nonimmigrant children. *J Pediatr*. 2018;192:209-215.e201.

48. Allen H, Wright BJ, Vartanian K, Dulacki K, Li HF. Examining the prevalence of adverse childhood experiences and associated

cardiovascular disease risk factors among low-income uninsured adults. *Circ Cardiovasc Qual Outcomes*. 2019;12(9):e004391.

49. Caballero TM, Johnson SB, Buchanan CRM, DeCamp LR. Adverse childhood experiences among Hispanic children in immigrant families versus US-native families. *Pediatrics*. 2017;140(5): e20170297.

50. U.S. Department of Health & Human Services, Administration for Children and Families, Administration on Children, Youth and Families, Children's Bureau. Child Maltreatment 2018; 2020. https://www.acf.hhs.gov/cb/research-data-technology/ statistics-research/child-maltreatment

51. Centers for Disease Control and Prevention. PRAMS data: selected 2016 through 2019 Maternal and Child Health (MCH) indicators by state. 2021. Accessed January 21, 2022. https://www.cdc.gov/ prams/prams-data/2019-selected-mch-indicators.html

52. Child and Adolescent Health Measurement Initiative. 2018–2019 National Survey of Children's Health (NSCH) data query. Data Resource Center for Child and Adolescent Health supported by the U.S. Department of Health and Human Services, Health Resources and Services Administration (HRSA), Maternal and

Child Health Bureau (MCHB). Accessed April 6, 2021. http:// www.childhealthdata.org/

53. Flores G, Salazar JC. Immigrant Latino children and the limits of questionnaires in capturing adverse childhood events. *Pediatrics*. 2017; 140(5):e20172842.

54. Finkelhor D, Shattuck A, Turner H, Hamby S. A revised inventory of Adverse Childhood Experiences. *Child Abuse Negl*. 2015;48:13-21.

SUPPORTING INFORMATION

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