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Keeping children safe: a model for predicting families at risk for recurrent childhood injuries

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ABSTRACT

Objective: Existing research on recurrent unintentional injury (UI) focuses on the individual child rather than family risks. This study developed a statistical model for identifying families at highest risk, for potential use in targeting public health interventions.
Study design: A retrospective birth cohort study of hospital and emergency room (ER) medical records of children born in Ziv hospital between 2005 and 2012, attending ER for UI between 2005 and 2015, was conducted.
Methods: Using national IDs, we assigned children to mothers and created the family entity. Data were divided into two time periods. Negative binomial regression was used to examine predictive factors in the first period for recurrent child UI in the second period. Sensitivity analyses were conducted to examine the model's robustness.
Results: Eight predictive factors for child injury ($P < 0.05$) were found: male gender, the number of UI visits, the number of illness visits, age 36–59 months, birth weight <1500 g, maternal ER visits, siblings' UI visits, and the number of younger siblings. Some predictive factors are documented in the literature; others are novel. Five were significant in all sensitivity analyses.
Conclusions: These factors can assist in predicting risk for a child's repeat UI and family's cumulative UI risk. The model may offer a valuable and novel approach to targeting interventions for families at highest risk.

Introduction

Injury is a leading cause of death and disability in childhood.[1] In 2004, approximately 950,000 children worldwide younger than 18 years died of an injury. Most of these child injuries were the result of unintentional injuries. Among 1- to 19-year-olds, UI due to drowning, road traffic accidents, and fire-related burns are among the top 15 causes of death. Deaths

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represent only a small proportion of injury burden; about 50% of children younger than 12 years who have suffered an unintentional injury (UI) and presented to the emergency room (ER) are left with some form of disability (40% short term, 12% long term, 2% permanent).[2] Unlike many other causes of mortality and morbidity among children, most injuries are preventable.[3]

Studies have identified factors, including child, family, and environmental characteristics, that predispose children to injury.[4–11] Child risk factors include age,[7] male gender,[5,7] and aggressive behavior;[5] family risk factors include young[5,12] and unemployed mothers,[6] siblings' injury in the previous 90 days,[11] supervision by older siblings,[5,9,10] and fewer younger siblings;[5] and sociodemographic factors poverty,[7] low socioeconomic status of hometown, and homes in need of renovation.[6]

One striking observation is that the occurrence of a medically significant injury is associated with increased risk of repeat injury;[5,13–16] this correlates with the number of previous[5] attendances and their severity.[15] Patients aged >14 years with a history of previous significant traumatic events were found to be 10 times more likely to have recurrent trauma than patients without previous traumatic events.[15]

According to the 2017 national report on child injuries,[17] Israel has a high injury rate, with 202,000 of its 2,700,000 children visiting an ER for UI every year. Around 20,600 are hospitalized, and approximately 120 die as a result of their injuries. About 38% of hospitalized children are injured at home, with preschool children particularly at risk. The northern region has the second highest rate of ER visits in the country.

To date, research in Israel has largely focused on comparisons between ethnic groups rather than risk of repeat injury.[18–20] Most studies focus on the individual child, and only a few have integrated different risk factors into a model for predicting recurrent UI.[5,6,9] This study aimed to identify risk factors and to build a predictive model for recurrent familial risk of UI. Such a model, if shown to be effective, could be used to target families most at risk, allowing efficient allocation of resources to those most in need.

Methods

Setting

The research was carried out at Ziv Medical Center in Safed, a city in Northern Israel with the highest rate of ER visits per capita in the country.[21] The hospital's catchment area includes approximately 250,000 residents, serving 18 municipalities: 11 Jewish and seven Arab. Under the National Health Insurance Law, all Israeli citizens are covered by universal health care through one of four health funds. Visits to the ER are covered by health insurance if the individual has a referral from their physician. Individuals are limited as to which ER they can visit, according to their locality.

Around 70,000 patients attend the ER at Ziv Medical Center annually, of whom approximately 10,000 (14%) are children aged 0–10 years. Around 3700 (37%) of the visits are for UI, with 420 (11.3%) of these requiring hospitalization.

Data sources

Our cohort was devised from the birth registry involving babies born at Ziv Hospital between January 2005 and December 2012. Birth data were linked to two other computerized data sets: 1) obstetric records to identify maternal ID and link children from the same family; and 2) maternal and child ER data. Fig. 1 outlines the relationship between the different records. At birth in Israel, each infant is given a unique ID and hospital case number. The child's unique ID was used to link all ER visits of a child, and the birth case number was used to match the mother with all her children. Maternal ER visits were identified by her ID.

Study population

Cohort data were divided into two time periods: January 2005–December 2012 (75% of data) and December 2012–July 2015 (25% of data). The first time period observations were used to 'predict' future observations for the second time period. Children's age was included in the first time period observations, with children being 0–7 years old during this time period. To accurately estimate the risk of recurrent UI requiring visits to the ER, we excluded families who would have skewed the results due to confounders unrelated to the actual risk of recurrent UI, namely the following groups: families living outside the Safed Ministry of Health (MOH) district; families who had moved outside of the catchment area (these families were identified by comparing the municipality of the first and last ER visit of the family); families who had not attended the ER at least once in both time periods and therefore could not be assessed for relocation; and families in whom there had been a child death (32 children from 10 families).

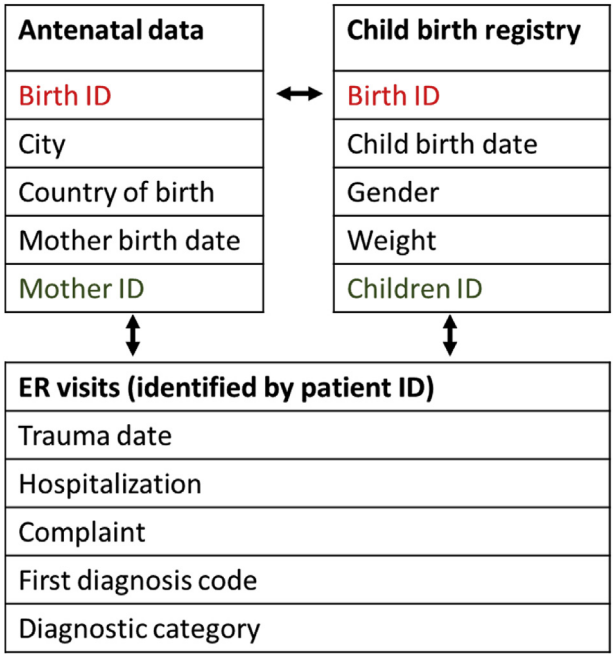

Fig. 1 – Linking process of the different databases to build the cohort and its database. ER, emergency room.

Mothers and their children were grouped to create the family units (assuming each family had only one mother). ER visits were assigned to the family units. Each child's ER visits were categorized into three categories: visits due to UI, illness, and others. Mothers' visits were assigned without reference to the different categories. ER visits were defined as UI if the diagnostic category was poisoning, penetrating, drowning, burn, electric/heat shock, fall/bruise/cut, animal (bite/sting/scratch), bicycle, sport, fire, car accident, or other unintentional injury. ER visits for follow-up of a single UI event (up to two weeks after injury) were not included in the analysis to avoid overestimation. The cutoff of two weeks was based on preliminary work that we conducted which showed that 92.7% of recurrent ER visits in the first two weeks were for the same injury (see Figure S1 in the supplementary material).

Statistics

Variables were divided into two categories: child and family. Child variables were determined at the end of the first time period and included age (at the end of the first time period), gender, birth weight, the number of UI visits and illness visits, time from last ER visit due to UI, and the number of hospitalizations. Child age was categorized into developmental stages: babies, <12 months; toddlers, 13–35 months; and preschoolers, 36–59 months and >60 months. Child birth weight was categorized into <1500 g (extreme and very low birth weight) and >1500 g (low and normal birth weight). Family variables, determined at the end of the first time period, included maternal country of birth, maternal age, maternal visits to ER, siblings' visits for UI, and the number of younger and older siblings.

Descriptive and inferential statistical analyses were preformed using SPSS.[22] Descriptive statistics included exploration of 1) children's characteristics and 2) distribution of the different types of UI. Inferential statistics included 1) building a model for the prediction of child future UI, or in other words, child risk for recurrent UI, and 2) assessing the robustness of this model by several sensitivity analyses.

A negative binomial regression model was used to predict UI during the second time period using the independent variables (for analyses of count data, negative binomial regression is more robust than Poisson regression when the variance is not equivalent to the mean of the distribution).[23] To ensure independence of observations while keeping the model simple and practical, one child was randomly selected in each family and included in the regression analysis.

In the first model, variable selection was implemented by examining the relationship between each variable and child's UI in the second time period. Only variables with a significant relationship at $P < 0.2$ were retained and included as potential variables in the final model. In the final model, only variables with a significant model effect of $P < 0.05$ were retained.

Five sensitivity analyses examined how different inclusion and exclusion criteria affected the model's robustness: 1) including children from municipalities other than Safed districts; 2) including recurrent ER visits in the two weeks after the first ER visit (excluded as 'follow-up' visits); 3) including children who relocated in the same municipality between the two time periods. We also used different splits of the cohort periods: 4) shortening the time to prediction to January 2005–November 2011 (65% of the data) and lengthening time of the 'future observations' to November 2011–July 2015 (35% of the data); 5) lengthening the prediction time periods to January 2005–December 2013 (85% of the data) and shortening the 'future observations' to December 2013–July 2015 (15% of the data).

Results

A total of 24,193 children were born in Ziv hospital between January 2005 and December 2012.A total of 14,296 children were excluded after applying the exclusion criteria listed previously in the methods section. After randomly selecting one child per family, 8357 children with 3223 ER visits due to UI were included in the main analysis (Fig. 2).

A total of 4338 (52%) were boys and 68 (0.8%) had birth weights <1500 g. Children's age was uniformly distributed, with 1045 ± 128 children per age category. The demographics of the population are shown in Table 1.

Of the 8357 children, 2283 visited the ER in the first time period; they had 3223 ER visits in total due to UI, with 424 requiring hospitalization. A total of 4314 visited the ER due to illness ≥1 times, making a total of 8876 ER visits due to illness; the rate of illness due to UI was 2.7. The commonest cause of UI was fall/bruise/cut (2,433, 75.5%), followed by penetrating injury (222, 6.9%). A total of 1196 children (14.3%) had sibling/s who visited the ER due to UI, and 2531 children (30.3%) had mothers who visited the ER.

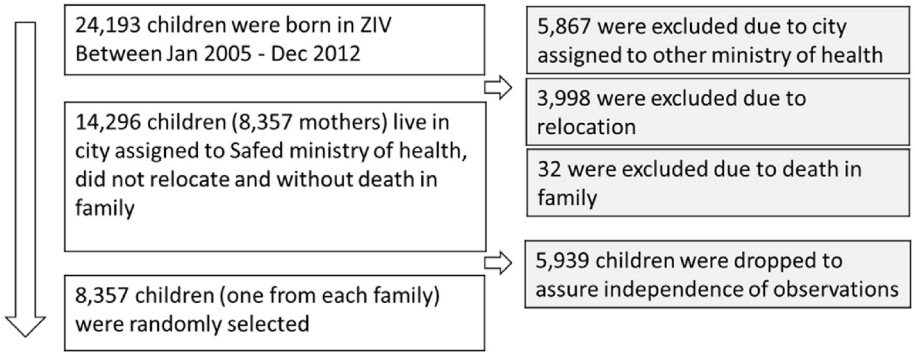

Fig. 2 – Cohort development.

Table 1 – Demographics of 8357 children included in the cohort.

Characteristic	Mean or percent (95% CI)	n
Child characteristics		
Gender		
Male (%)	51.9 (51.5, 52.3)	4338
Female (%)	48.1 (47.7, 48.5)	4019
Birth weight (mean)	3212 (3201, 3223)	
≥1500 g (%)	99.2 (99.1, 99.3)	8289
<1500 g (%)	0.8 (0.7, 0.9)	68
Age (mean)	3.75 (3.7, 3.8)	
<12 months (%)	14 (13.7, 14.3)	1170
13–35 months (%)	28.5 (28.1, 28.9)	2383
36–59 months (%)	23.9 (23.5, 24.2)	1994
>60 months (%)	33.6 (33.2, 34)	2810
ER visits due to UI (n = 3223)		
0 (%)	72.7 (72.1, 73.3)	6074
1 (%)	19.6 (19.1, 20.1)	1639
≥2 (%)	7.7 (7.3, 8.1)	644
Hospitalizations (n = 424)		
0 (%)	95.2 (95.1, 95.4)	7959
1 (%)	4.5 (4.3, 4.6)	372
≥2 (%)	0.3 (0.3, 0.4)	26
ER visits due to illness (n = 8876)		
0 (%)	48.4 (48, 48.8)	4043
1 (%)	26.5 (26.1, 26.8)	2212
≥2 (%)	25.2 (24.8, 25.5)	2102
ER visits due to UI in the second time period (n = 2702)		
0 (%)	73.5 (73.1, 73.9)	6142
1 (%)	21.7 (21.4, 22.1)	1816
≥2 (%)	4.8 (4.6, 5)	399
Maternal/family characteristics		
Mother country of birth		
Israel (%)	90.8 (90.5, 91)	7586
Former Soviet Union (FSU) (%)	4.5 (4.4, 4.7)	379
Europe-America (%)	2.9 (2.7, 3)	240
Africa (%)	0.8 (0.7, 0.9)	66
Asia (%)	1 (0.9, 1.1)	86
Maternal age (mean)	33.8 (33.7, 33.9)	
18–19 yrs (%)	0.3 (0.2, 0.4)	26
20–24 yrs (%)	8.0 (7.4, 8.5)	665
25–29 yrs (%)	21.2 (20.4, 22.1)	1777
≥30 yrs (%)	70.4 (69.5, 71.4)	5889
Maternal ER visits (n = 3470)		
0 (%)	69.7 (69.3, 70.1)	5826
1 (%)	22.4 (22.1, 22.8)	1874
≥2 (%)	7.9 (7.6, 8.1)	657
Siblings' ER visits due to UI (n = 1746)		
0 (%)	85.7 (85.4, 86)	7161
1 (%)	10.1 (9.8, 10.3)	840
≥2 (%)	4.3 (4.1, 4.4)	356
Younger siblings (n = 2846)		
0 (%)	73 (72.6, 73.4)	6101
1 (%)	21.4 (21.1, 21.8)	1790
≥2 (%)	5.6 (5.4, 5.8)	466
Older siblings (n = 2878)		
0 (%)	72.6 (72.2, 72.9)	6065
1 (%)	22 (21.6, 22.3)	1836
≥2 (%)	5.5 (5.3, 5.6)	456

CI, confidence interval; ER, emergency room; UI, unintentional injury.

Table 2 – Risk factors identified as being predictive for recurrent UI in childhood.

Characteristic	Rate ratio (95% CI)	P value
Child characteristics		
Gender		
Female	1 (Ref)	
Male	1.36 (1.24, 1.49)	<0.001
Age group		
<12 months	0.94 (0.81, 1.10)	0.466
13–35 months	0.98 (0.87, 1.10)	0.700
36–59 months	0.81 (0.72, 0.92)	<0.001
>60 months	1 (Ref)	
Fall/bruise/cut	1.10 (1.03, 1.17)	0.005
Illness	1.05 (1.03, 1.08)	<0.001
Birth weight		0.006
≥1500 g	1 (Ref)	
<1500 g	0.33 (0.15, 0.73)	0.006
Maternal/family characteristics		
Younger siblings	0.91 (0.85, 0.99)	0.020
Mother's ER visits	1.11 (1.05, 1.17)	<0.001
Fall/bruise/cut siblings	1.10 (1.03, 1.17)	0.005

Note that entries are incidence rate ratios, with 95% confidence intervals in parentheses. Ref indicates reference value.
ER, emergency room; UI, unintentional injury; CI, confidence interval.

Risk for recurrent UI

Using a negative binomial model for prediction of recurrent UI, we found eight risk and protective factors (Table 2). At the child level, significant risk factors were male gender (Relative Risk (RR): 1.36, 95% confidence interval [CI]: 1.24–1.49), the number of UI visits for fall/bruise/cut (RR: 1.10, 95% CI: 1.03–1.17), and the number of visits for illness (RR: 1.05, 95% CI: 1.03–1.08). Significant protective factors were age 36–59 months (RR: 0.81, 95% CI: 0.72–0.92) and birth weight <1500 g (RR: 0.33, 95% CI: 0.15–0.73). Non-significant variables included the number of hospitalizations and time from the last visit for UI. At the family level, significant risk factors were maternal visits to ER (RR: 1.11, 95% CI: 1.05–1.17), siblings' visits due to fall/bruise/cut (RR: 1.10, 95% CI: 1.03–1.17), and the number of younger siblings (RR: 0.91, 95% CI: 0.85–0.99).

Sensitivity analyses

Each sensitivity analysis changed the sample size, and results were generally robust (see Tables S1, S2 in the supplementary material). Five of the eight variables were significant in all analyses, with similar rate ratios. The main differences were obtained in the 4th and 5th sensitivity analyses – birth weight and age group of 36–59 months becoming insignificant – and in the 5th sensitivity analysis – when the number ER visits due to illness became insignificant.

Discussion

In this study, we detected risk factors for recurrent child UI at two different levels: child and family. Some risk factors, namely male gender,[5,24] previous ER visits,[5,13] and previous sibling visits,[11] have previously been reported. However, the unique contribution of this research is the way it combined these risk factors with other predictors and incorporated the results into a model which has potential for practical

application. Two novel risk factors were identified: previous ER visits due to illness and maternal ER visits. Three protective factors were found: the number of younger siblings, birth weight <1500 g, and age 36–59 months.

To our knowledge, this is the first study to find an association between frequency of children's ER visits for UI and children's ER visits for illness, siblings' visits for UI, and maternal ER visits. These associations may simply reflect some parents' tendencies to visit the ER as a form of healthcare behavior rather than actual risks of significant childhood injury and could relate to anxiety, a perception that tests are needed or that hospital doctors are more competent than those in primary care. As ER visits are a costly and undesirable way of providing health care, patterns of excessive use merit attention whatever the cause.

Very low birth weight (VLBW) is associated with a number of physical and mental health consequences.[25] A study of <10 million births reported that low birth weight is associated with increased infant mortality due to UI,[26] although the findings for prematurity are inconsistent.[27] In contrast with the literature, we found that children whose birth weights were <1500 g were significantly less likely to visit the ER for UI. Once again, this may be an indicator of parental protective behavior rather than a true predictor of UI.

Younger siblings have previously been described as a protective factor,[5] and reporting bias has been implicated on the supposition that parents may underreport injuries of children with several younger siblings. Our study, which is based on hospital records rather than self-reporting, indicates that this is an unlikely explanation. An alternative plausible explanation might be that experienced parents are less likely to return for trivial UI. Our finding that children aged 36 to 59 months had decreased risk for future UI reflects the decline in the rate of ER visits in children aged 5 years, consistent with USA Centers for Disease Control (CDC) data.[28]

When planning the evaluation of an intervention, it is important to define the principal outcome measure: usually numbers of ER visits, hospitalizations, and/or deaths are used. These measures do not necessarily correlate or even have an inverse correlation with each other.[20] The advantage of using ER visits is the greater number involved, although a disadvantage is that less serious injuries will be included. Whatever the severity, costs incurred through ER visits are always significant; research from the USA[29] shows that the total cost of ER visits that does not result in hospitalization are 1.75 times more than those that require hospitalization.

Our study provides a model whose output can be used as an outcome measure for interventions. It also offers a way of targeting those families most at risk. Currently, families are targeted mostly on socio-economic factors, such as living in disadvantaged areas, low socio-economic status, unemployed parents, and young single mothers.[30] We suggest that integrating already known factors with the novel factors identified in this research could lead to more cost-effective interventions. The merit of our predictors is that they are retrievable from hospital records without the need for surveying families for personal information.

In the literature, a number of interventions have successfully reduced unintentional child injuries. Kendrick et al.[31] reported that parenting interventions, most commonly provided within the home using multifaceted interventions, were effective in reducing child injury. A few studies have found that verbal educational materials and safety device disbursement in the ED setting were effective at improving the home safety practices of caregivers of young children.[32] The ED visit for child injury may afford an opportune time for staff to educate caregivers about various child injuries.[33]

The limitations of the study must be considered. A major limitation is the lack of availability of data on severity of the injuries; families' socio-economic status (SES), notably family income, education, and employment; religious status, and paternal data. No doubt we were missing out children – if born elsewhere, attended other ERs, or were born before the start of the cohort time frame. It would also have been useful to ascertain proximity of the home to hospital and transport options and to be able to distinguish accurately new ER visits from 'follow-up' visits. The exclusion of families who did not attend the ER at the second time period was important for ascertaining migration and might have affected rate ratios. However, most of the visits were maternal or due to illness and thus were not likely to significantly affect the conclusions.

This study is innovative for two main reasons. First, we created a family unit for evaluation by using birth data, which allows an examination of familial risk factors. These results can be used to identify families at high risk by summing the children's predicted UI. Second, this has applicability for more effectively targeting high-risk families and for use as an outcome measure for injury prevention interventions. A study examining this has already been initiated. Further prospective studies are needed to strengthen our findings, which will follow families at high risk for recurrent UI as predicted by this model.

Conclusions

UIs are a leading cause of death and disability in childhood. The emotional trauma to families and the burden to society (and the family) are substantial. In this study, eight predictive factors for child injury were found, namely male gender, previous visits for UI and illness, age, birth weight, maternal ER visits, siblings' UI visits, and the number of younger siblings. Some of these factors are documented in the literature; others are novel. The unique contribution of this research is the way it incorporates the results into a model which has potential for identifying families at highest risk of recurrent UI, for the purposes of targeting and measuring outcomes of injury prevention interventions. With further prospective refinement, the model could be adopted into health services, highlighting children with the highest risk of repeat injuries and so allowing targeted intervention to those families at highest need which may reduce the cost per intervention (cost-benefit ratio).

Author statements

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Ethical approval

The study received ethics approval from Ziv Medical Center.

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Competing interests

None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2019.02.003.