# Antenatal and early childhood exposures associated with non-fatal infant injury: evidence from a longitudinal birth cohort in New Zealand

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## ABSTRACT

**Objective** To identify antenatal and early childhood exposures of unintentional injury among infants in New Zealand (NZ).

**Method** The theoretical life-course framework of child injury prevention domains was utilised to analyse data from a prospective longitudinal NZ birth cohort (Growing Up in NZ). Risk and protective factors for injury were identified using Robust Poisson regression models.

**Result** Among children included for the analysis(n=6304), 52% were male, 55% were born to European mothers, and 37% lived in a household with high levels of deprivation. Mothers reported that 6% of infants (n=406) had sustained at least one injury by 9 months. Multivariate analysis showed injury risk among single mothers with antenatal depression were more than twice that (IRR=2.20) of children of mothers with partners and without depression.

**Conclusion** Understanding antenatal risk and protective factors for infant injury will assist in implementing injury prevention programmes or modifying the existing policies that affect these vulnerable age groups.

### WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ At an early stage of life, children's health outcomes are impacted either directly or indirectly by a multiplicity of factors.
⇒ Infants are more vulnerable to injuries compared with older children.

### WHAT THIS STUDY ADDS

⇒ Maternal mental health status is related to the risk of injury among infants.
⇒ Infants' factors experiencing environments with multiple disadvantage factors have more susceptibility to injury than those without.
⇒ Early opportunities to obtain evidence of what cluster of factors influence the risk of infancy injuries may help to reduce the incidence of injury occurrence among young children.

## INTRODUCTION

In New Zealand (NZ), as is the case globally, unintentional injuries are the primary cause of child morbidity and mortality and one of the most common reasons medical care is sought.[1 2] Infants (children under 12 months of age) are susceptible to injury[3 4] due to their smaller body size, limited coordination, exploratory nature with an inability to predict danger, and exposure to home hazards.[5] In light of this, children's stages of development need to be considered when assessing factors associated with injury and developing injury-prevention interventions.

Despite the recent progress in the decline of injury among children in NZ,[6] in 2018, unintentional injuries accounted for three-quarters of all injury hospital admissions for children under the age of 19 years, with less than 3% of these intentional.[7] There is little information about the pattern of unintentional infant injury in NZ, as publicly available data is usually aggregated within children younger than 5 years old.[6] Children in infancy are particularly susceptible to the interplay of parental, family and home environmental factors. This study aimed to describe the characteristics of unintentional injury among a cohort of infants in NZ, and explore risk or protective factors associated with these injuries to inform future injury prevention efforts. This study is part of a larger research project exploring the combination of and incidents that occur over a period of time, which impact the likelihood of young children experiencing unintentional injuries.[8]

## METHODOLOGY

### Study participants and data source

Data from Growing Up in New Zealand (GUiNZ), a contemporary and population-relevant NZ longitudinal birth cohort, was analysed.[9] Data for the cohort have been collected using face-to-face, telephone, and computer-mediated interviews and through linkage to routine health records with parental consent (DCWs). Multidisciplinary longitudinal information has been gathered about the child and their environments from interviews, direct observation by interviewers, and maternal and partner reports (further details of the GUiNZ cohort are available here (https://www.growingup.co.nz/). This study utilised GUiNZ antenatal, perinatal, and injury data gathered during the 9 month (9M) DCW to identify antenatal and early childhood risk or protective factors for early childhood injury (birth to 9M).

### Measures

Explanatory variables from antenatal and perinatal data preceded the measurement of the outcome variables considered (ie, injury data from birth until 9M) to allow temporal sequencing of the explanatory variables and outcome measures. Potential risk



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factors for injury among young children considered included parental sociodemographic characteristics, perinatal factors, family social connectedness, and household and neighbourhood physical environments (further information on the methodology, including the measures, are detailed in the study protocol).[8] Maternal demographics were collected during the antenatal interview, including age, ethnicity, highest education, and parity.

### Outcome of interest

Child injury information was sought at the 9M DCW, and data were derived from the primary caregiver's response to the question, 'Has your child had an injury, including eating/drinking harmful substances (poisoning) where medical treatment was required?'. Note, no information was collected regarding the nature of injury or mechanisms of injury in the 9 month data collection wave.

### Statistical analysis

Descriptive statistics have been used to summarise the characteristics of the cohort, the distribution of variables, and number of valid participants. Univariate analysis of relevant variables was conducted to consider the strength of the relationship between exposure and each outcome and ensure the data are meaningful for analysis and meet model assumptions. Following the univariate analysis, a robust Poisson regression analysis was conducted to calculate incidence risk ratios (IRR) for the binary injury outcome.[10] Further, relationships among and between significant factors and child injury with the interaction effects model were assessed where applicable.

Sensitivity analyses, such as multiple imputations for the missing data, were carried out to address the missingness in the data. Both data with and without imputed values were fitted for the final regression analysis.

## RESULTS

Of the 6853 children in the initial 9M DCW, 95% (n=6474/6853) met the eligibility criteria for this analysis (figure 1). The probability of injury between the singletons and multiple births was explored and showed no significant difference. Multiple births (3%, n=170/6474) were excluded for further analysis due to the known expected correlation between children born to the same mother.

Among those who were included (n=6304), 52% were males (n=3344/6,304), 55% were born to European mothers (55%), and 37% were from high levels of deprivation (table 1). Those included were not significantly different from those excluded by sex or the presence of injury.

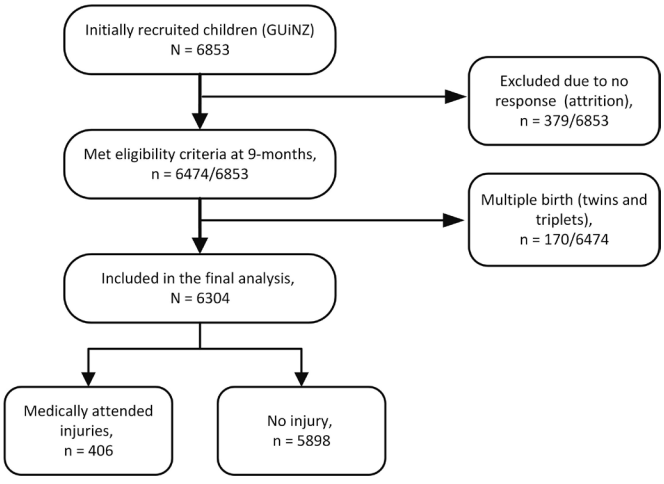


**Figure 1** Inclusion process of eligible participants.

**Table 1** Child and maternal characteristics of participants (column percentage)

| Sociodemographics | n=6304 Included n (%) | n=549 Excluded n (%) | Pearson's Chi-square P-value |
|---|---|---|---|
| Sex (at birth) | | | p=0.092 |
| Male | 3268 (51.8) | 264 (48.1) | |
| Female | 3036 (48.2) | 285 (51.9) | |
| Prioritised maternal ethnicity | | | p<0.001 |
| European | 3443 (54.8) | 143 (31.5) | |
| Māori | 848 (13.5) | 91 (20.0) | |
| Pacific | 866 (13.8) | 120 (26.4) | |
| Asian | 913 (14.5) | 79 (17.4) | |
| Others | 216 (3.4) | 21 (4.6) | |
| Maternal age in years | | | p<0.001 |
| <25 | 1174 (18.6) | 135 (29.6) | |
| 25 to 34 | 3523 (55.9) | 229 (50.2) | |
| >=35 | 1606 (25.5) | 92 (20.2) | |
| NZDep 2006 | | | p<0.001 |
| Low (<=3) | 1604 (25.5) | 80 (17.5) | |
| Medium (4-7) | 2341 (37.2) | 128 (28.1) | |
| High (8-10) | 2356 (37.4) | 248 (54.4) | |
| Injury occurrence recorded | | | p=0.746 |
| No | 5898 (93.6) | 158 (92.9) | |
| Yes | 406 (6.4) | 12 (7.1) | |

### Risk and predictive factors for child injury from maternal reported injury data

An exploratory analysis of each independent variable with reported injury was analysed using unadjusted robust Poisson regression (table 2, Model 1). Children of younger mothers (<25 years) (IRR=1.63; 95% Confidence Interval (CI)1.24 to 2.15), and those born to mothers of Māori (NZ's indigenous population; IRR=1.50; 95%CI 1.13 to 1.89) or Pacific maternal ethnicity (IRR=1.57; 95%CI 1.22 to 2.01) were more likely to experience injury compared with children with older mothers and born to European mothers, respectively. There was no significant difference in injury occurrence by gender (boys 6.8% cf. girls 6.1%; p=0.237). There were no significant differences between the medically attended injury group by early childhood factors such as gestation age, birth weight, and complications at birth.

Children were more likely to have experienced injury if their mother experienced poor health (IRR=1.76; 95%CI 1.37 to 2.26) or had higher maternal depression scores during pregnancy (IRR=1.46; 95%CI 1.03 to 1.06) (table 2, Model 1). Additionally, children living in highly deprived neighbourhoods (IRR=1.52; 95%CI 1.20 to 1.95); and public rentals (IRR=1.55; 95%confidence interval 1.10 to 2.18) had a higher risk of experiencing injury compared with children who lived in lower deprivation area and their own homes, respectively

Table 2, Model two includes the selected effect of significant variables from the univariate analyses (table 2, Model 2) adjusting for children's sex at birth. Young maternal age (IRR=1.40; 95%CI 1.01 to 1.99), smoking during pregnancy (IRR=1.36; 95%CI 1.10 to 1.85), a high maternal depression

**Table 2** Results of multivariable analysis for risk or protective factors for injury among your children (n=5593)

| Variables | | No injury n=5898 n(%) | Injury n=406 n(%) | Model 1 Unadjusted IRR (95% CI) | Model 2 Adjusted IRR (95% CI) | Model 3 Adjusted IRR (95% CI) With interaction |
|---|---|---|---|---|---|---|
| Demographics | | | | | | |
| Gender | Female | 2852 (93.9) | 184 (6.1) | 1 | 1 | 1 |
| | Male | 3046 (93.2) | 222 (6.8) | 1.12 (0.93 to 1.35) | 1.17 (0.95 to 1.44) | 1.19 (0.96 to 1.46) |
| Maternal age | <25 years | 1069 (91.1) | 105 (8.9) | **1.63 (1.24 to 2.15)** | **1.40 (1.01 to 1.99)** | **1.54 (1.20 to 2.16)** |
| | 25 to 34 years | 3310 (93.9) | 213 (6.1) | 1.10 (0.87 to 1.40) | 1.18 (0.87 to 1.48) | 1.17 (0.88 to 1.53) |
| | ≥ 35 years | 1518 (94.5) | 88 (5.5) | 1 | | |
| Maternal education level | No secondary school | 375 (90.1) | 41 (9.9) | **1.54 (1.06 to 2.23)** | 0.68 (0.41 to 1.13) | 0.63 (0.38 to 1.04) |
| | Secondary school | 1381 (93.9) | 89 (6.1) | 0.94 (0.69 to 1.29) | 0.66 (0.46 to 0.97) | 0.63 (0.43 to 0.92) |
| | Diploma/Trade | 1814 (93.6) | 123 (6.4) | 0.99 (0.74 to 1.32) | 0.72 (0.51 to 1.03) | 0.71 (0.50 to 1.00) |
| | Bachelors degree | 1362 (93.9) | 88 (6.1) | 0.95 (0.69 to 1.29) | 0.89 (0.64 to 1.26) | 0.85 (0.63 to 1.25) |
| | Higher degree | 947 (93.6) | 65 (6.4) | 1 | 1 | 1 |
| Maternal ethnicity | European | 3240 (94.1) | 203 (5.9) | 1 | 1 | 1 |
| | Māori | 775 (91.4) | 73 (8.6) | **1.50 (1.13 to 1.89)** | 1.22 (0.90 to 1.64) | 1.17 (0.87 to 1.59) |
| | Pacific | 786 (90.7) | 80 (9.3) | **1.57 (1.22 to 2.01)** | 1.12 (0.80 to 1.56) | 1.12 (0.80 to 1.56) |
| | Asian | 877 (96.1) | 36 (3.9) | **0.64 (0.45 to 0.92)** | **0.66 (0.45 to 0.99)** | **0.67 (0.45 to 0.99)** |
| | Others | 202 (93.5) | 14 (6.5) | 1.09 (0.62 to 1.90) | 0.89 (0.64 to 1.26) | 0.81 (0.42 to 1.58) |
| Early childhood factors | | | | | | |
| Birth complications for baby* | No | 748 (92.9) | 57 (7.1) | 1 | – | – |
| | Yes | 5018 (93.6) | 342 (6.4) | 0.90 (0.69 to 1.18) | | |
| Gestational age | Preterm | 294 (95.2) | 15 (4.9) | 1 | | |
| | Term | 5448 (93.5) | 380 (6.5) | 1.34 (0.81 to 2.22) | – | – |
| | Post-term | 146 (93.6) | 10 (6.4) | 1.32 (0.61 to 2.87) | – | – |
| Birth weight | Low | 202 (92.2) | 17 (7.8) | 1.314 (0.75 to 2.29) | – | – |
| | Normal | 4693 (93.5) | 325 (6.5) | 1.081 (0.82 to 1.43) | | |
| | High | 999 (94.0) | 64 (6.0) | 1 | | |
| Maternal well-being | | | | | | |
| Smoking status during pregnancy | Current smoker | 507 (89.3) | 61 (10.7) | **1.94 (1.48 to 2.54)** | **1.36 (1.10 to 1.85)** | **1.50 (1.08 to 1.06)** |
| | Former smoker | 518 (92.5) | 42 (7.5) | **1.42 (1.03 to 1.94)** | 1.20 (0.85 to 1.68) | 1.15 (0.82 to 1.63) |
| | Non-smoker | 4379 (94.6) | 248 (5.4) | 1 | 1 | 1 |
| Maternal health | Poor to fair | 551 (89.4) | 65 (10.6) | **1.76 (1.37 to 2.26)** | – | – |
| | Good to excellent | 5333 (94.0) | 341 (6.0) | 1 | | |
| Maternal stress score† | | 13.01 (6.4) | 14.59 (6.3) | **1.04 (1.02 to 1.05)** | – | – |
| Maternal depression‡ | No | 4526 (94.33) | 272 (5.67) | **1.46 (1.14 to 1.86)** | **1.03 (1.01 to 1.05)** | 1.05 (0.79 to 1.41) |
| | Yes | 823 (91.75) | 74 (8.25) | 1 | 1 | 1 |
| Relationship status | Single | 262 (89.4) | 31 (10.6) | **1.73 (1.20 to 2.48)** | 1.19 (0.79 to 1.80) | 0.90 (0.52 to 1.57) |
| | With partner | 5145 (94.1) | 322 (5.9) | 1 | 1 | 1 |
| Socioeconomic status | | | | | | |
| Employment status | Employed | 2391 (93.0) | 180 (7.0) | 1 | 1 | 1 |
| | Not employed | 3314 (94.2) | 203 (5.8) | 1.19 (0.98 to 1.45) | 1.13 (0.91 to 1.41) | 0.90 (0.72 to 1.13) |
| | Family stress | 10.56 (4.2) | 11.10 (4.0) | **1.03 (1.00 to 1.05)** | 1.01 (0.98 to 1.03) | – |
| Household Income tested benefit | No | 4966 (94.2) | 305 (5.8) | **1.64 (1.16 to 2.34)** | – | – |
| | Yes | 294 (90.5) | 31 (9.5) | 1 | – | |
| Deprivation index | Low (1-3) | 1518 (94.6) | 86 (5.4) | 1 | 1 | **1** |
| | Medium (4-7) | 2214 (94.6) | 127 (5.4) | 1.01 (0.78 to 1.32) | 1.08 (0.80 to 1.44) | 1.07 (0.80 to 1.43) |
| | High (8-10) | 2162 (91.8) | 193 (8.2) | **1.52 (1.20 to 1.95)** | **1.38 (1.02 to 1.87)** | **1.35 (1.00 to 1.82)** |
| Dwelling | Ownership | 2865 (94.4) | 169 (5.6) | 1 | 1 | 1 |
| | Private rental | 2065 (93.9) | 135 (6.1) | 1.10 (0.89 to 1.37) | 0.98 (0.66 to 1.45) | 0.96 (0.65 to 1.21) |
| | Public rental | 382 (91.4) | 36 (8.6) | **1.55 (1.10 to 2.18)** | 0.98 (0.78 to 1.23) | 0.96 (0.76 to 1.43) |
| Interaction effect | With partnerwith no maternal depression | | – | – | – | 1 |
| | Single parent with depression | | | | | **2.20 (1.04 to 4.64)** |
| Deviance goodness-of-fit | | | | | 1846.1 (p=1.000) | 1840(p=1.000) |
| Pearson goodness-of-fit | | | | | 5317.57 (p=0.995) | 5301.1(p=0.995) |

Continued

**Table 2** Continued

| Variables | No injury n=5898 n(%) | Injury n=406 n(%) | Model 1 Unadjusted IRR (95% CI) | Model 2 Adjusted IRR (95% CI) | Model 3 Adjusted IRR (95% CI) With interaction |
|---|---|---|---|---|---|

Significant factors are in bold.
*admission to neonatal intensive care, hypoglycaemia, infections, jaundice, meconium aspiration, breathing difficulties and distress, and the use of a ventilator captured during the 16 month data collection wave.
†maternal stress score = Perceived stress anxiety.
‡maternal depression score=Edinburgh Postnatal Depression Scale[20] (*10-item questions total score=30*).
1, reference group; IRR, incidence Risk Ratio; NCEA, National Certificate of Educational Achievement.

score (IRR=1.03; 95% CI 1.01 to 1.05) and living in a highly deprived area (IRR=1.38; 95% CI 1.02 to 1.87) were significantly associated with injury whereas the Asian maternal ethnicity was consistently a protective factor (IRR=0.67; 95% CI 0.45 to 0.99).

The effect of antenatal depression on the risk of injury differs between mothers with a partner and without a partner/single (table 2, Model 3). Further predictive margins effects for changes in the antenatal depression response for change in a covariate (mothers with a partner and without a partner) are illustrated in figure 2. For mothers with partners, the probability of childhood injury is similar between mothers with or without postnatal depression. Still, with single mothers, the probability of childhood injury for mothers with depression is much higher than for mothers without depression.

## DISCUSSION

The aim of this study was to identify antenatal and early childhood risk or protective factors for early childhood injury (birth to 9M) using data drawn from the GUiNZ birth cohort. The findings revealed that young maternal age and lower educational attainment were significantly associated with increased risk of injury among young infants (0–9 months). This is consistent with a recently published review of injury risk factors in NZ[11] and a recent analysis of an Australian birth cohort.[12]

Other interlinked maternal factors included smoking during pregnancy (after the first trimester), higher scores on maternal depression assessments and living in highly deprived areas were also identified as antenatal risk factors for injury in this study. Previous authors have noted that vulnerabilities inherent to households with lower socioeconomic status, such as increased parental stress, depression and relationship conflict, may influence children's behaviours,[13] which may influence injury risk for these children. Maternal depression is also linked to multiple poor child health and social outcomes. Mothers with depression may have a reduced capacity to maintain supervision of their child,[14] and safety practices at home may be compromised,[15] which can impact everyday vigilance of mothers and protective parenting behaviours.[16]

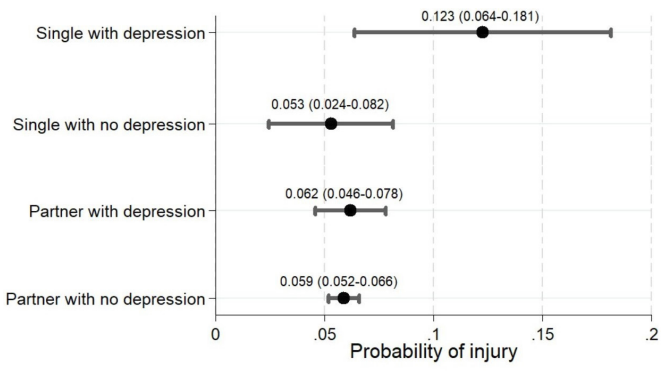


**Figure 2** Predictive margins of relationship status and depression with 95% CIs.

### Strengths and limitations

One of the main strengths of this study is the use of longitudinal data, with large sample size and the prospective nature of the data collection.[17] However, the mothers of children who were excluded from these analyses were more likely to be younger ($p<0.001$), have lower educational attainment ($p<0.001$) and live in highly deprived areas ($p<0.001$), which is common in other longitudinal studies[18] and may imply that the observed effect sizes might potentially be smaller or larger than their actual size depending on the effect. The child injury information in this study relied on maternal self-report, which can be subject to response bias.[19] Despite these limitations, this study contributes to understanding risk factors for unintentional injury among young children in NZ and helps guide future studies into which factors merit further investigation.

## CONCLUSION

Maternal well-being during the antenatal period significantly affects an infant's health outcomes, and the findings of this study highlight the importance of maternal mental health, particularly during pregnancy, for impacting child injuries. Often antenatal depression is not identified early and is not appropriately treated. There is an ongoing study to investigate further the effect of these antenatal and perinatal factors in addition to wider social and environmental features among older preschool children within the same cohort. Identifying the familial and environmental factors associated with non-fatal infant injury risk are necessary starting points for designing context-specific injury prevention programmes

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**Contributors** LG participated in planning the research, acquired and organised the data, conducted the data analysis, interpreted results and wrote the first draft of the manuscript. BK provided oversight of research planning and execution, with substantial contributions to data analysis, interpretation, and manuscript writing. AL

advised the initial statistical approach, planning and interpretation of the analysis. SM provided oversight of the research activity and evaluation of the selected datasets from the longitudinal study. All authors critically reviewed the manuscript draft and approved the final manuscript.

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