Development and Psychopathology (2024), **36**, 1719–1727
doi:10.1017/S0954579423001062

CAMBRIDGE UNIVERSITY PRESS

Regular Article

Linked head injury and conduct problem symptom pathways from early childhood to adolescence and their associated risks: Evidence from the millennium cohort study

Hannah R. Carr[1], Valerie C. Brandt[1,2], Dennis Golm[1] and James E. Hall[3]

[1]School of Psychology, Centre for Innovation in Mental Health, University of Southampton, Southampton, UK, [2]Clinic of Psychiatry, Social Psychiatry and Psychotherapy, Hannover Medical School, Hanover, Germany and [3]Southampton Education School, University of Southampton, Southampton, UK

Abstract

Conduct problems and head injuries increase the risk of delinquency and share a bidirectional association. However, how they link across development is unknown. The present study aimed to identify their linked developmental pathways and associated risk factors. Latent class analysis was modeled from Millennium Cohort Study data ($n = 8{,}600$) to identify linked pathways of conduct problem symptoms and head injuries. Head injuries were parent-reported from ages 3 to 14 and conduct problems from ages 3 to 17 using the Strengths and Difficulties Questionnaire (SDQ). Multinomial logistic regression then identified various risk factors associated with pathway membership. Four distinct pathways were identified. Most participants displayed low-level conduct problem symptoms and head injuries ($n = 6{,}422$; 74.7%). Three groups were characterized by clinically relevant levels of conduct problem symptoms and high-risk head injuries in childhood ($n = 1{,}422$; 16.5%), adolescence ($n = 567$; 6.6%), or persistent across development ($n = 189$; 2.2%). These clinically relevant pathways were associated with negative maternal parenting styles. These findings demonstrate how pathways of conduct problem symptoms are uniquely linked with distinct head injury pathways. Suggestions for general preventative intervention targets include early maternal negative parenting styles. Pathway-specific interventions are also required targeting cumulative risk at different ecological levels.

Keywords: Birth cohort; conduct problems; head injury; latent class analysis

(Received 22 May 2023; revised 2 August 2023; accepted 3 August 2023; First Published online 4 September 2023)

Introduction

Evidence suggests that conduct problems (i.e., violations of age-appropriate societal norms including fighting and threatening behaviors (Girard et al., 2019)) are partially predicted by previous head injuries (a bang on the head with or without a loss of consciousness (Davis & Ings, 2015; Yates et al., 2006)) and vice versa (Brandt et al., 2022; Carr et al., 2023). However, despite the high prevalence of childhood head injuries (33%–55% of the 1.4 million head injury admissions in the UK (National Clinical Guideline Centre, 2014)), the link between conduct problems and head injuries over time and the risks associated with their co-occurrence are vastly under researched (McKee & Daneshvar, 2015) compared to the association between traumatic brain injuries (TBI) and conduct problems (Bellesi et al., 2019).

Research indicates that there are distinct developmental pathways to conduct problems (Gutman et al., 2019) and head injuries (Keenan et al., 2020). The DSM-5 describes two conduct disorder pathways: childhood-onset (presentation before age 10) and adolescent-onset (presentation after age 10 (*Diagnostic and statistical manual of mental disorders*, 2013)). While further research suggests an additional childhood-limited high conduct problems pathway (Gutman et al., 2019). Similarly, head injuries have developmental pathways based on their initial severity and impact on infant cognition (Keenan et al., 2020).

The consequences of both conduct problems and head injuries are well known and include increased likelihood of delinquency and criminal behavior (Kennedy et al., 2017; Mongilio, 2022). A better understanding of how their pathways link during development is therefore important for intervention and prevention practices aimed at jointly reducing both. To create effective intervention and prevention practices we need to not only understand how conduct problems and head injuries link but also the risk factors for these links (e.g., childhood maltreatment may increase the risk for developmentally stable high risk of both head injuries and conduct problems).

The bidirectional association between childhood head injuries and conduct problems has been previously linked to cumulative risk at the child, mother, and household levels, such as alcohol consumption during pregnancy, mother psychological distress, and a low income household (Carr et al., 2023). In turn, cumulative risk indices (CRIs) are commonly used to inform interventions and prevention policies (Hogye et al., 2022). Negative parenting styles (i.e., harsh, avoidant, and abusive parenting) have been associated with increased conduct problems (Hukkelberg & Ogden, 2021;

Corresponding author: H. R. Carr; Email: hrc1n20@soton.ac.uk

Cite this article: Carr, H. R., Brandt, V. C., Golm, D., & Hall, J. E. (2024). Linked head injury and conduct problem symptom pathways from early childhood to adolescence and their associated risks: Evidence from the millennium cohort study. *Development and Psychopathology* **36**: 1719–1727, https://doi.org/10.1017/S0954579423001062

Speyer et al., 2022) and could create increased opportunities to sustain a head injury (Schnitzer et al., 2015). These associations, however, are yet to be investigated in a model of both head injuries and conduct problems.

The current study thus investigates distinct development pathways linking conduct problem symptoms and head injuries between early childhood and adolescence. By drawing on secondary data from a longitudinal cohort study, it provides an in-depth perspective on the patterns of linked head injury and conduct problems symptoms across development that is not possible from a cross-sectional design. We utilized latent class modeling on this longitudinal dataset to reveal the different pathways linking head injury and conduct problem symptoms from ages 3 to 17 years. It further elaborates to identify if distinct developmental pathways are associated with accumulated risks at the child, mother, and household levels, such as alcohol consumption during pregnancy, mother psychological distress, and a low-income household, as well as negative parenting styles.

Methods

Participants

The Millennium Cohort Study (MCS; https://www.cls.ioe.ac.uk/mcs) is an ongoing longitudinal UK birth cohort of 18,786 individuals born in the UK, aged 9 months at the first measurement timepoint (T1) between 2000 and 2002 (Fitzsimons et al., 2020). Participants were studied at six further timepoints at the ages of 3 (T2), 5 (T3), 7 (T4), 11 (T5), 14 (T6), and 17 years (T7). For this study, we included participants who completed the last wave at age 17, who were first-born children, whose main respondent in the study was their biological mother, and who had complete CRI data ($N = 8,600$; 4,320 female [50.2%]; 7,136 [83%] 'White British'). For more information and justifications for these exclusions and for the participant flow chart see supplementary materials, Appendix A and Figure S1 respectively.

Written informed consent was provided to the MCS by the parent of each child. Ethical approval for this analysis was given by the University of Southampton Ethics Committee (ID = 62100). This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for cohort studies.

Measures

Conduct problem symptoms

Conduct problem symptoms were parent-reported at T2 (age 3) to T7 (age 17), using the five items from the Strength and Difficulties Questionnaire (SDQ) Conduct Problem Subscale (Goodman, 2001). This subscale is widely used as a reliable and valid measure of conduct problems and externalizing behavior (Patalay & Hardman, 2019; Zendarski et al., 2021). The items were coded from 0 (*not true*) to 2 (*certainly true*) and were summed to create a total score at each timepoint (possible range: 0 – 10). Based on the newer 4-band categorization, scores reflect the following levels of conduct problems: 0–2 = "close to average," 3 = "slightly raised," 4–5 = "high" (clinically relevant), and 6–10 = "very high" (clinically relevant; see www.sdqinfo.org).

Head injuries

Head injuries were parent-reported from T2 (age 3) to T6 (age 14). Parents reported their child sustaining a "bang to the head" or "loss of consciousness after bang to the head." Uniting both responses regarding head injury was a replication of the head injury variables created in previous published MCS analyses (Brandt et al., 2022; Carr et al., 2023; Mongilio, 2022).

Though head injuries were reported at T1 these were not included due to the temporal ordering of the risk factors below.

Potential risk factors

Risk factors were distinguished across three levels (child, mother, and household) and were assessed via the creation of CRIs (Bronfenbrenner, 1977). CRIs refer to the summation of risk factors. That is, each risk factor is dichotomized and then summed to emphasize volume of risk rather than individual relationships of risk factors (Hall et al., 2010; Rutter, 1979). The factors included in the CRIs replicate those used previously in the modeling of the bidirectional association between conduct problems and head injuries (Carr et al., 2023).

At each ecological level, five potential risks for conduct problems and/or head injuries were identified and labeled as either "present" or "high risk" (1), as compared to "absent" or "low risk" (0). The high-risk thresholds were informed by previous literature (see below). These risks were summed to create the three CRIs (score ranging from 0–5 at each level):

Child-level risks. Potential risks included: low birth weight (<2.5 kg) and premature birth (<=252 days gestation (Reijneveld et al., 2006; Whiteside-Mansell et al., 2009)), male sex (Fullerton et al., 2019; McKinlay et al., 2010), and whether the child's biological mother smoked or drank alcohol during pregnancy (Van Adrichem et al., 2020). These were all measured at T1.

Mother-level risks. Potential risks included: unemployment (Van Adrichem et al., 2020), no high-school qualification (Greitemeyer & Sagioglou, 2016; Trentacosta et al., 2008; Van Adrichem et al., 2020), pregnancy before age 18 (McKinlay et al., 2010; Trentacosta et al., 2008), low attachment with child (<= 22 on the Condon Maternal Attachment Scale; six 5-point items [1 = "almost all the time"; 5 = "never"] summed; (Condon & Corkindale, 1998; Curran et al., 2016), and high maternal psychological distress (>=4 on Rutter Malaise Inventory; nine binary items [0 = "no"; 1 = "yes"] summed (McKinlay et al., 2010; Rutter et al., 1970)). These were all measured at T1.

Household-level risks. Potential risks included: low household occupational status (semi-skilled or lower; (Greitemeyer & Sagioglou, 2016), low household income (< 60% of median household income (Northerner et al., 2016; Trentacosta et al., 2008)), single parent household (Northerner et al., 2016; Trentacosta et al., 2008), household overcrowding (fewer rooms than people (Northerner et al., 2016; Trentacosta et al., 2008)), and low-quality home learning environment (bottom quartile of the (early) Home Learning Environment scale [HLE] (Sylva et al., 2004)). The (early) HLE scale was comprised of six items that assessed the frequency of child engagement in early learning activities such as being read to. The items were scored from 0 (*not at all*) to 7 (*every day*) and summed (possible range: 0–42). A higher score indicated a higher quality home learning environment. All were measured at T1 except for the (early) HLE, which was measured at T2.

https://doi.org/10.1017/S0954579423001062 Published online by Cambridge University Press

ADHD

ADHD is a risk factor due to its comorbidity with conduct problems (Gnanavel et al., 2019) and sustaining a head injury (Ramos Olazagasti et al., 2013). ADHD was measured by parents reporting if their child had received an ADHD diagnosis between T3 to T6 (age 5–14). A binary variable was created (0 = no diagnosis, 1 = diagnosis of ADHD).

Epilepsy

Epilepsy is a risk factor due to its comorbidity with conduct problems (Lin et al., 2012) and sustaining a head injury (Annegers & Coan, 2000). Epilepsy was measured by parents reporting if their child had received an epilepsy diagnosis between T2 to T6 (ages 3–14). A binary variable was created (0= no diagnosis, 1 = diagnosis of epilepsy).

Negative parenting styles

Negative parenting styles were measured at T3 (age 5) using the Parent-Child Conflict Tactic Scale (Straus et al., 1998). This measures how often the mother engages in harsh parenting (smacking, shouting at, and telling off) and withdrawal tactics (ignoring, sending to room, or taking away toys). Mothers were asked to report the frequency of these behaviors on a 5-point Likert scale ranging from 1 (*never*) to 5 (*daily*). The three items for each parenting style were summed to create a score (possible range: 3–15). A higher score indicated harsher parenting or greater levels of withdrawal.

Statistical analysis

Analyses were conducted using Mplus v7.4 (Muthén & Muthén, 2017). Latent class analysis was used to identify distinct development pathways linking conduct problem symptoms and head injuries from 3 to 17 years. The first step was to identify the optimum number of classes starting with a two-class model and increasing the number of classes until the solution that best fitted the data was found. This was established by comparing model fit indices between competing potential solutions (Weller et al., 2020) and interpretability (see supplementary materials, Appendix B).

Missing data from T2 to T6 were accounted for by using Full Information Maximum Likelihood (FIML).

MCS sample weights from T7 were included (accounting for stratification, nonresponse bias, and attrition) to facilitate generalization of findings to the UK population. ADHD, epilepsy, and three CRIs at the child, mother, and household level were included in the analysis and were tested for their association with an individual's distinct developmental pathway via multinomial logistic regression. Post hoc analyses further probed if negative parenting styles (harsh parenting or withdrawal tactics) at T3 were associated with class membership (see supplementary materials, Appendix C). Though exclusions were applied to the sample (refer to supplementary materials, Appendix A and Figure S1), additional analysis without these exclusions was completed on the final class solution to ensure the exclusions did not alter the interpretability of the linked pathways identified.

Data availability

The MCS data that support the findings of this study are openly available at the UK Data Service (https://discover.ukdataservice.ac.uk/series/?sn = 2000031). To access the data, one must register to the UK Data Service and submit a data request.

Results

Participants and demographics

Sample characteristics, variable differences between the analytical and excluded sample, and information on missing data can be seen in Table 1. Though there were significant differences between the included and excluded samples these effects were typically small (Cohen's *d* effect sizes: −.02–.18; Cramér's *V* effect sizes: .03–.10).

Identification of distinct linked developmental pathways

Upon comparison of latent class models with two-five classes, a 4-class solution appeared to best fit the MCS data based on model fit (see Table 2) and interpretability.

The 4-class solution identified four distinct and interpretable classes of linked conduct problem symptoms (Fig. 1a) and head injuries (Fig. 1b). The first class ($n = 6{,}422$ [74.7%]) was labeled *stable low-level conduct problem symptoms and head injuries*. Members of this class were characterized by consistent "close to average" levels of conduct problem symptoms as well as low levels of head injuries at all waves. The second class ($n = 1{,}422$ [16.5%]) was labeled *childhood-only high conduct problem symptoms and head injuries*. Members of this class presented with "high" levels of conduct problem symptoms at age 3, which declined into the lower range by age 7. Similarly, levels of head injury were highest at age 3, declining until age 14. The third class ($n = 567$ [6.6%]) was labeled *high adolescent conduct problem symptoms and childhood onward head injuries*. Members of this class showed "high" levels of conduct problem symptoms from age 14 to 17 as well as an increase in head injuries from age 11 to 14. The fourth class ($n = 189$ [2.2%]) was labeled *persistent high conduct problem symptoms and childhood-limited head injuries*. Members of this class showed persistently "slightly raised" to "very high" levels of conduct problem symptoms and the highest level of head injuries from ages 3 to 17 with a particular increase in head injuries during ages 7 and 11.

Classes two to four indicated distinct developmental pathways that were deemed to be "clinically relevant" due to the levels of conduct problem symptoms shown by their members in accordance with the SDQ categorizations (see Methods).

Supplementary analysis identified a similar 4-class solution when no exclusions were applied to the sample (see supplementary materials, Figure S2).

Association between distinct linked developmental pathways and potential risk factors

Multinomial logistic regression showed that higher scores on all three CRIs were generally associated with a greater likelihood of a child belonging to a clinically relevant developmental pathway compared to the stable low-level conduct problem symptoms and head injuries pathway (see Table 3). The only exception being the mother-level, which showed no evidence of an association with the adolescent-onset pathway (class 3).

Compared to the stable low-level conduct problem symptoms and head injuries pathway, ADHD had a strong association with all the clinically relevant classes (see Table 3), while epilepsy was only significantly associated with the adolescent-onset class (see Table 3).

https://doi.org/10.1017/S0954579423001062 Published online by Cambridge University Press

Table 1. Sample characteristics and differences between the analytical and excluded samples

	Analytical Sample ($n = 8,600$)		Excluded Sample ($n = 10,186$)				
Variable	N (%)	Mean (SD)	N (%)	Mean (SD)	Chi-square (df)	p	Cramér's V
Sex					14.68 (1)	< .001	.03
Male	4,280 (49.8)	–	5,355 (52.6)	–	–	–	–
Female	4,320 (50.2)	–	4,831 (47.4)	–	–	–	–
Ethnicity					15.90 (5)	.007	.03
White	7,136 (83.0)	–	8,346 (80.8)	–	–	–	–
Mixed	246 (2.9)	–	316 (3.2)	–	–	–	–
Black	265 (3.1)	–	413 (4.2)	–	–	–	–
Indian	222 (2.6)	–	247 (2.6)	–	–	–	–
Pakistani	600 (7.0)	–	663 (7.3)	–	–	–	–
Other	117 (1.4)	–	147 (1.6)	–	–	–	–
Conduct problems[c]							
Wave 2	7,645 (88.9)	2.69 (2.00)	6,713 (64.1)	2.95 (2.12)	7.61 (14,356)[a]	< .001	.13[b]
Wave 3	7,692 (89.4)	1.42 (1.46)	6,431 (66)	1.61 (1.56)	7.46 (14,391)[a]	< .001	.13[b]
Wave 4	7,809 (90.8)	1.29 (1.48)	5,341 (56.4)	1.52 (1.63)	8.36 (13,148)[a]	< .001	.15[b]
Wave 5	7,968 (92.7)	1.28 (1.49)	4,433 (50)	1.56 (1.68)	9.55 (12,399)[a]	< .001	.18[b]
Wave 6	7,796 (90.1)	1.33 (1.57)	3,261 (39.5)	1.57 (1.72)	7.14 (11,055)[a]	< .001	.15[b]
Wave 7	8,600 (100)	1.17 (1.48)	452 (17.7)	1.14 (1.41)	-.378 (9,050)[a]	.705	-.02[b]
Head injuries[d]							
Wave 2	1,018 (11.8)	–	868 (8.5)	–	55.42 (1)	< .001	.05
Wave 3	768 (8.9)	–	636 (6.8)	–	47.89 (1)	< .001	.05
Wave 4	579 (6.7)	–	383 (4.2)	–	84.54 (1)	< .001	.07
Wave 5	503 (5.8)	–	274 (3.1)	–	115.75 (1)	< .001	.08
Wave 6	392 (4.6)	–	119 (1.5)	–	200.54 (1)	< .001	.10

If n totals less than 8,600 or 10,186, respectively, this indicates missing data.
[a]Independent t-test.
[b]Cohen's D.
[c]As measured by the Parent-version of the Strengths and Difficulties Questionnaire Conduct Problem Subscale.
[d]As measured by parent reports of accidents resulting in a bang to the head with or without a loss of consciousness.

Table 2. Model fit indices of a latent class analysis of conduct problems and head injuries

k	AIC	BIC	Entropy	Smallest class (%)
2	162,544.69	162,754.30	.93	9.5
3	160,846.61	161,437.83	.84	4.7
4	**159,485.75**	**160,106.99**	**.86**	**2.7**
5	158,602.55	159,343.80	.86	2.1

AIC = Akaike's information criterion; BIC = bayesian information criterion; K = classes. Bold typeset indicates final class solution.

Association between distinct linked developmental pathways and maternal negative parenting styles

Post hoc multinomial logistic regression revealed that both greater use of maternal withdrawal tactics and harsh parenting at age 5 was significantly associated with a child's membership to all three clinically relevant developmental pathways compared to the stable low-level conduct problem symptoms and head injuries pathway. Maternal withdrawal tactics and harsh parenting were most strongly associated with the persistent pathway ($OR = 1.33$, 95% CI: 1.14–1.54; $OR = 1.38$, 95%CI: 1.22–1.56, respectively) followed by the child-limited pathway ($OR = 1.28$, 95% CI: 1.20–1.35; $OR = 1.26$, 95%CI: 1.19–1.34, respectively) and most weakly associated with the adolescent-onset pathway ($OR = 1.09$, 95% CI: 1.01–1.17; $OR = 1.16$, 95%CI: 1.09–1.24, respectively).

Discussion

This study identified four distinct developmental pathways linking conduct problem symptoms and head injuries between early childhood and adolescence (between 3 and 17 years). As expected, the majority of the sample (75%) displayed low levels of conduct problem symptoms and a low likelihood for head injuries from 3 to 17 years (class 1). However, three clinically relevant pathways were identified. Seventeen percent displayed clinically relevant levels of conduct problem symptoms and an elevated risk for head injuries in childhood, but both declined after childhood (child-limited; class 2). A further 6% developed clinically relevant levels of conduct problem symptoms in adolescence and showed an

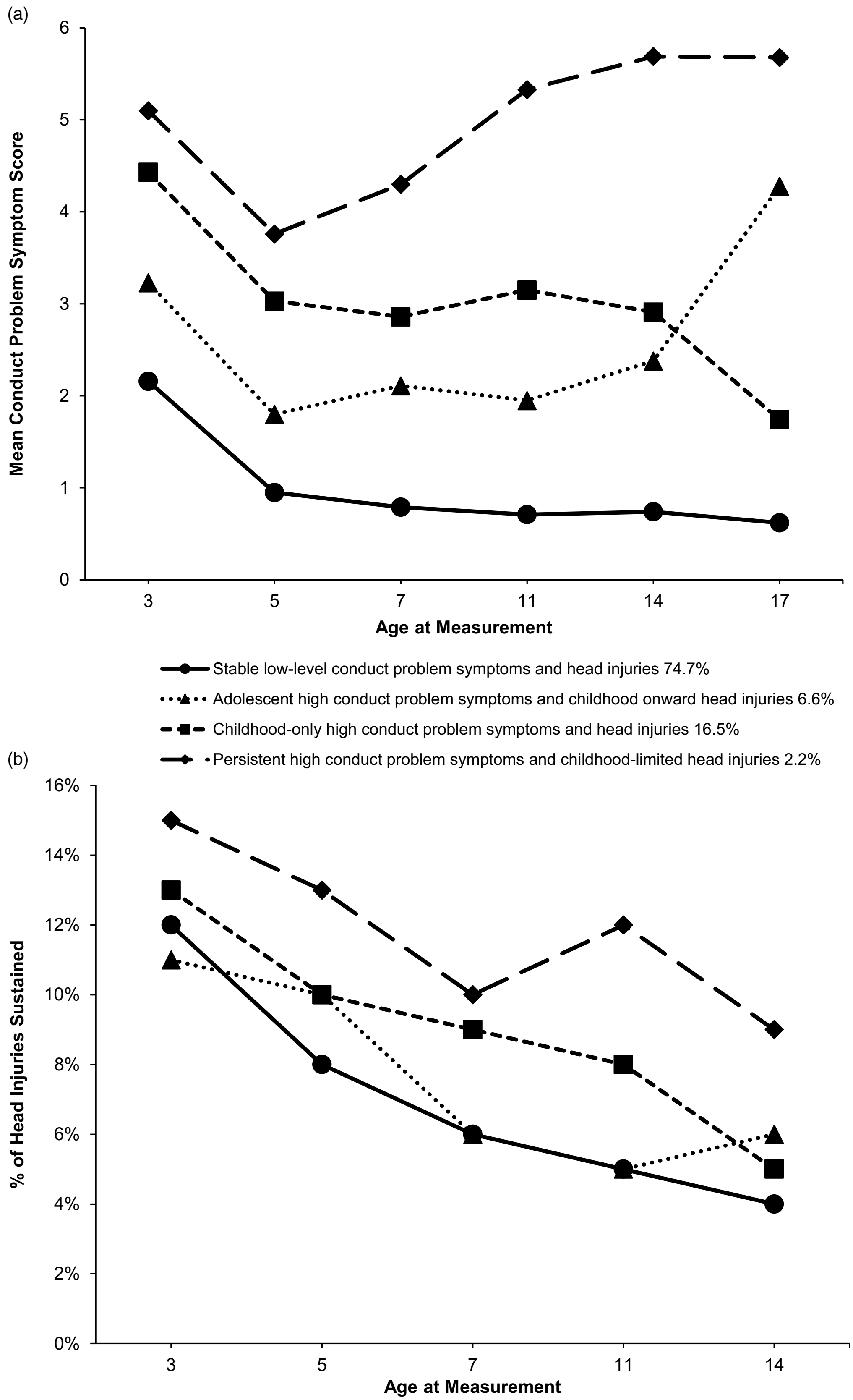

Figure 1. A figure of the linked pathways of mean conduct problem symptoms and head injuries at each timepoint for the 4-class solution. This figure shows the linked pathways of (***a***) mean conduct problem symptoms and (***b***) frequency of head injuries within the 4-class solution where conduct problem symptoms were measured using the conduct problem subscale of the SDQ and head injuries were parent-reported based on a history of a bang on the head with or without a loss of consciousness. The circles represent the "typically developing" group with low levels of conduct problem symptoms and sustained head injuries. The squares represent those with higher early levels of conduct problems symptoms and head injuries, which decline during development. The triangles represent those with low early levels of conduct problem symptoms and head injuries which both begin to rise from late childhood to adolescents. The diamonds represent persistently higher levels of head injuries and conduct problem symptoms.

elevated risk of head injuries from ages 11 to 14 (adolescent-onset; class 3). The final 2% displayed consistently high levels of conduct problem symptoms across development and displayed the highest rates of head injury with a particular sharp increase during ages 7–11 (persistent; class 4). The three developmental pathways show patterns of clinically relevant conduct problem symptoms that are

https://doi.org/10.1017/S0954579423001062 Published online by Cambridge University Press

Table 3. Multinomial logistic regression of the associations with class membership

Covariates	Childhood-only high conduct problem symptoms and head injuries (class 2)[a] OR (95% CI)	High adolescent conduct problem symptoms and childhood onward head injuries (class 3)[a] OR (95% CI)	Persistent high conduct problem symptoms and childhood-limited head injuries (class 4)[a] OR (95% CI)
Child CRI	**1.28* (1.10–1.49)**	**1.20* (1.01–1.43)**	**1.58* (1.05–2.40)**
Mother CRI	**1.51** (1.27–1.78)**	1.31 (.99-1.74)	**2.21* (1.40–3.49)**
Household CRI	**1.55** (1.37–1.76)**	**1.41** (1.18–1.70)**	**1.53* (1.12–2.08)**
ADHD	**10.43** (5.94–18.31)**	**5.06* (2.00–12.81)**	**122** (53.14–280.07)**
Epilepsy	1.44 (.90–2.31)	**2.35** (1.51–3.65)**	1.42 (.60–3.38)

OR = odds ratio; CRI = cumulative risk index.
[a] versus stable low-level conduct problem symptoms and head injuries (class 1).
* $p < .05$.
**$p < .001$.

consistent with the DSM-5's conduct disorder classifications (Diagnostic and statistical manual of mental disorders, 2013) and conduct disorder pathways previously identified within the MCS dataset (Gutman et al., 2019). These results, however, provide new insight into how such developmental pathways of conduct problem symptoms link with pathways of head injuries. It teases apart the previously identified bidirectional association between conduct problems and head injuries (Carr et al., 2023) and suggests that this bidirectional association may not be relevant to all individuals but to specific subsets of individuals at different periods from early childhood to adolescence.

Though three clinically relevant pathways were identified, emphasis should be placed on the linked pathways of classes 3 (adolescent-onset) and 4 (persistent). These are the only two classes to display increasing levels of conduct problem symptoms in adolescents and increasing levels of head injuries during development. These characteristics are associated with an increased risk for adolescent delinquency (Kennedy et al., 2017; Mongilio, 2022) and greater odds of problematic behaviors in adulthood (Bevilacqua et al., 2018). Taken together, these features, thus, suggest the need for prevention work to stop individuals from entering these clinically relevant developmental pathways.

Such preventions may target risk factors associated with membership of these pathways. ADHD was highly associated with all clinically relevant pathways and most strongly with the class displaying persistent conduct problem symptoms (class 4). This finding is unsurprising due to ADHD's strong association with conduct problems (particularly persistent or child-onset conduct problems (Fairchild et al., 2019; Silberg et al., 2015)) and head injuries (Ramos Olazagasti et al., 2013), as well as interactions between ADHD and harsh parenting (Golm & Brandt, 2023). The strength of the association provides further support for the relevance of interventions to manage conduct disorder with comorbid ADHD, e.g., psychosocial intervention for the conduct disorder symptoms and stimulant medication for the ADHD symptoms (Fairchild et al., 2019). By doing so, such interventions may also inadvertently reduce the risk of sustaining a head injury during development and the associated implications of this.

It must be noted that whilst ADHD was strongly associated with group membership it is important to acknowledge potential sex differences. That is, males have a stronger association with both conduct disorder and co-morbid ADHD (Fairchild et al., 2019; Konrad et al., 2022). These sex differences could play a role in the associations that ADHD shares with these linked developmental pathways and the development of the pathways themselves. Whilst for the purpose of this research, we aimed to provide a novel understanding of how head injuries and conduct problem symptoms co-occur across development irrespective of sex (and other potential confounders), future research may wish to look at how the identified linked developmental pathways differ between males and females and how sex may influence potential risk factors associated with pathway membership (particularly with reference to the role of ADHD). This could provide important findings that will further aid the development of such interventions as those proposed above and their appropriate target population.

Our findings further suggest that early (by age 3) accumulation of risk at the child, mother, and household-level (Carr et al., 2023) are associated with membership to the clinically relevant classes, again replicating that of previous literature (Gutman et al., 2019). For the persistent pathway (class 4), the strongest association of cumulative risk was at the mother-level. This supports previous literature, which identifies mother-level risk as strongly associated with a risk for both persistent conduct problems (Gutman et al., 2019) and head injuries (McKinlay et al., 2010). Thus, preventions that might reduce the likelihood of individuals entering this development pathway might aim to primarily reduce undesired maternal unemployment, (potential future) mothers leaving high school with no qualifications, pregnancies before 18 years, low mother attachment with child, and high maternal psychological distress. Future research might determine which of these risk factors are particularly important, in order to develop targeted interventions, such as early support for mother-child attachment for mothers experiencing mental health difficulties.

While the mother-level was the strongest accumulated risk for the persistent pathway, there was no evidence for an association between the mother-level and the adolescent-onset pathway (class 3). This is not in line with previously identified association between mother-level factors (e.g., maternal depression) and an increased risk of head injury by adolescence (McKinlay et al., 2010). However, only early mother-level risk factors (by age 3) were taken into account in our study, and it is possible that mother-level risk later in development is more relevant to this adolescent-onset pathway that links head injury and conduct problem symptoms. The adolescent-onset pathway was instead most strongly associated with household risk factors, i.e., low household income, single parent household, household overcrowding, and low-quality home learning environment. This continues to support previous literature, which has shown this pathway of conduct problems to

https://doi.org/10.1017/S0954579423001062 Published online by Cambridge University Press

be most strongly associated with socioeconomic status (SES (Gutman et al., 2019)). This also provides further support for the hypothesis that there are potential latency effects from child and household accumulative risk to later emerging conduct problem symptoms (Gutman et al., 2019; Schoon et al., 2003) and its associated higher levels of late childhood head injuries. Thus, preventative measures might aim to primarily reduce household risk factors, or provide effective interventions that are appropriate for families from a low SES background (Leijten et al., 2017). It could further provide interventions to improve the early home learning environment, such as improving the interaction between preschool staff and parents particular those with a low SES (Kuger et al., 2019).

Our findings identify a further opportunity for preventions to reduce the likelihood of a child entering these developmental pathways of conduct problems and head injuries via provision of greater support to mothers to prevent the emergence of negative parenting styles with children through to age 5. Mother's negative parenting styles were associated with all clinically relevant pathways. It must be noted that while the mother-level cumulative risk was not associated with the adolescent-onset pathway, mother's negative parenting styles were. Though this effect was small for this pathway, adolescent head injuries have been previously associated with negative parenting styles (McKinlay et al., 2010). Efforts to prevent the emergence of maternal withdrawal tactics and harsh parenting (Speyer et al., 2022) should therefore be addressed to reduce both conduct problem symptoms and head injuries in all clinically relevant pathways. Such interventions could include parent feedback and coaching (McConnell et al., 2020) and/or parental well-being courses (Tapp et al., 2018).

Strengths and limitations

A key strength of this study is that it is the first to reveal multiple distinct pathways linking conduct problems and head injuries from 3 to 17 years of age. This will have important implications for when interventions should be administered and to whom. This study benefits from its analysis of data belonging to a large population representative national cohort study, which aids statistical power and generalizability.

The study, however, also has limitations. Note that we refer to 'clinically relevant' levels of conduct problems symptoms. The SDQ is not a diagnostic measure of conduct problems. Therefore, the described developmental pathways can only infer clinically relevant symptoms. Such use of parent-report measures may also lead to social desirability bias in the reporting of both key variables (Bornstein et al., 2015). Future research may use health and clinical records, for example, to remove such potential bias from the results. Further, the measure of harsh parenting used in the MCS omits the severe harsh parenting items included in the original scale. This may explain why only a small effect is evident. Further research may wish to investigate this association further outside of the MCS where the more severe harsh parenting items can be explored. Finally, we encourage follow-up of this epidemiological research with smaller-scale neurological investigation to uncover possible neurological mechanisms at play between the distinct developmental pathways found in this paper.

Conclusions

This study identifies four distinct developmental pathways that link conduct problems and head injuries between 3 and 17 years of age. Two of these pathways showed a tendency toward clinically relevant levels of conduct problem symptoms and increasing levels of head injuries at some point during this period. Children were more likely to exhibit one of these pathways in the presence of negative parenting styles through to age 5 years or alongside diagnosed ADHD. Cumulative risk at various ecological levels had unique associations with these pathways and should also be utilzed in early interventions to prevent membership to clinically relevant pathways of linked head injuries and conduct problems. Such interventions are necessary to prevent subsequent outcomes associated with these pathways including delinquency and criminality.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0954579423001062.

Acknowledgments. We are grateful to the Centre for Longitudinal Studies (CLS), UCL Social Research Institute, for the use of the MCS dataset and to the UK Data Service for making them available. Neither CLS nor the UK Data Service bear any responsibility for the analysis or interpretation of these data. We are also very grateful to the families who have taken part in the MCS study and to the MCS team.

HC had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

No funding was received toward this work, but HC has received PhD funding from the Economic and Social Research Council South Coast Doctoral Training Partnership (Grant Number ES/P000673/1) and would like to thank them for the research opportunity. The authors report no competing interests.

Funding statement. This research received no specific grant from any funding agency, commercial, or not-for-profit sectors.

Competing interests. None.

References

Annegers, J. F., & Coan, S. P. (2000). The risks of epilepsy after traumatic brain injury. *Seizure*, *9*(7), 453–457. https://doi.org/10.1053/seiz.2000.0458

Bellesi, G., Barker, E. D., Brown, L., & Valmaggia, L. (2019). Pediatric traumatic brain injury and antisocial behavior: Are they linked? A systematic review. *Brain Injury*, *33*(10), 1272–1292. https://doi.org/10.1080/02699052.2019.1641621

Bevilacqua, L., Hale, D., Barker, E. D., & Viner, R. (2018). Conduct problems trajectories and psychosocial outcomes: A systematic review and meta-analysis. *European Child & Adolescent Psychiatry*, *27*(10), 1239–1260. https://doi.org/10.1007/s00787-017-1053-4

Bornstein, M. H., Putnick, D. L., Lansford, J. E., Pastorelli, C., Skinner, A. T., Sorbring, E., Tapanya, S., Uribe Tirado, L. M., Zelli, A., Alampay, L. P., Al-Hassan, S. M., Bacchini, D., Bombi, A. S., Chang, L., Deater-Deckard, K., Di Giunta, L., Dodge, K. A., Malone, P. S., Oburu, P. (2015). Mother and father socially desirable responding in nine countries: Two kinds of agreement and relations to parenting self-reports. *International Journal of Psychology*, *50*(3), 174–185. https://doi.org/10.1002/ijop.12084

Brandt, V., Hall, C., Eisenbarth, H., & Hall, J. (2022). Mutual relationships between head injury and conduct problems in children aged 9 months to 14 years in the UK millennium cohort study. *medRxiv*, (Preprint). https://doi.org/10.1101/2022.01.09.22268970

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist*, *32*(7), 513–531. https://doi.org/10.1037/0003-066X.32.7.513

Carr, H. R., Hall, J. E., Eisenbarth, H., & Brandt, V. C. (2023). The bidirectional relationship between head injuries and conduct problems: Longitudinal modelling of a population-based birth cohort study. *European Child & Adolescent Psychiatry*, 1–10. https://doi.org/10.1007/s00787-023-02175-y

Condon, J. T., & Corkindale, C. J. (1998). The assessment of parent-to-infant attachment: Development of a self-report questionnaire instrument. *Journal* *of Reproductive and Infant Psychology*, *16*(1), 57–76. https://doi.org/10.1080/02646839808404558

Curran, E. A., Cryan, J. F., Kenny, L. C., Dinan, T. G., Kearney, P. M., & Khashan, A. S. (2016). Obstetrical mode of delivery and childhood behavior and psychological development in a british cohort. *Journal of Autism and Developmental Disorders*, *46*(2), 603–614. https://doi.org/10.1007/s10803-015-2616-1

Davis, T., & Ings, A. (2015). Head injury: Triage, assessment, investigation and early management of head injury in children, young people and adults (NICE guideline CG 176). *Archives of Disease in Childhood-Education and Practice*, *100*(2), 97–100.

Diagnostic and statistical manual of mental disorders (2013). (5th ed.). American Psychiatric Publishing, Inc.. https://doi.org/10.1176/appi.books.9780890425596

Fairchild, G., Hawes, D. J., Frick, P. J., Copeland, W. E., Odgers, C. L., Franke, B., Freitag, C. M., & De Brito, S. A. (2019). Conduct disorder. *Nature Reviews Disease Primers*, *5*(1), 43. https://doi.org/10.1038/s41572-019-0095-y

Fitzsimons, E., Haselden, L., Smith, K., Gilbert, E., Calderwood, L., Agalioti-Sgompou, V., Veeravalli, S., Silverwood, R., & Ploubidis, G. (2020). *Millennium cohort study: Age 17 Sweep (MCS7) user guide* (vol. *1*, pp. 97). London: UCL Centre for Longitudinal Studies.

Fullerton, A. F., Jackson, N. J., Tuvblad, C., Raine, A., & Baker, L. A. (2019). Early childhood head injury attenuates declines in impulsivity and aggression across adolescent development in twins. *Neuropsychology*, *33*(8), 1035–1044. https://doi.org/10.1037/neu0000570

Girard, L.-C., Tremblay, R. E., Nagin, D., & Côté, S. M. (2019). Development of aggression subtypes from childhood to adolescence: A group-based multi-trajectory modelling perspective. *Journal of Abnormal Child Psychology*, *47*(5), 825–838. https://doi.org/10.1007/s10802-018-0488-5

Gnanavel, S., Sharma, P., Kaushal, P., & Hussain, S. (2019). Attention deficit hyperactivity disorder and comorbidity: A review of literature. *World Journal of Clinical Cases*, *7*(17), 2420–2426. https://doi.org/10.12998/wjcc.v7.i17.2420

Golm, D., & Brandt, V. (2023). The longitudinal association between infant negative emotionality, childhood maltreatment, and ADHD symptoms: A secondary analysis of data from the fragile families and child wellbeing study. *Development and Psychopathology*, 1–8. https://doi.org/10.1017/S0954579423000457

Goodman, R. (2001). Psychometric properties of the strengths and difficulties questionnaire. *J Am Acad Child Adolesc Psychiatry*, *40*(11), 1337–1345. https://doi.org/10.1097/00004583-200111000-00015

Greitemeyer, T., & Sagioglou, C. (2016). Subjective socioeconomic status causes aggression: A test of the theory of social deprivation. *Journal of Personality and Social Psychology*, *111*(2), 178–194. https://doi.org/10.1037/pspi0000058

Gutman, L. M., Joshi, H., & Schoon, I. (2019). Developmental trajectories of conduct problems and cumulative risk from early childhood to adolescence. *J Youth Adolesc*, *48*(2), 181–198. https://doi.org/10.1007/s10964-018-0971-x

Hall, J., Sammons, P., Sylva, K., Melhuish, E., Taggart, B., Siraj, I., & Smees, R. (2010). Measuring the combined risk to young children's cognitive development: An alternative to cumulative indices. *The British Journal of Developmental Psychology*, *28*(2), 219–238. https://doi.org/10.1348/026151008X399925

Hogye, S. I., Lucassen, N., Jansen, P. W., Schuurmans, I. K., & Keizer, R. (2022). Cumulative risk and internalizing and externalizing problems in early childhood: Compensatory and buffering roles of family functioning and family regularity. *Adversity and Resilience Science*, *3*(2), 149–167. https://doi.org/10.1007/s42844-022-00056-y

Hukkelberg, S. S., & Ogden, T. (2021). Parenting practices and child conduct problems in a norwegian subclinical sample: Variable and person-centered approaches. *Family Relations*, *70*(4), 1102–1116. https://doi.org/https://doi.org/10.1111/fare.12538

Keenan, H. T., Clark, A. E., Holubkov, R., Cox, C. S., Patel, R. P., Moore, K. R., & Ewing-Cobbs, L. (2020). Latent class analysis to classify injury severity in pediatric traumatic brain injury. *Journal of Neurotrauma*, *37*(13), 1512–1520. https://doi.org/10.1089/neu.2019.6874

Kennedy, E., Heron, J., & Munafò, M. (2017). Substance use, criminal behaviour and psychiatric symptoms following childhood traumatic brain injury: Findings from the ALSPAC cohort. *European Child & Adolescent Psychiatry*, *26*(10), 1197–1206. https://doi.org/10.1007/s00787-017-0975-1

Konrad, K., Kohls, G., Baumann, S., Bernhard, A., Martinelli, A., Ackermann, K., Smaragdi, A., Gonzalez-Madruga, K., Wells, A., Rogers, J. C., Pauli, R., Clanton, R., Baker, R., Kersten, L., Prätzlich, M., Oldenhof, H., Jansen, L., Kleeven, A., Bigorra, A., & Freitag, C. M. (2022). Sex differences in psychiatric comorbidity and clinical presentation in youths with conduct disorder. *Journal of Child Psychology and Psychiatry*, *63*(2), 218–228. https://doi.org/https://doi.org/10.1111/jcpp.13428

Kuger, S., Marcus, J., & Spiess, C. K. (2019). Day care quality and changes in the home learning environment of children. *Education Economics*, *27*(3), 265–286. https://doi.org/10.1080/09645292.2019.1565401

Leijten, P., Raaijmakers, M. A. J., Orobio de Castro, B., van den Ban, E., & Matthys, W. (2017). Effectiveness of the incredible years parenting program for families with socioeconomically disadvantaged and ethnic minority backgrounds. *Journal of Clinical Child & Adolescent Psychology*, *46*(1), 59–73. https://doi.org/10.1080/15374416.2015.1038823

Lin, J. J., Mula, M., & Hermann, B. P. (2012). Uncovering the neuro-behavioural comorbidities of epilepsy over the lifespan. *The Lancet*, *380*(9848), 1180–1192. https://doi.org/https://doi.org/10.1016/S0140-6736(12)61455-X

McConnell, M., Closson, L., Morse, B., Wurster, H., Flykt, M., Sarche, M., & Biringen, Z. (2020). The "EA brief": A single session of parent feedback and coaching to improve emotional attachment and emotional availability (EA). *Infant Mental Health Journal*, *41*(6), 783–792. https://doi.org/https://doi.org/10.1002/imhj.21867

McKee, A. C., & Daneshvar, D. H. (2015). The neuropathology of traumatic brain injury. *Handb Clin Neurol*, *127*, 45–66. https://doi.org/10.1016/B978-0-444-52892-6.00004-0

McKinlay, A., Kyonka, E. G., Grace, R. C., Horwood, L. J., Fergusson, D. M., & MacFarlane, M. R. (2010). An investigation of the pre-injury risk factors associated with children who experience traumatic brain injury. *Injury Prevention*, *16*(1), 31–35. https://doi.org/10.1136/ip.2009.022483

Mongilio, J. (2022). Childhood head injury as an acquired neuropsychological risk factor for adolescent delinquency. *Journal of Research in Crime and Delinquency*, *59*(6), 756–790. https://doi.org/10.1177/00224278221081140

Muthén, L. K., & Muthén, B. O. (1998–2017). *Mplus user's guide* (8th ed.). Muthén & Muthén.

National Clinical Guideline Centre 2014). *Head injury: Triage, assessment, investigation and early management of head injury in children, young people and adults*. National Institute for Health and Clinical Excellence.

Northerner, L. M., Trentacosta, C. J., & McLear, C. M. (2016). Negative affectivity moderates associations between cumulative risk and at-risk toddlers' behavior problems. *Journal of Child and Family Studies*, *25*(2), 691–699. https://doi.org/10.1007/s10826-015-0248-x

Patalay, P., & Hardman, C. A. (2019). Comorbidity, codevelopment, and temporal associations between body mass index and internalizing symptoms from early childhood to adolescence. *JAMA Psychiatry*, *76*(7), 721–729. https://doi.org/10.1001/jamapsychiatry.2019.0169

Ramos Olazagasti, M. A., Klein, R. G., Mannuzza, S., Belsky, E. R., Hutchison, J. A., Lashua-Shriftman, E. C., & Castellanos, F. X. (2013). Does childhood attention-deficit/hyperactivity disorder predict risk-taking and medical illnesses in adulthood? *Journal of the American Academy of Child and Adolescent Psychiatry*, *52*(2), 153–162.e4. https://doi.org/10.1016/j.jaac.2012.11.012

Reijneveld, S. A., de Kleine, M. J., van Baar, A. L., Kollée, L. A., Verhaak, C. M., Verhulst, F. C., & Verloove-Vanhorick, S. P. (2006). Behavioural and emotional problems in very preterm and very low birthweight infants at age 5 years. *Archives of Disease in Childhood. Fetal and Neonatal Edition*, *91*(6), F423–428. https://doi.org/10.1136/adc.2006.093674

Rutter, M. (1979). Protective factors in children's responses to stress and disadvantage. In M. Kent & J. Rolf (Eds.), *Primary prevention of psychopathology, Vol. III: Social competence in children*. University Press of New England.

Rutter, M., Tizard, J., & Whitmore, K. (1970). *Education, health and behaviour: Psychological and medical study of childhood development*. Wiley.

Schnitzer, P. G., Dowd, M. D., Kruse, R. L., & Morrongiello, B. A. (2015). Supervision and risk of unintentional injury in young children. *Injury Prevention*, *21*(e1), e63–70. https://doi.org/10.1136/injuryprev-2013-041128

Schoon, I., Sacker, A., & Bartley, M. (2003). Socio-economic adversity and psychosocial adjustment: A developmental-contextual perspective. *Social Science & Medicine*, *57*(6), 1001–1015. https://doi.org/10.1016/s0277-9536(02)00475-6

Silberg, J., Moore, A. A., & Rutter, M. (2015). Age of onset and the subclassification of conduct/dissocial disorder. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *56*(7), 826–833. https://doi.org/10.1111/jcpp.12353

Speyer, L. G., Hang, Y., Hall, H. A., & Murray, A. L. (2022). The role of harsh parenting practices in early- to middle-childhood socioemotional development: An examination in the millennium cohort study. *Child Development*, *93*(5), 1304–1317. https://doi.org/10.1111/cdev.13761

Straus, M. A., Hamby, S. L., Finkelhor, D., Moore, D. W., & Runyan, D. (1998). Identification of child maltreatment with the parent-child conflict tactics scales: Development and psychometric data for a national sample of American parents. *Child Abuse & Neglect*, *22*(4), 249–270.

Sylva, K., Melhuish, E., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (2004). *The effective provision of pre-school education (EPPE) project technical paper 12: The final report-effective pre-school education*. in: Institute of Education, University of London/Department for Education and Skills.

Tapp, B., Gandy, M., Fogliati, V. J., Karin, E., Fogliati, R. J., Newall, C., McLellan, L., Titov, N., & Dear, B. F. (2018). Psychological distress, help-seeking, and perceived barriers to psychological treatment among Australian parents. *Australian Journal of Psychology*, *70*(2), 113–121. https://doi.org/10.1111/ajpy.12170

Trentacosta, C. J., Hyde, L. W., Shaw, D. S., Dishion, T. J., Gardner, F., & Wilson, M. (2008). The relations among cumulative risk, parenting, and behavior problems during early childhood. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *49*(11), 1211–1219. https://doi.org/10.1111/j.1469-7610.2008.01941.x

Van Adrichem, D. S., Huijbregts, S. C. J., Van Der Heijden, K. B., Van Goozen, S. H. M., & Swaab, H. (2020). Aggressive behavior during toddlerhood: Interrelated effects of prenatal risk factors, negative affect, and cognition. *Child Neuropsychology*, *26*(7), 982–1004. https://doi.org/10.1080/09297049.2020.1769582

Weller, B. E., Bowen, N. K., & Faubert, S. J. (2020). Latent class analysis: A guide to best practice. *Journal of Black Psychology*, *46*(4), 287–311. https://doi.org/10.1177/0095798420930932

Whiteside-Mansell, L., Bradley, R. H., Casey, P. H., Fussell, J. J., & Conners-Burrow, N. A. (2009). Triple risk: Do difficult temperament and family conflict increase the likelihood of behavioral maladjustment in children born low birth weight and preterm? *Journal of Pediatric Psychology*, *34*(4), 396–405. https://doi.org/10.1093/jpepsy/jsn089

Yates, P. J., Williams, W. H., Harris, A., Round, A., & Jenkins, R. (2006). An epidemiological study of head injuries in a UK population attending an emergency department. *J Neurol Neurosurg Psychiatry*, *77*(5), 699–701. https://doi.org/10.1136/jnnp.2005.081901

Zendarski, N., Mensah, F., Hiscock, H., & Sciberras, E. (2021). Trajectories of emotional and conduct problems and their association with early high school achievement and engagement for adolescents with ADHD. *Journal of Attention Disorders*, *25*(5), 623–635. https://doi.org/10.1177/1087054719833167