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Predicting Family Burden Following Childhood Traumatic Brain Injury: A Cumulative Risk Approach

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Abstract

Objective—To examine the utility of a cumulative risk index (CRI) in predicting the family burden of injury (FBI) over time in families of children with traumatic brain injury (TBI).

Participants—One hundred eight children with severe or moderate TBI and their families participated in the study.

Measures—The measures used in the study include the Socioeconomic Composite Index, Life Stressors and Social Resources Inventory—Adult Form, Vineland Adaptive Behavior Scales, Child Behavior Checklist, Children's Depression Inventory, McMaster Family Assessment Device, Brief Symptom Inventory, and Family Burden of Injury Interview. In addition, information on injury-related risk was obtained via medical charts.

Methods—Participants were assessed immediately, 6, and 12 months postinjury and at a 4-year extended follow-up.

Results—Risk variables were dichotomized (ie, high- or low-risk) and summed to create a CRI for each child. The CRI predicted the FBI at all assessments, even after accounting for autocorrelations across repeated assessments. Path coefficients between the outcome measures at each time point were significant, as were all path coefficients from the CRI to family burden at each time point. In addition, all fit indices were above the recommended guidelines, and the χ^2 statistic indicated a good fit to the data.

Conclusions—The current study provides initial support for the utility of a CRI (ie, an index of accumulated risk factors) in predicting family outcomes over time for children with TBI. The time

period immediately after injury best predicts the future levels of FBI; however, cumulative risk continues to influence the change across successive postinjury assessments. These results suggest that clinical interventions could be proactive or preventive by intervening with identified “at-risk” subgroups immediately following injury.

Keywords

childhood traumatic brain injury; cumulative risk index; family burden of injury

In the United States, traumatic brain injuries (TBIs) annually affect approximately 180 per 100,000 children younger than 15 years and can result in significant cognitive and behavioral difficulties.^{1–2} Children with moderate-to-severe brain injuries are at risk for short- and long-term neurobehavioral consequences, including difficulties in nonverbal skills, attention and other executive functions, memory, and adaptive behavior.^{1–7} These neurobehavioral sequelae have the potential to compromise family adaptation to TBI. Families of children with TBI report increased injury-related burden, stress, and psychological symptoms, as well as poorer family functioning 1, 3, and 4 years postinjury as compared with preinjury levels.^{7–11} The above findings, in combination with data showing that family adaptation can affect recovery in children with TBI,^{6,12–14} underscore the importance of examining the predictors of family adaptation to TBI over time.

Research has described the impact of multiple risk factors for family adaptation, including injury, demographic, child adjustment, and family environment variables. For example, caregivers of children with severe TBI are more likely to experience greater injury-related burden up to 4 years postinjury compared with families of children with orthopedic injury.^{9,10} Preinjury family environments characterized by high caregiver distress and multiple stressors have been associated with increased injury-related family burden.^{15,16} Increased injury-related burden also has been associated concurrently with impaired child functioning, specifically more depressive symptoms and behavior problems, as well as worse adaptive functioning.¹⁷ Similarly, sociodemographic status has been associated with poorer outcomes for children with TBI and their families.^{18,19}

However, these multiple risk factors have rarely, if ever, been examined simultaneously and cumulatively in predicting family outcomes after TBI. Several researchers theorize that the accumulation of risk factors across multiple domains is more important in identifying adjustment outcomes than are single risk factors considered individually.^{20,21} Novel approaches to grouping multiple risk factors, such as a single cumulative risk index (CRI) calculated for each child/family, have been supported empirically across multiple domains of outcomes (eg, intelligence,^{21,22} emotional and behavioral problems,^{23–25} psychiatric diagnosis,^{20,26,27} suicidality,²⁸ alcohol use,²⁹ and language/cognitive outcomes³⁰) both concurrently and prospectively. For example, in a study examining the stability of intelligence from preschool to adolescence, the CRI accounted for 34% of the variance in IQ at age 4 and 37% of the variance at age 14.²² Using a CRI, multiple risk factors can be examined simultaneously, which may be helpful for studies with small samples and/or correlated risk factors as is often the case in pediatric populations, such as those with TBI.³¹

Empirical work also has underscored the importance of conceptualizing cumulative risk within a contextual framework^{21,23,26} (ie, Bronfenbrenner's social ecological model³²), as this allows assessment of risk from a broader and more inclusive perspective and aids the selection of risk factors. Consistent with the socioecological model,³² a physical illness in a child may trigger or exacerbate preexisting vulnerabilities and psychosocial difficulties within a family system, placing the family at an increased risk for maladaptive functioning. To identify preinjury risk factors for inclusion in the CRI, the current study utilized a socioecological framework³² in conjunction with previous empirical support for the impact of selected risk factors on family adaptation to the child's injury. Risk factors included child adjustment variables (ie, depressive symptoms, behavior problems, adaptive skills) representing the *individual level*, family functioning variables (ie, general functioning, parental distress) and family stressors/resources variables (ie, across the realms of physical health, work, spouse/partner, relatives, friends) representing the *microsystem level*, and demographic variables (ie, socioeconomic level, marital status, public assistance, race, and neighborhood stressors) representing the *exosystem* and *macrosystem levels*. A socioecological model is particularly useful in conceptualizing the impact of cumulative risk as it includes multiple domains of risk and encompasses the interactions between domains of influence (ie, bidirectional influences of risk factors). In addition to risk factors based on the socioecological model, injury variables (ie, Glasgow Coma Scale ratings, length of unconsciousness, duration of hospitalization, injury severity, results of computerized tomography scan) were included to represent risk related to the brain injury. Rather than sorting out the influence of individual risk factors, the cumulative risk approach emphasizes the effects of aggregate or combined risk as a means of enhancing the prediction of individual outcomes.

Although a CRI has seldom been used in empirical examinations of pediatric conditions and psychological outcomes, previous studies have demonstrated its value in both failure-to-thrive and low-birth-weight populations.^{33,34} The current study extends our knowledge of cumulative risk by utilizing a CRI in a sample of children with TBI. This population serves as an exemplar health condition for the investigation of cumulative risk for several reasons. First, researchers have identified multiple risk factors for adverse family outcomes after pediatric TBI, but as yet have not examined their cumulative influences. Second, this methodology permits a wide range of relevant predictors to be collapsed into a single index based on theoretically and/or empirically derived domains. By collapsing multiple risk factors into one or more categories of risk, the CRI can partially address the statistical power challenges present in longitudinal studies for certain pediatric populations, where relatively small sample sizes and attrition are common.³¹ Third, as is the case with many health conditions, predictors of TBI outcomes are often highly correlated and composite indices account for possible multicollinearity among the predictors. Finally, understanding how the accumulation of risk factors affects family outcomes over time may inform preventive clinical interventions by identifying the subgroups of children at highest risk and, therefore, in need of early intervention.

This study was designed to explore the utility of a CRI in predicting the effects of pediatric TBI on families. Data were collected as part of a long-term follow-up study of school-age

children with moderate-to-severe TBI and their families. The family outcome measure (ie, family burden of injury [FBI]) was assessed at baseline and conducted for a mean of 3 weeks postinjury, 6 and 12 months after the baseline, and at an “extended” follow-up at a mean of 4 years after injury. Consistent with past studies,^{21–31} a single CRI was defined as the sum of dichotomized (low vs high) risk variables selected from measures in the domains of injury-related, demographic characteristics, family stressors, family resources, family functioning, and child adjustment to reflect the ecological conceptualization of risk, inclusive of preinjury and injury-related risk factors.

We hypothesized that the CRI would predict baseline FBI as well as FBI over time (ie, residualized change). Specifically, a larger CRI would predict higher levels of FBI at all time points. To determine the impact of cumulative risk on FBI over time, we first sought to describe the nature of family burden over time. Previous analyses of family outcomes (utilizing the current sample plus a control group) indicated that levels of FBI were higher in the moderate and severe TBI groups than the levels in an orthopedic injury comparison group, and that, although the burden decreased over time for the sample as a whole, this difference remained throughout the follow-up.¹¹ Unlike previous examinations, the method of statistical analysis in the current study (ie, autoregressive modeling [ARM]) allowed for the examination of influences on residualized change in family outcomes across consecutive postinjury time intervals. In other words, a family burden score at one time interval was predicted by the risk factors after accounting for family burden at the previous time period. Although multiple risk factors have been identified for children with TBI and their families, this study is the first to examine the cumulative impact of multiple risk factors on family burden at baseline and over time postinjury, while accounting for the previous levels of family burden (ie, autocorrelations across the repeated assessments) (Figures 1 and 2).

METHOD

Participants

At baseline, the sample consisted of 108 children with moderate or severe TBI between 6 and 12 years of age at the time of injury ($M = 9.7$, $SD = 2.0$) who were predominantly male (74%, $n = 80$) and White (76%, $n = 82$). At baseline, most informants were mothers (93%, $n = 100$) with at least a high school (HS) education (12.5% less than HS education, 46.2% HS education, and 41.3% higher than HS education). Hollingshead³⁵ scores for the family ranged from 8 to 66 ($M = 33.8$, $SD = 14.9$). Attrition increased over time, with 99 children and families (91%) participating at 6 months, 97 (89%) at 12 months, and 84 (77%) at the 4-year extended follow-up assessment. Reasons for withdrawal from the study included family moves, multiple missed appointments, and disinterest in continuing with the study. Comparison of families that dropped out by the 4-year assessment with those who remained failed to reveal differences in race, injury severity, sex, or age at injury. However, families that dropped out were of lower socioeconomic status (as measured by a composite index described below) than families that remained.

Procedure

Children diagnosed with moderate-to-severe TBI and their families were recruited from 4 hospitals in north-central Ohio. All child participants were admitted to the hospital for at least 1 night, had no history of neurologic disorder or child abuse, and spoke English as their primary language. Informed consent was provided by parents shortly after injury and the initial, or baseline, child and family assessment was completed at a mean of 3 weeks postinjury. Fifty-nine parents of potentially eligible children declined participation. Although we cannot be certain that all of these children would have met all eligibility criteria, more parents of females than males refused participation. However, the children for whom participation was declined did not differ from those enrolled in the study on the grounds of race, age at injury, or injury severity. Once the informed consent was obtained, parents completed a demographic questionnaire and multiple measures assessing the levels of preinjury family stressors/resources, family functioning, and child adjustment. Parent report of injury-related burden was repeated at each assessment.

Measures

Outcome measure—The Family Burden of Injury Interview (FBII) assesses perceived burden on the family, specifically associated with the sequelae of pediatric TBI.¹⁷ The FBII scales assess injury-related stress in the areas of (1) concerns with the child's recovery and adjustment, (2) reactions of extended family and friends, and (3) spouse's reactions. The FBII total score is a summative measure of overall family impact of TBI. Adequate reliability and validity have been demonstrated.^{9,11,16,17}

Risk variables by domain

Injury: Information for the injury variables was obtained via the review of hospital chart and included an injury severity rating (Injury Severity Score³⁶), duration of unconsciousness, duration of hospitalization, computerized tomography scan findings, and the lowest recorded Glasgow Coma Scale³⁷ score.

Demographics: Demographic information was obtained via parent interview and included socioeconomic level, marital status, public assistance status, and race. Socioeconomic level, as was assessed via the Socioeconomic Composite Index, was defined as the mean of the sample z scores for parent occupation measured by the Duncan Socioeconomic Index,³⁸ maternal education level, and family income level. Family income level was obtained from item(s) on the Life Stressors and Social Resources Inventory—Adult Form (LISRES-A), an interview-based measure of parental perceptions of social resources/stressors.³⁹ The LISRES-A also was used to assess the parent report of neighborhood stressors at the time of injury. Adequate internal consistency for the LISRES-A has been demonstrated (ie, ranging from 0.77 to 0.93 for the Stressor scales and from 0.50 to 0.92 for the Social Resources scales, with 14 of the 16 scales evidencing internal consistencies in the range of 0.80–0.93).^{39,40}

Child adjustment: Information for the child adjustment variables was obtained via the Vineland Adaptive Behavior Scales (VABS),⁴¹ the Child Behavior Checklist (CBCL),⁴² and the Children's Depression Inventory (CDI).⁴³ The Adaptive Behavior Composite on the

VABS was used as a measure of parental perceptions of child adaptive skills. The Total Problems *t* score on the CBCL was used as a measure of parental perceptions of child behavior problems. The Total *t* score on the CDI yielded a measure of child report of depressive symptomatology. The VABS, CBCL, and CDI have demonstrated acceptable reliability and validity.^{41–43}

Family stressors and resources: Information for the family stressors and resources variables was obtained via several subscales of the LISRES-A, and included physical health stressors, work stressors, work resources, spouse/partner stressors, spouse/partner resources, relative stressors, relative resources, friend stressors, and friend resources.³⁹

Family functioning: Information for the family-functioning variables was obtained via the total scores on the McMaster Family Assessment Device⁴⁴ and the Brief Symptom Inventory (BSI).^{45,46} The Family Assessment Device⁴ is a parent report of global family functioning and has demonstrated adequate reliability and validity.⁴⁴ The General Functioning Scale was used as a summary index of family functioning. The BSI is a parent report of parental psychological adjustment and has demonstrated adequate reliability and validity.^{45,46} The Global Severity Index of the BSI provided a summary indicator of adjustment.

Cumulative risk index—The total CRI was computed in 4 steps. First, each of the 24 individual risk variables was analyzed individually to determine appropriate dichotomous classification (1 = high risk, 0 low risk). Table 1 summarizes the criteria and rationale for dichotomization. Three risk factors were dichotomized on the basis of presence or absence of the risk factor. Sixteen risk factors were assessed via standardized measures, and cutoffs were based on preexisting classifications, published instrument cutoffs, or scores that had discriminated clinical from nonclinical groups in previous studies. One risk factor was dichotomized on the basis of clinical judgment. The remaining 4 risk factors were dichotomized on the basis of sample distributions (ie, median split, top quartile). Second, the individual risk factors within each of the 6 domains (ie, injury, demographics, child adjustment, family stressors, family resources, and family functioning) were summed to create 6 domain risk scores. Third, the 6 domain risk scores were standardized. Fourth, the 6 standardized domain risk scores were summed to obtain the total CRI. Standardization of the domain risk scores was performed to equally weight the domains; this was justified by the lack of empirical support for the importance of one domain over another.

Data analysis

Bivariate correlations among the risk factors (ie, 24 individual risk factors and 6 domain risk scores) and the FBI outcome variable were calculated. When a risk domain and the individual risk factors comprising the domain were not significantly correlated with FBI at any time period, that domain of risk was removed from the total CRI and subsequent analyses.

To examine the nature of FBI over time, longitudinal analyses were conducted using ARM. Autoregressive modeling analysis is a linear prediction approach to modeling univariate

time series. Autoregressive modeling involves linear regression of the current value of the series against one or more prior values of the series. A major advantage of ARM, which assumes a causal relation between earlier and later measures of the same construct, is that it controls for autocorrelations between repeated assessments in examining factors associated with time-related change, with variables measured at a later time period having progressively lower correlations as a function of increasing time.⁴⁷ In other words, ARM allows for the prediction of an outcome at particular time point(s) while accounting for previous time point(s). Using this method, any change in the construct over time is a function of the direct impact of the immediately preceding measure of the construct plus any random disturbance (ie, error).⁴⁷ Once the relation between the repeated measures of the outcome is found to be stable, predictors (ie, CRI) can be added to the model to determine their influence on the outcome (ie, family burden), after accounting for previous assessments across each successive assessment interval. Use of structural equation modeling techniques has been supported for moderate samples sizes of 100 to 200.⁴⁸ AMOS by SPSS was used to test the goodness of fit for ARM.⁴⁹

AMOS allows analysis of incomplete data using Full Information Maximum Likelihood (FIML) estimation. The FIML estimation procedure in AMOS offers an advantage over listwise deletion in handling missing data by providing unbiased parameter estimates and full information for each parameter. The χ^2 statistic and overall fit indices—Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and the Root Mean Square Error of Approximation (RMSEA)—were used to evaluate both models. Models were considered an acceptable fit if the CFI and TLI were 0.95 or greater and the RMSEA was 0.06 or less.^{50,51}

To compare the utility of the CRI versus the domain risk scores, a series of secondary analyses was conducted in which the FBII was regressed on the CRI and on each of the domain risk scores separately. In other words, we sought to test whether the strongest predictor was the CRI or any one domain risk score.

RESULTS

Descriptives for predictor and outcome variables

Percentages of the sample categorized as “at-risk” for each individual risk factor are presented in Table 1. Sample means (SDs) for the Glasgow Coma Scale score, days hospitalized, and days of impaired consciousness were 9.58 (4.99), 9.75 (8.66), and 2.81 (5.39), respectively. Means (SDs) of family burden on the FBII were 1.01 (0.69) at baseline, 1.01 (0.76) at 6 months, 0.80 (0.82) at 1-year, and 0.64 (0.77) at the 4-year follow-up. Relative to the distribution of FBII scores for families of an orthopedic injury-only group assessed at the same follow-ups, 31.4% of the TBI sample had FBII scores in the upper 10% (based on the orthopedic injury-only group cutoff = 1.21) at baseline, 31.2% at 6 months, 20.8% at 1 year, and 19.8% at 4 years.

Bivariate correlations of individual risk variables, risk domain scores, and FBI are presented in Table 2. First, ARM analyses were computed using the CRI that comprised 6 equally weighted domains (24 risk factors). Second, to develop a more parsimonious model and because we viewed these analyses as a first step in understanding the impact of various

domains of cumulative risk on FBI, we conducted additional ARM analyses using a revised CRI, on the basis of selected domains. Specifically, 2 domains of risk, demographic and family resources, demonstrated no significant correlations with FBI at any time period. Therefore, the individual risk factors that comprised the demographic (5 risk factors) and family resources (4 risk factors) domains were excluded from the revised CRI and from the second set of ARM analyses. This resulted in a revised CRI comprised of 4 equally weighted domains (ie, injury, family stressors, family functioning, child adjustment domains, aggregating 15 risk factors). Tests of normality indicated acceptable skewness and kurtosis statistics for the CRI and the revised CRI.

Nature of FBI over time

Autoregressive modeling analyses using the outcome measure at all 4 time periods resulted in fit indices that were above (CFI = 0.984) or close to (TLI = 0.946; RMSEA = 0.084) the recommended guidelines and an acceptable χ^2 statistic ($\chi^2 = 5.3$, $df = 3$, $P = .153$). Examination of the autoregressions in this model indicated significant relations between consecutive time periods. All path coefficients were significant (ie, standardized beta weights for FBI-1 to FBI-2: $\beta = .57$, $P < .001$; FBI-2 to FBI-3: $\beta = .68$, $P < .001$; FBI-3 to FBI-4: $\beta = .67$, $P < .001$). Results from ARM analyses indicated that the FBI at any particular time period was best represented as a function of family burden at the previous time period plus any random disturbance, thus describing the nature of family burden over time.

CRI and FBI across follow-up

Our hypothesis that total CRI would predict FBI at baseline and over time was supported via bivariate correlations (Table 2) and ARM analyses (Figure 2). Predictors were added to the autoregressive model to evaluate the impact of the CRI on FBI at all 4 time points, which improved the fit of the model. First, ARM analyses were conducted utilizing the original CRI (6 domains of cumulative risk). Path coefficients between the outcome measures at each time point remained significant (ie, standardized beta weights for FBI-1 to FBI-2: $\beta = .47$, $P < .001$; FBI-2 to FBI-3: $\beta = .61$, $P < .001$; FBI-3 to FBI-4: $\beta = .61$, $P < .001$); however, only 2 path coefficients from the predictor (ie, CRI) to family burden at each time point were significant. Specifically, the standardized regression weights for CRI as a predictor of levels of FBI were significant at baseline ($\beta = .33$, $P < .001$) and at the 6-month follow-up ($\beta = .31$, $P < .001$). Fit indices were above (CFI = 0.993, TLI = 0.963) or close to (RMSEA = 0.062) the recommended guidelines, and the χ^2 statistic was acceptable ($\chi^2 = 4.23$, $df = 3$, $P = .238$).

Second, ARM analyses were conducted utilizing the revised CRI (4 domains of risk), which resulted in an improvement in fit to the model (Figure 2) over the ARM analyses utilizing the original CRI (6 domains of risk). Path coefficients between the outcome measures at each time point remained significant (ie, standardized beta weights for FBI-1 to FBI-2: $\beta = .45$, $P < .001$; FBI-2 to FBI-3: $\beta = .59$, $P < .001$; FBI-3 to FBI-4: $\beta = .58$, $P < .001$); however, all path coefficients from the predictor (ie, CRI) to family burden at each time point were also significant. Standardized regression weights for CRI as a predictor of levels of FBI were significant at baseline ($\beta = .40$, $P < .001$), as well as at the 6-month ($\beta = .29$, P

< .001), 12-month ($\beta = .18, P < .05$) and 4-year follow-up ($\beta = .21, P < .05$) time points. In addition, all fit indices were above the recommended guidelines (CFI = 0.999, TLI = 0.993; RMSEA = 0.026), and the χ^2 statistic indicated a good fit to the data ($\chi^2 = 3.2, df = 3, P = .359$). Both fit indices and the χ^2 statistic improved with the use of the revised CRI.

To graph the relation between the CRI and FBI at each assessment point (Figure 3), we used group mean levels of FBI and categorized the CRI on the basis of the number of risk factors present in a particular family. Due to small sample sizes in some of the original 15 levels of cumulative risk, families with a CRI = 0 or 1 were grouped together, and families with a CRI ≥ 6 were grouped together, resulting in 6 categories of risk. Graphical representation of FBI as a function of total cumulative risk was consistent with correlation and ARM analyses, as well as our hypothesis that a larger CRI would predict higher levels of FBI at all assessment points.

Predictive validity of CRI relative to domain risk scores

According to regression analyses, the CRI explained more variance in the FBI than any of the risk domains alone (Table 3). The CRI accounted for the most variance in predicting FBII at baseline (15%), 6 months (22%), 12 months (20%), and 4 years (23%). However, the injury domain was similar in its predictive validity in comparison with the CRI at 2 time points, accounting for 14% and 21% of the variance at baseline and 4 years, respectively. Furthermore, the injury domain accounted for more variance when compared with the other 3 domains.

DISCUSSION

The findings of this study support the hypothesis that total cumulative risk predicts greater levels of FBI at baseline and over time. Specifically, more individual risk factors (ie, higher CRI) were associated with greater FBI at all time points. Although the strength of these associations decreased over time, total cumulative risk predicted successive changes in family adaptation up to 4 years following injury.

These results are consistent with previous studies examining risk factors individually using these data¹¹ and other samples of children with TBI.^{7,8} The results of the current study offer support for the use of a CRI in a moderately sized sample of children with TBI. Secondary analyses also suggested that the CRI was a better predictor of FBI (in terms of explained variance) than any of the risk domains. These results are consistent with a small but growing body of research conceptualizing multiple risk factors as cumulative and support the utility of a CRI. Such an approach allows for statistical analyses that are informative, parsimonious, and can account for interactive or synergistic influences among risk factors (ie, as encompassed by total risk scores).

Whereas previous research with these and other data documents the associations of individual risk factors with family outcomes,^{7-11,15-19} results of the current study expand our knowledge about the impact of multiple risk factors (preinjury and injury) on change in family burden over time. Use of a CRI allowed us to build on previous findings, define risk more broadly, and assess the impact of risk on change in family burden across consecutive

follow-up assessments. Similar to findings within^{33,34} and outside^{21–31} the pediatric literature, we found that an accumulation of risk factors predicted poorer functioning, specifically greater injury-related burden on the family. Families with more risk factors reported greater burden pertaining to their concerns with the child's recovery/adjustment and reactions of extended family/friends/spouse. These findings are consistent with reviews in the pediatric and adult TBI literature, which indicates that families continue to evidence difficulties adjusting to the sequelae of TBI many years after injury, thus supporting the need for continued intervention.^{53–55}

Replication of cumulative risk methodology (ie, use of a CRI with selection of risk factors on the basis of theoretical and empirical support) may be particularly useful in various pediatric populations. Risk factors that are selected on the basis of a theoretical framework (ie, representing multiple social ecological levels)³² and are examined via a CRI provide a more comprehensive examination of risk. Cumulative risk methodology is practical in that it provides the ability to collapse a wide range of meaningful predictors into a few indices based on a priori domains and permits statistical analyses that are acceptable for the smaller sample sizes often present in longitudinal studies of pediatric health conditions. Also, risk factors do not act in isolation, often operating and interacting in multiple and complex ways to affect functioning, which may be accounted for via a CRI.

How might cumulative risk operate to influence burden in families of children with TBI? Consider the following very different risk scenarios. In the case of a single risk factor—severity of injury—caregivers learn to manage any physical limitations, cognitive and behavioral difficulties, and/or emotional problems that are consequences of injury severity. But what if a caregiver has also experienced elevated levels of psychological distress prior to the child's injury? Now the caregiver must manage the sequelae of the TBI in the face of his or her own impaired functioning. Add to this family stressors, such as health problems affecting the care-giver or a family member or negative interactions with a spouse, friend, or coworker, and the impact of the child's injury-related difficulties becomes even more burdensome. This illustrates how risk factors may act in a cumulative manner across multiple domains to heighten family burden, as borne out by the data in the current study. In addition, the results of the current study support this type of scenario regardless of baseline levels of FBI.

Furthermore, the findings of this study provide information regarding the nature of FBI over time. Results from ARM show that the strongest predictor of injury-related burden at any time period is the level of injury-related burden at the previous time period. A major implication of this finding is that families at greatest risk for burden over time are those that have the highest levels of burden immediately following the injury. Thus, the finding that the CRI predicted FBI at any one time period, even *after* accounting for the impact of FBI at a previous time period, constitutes a more stringent test for examining the influence of cumulative risk on family burden and provides further support for the utility of the CRI. In other words, although the level of family burden at baseline is an important predictor of future levels of family burden, the number of risk factors continues to exert a unique influence on this outcome. These results complement findings from a previous study with this sample using general linear mixed-model analyses that examined absolute levels of

family burden over time, but not the process through which risk influences change in burden over time.¹¹ Our results support the conclusion that risk continues to influence negative changes, suggesting that even delayed treatment may be helpful. Thus, the initial levels of both family burden and cumulative risk are useful in the identification of families in need of intervention.

This study has several limitations that may help guide future research. Although a theoretical framework (ie, Bronfenbrenner's socioecological model³²) was utilized, not all of Bronfenbrenner's domains of influence were represented, and those domains that were examined may not have been adequately assessed. Risk factors at the mesosystem level (eg, organizational or institutional factors) and chronosystem level (eg, environmental events, transitions) were not assessed in this study, but likely affect FBI as well. A further limitation is that our relatively small sample size may have provided insufficient power and yielded nonsignificant χ^2 statistics. We employed strategies appropriate for the sample size, including the use of (1) FIML, which produces unbiased parameter estimates and standard errors, accounting for missing data at all time points and (2) fit statistics that are less sensitive to sample size (eg, RMSEA, CFI). However, it will be important to replicate and extend tests of the CRI approach by recruiting larger samples and utilizing multiple risk factors representative of all domains of influence outlined by Bronfenbrenner.³²

We recognize that the use of a CRI sacrifices information on the effects of individual risk factors by aggregating risk. Specifically, examination of individual risk factors would provide potentially important information concerning the relative contribution of each factor to relevant outcomes and causal processes. By dichotomizing risk variables, the variability that would be present if variables were analyzed continuously is also lost. Thus, the impact of more subtle gradations of cumulative risk is unknown. Although certain risk factors may affect FBI more strongly than others, aggregating risk factors gives each risk factor equal weight. Generalizability also may be limited by the use of some cutoff points that were sample dependent. For example, although certain demographic variables have been identified as risk factors for FBI, this was not supported in this study. It may be that cutoffs used in this study did not adequately dichotomize and/or characterize risk for this sample. Other researchers using cumulative risk methodology acknowledge these as common problems and suggest that results may have limited generalizability such that findings may apply to only samples with similar characteristics.^{22,24,26}

Despite these limitations, this study provides initial support for the utility of a CRI in predicting family outcomes for children with chronic health conditions over time. Future studies should assess the utility of cumulative risk methodology using theoretically and empirically derived risk factors in other samples of children with TBI and in children with other pediatric conditions. It will also be important for future studies to include both individual and aggregated risk in studies on family outcomes whenever possible, thus providing a more comprehensive examination of risk.

Clinical implications

Understanding how an accumulation of risk factors affects outcomes over time following illness or injury would inform clinical interventions that could be proactive or preventive by

intervening with identified “at-risk” subgroups immediately following illness or injury. Clinical interventions could maximize limited resources if families at greatest risk for poorer adaptation (ie, greater family burden) were identified. Given the reciprocal influence of family adaptation on neurobehavioral outcomes in children with TBI,¹³ this strategy seems particularly valuable. For example, clinicians could identify families in the highest risk category (ie, highest levels of family burden) on the basis of a predetermined cutoff score (ie, specific number of risk factors). In this way, the most vulnerable families (ie, greatest number of risk factors) could be referred for interventions tailored to their risk profile. Furthermore, irrespective of the level of risk present and the initial levels of FBI, the best predictor of family burden at any time period was family burden at the previous time period. This would suggest that the time period immediately postinjury (ie, baseline) is critical as it determines future levels of family burden and points to the need to focus interventions on risk factors associated with baseline levels of burden. At the same time, the finding that risk continues to exert an influence on change across successive postinjury assessments implies that risk may have ongoing cumulative effects on outcomes. Earlier interventions are thus optimal for families, but treatment at any point following injury is justified in an effort to interrupt the negative spiral of family outcomes.

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Figure 1.

Autoregressive model: Family burden of injury (FBI) at baseline, 6 months, 12 months, and an extended 4-year follow-up.

Note: FBI indicates Family Burden of Injury at baseline (FBI 1) and at the follow-up of 6 months (FBI 2), 12 months (FBI 3), and 4 years (FBI 4) as assessed by the Family Burden of Injury Interview.

$\chi^2 = 5.3$, $df = 3$, $P = .153$; CFI = 0.984, TLI = 0.946, RMSEA = 0.084. All beta weights are standardized; *** $P < .001$.

Figure 2.

Cumulative risk index (CRI) predicting the family burden of injury (FBI) at baseline, 6-month, 12-month, and an extended 4-year follow-up.

Note: FBI indicates Family Burden of Injury at baseline (FBI 1) and at the follow-up of 6 months (FBI 2), 12 months (FBI 3), and 4 years (FBI 4) as assessed by the Family Burden of Injury Interview. CRI indicates cumulative risk index, obtained by first, calculating 4 domain risk scores (using the injury, family functioning, family stressors, and child adjustment domains or the aggregate of the 15 individual risk factors within these domains); second, standardizing the domain risk scores; and third, summing the standardized domain risk scores.

$\chi^2 = 3.2$, $df = 3$, $P = .359$; CFI = 0.999, TLI = 0.993, RMSEA = 0.026. * $P < .05$, *** $P < .001$.

Figure 3. Mean levels of family burden of injury (FBI) as a function of cumulative risk index (CRI). Note: CRI was grouped into categories on the basis of the number of risk factors present in a particular family. Due to small sample sizes in some of the original 15 levels of risk, families with a CRI = 0 or 1 were grouped together and families with a CRI ≤ 6 were grouped together, resulting in 6 categories of risk.

TABLE 1

Variables comprising the domain risk scores and the total cumulative risk index

Variable*	Cutoff		Sample categorized as at-risk, %	Rationale
	0 = low risk	1 = high risk		
Injury variables				
Glasgow Coma Scale (<i>N</i> = 108)	13–15	0–12	56.5	Preexisting cutoffs for group classifications ³⁷
Duration of days unconscious (<i>N</i> = 108)	0	1	50.9	Median split
Duration of days hospitalized (<i>N</i> = 108)	1–5	6	54.6	Median split
Severity rating (<i>N</i> = 108)	2–25	26	17.6	Worst 15% (approximate)
Computerized tomography scan (<i>N</i> = 108)	Normal	Abnormal	63.0	Based on radiologist's reading
Demographic variables				
Socioeconomic level (<i>N</i> = 108)	–.18	<.18	48.1	Median split
Marital status of caregiver (<i>N</i> = 108)	Two parent	Single parent	35.2	Previously identified risk factor ²⁰
Public assistance (<i>N</i> = 108)	No	Yes	27.8	Previously identified risk factor ²⁰
Race (<i>N</i> = 108)	White	Minority	24.1	Previously identified risk factor ¹⁹
Neighborhood stressors, <i>t</i> score (LISRES-A), (<i>N</i> = 106)	<65	65	22.2	Standard cutoff ³⁹
Family stressors variables				
Physical health stressors, <i>t</i> score (LISRES-A) (<i>N</i> = 108)	<65	65	2.8	Standard cutoff ³⁹
Work stressors, <i>t</i> score (LISRES-A) (<i>N</i> = 58)	<65	65	6.5	Standard cutoff ³⁹
Spouse/partner stressors, <i>t</i> score (LISRES-A) (<i>N</i> = 75)	<65	65	6.5	Standard cutoff ³⁹
Relatives stressors, <i>t</i> score (LISRES-A) (<i>N</i> = 105)	<65	65	15.7	Standard cutoff ³⁹
Friend stressors, <i>t</i> score (LISRES-A) (<i>N</i> = 104)	<65	65	7.4	Standard cutoff ³⁹
Family resources variables				
Work resources, <i>t</i> score (LISRES-A) (<i>N</i> = 58)	<65	65	0	Standard cutoff ³⁹
Spouse/partner resources, <i>t</i> score (LISRES-A) (<i>N</i> = 75)	<65	65	0	Standard cutoff ³⁹
Relatives resources, <i>t</i> score (LISRES-A) (<i>N</i> = 105)	<65	65	4.6	Standard cutoff ³⁹
Friend resources, <i>t</i> score (LISRES-A) (<i>N</i> = 104)	<65	65	8.3	Standard cutoff ³⁹
Family functioning variables				
General functioning (FAD) (<i>N</i> = 04)	<2.17	2.17	11.1	Standard cutoff ⁴⁴
Parental distress, <i>t</i> score (BSI) (<i>N</i> = 106)	<63	63	25.9	Standard cutoff ^{45,46}
Child adjustment variables				
Adaptive skills, standard score (VABS) (<i>N</i> = 108)	80	<80	6.5	Standard cutoff ⁴¹
Depressive symptoms, <i>t</i> score (CDI) (<i>N</i> = 104)	<60	60	3.7	Standard cutoff ⁴³
Behavior problems, <i>t</i> score (CBCL) (<i>N</i> = 107)	<60	60	22.2	Standard cutoff ⁴²

* SCI indicates Socioeconomic Composite Index; LISRES-A, Life Stressors and Social Resources Inventory—Adult Form; FAD, McMaster Family Assessment Device; BSI, Brief Symptom Inventory; VABS, Vineland Adaptive Behavior Scales; CDI, Children's Depression Inventory; CBCL, Child Behavior Checklist.

TABLE 2

Correlations: individual risk variables and domain risk scores at baseline and outcome variable at baseline, 6 months, 12 months, and four years

Risk factors	Family burden* baseline	Family burden* follow-up (6 mo)	Family burden* follow-up (12 mo)	Family burden* follow-up (4 y)
Injury-related risk domain [†]	0.39 [#]	0.32 [#]	0.38 [#]	0.47 [#]
Glasgow Coma Scale	0.33 [#]	0.32 [#]	0.34 [#]	0.36 [#]
Days unconscious	0.33 [#]	0.34 [#]	0.41 [#]	0.37 [#]
Days hospitalized	0.29 [#]	0.16	0.20 [¶]	0.31 [#]
Severity rating	0.09	0.14	0.13	0.23 [¶]
Computerized tomography scan	0.21 [¶]	0.09	0.15	0.27 [¶]
Family stressors risk domain [‡]	0.06	0.24 [¶]	0.11	0.07
Physical health stressors (LISRES-A)	0.17	0.30 [#]	0.23 [¶]	0.21
Work stressors (LISRES-A)	0.16	0.24	0.14	−0.05
Spouse/partner stressors (LISRES-A)	−0.01	0.00	0.11	0.20
Relatives stressors (LISRES-A)	0.06	0.16	0.01	−0.07
Friend stressors (LISRES-A)	−0.12	0.04	−0.03	−0.02
Family functioning risk domain [§]	0.33 [#]	0.24 [¶]	0.28 [#]	0.37 [#]
General functioning (FAD)	0.09	0.08	0.06	0.07
Parental distress (BSI)	0.36 [#]	0.25 [¶]	0.32 [#]	0.44 [#]
Child adjustment risk domain ^{//}	0.15	0.32 [#]	0.31 [#]	0.21 [#]
Adaptive skills (VABS)	0.20 [¶]	0.27 [#]	0.20	0.09
Depressive symptoms (CDI)	0.18	0.21 [¶]	0.13	0.16
Behavior problems (CBCL)	0.01	0.22 [¶]	0.25 [¶]	0.14
Total cumulative risk index (CRI)	0.31 [#]	0.48 [#]	0.42 [#]	0.40 [#]

* Obtained from the Family Burden of Injury Interview.

[†] Obtained from medical charts.

[‡] Obtained from LISRES-A (Life Stressors and Social Resources Inventory—Adult Form).

[§] Obtained from FAD (McMaster Family Assessment Device) and BSI (Brief Symptom Inventory).

^{//} Obtained from VABS (Vineland Adaptive Behavior Scales), CDI (Children's Depression Inventory), CBCL Child Behavior Checklist).

Note: Domain risk scores were calculated by first summing the relevant individual risk factors and second standardizing the domain risk scores. Bivariate correlations between each domain and the FBII were performed using this standardized domain sum.

[¶] $P < .05$, 2-tailed.

[#] $P < .01$, 2-tailed.

TABLE 3

Regressions: Variance accounted for by CRI versus domain risk scores predicting family burden of injury (FBI) at baseline, 6 months, 12 months, and 4 years*

Variable	FBI (baseline) adjusted R^2	FBI (6 mo) adjusted R^2	FBI (12 mo) adjusted R^2	FBI (4 y) adjusted R^2
Total cumulative risk index	0.15 [§]	0.22 [§]	0.20 [§]	0.23 [§]
Domains				
Injury-related risk factors	0.14 [§]	0.10 [‡]	0.13 [§]	0.21 [§]
Child adjustment risk factors	0.01	0.09 [‡]	0.08 [‡]	0.03
Family stressors risk factors	−0.01	0.05 [‡]	0.00	−0.01
Family functioning risk factors	0.10 [‡]	0.05 [‡]	0.07 [‡]	0.12 [‡]

* FBI indicates Family burden of injury obtained by the Family Burden of Injury Interview. Note: Two sets of hierarchical multiple regression analyses were conducted: in the first set, FBI was regressed on the CRI and in the second set, FBI was regressed on each of the domain risk scores separately.

[†] $P < .05$.

[‡] $P < .01$.

[§] $P < .001$.