



Toward Measurement for a Whole Child Health Policy: Validity and National and State Prevalence of the Integrated Child Risk Index

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ABSTRACT

OBJECTIVE: To develop, validate and estimate national and across state prevalence on a multidimensional index that assesses the complex medical, social, and relational health risks experienced by United States children.

METHODS: Data from the National Survey of Children's Health were used to construct the Integrated Child Risk Index (ICRI) which includes medical health risk (MHR), social health risk (SHR) and relational health risk (RHR) domains. Confirmatory factor analysis and logistic regression analyses were employed to assess construct and predictive validity. Validity outcomes were child flourishing, school engagement/readiness, emergency room utilization and forgone care.

RESULTS: Confirmatory factor analysis confirmed the ICRI 3-domain structure and greater correlation between MHR and RHR than MHR and SHR. Logistic regressions confirmed strong predictive validity of the ICRI for all study outcomes and ICRI scoring approaches. Nearly two-thirds of children (64.3%) with MHR also experienced SHR and/or RHR. Nearly one-third of United States children experienced risks on 2 or more ICRI domains and 15% of publicly insured children had

risks on all domains (16.2%; 9.0%–25.7% across states). Significant variations were observed across states and by age, race/ethnicity, health insurance and household income.

CONCLUSIONS: The ICRI is a valid national and state level index associated with children's flourishing and educational preparedness and emergency and forgone care. National child health policies and Medicaid risk stratification and payment models should consider children's RHR in addition to SHR and MHR. Results call for integrated systems of care with the capacity to address medical, social and relational health risks and promote well-being. Substate and clinical applications require research.

KEYWORDS: child health; medicaid; risk assessment; social determinants of health; relational health; National Survey of Children's Health (NSCH); adverse childhood experiences (ACEs); children with special health care needs (CSHCN); complex needs; integrated care; Flourishing; School Readiness

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WHAT'S NEW

The Integrated Child Risk Index assesses the complexity of children's health risks across medical, social and relational domains, predicts important outcomes and may help inform and evaluate policies to improve child health equity and establish integrated systems of care.

THE CORONAVIRUS PANDEMIC has highlighted the reality that our children's physical, mental, social, and relational lives are inextricably intertwined and collectively promote or diminish both their early development and lifelong well-being.¹⁻⁷ If nothing else, the disparities in

morbidity and mortality unveiled by the pandemic confirm what our best science has told us for decades: physical and mental health do not occur in a vacuum and are strongly impacted by social inequities and the toxic stress and trauma that can arise in the presence of relational risks.^{2,7-9} Socially, children must have basic needs met, like food,^{10,11} safe housing,^{11,12} and neighborhoods free from violence¹³ and racism.¹⁴ Relationally, healthy development requires the presence of safe, stable and nurturing relationships across all contexts where children learn, play and grow.^{1,3,4,7,9,15-20}

Americans value the well-being of children.²¹ Yet, the United States (US) remains persistently low in

international rankings in overall child well-being.²² A synthesis of recent National Academy of Sciences expert reports reveals the urgent need for the US to prioritize policies that promote the health and well-being of its children, and each call for integrated and upstream strategies to address the constellation of child-, family-, and community-level risks that impact child health, rather than focusing on single risk factors.²³ Recommendations include: 1) collaborative efforts across health, education, and social services sectors; 2) team-based approaches to prevent and mitigate risks by proactively promoting child-, family-, and community-level protective factors; and 3) training, payment and performance measurement strategies focused on healthy child development and positive health and educational outcomes.²³ In turn, these efforts require integrated assessments that consider the complex array of children's physical, mental, social, and relational health risks associated with health and educational outcomes in order to assess, plan for and target services based on child and family needs.²³⁻²⁸

Despite growing consensus on the need for such integrated assessment approaches, prominent risk stratification and associated payment methods primarily focus narrowly on medical health risks (MHRs) — children's existing physical, mental or developmental medical diagnoses — that are associated with increased costs of medical care.²³⁻²⁸ Such narrow assessments are inherently reactive (vs preventive), biased against children with poorer access to diagnostic services and/or who experience negative impacts, perhaps due to social and relational health risks, but lack a physical, mental or developmental medical diagnoses. Predominant medical cost-driven and diagnostic-based methods typically do not account for the mitigatable community-level social health risks (SHR) that pose threats to children's health (eg, poverty,^{2,29,30} food insecurity,^{10,11} exposure to community violence¹³ or racism^{14,31}) or the family-level relational health risks (RHR) that threaten children's well-being (eg, Adverse Childhood Experiences [ACEs]^{1-3,7,9,15-20,32,33} or caregivers who lack support or are distressed).^{3,4,34,35}

With the exception of interpersonal safety, a recent review of evidence on social risks screening and interventions conducted for the US Preventive Services Task Force limited the concept of social risks to income-associated factors.³⁶ This review found evidence that interventions to address such risks may reduce health care costs but that few studies examined associations with health outcomes. Also found was lack of validation for most multidomain social risk screening tools and documentation that these tools — with the exception of interpersonal safety — do not include relational health risks, like ACEs or lack of social/emotional support. This also appears to be true for risk assessment approaches being employed in the Integrated Care for Kids (InCK) state demonstrations.²⁶⁻²⁸ However, research documents independent associations between the health of adults and children and such relational health risks, even among those lacking income-associated social risks.^{16,32} Further emphasizing the importance of considering relational health risks is a

recent study revealing a 2.8 times higher rate of mental, emotional and behavioral health problems among US children when they experience 2-4 relational health risks but do not experience social health risks.³⁷ The importance of a distinct focus on preventing and addressing relational health risks is also strongly recommended by the American Academy of Pediatrics in its 2021 revised policy statement on childhood toxic stress that documents the foundational role of relational health to fostering healthy, resilient children, and recommends the proactive assessment and promotion of relational health for all children.⁷

In response to the gaps in research on integrated assessment approaches for children,³⁶⁻⁴⁰ this study aimed to 1) design and evaluate the construct validity of an index that integrates information about the complexity of the risks children experience across medical (physical/mental health problems and functional difficulties), social (economic hardship, food insecurity, community safety, racism), and relational (Adverse Childhood Experiences, parent/caregiver distress) health domains; 2) evaluate predictive validity of the index using positive health and health care utilization outcomes; 3) examine associations among risk domains to document their interacting and/or independent impacts; and 4) estimate national and across state prevalence across child subgroups.

METHODS

DATA AND POPULATION

Data from the 2016–2019 National Survey of Children's Health (NSCH) were used.^{41,42} The NSCH is an annual survey led by the US Health Resources and Services Administration's (HRSA) Maternal and Child Health Bureau (MCHB) in collaboration with the US Bureau of the Census.⁴¹ Unlike some state-level efforts to assess children's medical and social risks using system-level data,⁴³ the NSCH has the advantage of providing state data at the child level across numerous topics and enables stratification across a wide range of child characteristics. Here we used the combined 2016–2018 NSCH data (n = 102,341) to create and validate the Integrated Child Risk Index (ICRI), and then used the 2019 NSCH data (n = 29,344) to assess the reliability of study findings. Data were weighted to be representative of the nation and each state's population. Missing value rates were less than 3% for any individual item used in the study, which is well under the suggested 5%–10%.⁴⁴ See Technical Appendix A1-A2 for details.⁴⁴

APPROACH TO THE DESIGN OF THE INTEGRATED CHILD RISK INDEX (ICRI)

The ICRI is based on the eco-bio-developmental model¹ of child health and builds on a body of work undertaken by the Child and Adolescent Health Measurement Initiative (CAHMI) and its leadership of the National Maternal and Child Health Measurement Research Network (MCH MRN) and the MCH MRN's *Positive and Relational Health and Social Determinants*

of Health Technical Working Groups.^{45,46} The purpose of this initial work was to inform risk stratification approaches under consideration by states applying for funds to implement the Center for Medicare and Medicaid Services (CMS) Integrated Care for Kids (InCK) model.^{25,47-48}

ICRI development married cumulative risk (CR) and factor analytic approaches to create a child-level cumulative risk index with 3 distinct domains of risk (MHR, SHR, RHR).^{49,50} While CRs emphasize risk quantity and diversity and have higher predictive value across many different outcomes compared to individual risk variables, they lack specificity in terms of types of risks experienced. Alternatively, factor analyses capture risk intensity and differentiate between risk types through the identification of latent risk factors but are highly sample dependent.^{49,50} Our multifaceted approach adopts the simplicity of CR while leveraging the nationally and state level representative nature of the NSCH dataset to evaluate the ICRI factor structure and set forth national and across state prevalence.

SELECTION OF INDIVIDUAL RISK MEASURES WITHIN ICRI DOMAINS

NSCH items and measures used to create individual ICRI measures were drawn from previously validated instruments and underwent the NSCH's standard mixed-method development process to optimize the face, construct, and convergent/divergent validity of items and multi-item NSCH measures.^{41,42} To select individual measures for the ICRI, we built on Sameroff and colleague's approach, whereby risk measures were selected based on: 1) prominent models and measures with significant literature basis on the risk's impact on child health and development; and 2) high reliability of individual risk measures.^{51,52} We used dichotomous high/low cutoff scores for each measure, with specific criteria based on values known to be predictive of child health and development outcomes or clinical/diagnostic criteria.^{34,53} Sensitivity analysis of individual items was conducted. When setting cutoffs, we took a conservative approach that erred on the side of positive predictive value over negative predictive value, such that if a child was positively identified on any measure, there would be unarguable evidence that the child was at risk (eg, children met cutoff criteria if they had "poor or fair" overall health status or "poor or fair" caregiver mental health status, even though "good" ratings often suggest children are at increased risk compared to those with "very good" and "excellent" ratings^{54,55}).

RISK DOMAINS

A total of 12 health risk measures were included. Below, we provide an overview of each measure by risk domain. Due to space limitations, further details about each measure is provided in Technical Appendix A3-A5.^{41,44}

The *Medical Health Risk (MHR)* domain includes 4 measures that identify children experiencing: 1) a more complex special health care need based on responses to

the validated CSHCN Screener;⁵⁶ 2) two or more of the chronic or life-long diagnosed conditions asked about in the NSCH;⁵⁷ 3) one or more of 11 frequent, chronic and/or serious functional difficulties aligned with domains included in the International Classification of Functioning for Children and Youth;⁵⁸ and 4) fair or poor overall health status.⁵⁹

The *Social Health Risk (SHR)* domain includes 4 measures that identify children whose caregivers reported that they: 1) *sometimes* or *often* could not afford enough food to eat;^{10,11} 2) *somewhat often* or *very often* found it hard to cover the costs of basics needs, including housing;^{29,30} 3) lived in an unsafe neighborhood or where the child was a victim of or witnessed violence;^{13,39} and 4) witnessed their child being treated or judged unfairly due to his or her race or ethnic group.^{14,31}

The *Relational Health Risk (RHR)* domain includes 4 measures that identify children based on risks to the safety, stability and nurturing qualities of their relationships in the home. The RHR domains identifies children who: 1) experienced 2 or more of 6 household level adverse childhood experiences (ACEs) using the validated NSCH_ACEs indicator and cutoff shown to predict poorer outcomes;^{60,61} 2) had 1 or 2 caregivers with fair/poor mental health;³⁴⁻³⁷ 3) had a caregiver report frequent aggravation with their child;⁶² and 4) had a caregiver who lacked emotional support or was not coping well.^{20,35,63}

Together, the social and relational risk measures represent 11 of the 13 topics addressed in the Accountable Health Communities (AHC) Health-Related Social Needs (HRSN) Screening Tool and all but one of the topics addressed in the recent USPSTF evidence review.^{36,64-65} See Technical Appendix B for a comparison of ICRI measures and other social determinants of health assessments.⁴⁴

PREDICTIVE VALIDITY OUTCOME MEASURES

HEALTHCARE UTILIZATION

Hospital Emergency Room Utilization (ER) assesses whether children had at least one emergency room visit (ER) in the past 12 months based on caregiver response to the question, "During the past 12 months, how many times did this child visit a hospital emergency room?"⁴²

Forgone Care assesses whether a child had to forgo receiving needed healthcare in the past 12 months based on caregiver response to the question, "During the past 12 months, was there any time when this child needed health care, but it was not received?"⁴²

POSITIVE HEALTH AND EDUCATIONAL PREPAREDNESS AND ENGAGEMENT

Child Flourishing Index (CFI) evaluates whether children demonstrate characteristics associated with key flourishing constructs and was developed and validated for use in the NSCH.^{17,66} The CFI varied by child's age and assesses child curiosity and interest in learning, positive social and emotional characteristics, ability to focus and complete tasks and self-regulation. Using validated

scoring methods, dichotomous indicators were created, where a score of 4 for 6-month to 5-year-olds and a score of 3 for 6-17-year-olds was coded as “1” (“flourishing”) and lesser scores were coded as “0” (“not flourishing”). Due to changes in the NSCH for CFI items between 2017 and 2018, only data from 2016 and 2017 was used in regression analyses using the CFI as the dependent variable. See Technical Appendix A5 for measurement details.⁴⁴

Educational preparedness and engagement assesses whether or not a child was prepared to engage in school (ages 3–5) or met criteria for school engagement (ages 6–17). Children ages 3–5 were classified as “prepared to engage in school” if their caregivers reported they were *very* or *completely confident* that their child was ready for or would be successful in school – an item highly correlated with a more robust school readiness indicator.^{42,67} School-age children (age 6–17) met criteria for school engagement if their caregivers reported *always/definitely true* or *usually* that their child “cares about doing well in school” and “does all required homework.”⁴² Readiness to engage/school engagement was coded as “1” for meeting criteria and “0” for not meeting criteria. See Technical Appendix A5 for measurement details.⁴⁴

DEMOGRAPHIC MEASURES

Demographic variables were measured using standard NSCH categories⁴² and included: child age (0–5, 6–11, 12–17); sex (male = 1, female = 0); race and ethnicity (Hispanic, Non-Hispanic Black, Non-Hispanic White, Other/Multi-Racial, Asian, Non-Hispanic, American Indian/Alaska Native, Non-Hispanic, Native Hawaiian/Other Pacific Islander, Non-Hispanic); household income, calculated as a percentage of the federal poverty level (0%–99%, 100%–199%, 200%–399%, \geq 400%); and type of health insurance (public, uninsured, private).

ANALYTIC PROCEDURES

CONFIRMATORY FACTOR ANALYSIS

We first computed Pearson’s correlations among all 12 ICRI measures to evaluate information redundancy using standard intervals established in the literature to evaluate the strength of correlations ($r = 0$, *no correlation*; $r =$ below ± 0.10 , *low*; $r = \pm 0.30$, *moderate*; $r \geq \pm 0.50$, *large*; $r = 1$, *perfect correlation*).⁶⁸ We then conducted a 3-factor CFA model allowing for correlated factors, where each factor represented one of the 3 risk domains, each comprised of 4 individual risk items. We compared this model with a unidimensional one (ie, all 12 items on one factor). We evaluated model fit using multiple fit indices with standard acceptable fit criteria: χ^2 , comparative fit index (CFI) and Tucker-Lewis Index (TLI) > 0.95 ; root mean-square error of approximation (RMSEA) < 0.08 ; and standardized root mean squared residual (SRMR) < 0.08 .⁶⁸⁻⁷¹ We further evaluated associations among ICRI domains by estimating prevalence of MHR by the SHR and RHR children experience.

ICRI SCORING

A goal for the ICRI was to create a dynamic instrument useful for epidemiological research, population health policymaking and management and with relevance as an assessment model for clinical practice. As such, we conducted a thorough investigation of potential scoring options and discuss the benefits and trade-offs for each one in Table 1. The 3 options include *Domain Count* (number of domains with at least one risk), *Domain Combination* (8 mutually exclusive categories of combinations of MHR, SHR, RHR) and *Cumulative Risk* (count of individual risks). Prevalence and validity analyses were conducted separately for each option and results were compared to understand the utility of each option in providing a robust and pragmatic scoring system for the ICRI.

PREDICTIVE VALIDITY

To evaluate the predictive validity of the ICRI, for each ICRI scoring option and study outcome we conducted logistic regressions using the ICRI as the primary predictor. For health care utilization, the reference category for ICRI scores was the lowest level of risk. For positive outcomes the reference category was the highest level of risk. Each model controlled for children’s sex, age, race/ethnicity, household income, and insurance type. Results are presented as adjusted odds ratios [aORs] with 95% confidence intervals (95% CI).

NATIONAL AND STATE PREVALENCE

National and state prevalence was calculated for each ICRI scoring option, individual domain and risk measure and compared by child age, sex, race/ethnicity, income, and type of health insurance using chi squares tests of differences. Nested t-tests were employed to test the significance of differences between the prevalence of children in the nation versus each state who experience at least 2 ICRI domains. This was evaluated for all children and separately for children in each state who lived in households with incomes below 200% FPL to approximate prevalence for more economically vulnerable children. Finally, we compared findings using 2016–2018 NSCH with those using the 2019 NSCH as a final test of reliability.

RESULTS

CONFIRMATORY FACTOR ANALYSIS VALIDATION

The 12 ICRI measures were not statistically redundant. Each of the 66 Pearson’s correlations were significant ($P < .05$), yet all but 5 was low to moderate. Four sets of risk criteria exceeded the moderate correlation classification, and one correlation was large ($r = 0.596$; “more complex CSHCN” and “2+ chronic conditions”). See Technical Appendix A4.⁴⁴ Results from the 3-factor CFA confirmed good model fit ($\chi^2(51) = 1,560.14$, $P < .001$; RMSEA = 0.02; SRMR = 0.08; CFI = 0.96; TLI = 0.95; Figure 1, Panel A). All paths were significant ($P < .05$), but the parameter estimate of caregiver emotional

Table 1. Description of ICRI Scoring Options and the Benefits and Tradeoffs of Each Option

Scoring Option	Description	Benefits	Tradeoffs/Solutions
1. Domain Count	Total number of domains experienced (0–3), where higher values represent greater complexity	Straightforward, single metric	Lacks specificity on which domains are experienced and the density of risks (ie, how many) within each domain. Can easily report domains and single items as needed.
2. Domain Combinations	Eight mutually-exclusive combinations of domains based on scores within any single domain: <ul style="list-style-type: none"> - <i>None</i> (0 risks) - <i>Only medical</i> (≥ 1 MHR, 0 SHR, 0 RHR) - <i>Only social</i> (≥ 1 SHR, 0 MHR, 0 RHR) - <i>Only relational</i> (≥ 1 RHR, 0 MHR, 0 SHR) - <i>Medical and social only</i> (≥ 1 MHR, ≥ 1 SHR, 0 RHR) - <i>Medical and relational only</i> (≥ 1 MHR, ≥ 1 RHR, 0 SHR) - <i>Social and relational only</i> (≥ 1 SHR, ≥ 1 RHR, 0 MHR) - <i>Medical, social, and relational</i> (≥ 1 MHR, ≥ 1 SHR, ≥ 1 RHR) 	Specific, enables identification of risk profiles	Requires a large sample size to ensure sufficient power to assess combinations with lower prevalences.
3. Cumulative Risk	Total number of individual risks a child experienced out of the 12 possible risks, collapsed into a categorical variable with a range of 0-5 or more given the skewness of the data (93% of children experienced fewer than 5 risks).	Simple, intuitive	Lacks complexity by not specifying which domains a child experienced. Lacks specificity as to which criteria are met

support/coping was low ($\beta = 0.10$) and accounted for a negligible amount of variance ($R^2 = 0.01$, $SE = 0.00$). A revised CFA without this variable was conducted but the model fit was near identical ($\chi^2(41) = 1,398.23$, $P < .001$; RMSEA = 0.02; SRMR = 0.08; CFI = 0.97; TLI = 0.96), as were parameter estimate values for the remaining 11 risk items. We also examined a unidimensional model with all items loading on a single latent factor, but that fit was inferior ($\chi^2(54) = 4385.47$, $P < .001$; RMSEA = 0.03; SRMR = 0.11; CFI = 0.90; TLI = 0.88; Figure 1, Panel B). The SHR and RHR domains were highly correlated ($r = 0.88$), yet we retained the distinct risk domains given: 1) the qualitative difference between SHRs and RHRs and their potentially different intervention approaches (social, familial, both), and 2) the higher correlation between RHR and MHR ($r = 0.78$) compared to SHR ($r = 0.43$) and potentially different associations with study outcomes. In addition, only 40.6% of children with RHR also experienced SHR such that independent impacts of RHR on MHR and study outcomes would be obscured by combining RHR with SHR.

The retainment of separate SHR and RHR domains was further corroborated by findings showing both independent and interacting associations between MHR and children's SHR and RHR. Specifically, as shown in Figure 2, prevalence of MHR was 24.9% for children with neither SHR nor RHR and was highest for children with 2–4 RHR and 2–4 SHR (69.9%). Yet, even with no SHR,

54.4% of children with 2–4 RHR had MHR and 65.2% with 2–4 RHR and only 1 SHR experienced MHR. Comparatively, 46.6% of children with 2–4 SHR and no RHR experienced MHR. All adjusted odds ratios were significant. See Technical Appendix C4⁴⁴ for detailed regression findings showing all variations resulted in significant adjusted odds ratios.

PREDICTIVE VALIDITY

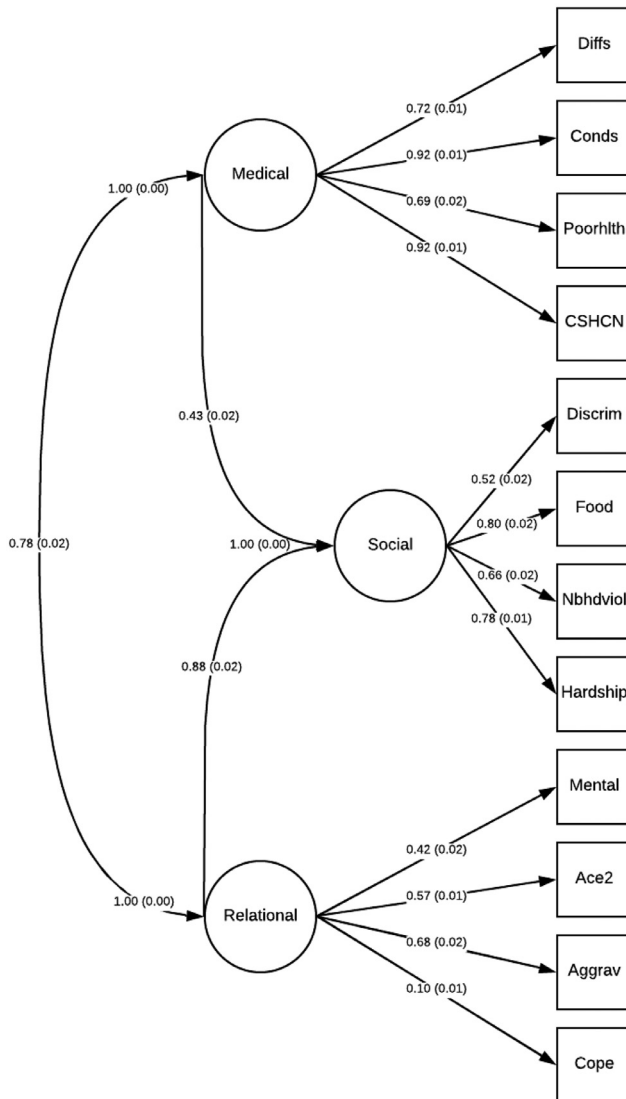
HEALTHCARE UTILIZATION

Children who experienced risks across more ICRI domains or individual criteria were systematically more likely to visit the emergency room and have forgone care in the past 12 months (Table 2). For example, children experiencing 2 domains were twice as likely to visit the emergency room (26.7% vs 13.4%; aOR: 2.05; 95% CI: 1.83–2.29) and 9.2 times more likely to have forgone care (4.6% vs 0.5%; aOR: 7.21; 95% CI: 5.01–10.36) compared to children without risks on any domain. The adjusted odds of forgone care were 6.12 (95% CI 3.77–9.93) times greater for children with only SHR and RHR (no MHR) compared to no risks.

POSITIVE HEALTH AND EDUCATIONAL PREPAREDNESS/ENGAGEMENT

Children with risks in fewer ICRI domains or on fewer individual ICRI measures were more likely to

PANEL A (3 Domain Model)^b



PANEL B (Unidimensional Model)^b

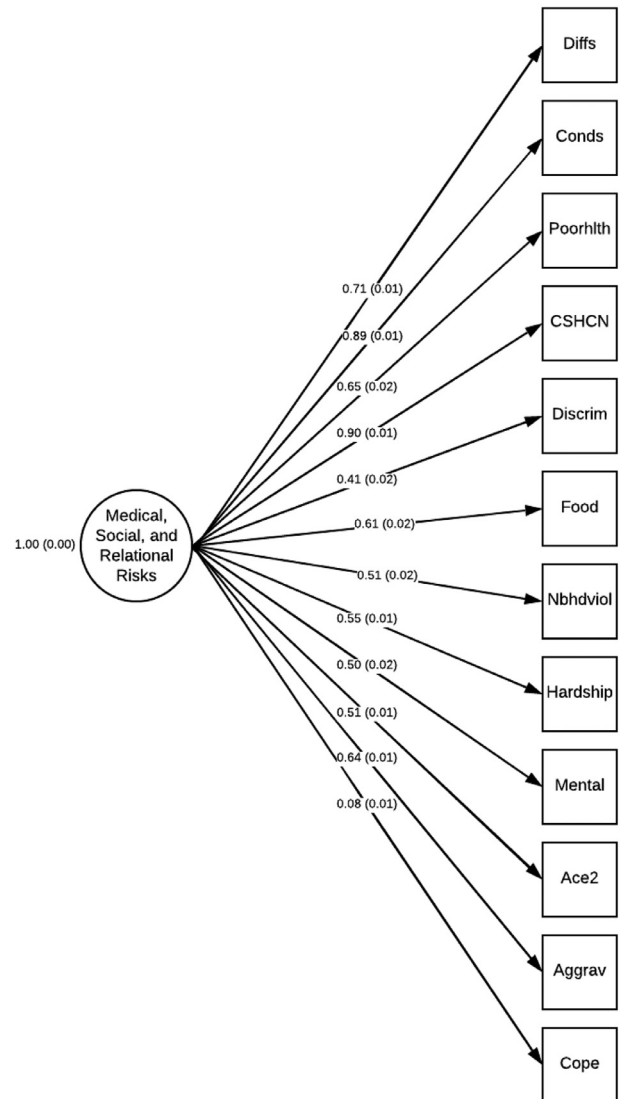


Figure 1. Standardized results from Confirmatory Factor Analyses (CFA) on the Integrated Child Risk Index (ICRI): Results from a 3 domain and unidimensional model^a Data: National Survey of Children’s Health. ^aWCCI=Whole Child Complexity Index; Diffs=1 or more functional difficulties; Conds=2 or more chronic conditions; Poorhlth= fair or poor overall health status; CSHCN=complex special healthcare needs; Discrim=discriminated against because of race/ethnicity; Food=sometimes/often could not afford food; Nbhdviol=unsafe neighborhood or witnessed/experienced violence; Hardship=difficulty meeting basic needs; Mental=caregiver poor/fair mental health status; Ace2=child experienced 2 or more ACEs; Aggrav=caregiver frequent aggravation or anger toward child; Cope=caregiver lacked emotional support/not coping well. ^b Path coefficients represent factor loading coefficients (standard errors) on the respective factors. All paths were significant at P < .01.

meet child flourishing index (CFI) and educational preparedness (3–5-year-olds) or school engagement (6–17-year-olds) criteria (Table 2). Compared to children experiencing all 3 risk domains, those without risks were about 3 times more likely to meet CFI criteria (61.8% vs 21.2%; aOR: 4.81, 95% CI 3.98–5.81) and nearly 2 times more likely to meet educational preparedness/engagement criteria (80.6% vs 43.8%; aOR 4.87, 95% CI 4.11–5.78).

See Technical Appendix C1 and D6-D9 for detailed regression findings by ICRI subdomains.⁴⁴ Of note,

associations between study outcomes and race/ethnicity and household income were largely insignificant after adjusting for children’s ICRI scores.

NATIONAL AND ACROSS STATE PREVALENCE ON THE INTEGRATED CHILD HEALTH INDEX

Overall, 28.8% of all children and 46% of publicly insured children experienced risks on 2 or more ICRI domains, and 8.8% of all US children had risks on all 3 domains. This was 16.2% for publicly insured children

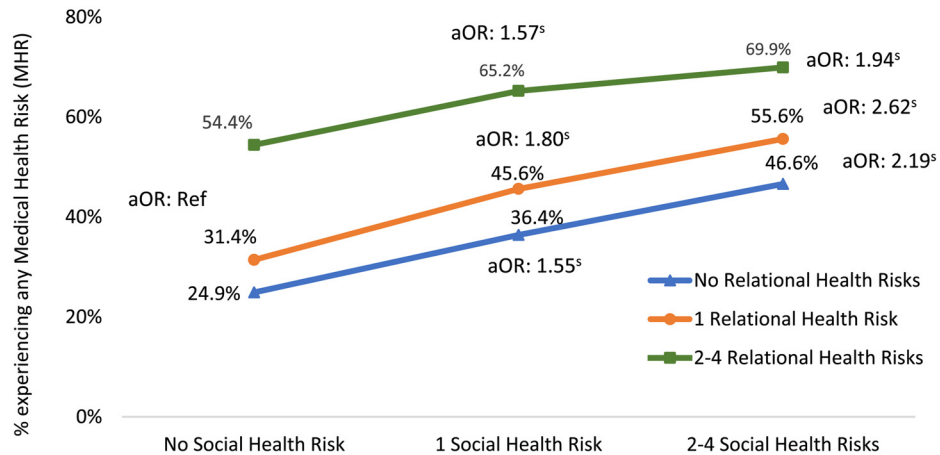


Figure 2. Prevalence of US children who experienced any ICRI Medical Health Risk (MHR) by their Relational Health Risk (RHR) and Social Health Risk (SHR) criteria count scores. Data: National Survey of Children's Health. Notes. All prevalence rates are weighted to represent the US child population. Adjusted Odds Ratios (aOR) are adjusted for age, sex, race/ethnicity, income and insurance coverage type. ^saORs are statistically significant after adjusting for age, sex, race/ethnicity, income and insurance coverage type.

with a range of 9.0% to 25.7% across states (Table 3, Scoring Option 1). For all ICRI scoring options, prevalence was higher for older, non-white, lower income, and publicly insured children ($P < .05$). Smaller differences were observed by child sex, with male children having generally higher rates of risk on the ICRI across all scoring options. This was driven by higher rates of MHR for male children. Prevalence of children experiencing risks on 2 or more ICRI domains ranged from 22.5% for White children to 43.2% for American Indian/Alaskan Native children, and from 47.1% for children with poverty level household incomes to 14.3% for children with household incomes 400% or greater than the Federal Poverty Level. See Table 3 and Technical Appendix C2 and C3.⁴⁴

The prevalence of children who experienced risks on 2 or more ICRI domains ranged from 23.3% to 38.4% across US states. This range was 35.6%–53.2% among children who lived in households with incomes less than 200% Federal Poverty Level. See Figure 3. See Technical Appendix E2⁴⁴ for detailed findings.

COMPARISON WITH 2019 NATIONAL SURVEY OF CHILDREN'S HEALTH

Predictive validity and prevalence findings on the ICRI domain count scoring option were consistent using either the 2016–2018 NSCH or the 2019 NSCH data. Overall prevalence rates were no more than 0.5% lower in 2019 across all domain count score categories (0, 1, 2, 3). The small differences found were driven by changes to the wording of the “economic hardship” measure in the 2019 NSCH – changes that led to fewer children being identified as experiencing this social health risk. See Technical Appendix E4⁴⁴ for detailed findings.

DISCUSSION

This study sought to develop a parsimonious and intuitive child-level risk index that acknowledges the complexity of children's medical, social, and relational health risks. To achieve this, we leveraged the practicality of

cumulative risk indices and the granularity of factor analytic techniques to allow for risk domains to be evaluated separately and in combination with each other. While still a data reduction approach, the ICRI allows for the possibility of different associations among risk domains and provides more specificity about the types of risks versus just total quantity of individual risks. The ICRI domain count scoring option showed strong validity consistent with that found for the cumulative risk scoring option yet may be more intuitive. The ICRI provides valid national and state level information about the complexity of children's risks associated with positive health, educational preparedness/engagement and emergency and forgone care. This information can be used to understand needs, document and track inequities, tailor and compare services quality and outcomes across child subgroups and help guide the design of integrated systems of care in states. The NSCH is collected annually, enabling the ICRI to track the impact of policies and innovations aiming to reduce the medical, social and relational health risks children experience and to promote health equity, including the implementation of integrated models of care and utilization of comprehensive, family centered primary care medical homes. Substate ICRI findings (eg, county or city) using the NSCH can be estimated using synthetic estimation methods. States can also elect to increase the NSCH sample in their state to enable more robust geographic and/or child subgroup analysis and tracking over time.

The ICRI complements emerging state-level approaches to assess complex risks of children using system-level data, like that set forth in Oregon.⁴³ Interestingly, our Oregon ICRI findings using the NSCH were consistent with findings from the Oregon systems-level data algorithm. The ICRI identified 15.8% of Oregon's publicly insured children with risks on all 3 of its medical, social and relational health domains whereas the Oregon algorithm identified 22.1% of such children meeting both its medical and social risk criteria. Here, the ICRI

Table 2. Associations Between Children Experiencing Each Study Outcome (Emergency Room Visits, Forgone Health Care, Child Flourishing, School Engagement/Ready to Engage in School) and Their Integrated Child Risk Index (ICRI) and ICRI Individual Medical, Social and Relational Health Risk Component Scores*

	All Children* Percent	Children Age 0–17 Who Experienced 1+ Hospital Emergency Room Visits in the Past 12 Months*		Children Age 0–17 Who Experienced Forgone Health Care in the Past 12 Months*		Children Age 6 Months –17 Years Who Met Child Flourishing Index Criteria†		Children Age 3–17 Who Met Criteria for Being Engaged (Age 6–17) or Caregiver Was Confident Child Was Prepared to Engage (age 3–5) in School†	
		Percent	Adjusted Odds Ratio‡	Percent	Adjusted Odds Ratio‡	Percent	Adjusted Odds Ratio‡	Percent	Adjusted Odds Ratio‡
All US children	100%	19.9%	N/A	3.1%	N/A	47.8%	N/A	69.1%	N/A
Experienced 1+ ICRI criteria	63.7%	23.5%	1.74 (1.60–1.89)	4.5%	6.22 (4.47–8.65)	40.1%	Ref	63.3%	Ref
Scoring Option 1: Domain									
Count: Number of ICRI domains experienced									
0	36.3%	13.4%	Ref	0.5%	Ref	61.8%	4.81 (3.98–5.81)	80.6%	4.87 (4.11–5.78)
1	34.9%	19.0%	1.43 (1.30–1.57)	2.1%	3.08 (2.11–4.48)	48.5%	3.08 (2.56–3.72)	72.3%	3.21 (2.74–3.77)
2	20.0%	26.7%	2.05 (1.83–2.29)	4.6%	7.21 (5.01–10.36)	34.9%	1.84 (1.51–2.24)	57.9%	1.70 (1.44–2.01)
3	8.8%	34.5%	2.92 (2.55–3.35)	13.8%	22.15 (15.50–31.65)	21.2%	Ref	43.8%	Ref
Scoring Option 2: Domain									
Combinations: Mutually exclusive combinations									
No ICRI risks experienced	36.3%	13.4%	Ref	0.5%	Ref	61.8%	4.59 (3.80–5.54)	80.6%	4.63 (3.90–5.48)
Only Medical Health Risks	12.0%	23.4%	2.03 (1.82–2.27)	2.4%	3.87 (2.57–5.84)	41.3%	2.12 (1.74–2.60)	65.2%	2.20 (1.83–2.63)
Only Social Health Risks	7.5%	19.2%	1.25 (1.07–1.46)	2.4%	3.63 (2.22–5.93)	51.4%	3.20 (2.59–3.96)	73.5%	3.29 (2.66–4.07)
Only Relational Health Risks	15.4%	15.4%	1.07 (0.92–1.23)	1.8%	2.24 (1.31–3.84)	52.2%	3.73 (3.02–4.61)	77.0%	4.08 (3.38–4.93)
Only Medical & Social Risks	4.7%	34.8%	2.81 (2.35–3.35)	5.7%	9.65 (6.38–14.61)	36.2%	1.81 (1.41–2.34)	55.6%	1.51 (1.19–1.92)
Only Medical & Relational Risks	8.1%	26.0%	2.07 (1.81–2.38)	4.1%	6.64 (4.46–9.88)	27.3%	1.23 (0.98–1.55)	50.5%	1.26 (1.04–1.53)
Only Social & Relational Risks	7.2%	22.1%	1.45 (1.22–1.73)	4.3%	6.12 (3.77–9.93)	41.2%	2.57 (2.03–3.25)	66.2%	2.41 (1.94–3.00)
Medical, Social & Relational Risks	8.8%	34.5%	2.80 (2.44–3.22)	13.8%	21.81 (15.26–31.15)	21.2%	Ref	43.8%	Ref
Scoring Option 3: Cumulative									
Risk: Number of ICRI criteria experienced									
0	36.3%	13.4%	Ref	0.5%	Ref	61.8%	7.12 (5.73–8.84)	80.6%	6.65 (5.53–8.02)
1	27.4%	17.1%	1.26 (1.13–1.40)	1.9%	2.52 (1.66–3.82)	51.7%	5.10 (4.10–6.35)	75.8%	5.20 (4.33–6.25)
2	15.0%	23.2%	1.75 (1.55–1.97)	2.7%	4.28 (2.78–6.58)	41.5%	3.45 (2.75–4.33)	66.8%	3.35 (2.75–4.08)
3 to 4	14.3%	29.1%	2.45 (2.17–2.76)	5.5%	9.19 (6.43–13.15)	30.2%	2.27 (1.80–2.86)	52.9%	1.89 (1.57–2.28)
5 to 12	7.1%	37.8%	3.54 (3.07–4.07)	16.6%	29.10 (20.27–41.77)	15.0%	Ref	36.1%	Ref
Medical Health Risk ICRI Domain: criteria count§									
0	66.4%	15.5%	Ref	1.4%	Ref	56.0%	2.53 (2.33–2.75)	77.2%	2.67 (2.45–2.91)
1+	33.6%	28.6%	2.10 (1.95–2.28)	6.3%	4.30 (3.46–5.34)	31.5%	Ref	54.0%	Ref
Social Health Risk ICRI Domain: criteria count§									
0	71.8%	16.9%	Ref	1.5%	Ref	52.7%	1.62 (1.47–1.78)	73.8%	1.77 (1.60–1.95)
1+	28.2%	27.3%	1.50 (1.37–1.64)	7.0%	4.08 (3.32–5.00)	36.9%	Ref	58.9%	Ref
Relational Health Risk ICRI Domain: criteria count§									
0	60.5%	17.8%	Ref	1.5%	Ref	54.2%	1.53 (1.41–1.67)	74.4%	1.59 (1.45–1.74)
1+	39.5%	23.1%	1.20 (1.10–1.30)	5.5%	2.74 (2.24–3.35)	38.2%	Ref	61.7%	Ref

NOTES All percentages are weighted to represent the child population nationally and in each state.

*Data source: 2016-2018 (3 years combined) National Survey of Children's Health.

†Data source: 2016-2017 (2 years combined) National Survey of Children's Health.

‡Adjusted Odds Ratios (aORs) are adjusted for age, sex, race/ethnicity, income and insurance coverage type. See Appendix A5⁴⁴ for detailed description of each study outcome variable. See Technical Appendix D1⁴⁴ for the prevalence of US children who experienced Integrated Child Risk Index criteria by child responses to each outcome measure. See Technical Appendix D2⁴⁴ for the prevalence of study outcomes by child's age, race/ethnicity and household income and insurance status and type groups. See Technical Appendix D3-D9⁴⁴ for regression analysis details.

§aORs are not adjusted for other domains.

Table 3. National and Across-state Prevalence of Children Experiencing Integrate Child Risk Index (ICRI) Criteria for Each ICRI Scoring Option and on Each of the 3 ICRI Domains (Medical, Social and/or Relational Health Risk): by Child's Insurance Status/type and Race/ethnicity^{*,†}

	Child Insurance Status and Type					Child Race/Ethnicity						
	All Children, Age 0-17 Years	Publicly Insured [‡]	Privately Insured	Uninsured	State Range for Publicly Insured Children (%)	Hispanic	White, Non-Hispanic	Black-Non-Hispanic	Asian, Non-Hispanic	American Indian/Alaska Native, Non-Hispanic	Native Hawaiian/Other Pacific Islander, Non-Hispanic	Multi-race, Non-Hispanic
All US children	100%	35.9%	57.8%	6.3%	N/A	24.9%	51.1%	13.2%	4.6%	0.4%	0.1%	5.0%
Experienced 1+ WCCI criteria	63.7%	81.1%	51.6%	73.5%	72.3–88.1	74.7%	55.0%	74.3%	69.4%	71.8%	81.3%	65.3%
Scoring Option 1: Domain Count:												
Number of domains in which any risks are experienced												
0	36.3%	18.9%	48.4%	26.5%	11.9–27.7	25.3%	45.0%	25.7%	30.6%	28.2%	18.7%	34.7%
1	34.9%	35.2%	34.2%	38.3%	24.9–41.5	38.5%	32.4%	35.1%	46.6%	28.5%	38.9%	31.0%
2	20.0%	29.7%	13.4%	23.2%	21.4–35.5	25.6%	15.8%	25.1%	17.7%	29.8%	28.2%	23.2%
3	8.8%	16.2%	3.9%	12.0%	9.0–25.7	10.5%	6.7%	14.1%	5.2%	13.4%	14.2% [§]	11.1%
Scoring Option 2: Domain Combinations: Mutually exclusive groups												
No ICRI risks experienced	36.3%	18.9%	48.4%	26.5%	11.9–27.7	25.3%	45.0%	25.7%	30.6%	28.2%	18.7%	34.7%
Only Medical Health Risks	12.0%	8.5%	14.6%	8.1%	3.5 [§] 14.8	8.8%	14.2%	10.9%	9.8%	7.3%	8.4% [§]	11.1%
Only Social Health Risks	7.5%	9.6%	6.1%	8.2%	6.3–19.2	7.0%	6.9%	10.5%	4.4%	10.1% [§]	9.0% [§]	9.8%
Only Relational Health Risks	15.4%	17.1%	13.6%	22.1%	7.9–25.6	22.7%	11.3%	13.7%	32.3%	11.0%	21.5% [§]	10.2%
Only Medical & Social Risks	4.7%	7.3%	3.2%	3.2%	4.1–10.5	5.2%	3.9%	7.2%	2.5%	5.5%	10.5% [§]	5.5%
Only Medical & Relational Risks	8.1%	10.1%	6.6%	9.1%	6.0–16.2	10.2%	7.0%	8.0%	9.1%	9.9%	4.1% [§]	8.2%
Only Social & Relational Risks	7.2%	12.3%	3.6%	11.0%	7.5–16.7	10.3%	4.9%	9.9%	6.0%	14.5%	13.7% [§]	9.4%
Medical, Social & Relational Risks	8.8%	16.2%	3.9%	12.0%	9.0–25.7	10.5%	6.7%	14.1%	5.2%	13.4%	14.2% [§]	11.1%
Scoring Option 3: Criterion Count: Number of ICRI criteria experienced												
0	36.3%	18.9%	48.4%	26.5%	11.9–27.7	25.3%	45.0%	25.7%	30.6%	28.2%	18.7%	34.7%
1	27.4%	27.1%	26.8%	33.1%	16.3–32.8	32.4%	24.6%	26.1%	41.2%	16.4%	30.7%	22.4%
2	15.0%	19.0%	12.0%	17.8%	14.2–26.9	18.2%	12.5%	17.9%	15.4%	17.8%	15.3% [§]	16.2%
3 to 4	14.3%	21.5%	9.7%	13.9%	15.9–34.0	16.5%	12.2%	17.9%	10.5%	24.0%	26.4%	16.6%
5 to 12	7.1%	13.5%	3.0%	8.7%	6.1–20.4	7.5%	5.6%	12.3%	2.4%	13.6%	8.9% [§]	10.2%
Medical Health Risk ICRI Domain: criteria count												
1+	33.6%	42.2%	28.4%	31.9%	28.4–55.0	34.5%	31.9%	40.1%	26.9%	36.8%	36.8%	36.0%
0	66.4%	57.8%	71.6%	68.1%	45.0–71.6	65.5%	68.1%	59.9%	73.1%	63.2%	63.2%	64.0%
Social Health Risk ICRI Domain: criteria count												
1+	28.2%	45.4%	16.8%	34.3%	37.9–57.1	33.0%	22.5%	41.7%	18.2%	43.6%	47.3%	35.8%
0	71.8%	54.6%	83.2%	65.7%	42.9–62.1	67.0%	77.5%	58.3%	81.8%	56.4%	52.7%	64.2%
Relational Health Risk ICRI Domain: criteria count												
1+	39.5%	55.5%	27.7%	53.6%	44.0–65.4	53.6%	29.8%	45.7%	52.7%	48.9%	53.4%	38.8%
0	60.5%	44.5%	72.3%	46.4%	34.6–56.0	46.4%	70.2%	54.3%	47.3%	51.1%	46.6%	61.2%

*Data source: 2016-2018 (3 years combined) National Survey of Children's Health.

†Variations within child subgroups are all statistically significant. Statistical significance of differences is set at $P < .05$ and is based on tests of independence comparing the percentage of children meeting ICRI scoring option criteria by children's age, household income and race/ethnicity.

‡Includes children with any public health insurance, even if they also had some form of private insurance as well.

§Estimate has a 95% confidence interval width exceeding 30 percentage points or 1.3 times the estimate and may not be reliable. See Appendix Part C3 for prevalence for each individual ICRI criteria.

with no ICRI risks did not meet flourishing criteria. And while children with risks on all 3 ICRI domains had 79% lower adjusted odds of flourishing compared to children with no risks, 21.2% of these children still met flourishing criteria. (Table 3) Overall, this study adds to existing evidence^{16,17} supporting a strengths-based approach to assessment that includes risks but also considers children's protective factors and positive health, like those measured in the child flourishing and school preparedness indicators used in this study.

LIMITATIONS

This study has several limitations. First, analyses use cross-sectional data preventing confirmation of causal relationships between the ICRI and study outcomes. Yet, the nationally representative NSCH data used here draw on previously validated measures and/or have undergone standardized NSCH validity analysis. The NSCH also provides important measurement generalizability and epidemiological insights which are not feasible to do longitudinally on such a large scale. Nonetheless, improvements to measures used may improve the ICRI, especially in the area of relational health risk assessment. Second, the ICRI may underestimate the prevalence of children's risks because: 1) measures represent higher levels of risk (eg, children with 2+ ACEs or more complex special health care needs, etc.), and 2) positive caregiver reporting bias may lower prevalence of risks.⁵⁷

CONCLUSIONS

The ICRI is a valid indicator associated with health care access and utilization and positive outcomes in US children. Available national and state ICRI data may inform existing and emerging policy efforts to build and finance the integrated systems of care required to reduce children's complex health risks, foster health equity and promote child, family and community well-being.^{7,23,24,28,47,73-82} Additional studies are required to evaluate local and clinical applications. Studies are forthcoming to evaluate the impact of malleable mitigating factors to protect against the complex risks experienced by many US children today.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at <https://doi.org/10.1016/j.acap.2021.12.001>.

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