BMC Pregnancy and Childbirth https://doi.org/10.1186/s12884-025-08129-3

Article in Press

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Received: 29 April 2024

Accepted: 26 August 2025

Published online: 25 November 2025

Cite this article as: Derseh B., Dadi A. & Guthridge S. Prenatal alcohol use effects on birth, development, and educational outcomes in the Aboriginal and non-Aboriginal populations in the Northern Territory of Australia: a study protocol. ***BMC Pregnancy Childbirth*** **(2025). https://doi.org/10.1186/s12884-025-08129-3**

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Prenatal alcohol use effects on birth, development, and educational outcomes in the Aboriginal and non-Aboriginal populations in the Northern Territory of Australia: a study protocol

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Abstract

Background: Prenatal alcohol use (PAU) is a global public health concern with far-reaching impacts on infants' cognitive, behavioural, and physical development. There have been few studies of the extent and impact of PAU in the population of the Northern Territory (NT) of Australia. This study aims to investigate the trend in the prevalence, find factors affecting PAU, and assess the impact of PAU on birth, development, and educational outcomes in the NT population.

Methods: In a series of retrospective cohort studies, the researchers will use data from the Child and Youth Development Research Partnership (CYDRP) data repository. Four distinct cohorts will be considered, encompassing pregnant women giving birth in the NT from January 1, 2000, to December 1, 2017, all births in the NT during the same period, NT-born children registered during the Australian Early Development Census (AEDC) in the years 2009, 2012, 2015, and 2018, and all NT-born children who have registered for National Assessment Program-Literacy and Numeracy (NAPLAN) tests in the years from 2005 to 2018. Furthermore, a systematic review and meta-analysis will assess global PAU's prevalence, trends, and adverse outcomes. The data linkage technique will connect records for the same individual across different datasets while ensuring confidentiality. The data analysis process will involve four key steps: (I) data management, (II) descriptive (exploratory) statistical analysis, (III) inferential data analysis, and (IV) model adequacy assessment.

Expected outcomes: This project examines the hypothesis that PAU significantly affects birth outcomes, child development and educational performance, with results that will be reported in about five scientific manuscripts suitable for publication in peer-reviewed journals in 2024 and 2025.

Conclusions: This project will provide valuable insights into the consequences of PAU for birth outcomes, child development, and educational outcomes, aiding the development of effective interventions.

Keywords: Alcohol, Birth outcome, Development, Education, Incidence, Prevalence.

Introduction

Prenatal alcohol use is a significant global public health concern, impacting infants' cognitive, behavioural, and physical development worldwide [1–4]. Apart from its health consequences, prenatal alcohol use also imposes significant economic and societal problems. The health conditions resulting from harmful alcohol use elevate healthcare expenditures, diminish workforce productivity, suppress gross domestic product (GDP), and influence human capital development by impacting children's educational achievements [1–6].

Approximately one in ten women worldwide consume alcohol during pregnancy (9.8%) [7]. The estimated prevalence of prenatal alcohol use in Australia ranges from 18.3% [8] to 46% [9]. International prevalence estimates range from a low of 4% in Denmark[10] to 50% in Japan [11] and greater than 50% in the United States of America [12] and the United Kingdom (UK) [13]. The high prevalence of PAU is attributed to social acceptance of alcohol, peer influence, and lack of awareness of the harmful effects of alcohol in pregnancy [14, 15]. Prevalence estimates vary widely because of actual differences, sample selection, health system strength, differences in measurement tools, and operational definitions [16].

Cultural and individual influences can significantly shape PAU, and Australia's well-established drinking culture substantially contributes to the ongoing prevalence of prenatal alcohol use [17]. Specifically, in 2016, 80% of individuals aged 14 and older in Australia engaged in alcohol use, often surpassing recommended alcohol consumption guidelines. Notably, 24% of individuals reported harm associated with alcohol use [18]. This context highlights the need to comprehensively understand PAU's social determinants when developing strategies to reduce such use.

The literature highlights attitudes and beliefs about the risks associated with PAU and the strategies employed to prevent alcohol-related problems. This body of evidence reports significant variations in how these risks are perceived across countries, influenced by contextual factors that shape research, prevention, and intervention approaches. Furthermore, differences in risk conceptualisation were evident even within individual countries. Discrepancies also emerged in the degree to which the concern of PAU has been downplayed or accentuated, along with variations in the extent to which responses are incorporated into public health interventions.

Several studies have examined the impact of PAU on adverse birth outcomes, including Alcohol Related Birth Defects (ARBD) [19], low birth weight (LBW) [20–24], placenta accreta [25], preterm birth (PTB) [20, 22], small for gestational age (SGA) [26], reduced birth length and head circumference [21], congenital anomalies [27], and a lifelong disability called Fetal Alcohol Spectrum Disorder (FASD) [6]. Furthermore, PAU is a risk for intellectual disability [28] and gross motor functions [29, 30]. However, some studies reported no evidence of an association between PAU and birth outcomes [31–33]. Conversely, other studies have yielded results suggesting a link between PAU and reduced risk of low birth weight and birth length [34]. However, research on the effects of PAU in the Northern Territory (NT) of Australia is limited, marked by empirical and population-related gaps [3, 4, 43–49, 35–42]. Moreover, there is a need for a more comprehensive trend analysis covering the period from 2000 to 2017, and a notable gap exists in our understanding of the factors affecting PAU in the NT. This study aims to address these gaps, investigate the prevalence trend, find factors affecting PAU, and assess the association between PAU and adverse birth outcomes, child development, and educational achievements in the NT.

General objective

The goal of this project is to analyse the prevalence and trend of PAU and its effects on birth, child development, and educational outcomes in the Northern Territory. The conceptual framework illustrates the relationship between exposure, outcome, and confounding variables under study (Fig. 1).

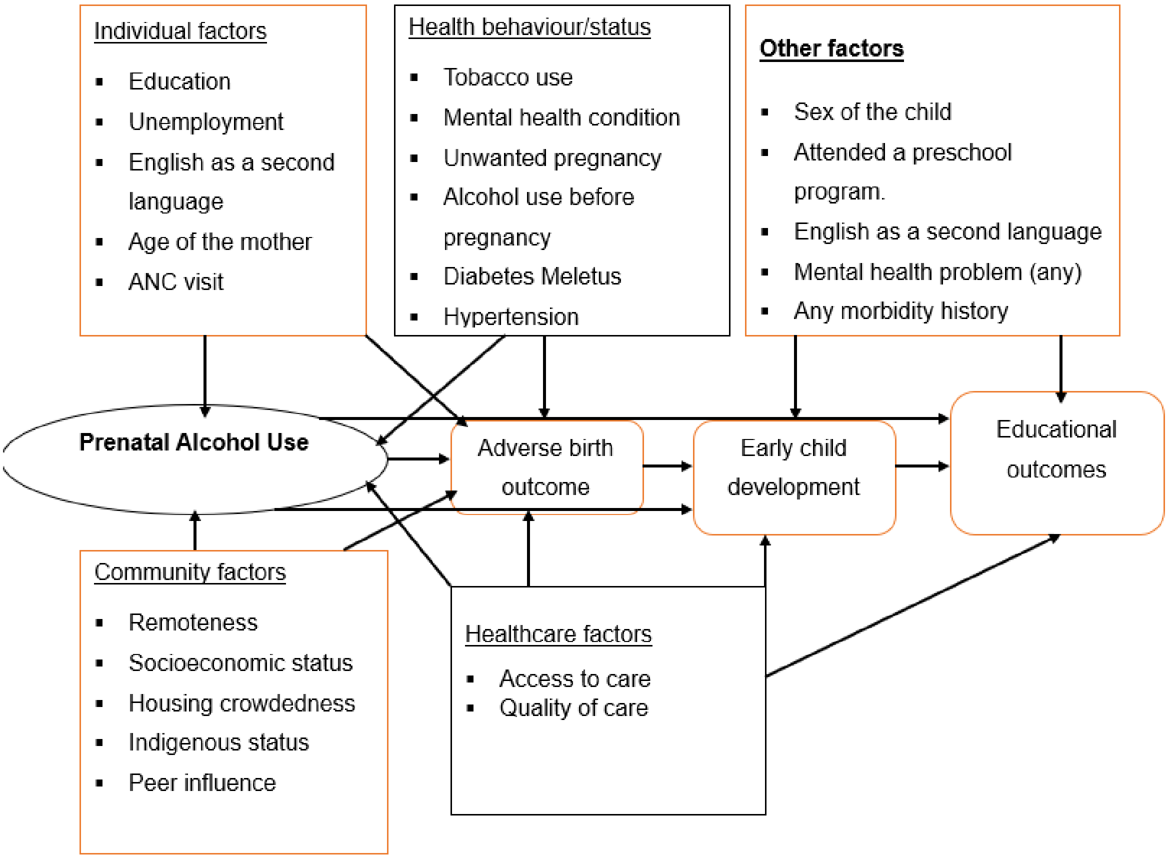

Figure 1: Conceptual framework for the effects of prenatal alcohol use on birth, development, and educational outcomes.

Specific objectives

- To conduct a comprehensive review of the worldwide prevalence, trends, and adverse consequences of PAU.
- To assess the prevalence of PAU and its associated factors among pregnant mothers in the Northern Territory.
- To explore the trends in the prevalence of PAU and its factors associated with pregnant mothers in the Northern Territory.
- To assess the association between PAU and birth outcomes in the Northern Territory.
- To assess the association between PAU and early child development in the Northern Territory.

- To assess the association between PAU and educational outcomes in the Northern Territory.

Methodology

Study setting.

The Northern Territory (NT) is in the northern and central parts of Australia, with the Australian states of Western Australia to the west, South Australia to the south, and Queensland to the east. The Timor Sea and the Arafura Sea are to the north. The NT covers an area of 1,349,129 square kilometres [50]. In 2021, the estimated population of the NT was 248,151, with nearly equal distribution of males (50.5%) and females (49.5%) [51] and a large proportion (30.8%) of Aboriginal peoples [51]. Four of Australia's ten poorest local government areas (LGAs) are in the NT [52].

Government-funded public hospitals provide tertiary healthcare services in the six major towns of Darwin, Palmerston, Alice Springs, Nhulunbuy, Katherine, and Tennant Creek. Despite ongoing investment, persistent health issues, including excessive alcohol consumption, remain a concern [53–55]. According to the National Drugs Strategy Household Survey of 2016, more than one-third of women (35%) reported drinking alcohol when pregnant [18]. According to the 2017 NAPLAN test results NT students' Year 3 scores were the lowest among all states and territories in Australia, with higher proportions of students' scores below National Minimum Standard (NMS) values (Reading 26%, Writing 26.2%, Spelling 30.4%, Grammar and Punctuation 31%, and Numeracy 21.6%), with Aboriginal student scores lower than non-Aboriginal students [56].

Study design and data source

A systematic review and meta-analysis of databases will be used to review the global PAU's prevalence, trends, and consequences. Retrospective cohort studies will be conducted to explore the association between PAU and adverse birth and child outcomes (development and educational performance). The datasets used in this study will be sourced from a repository of linked administrative datasets set up through the Child and Youth Development Research Partnership (CYDRP)—a collaboration between Menzies School of Health Research and NT Government agencies. The detailed data linkage process has been described elsewhere [57]. South Australia (SA)-NT DataLink carried out the first stage of the data linkage process using a probabilistic linkage method with a clerical review of uncertain matches [58]. The authors will undertake the second stage of linking the separate de-identified data files and preparing a dataset for analysis. We will use the following datasets: NT Perinatal Data Register [59–61], NT Hospital Emergency Department presentations, Hospital admissions [59], Mental Health Collection consultations, Australian Early Development Census (AEDC) [59, 62], NT Government School Attendance and Enrolments [60], National Assessment Program-Literacy and Numeracy (NAPLAN) [60, 61], and NT Deaths Register. The data linkage technique will connect records of the same individual across different datasets using a Project Specific Linkage Key (PSLK).

Selection of cohorts

This project encompasses mothers from the NT and their children. The eligibility criteria are as follows: (I) the mother must be a resident of the NT; (II) the mother must have given birth in the NT in 2000 or later; and (III) the assessment of PAU must have been recorded during antenatal care, emergency department presentation or hospital admission [63].

This project utilises four distinct cohort groups, each aligned with specific study objectives. These groups are (1) women who gave birth in the NT from 2000 to 2017 (for objectives II and III). (2) All births in the NT from 2000 to 2017 (for objective IV). (3) All children registered for AEDC in 2009, 2012, 2015, and 2018 (for objective V). (4) All children in the NT who were registered for the Year 3 NAPLAN test from 2005 to 2018 (for objective VI) (Fig. 2) [63].

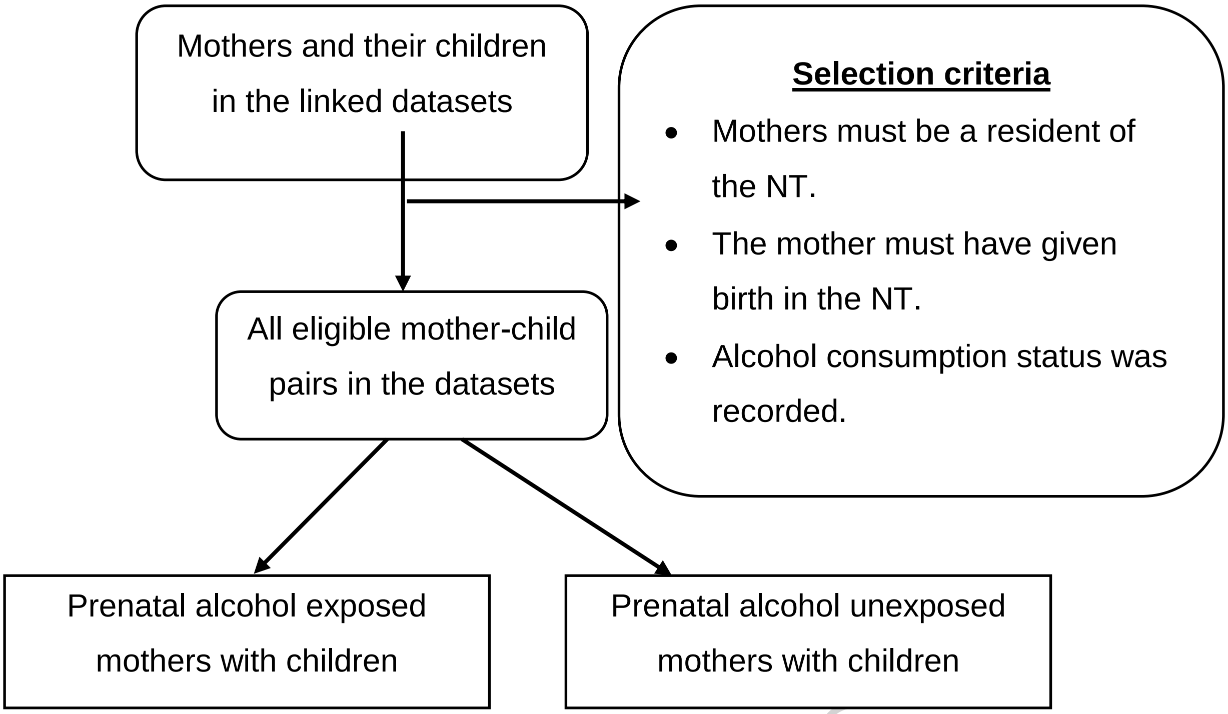

Figure 2: Diagrammatic representation of the selection of study cohorts.

Exposure ascertainment

Prenatal alcohol use is the exposure variable. The perinatal dataset has information about PAU (yes or no) reported for the first antenatal visit and third trimester of pregnancy. Additionally, we will use emergency department presentations and hospital admission records of alcohol-related conditions to supplement the perinatal record of alcohol use. We will categorise pregnant women into two or more exposure groups and test the suitability of exposure classification during the data analysis phase.

The population-attributable fraction (PAF) is a widely used epidemiological measure to assess the extent to which exposures (PAU) contribute to outcomes (birth, development, and education) within a population. We will calculate the PAF for prenatal alcohol use for each outcome variable. Levin's and Miettinen's equation will be employed for the indirect estimation of PAFs, while the average PAF will be directly derived through regression analysis. The PAF formula is derived by dividing the population-attributable risk by the total risk, expressed as (PAR/r). In essence, PAR (r – r0) represents the entirety of the risk (r) minus the risk in the non-exposed group (r0) [64, 65].

Outcome ascertainment

The outcomes are adverse birth, child development and educational outcomes.

Birth outcomes.

Information concerning birth outcomes will be extracted from the NT Perinatal Data Register [59–61] and operationally defined according to established standards. Adverse birth outcomes consist of low birth weight (< 2500gm), preterm birth (babies born before 37 weeks of gestation), and stillbirth (babies born with no signs of life at 20 weeks of gestation or more and weighing 400 grams or more) [66, 67].

Child development

The study uses early developmental assessments from the Australian Early Development Census collections (AEDC). In 2009, the Australian government adopted a survey measuring children's development across five domains. These domains are physical health and well-being, social competence, emotional maturity, language and cognitive skills (school-based), communication skills and general knowledge [68]. The Australian-adopted Early Development Instrument consists of 96 questions across all domains. The questionnaires for assessing AEDC were completed by classroom teachers early in the first year of formal schooling when children are around five years old. During the assessment of each domain, a child was assigned a score ranging from 0 to 10, where a lower value reflects a greater risk of developmental vulnerability. This study will use the AEDC datasets [59, 62] from 2009, 2012, 2015, and 2018 and link AEDC records with records in the NT Perinatal Data Register [59–61] to establish the study cohort. The researchers will aggregate domain-specific scores into a general indicator of children's overall readiness for school learning [62, 69].

This comprehensive measure is categorised into vulnerability summary indicator categories as developmentally vulnerable in one or more domains (DV1) and developmentally vulnerable in two or more domains (DV2). Children assessed as vulnerable in two or more domains have a higher developmental risk and may benefit from additional support in their early schooling [61, 62, 70]. Moreover, the score can be categorised into three groups: a child who scored ten or lower percentile of the total score indicates a child may be developmentally vulnerable (and coded as 1); if scored between 10th – 60th percentile, it suggests the child is developmentally at risk (coded as 2), and a score higher than 60th percentiles shows a child is developmentally on track (coded as 3) [71].

Educational outcomes

This project will assess educational outcomes using NAPLAN, a national academic assessment undertaken by children in Years 3, 5, 7 and 9. These tests cover writing, reading, spelling, grammar, and punctuation and numeracy skills. The test yields raw scores scaled out of 1000. NAPLAN data is available from 2005 to 2018, and this study uses Year 3 NAPLAN results [56, 61, 70, 72]. The researchers will analyse this continuous data using statistical techniques appropriate for scaled measurement.

Explanatory variables

The choice of explanatory variables will be guided by prior research proving an association between specific risk factors and adverse birth, developmental and educational outcomes. Within the NT Perinatal Data register [59–61], variables such as sociodemographic factors (age of the mother, unemployment, English as a second language), maternal characteristics (mother's smoking status, parity, mental health condition), child characteristics (sex of the child, APGAR score at 1', APGAR score at 5'), and community factors (Indigenous status, relative geographic remoteness) are accessible. Additionally, the NAPLAN dataset provides information on variables including student gender, student's Indigenous status, relative geographic remoteness, language background, and parental education [60, 73]. These variables will be assessed for their effects on the outcome variables during model development.

Confounding variables

Potential confounding factors found through a literature review will be tested during analysis. Confounding variables for each aim will be chosen from distinct datasets. For example, we will access factors like age, smoking, diabetes, hypertension, and APGAR scores from the Perinatal Data register [59–61] to evaluate their potential confounding effects. In the case of the NAPLAN dataset, we will consider variables such as age at assessment, attendance, English as a second language, whether a child attended preschool, and year of assessment to evaluate their confounding effect. Furthermore, the researchers will use the AEDC dataset to incorporate community-level factors, encompassing measures of geographic remoteness, housing overcrowding (assessed by average household size and persons per bedroom), and socioeconomic conditions (quantified using Socio-Economic Indexes for Areas (SEIFA)) [74]. Researchers will employ statistical methods, such as multivariate models, including sensitivity analysis, to address these potential confounders [75, 76].

Data analysis plan

Data analysis will involve four steps: (I) Data management, (II) Descriptive (exploratory) data analysis, (III) Inferential data analysis, and (IV) Model adequacy check.

The researchers will clean, code, and prepare the data for analysis. Various data exploration techniques will be utilised, encompassing missing data management and assumption testing. Multiple imputation methods will be deployed to handle data missing at random and 'completely at random' [77, 78]. In this project, the researchers will check all the assumptions based on the nature of the aims and data under study. Some of these assumptions are independence of residuals (graphically), normality of residuals (residual histogram and Q-Q plot), linearity, and homoscedasticity (graphically) will be checked for the trend analysis. Once the assumptions are checked, descriptive statistics will analyse the data. This section summarises the variables in terms of frequency (F), percentage (%), proportion (p), mean, median, standard deviation (SD), interquartile range (IQR), histogram, bar graph, line graph, and frequency distribution table. Then, inferential statistical models will be created based on the aims.

Data analysis for objective 1 (To conduct a comprehensive review of the worldwide prevalence, trends, and adverse consequences of PAU)

The researchers will conduct a systematic review and meta-analysis to combine estimates. The researchers will use preferred reporting items for systematic review and meta-analysis (PRISMA) and MOOSE guidelines. MOOSE (Meta-analysis Of Observational Studies in Epidemiology) is a set of guidelines and a checklist designed to enhance the reporting of systematic reviews and meta-analyses of epidemiological observational studies. Moreover, Population, Exposure, and Outcome (PEO) and Condition, Context, and Population (CoCoPop) mnemonics will be used to define terms, set criteria, and select study types. I-squared statistics will be used to measure the heterogeneity of the studies. The pooled prevalence and their corresponding 95% confidence intervals (CIs) will be calculated assuming the random-effects meta-analyses. Significant findings will be visually represented using forest plots, and the researchers will create funnel plots to explore the possibility of publication bias.

Data analysis for objective 2 (To assess the prevalence and associated factors of PAU in the Northern Territory)

A regression model will be employed to estimate the prevalence of PAU and understand the associated factors. For this purpose, the outcome variable can be categorised into two groups (Yes/No) or more (ranging from high to no exposure). This categorisation allows for the consideration of various scenarios, and thus, different regression techniques may come into play, such as logistic regression, ordinal logistic regression, or multinomial logistic regression.

In each of these scenarios, the researchers will conduct a comprehensive assessment of key assumptions. These include evaluating the proportional odds assumption (the relationship between the independent variables and the odds of a higher response category versus a lower one is constant across all levels of the ordinal dependent variable), ensuring the independence of observations, confirming the linearity of log odds, checking for the absence of multicollinearity, verifying there's no perfect prediction, and ensuring the sample size is sufficient for reliable results.

Odds Ratios (OR) and 95% Confidence Intervals (CIs) will be calculated to determine the association between PAU and the covariates. This measure of the association will give insights into the strength of the association between PAU and the various factors being studied.

Data analysis for objective 3 (To explore the trends and associated factors in the Northern Territory)

The researchers will perform a trend analysis to investigate the prevalence of PAU over time and the factors associated with any changes. Linear regression analysis will be used to determine the patterns of prenatal alcohol use over time. This analysis helps to identify the linear trends, patterns, or changes in prenatal alcohol use over a specific period (2000 to 2017). At the end of the trend analysis, we will report upward (increasing), downward (decreasing), or fluctuation patterns over time. Moreover, we will also examine whether the trend is linear or non-linear, such as exponential, cyclic, seasonal, or irregular.

The findings will be visually presented through trend analysis, employing various graphical representations such as line charts and time series plots. These visual tools will help show the observed trends and their associations effectively.

Data analysis for objective 4 (To assess the association between PAU and birth outcomes)

The researchers will employ a suitable statistical model to assess the association between PAU and birth outcomes. For example, when categorising the outcome variable into binary groups, such as low birth weight (1 for Yes, 0 for No), preterm birth (1 for Yes, 0 for No), and stillbirth (1 for Yes, 0 for No), a log-binomial regression model will be applied. Log-binomial models provide a suitable choice for epidemiologists to elucidate the connection between a group of factors and a binary outcome when the desired summary metric is a relative risk [79]. It extends the logistic regression model by representing the log odds of the binary outcome as a linear combination of predictor variables. This model is beneficial when the variable is infrequent, and the logistic regression model may not give accurate estimates.

On the other hand, if we treat the outcome variable as continuous, we will apply a multiple linear regression model to the data. For example, a multiple linear regression model will be employed in cases involving continuous outcome variables like birth weight and gestational age. The model selection assumes it will be checked during data analysis time.

Data analysis for objective 5 (To assess the association between PAU and early child development)

To assess the relationship between prenatal alcohol use (PAU) and child development, we will employ Generalized Estimating Equation (GEE) logistic regression. In this analysis, the outcome variable, child development, will be categorised into two groups: 'developmentally vulnerable in one or more domains (DV1) (Yes/No) and developmentally vulnerable in two or more domains' (Yes/No). GEE logistic regression enables estimating population-averaged effects while accounting for the inherent data clustering, giving robust standard errors. We will calculate the odds ratio and their 95% confidence intervals.

Data analysis for objective 6 (To assess the association between PAU and educational outcomes)

The researchers will use a Generalized Estimating Equation (GEE) multiple linear regression model to investigate the relationship between PAU and educational outcomes, specifically the Year 3 NAPLAN score, a continuous variable. GEE multiple linear regression model enables us to estimate population-averaged effects while accounting for the clustering structures within the data, supplying robust standard errors.

To ensure the validity of the multiple linear regression model, we will assess the normality of the dependent variable, the linearity of variables, homoscedasticity, and the absence of outliers. In the variable selection process, we will use a significance level of $p < 0.2$ for initial inclusion in the multivariable analysis [80]. Statistical significance will be declared at a p-value <0.05 within a 95% confidence interval (CI).

To control for potential confounding effects, the researchers will implement a multivariable model adjusted for various sociodemographic, community, and behavioural factors. Finally, a model adequacy check will evaluate the model's goodness of fit. The data analysis and interpretation will be conducted using STATA 17 software [81].

Communication plan

Throughout this study, the researchers will communicate the progress with stakeholders, including the First Nation Advisory Group (FNAG), Menzies School of Health Research, Charles Darwin University, and the NT Government. The researchers will report the findings of this project through journal publications, seminar presentations and national and international conferences. The results of this project will be presented/published in plain language summary reports for distribution to the policymakers and other stakeholders, including governmental and non-governmental organisations working on alcohol-related problems, maternal and child health, child development, and education.

Discussion

The study will generate critical evidence concerning the impact of prenatal alcohol use on birth, development, and educational outcomes in the Northern Territory of Australia. This evidence will inform practical guidelines for healthcare professionals, researchers, and program developers in maternal and child health, development, and education. Likewise, public health experts will rely on this evidence to craft interventions to mitigate problems related to prenatal alcohol use.

Prior research has presented inconsistent and narrowly focused findings concerning early development and educational outcomes. This study addresses these shortcomings using advanced data analysis techniques and a larger sample size. Specifically, it will examine the association between prenatal alcohol use and early child development using the Australian Early Development Census (AEDC) data and the association between prenatal alcohol use and educational performance using the National Assessment Program—Literacy and Numeracy (NAPLAN) results. The researchers will delve into all domains within AEDC and NAPLAN, employing both descriptive and analytical approaches to understand how prenatal alcohol use affects each domain. This comprehensive analysis will inform the development of targeted interventions for these domains.

Conclusions

The evidence produced in this project will benefit stakeholders by guiding the design of appropriate interventions. Furthermore, the comprehensive analysis provides insights for other researchers in related fields, enabling them to develop studies, programs, and projects to enhance health, education, and child development initiatives.

Abbreviation and acronyms

ABS: Australian Bureau of Statistics; **AEDC**: Australian Early Development Census; **ADHD:** Attention-deficit/hyperactivity Disorder; **ANC:** Antenatal Care; **APGAR:** Appearance, Pulse, Grimace, Activity, and Respiration; **ARBD:** Alcohol-Related Birth Defect; **ARIA+:** Accessibility and Remoteness Index of Australia (Plus)**; AUDIT-C:** Alcohol Use Disorders Identification Test; **CINAHL:** Cumulative Index to Nursing and Allied Health Literature; **COVID-19:** Corona virus, 2019; **CYDRP:** Child and Youth Development Research Partnership; **GEE:** Generalized Estimating Equations; **IRSD:** Index of Relative Socio-economic Disadvantage; **LBW:** Low Birth Weight; **LCT:** Life Course Theory; **LGA:** Local Government Area; **MAR:** Missing at Random; **MCAR:** Missing Completely at Random; **NAPLAN:** National Assessment Program-Literacy and Numeracy; **PAU:** Prenatal Alcohol Use; **PTB:** Preterm Birth; **SGA:** Small for Gestational Age; **VIF:** Variance Inflation Factor.

Declaration

Ethics and data security

The research processes are subject to ethical approval (NT HREC Reference Number: 2024-4852) from the Human Research Ethics Committee of the Northern Territory Department of Health and Menzies School of Health Research, including the Aboriginal Health Research Subcommittee. The researchers will maintain the confidentiality of the data during data management, analysis, and interpretation. Data security measures governing the use of data for this study will be managed under the protocols of the Child and Youth Development Research Partnership (CYDRP). The measures include protecting data from unauthorised bodies through passwords and firewalls, using secured servers administered by Menzies School of Health Research, and using de-identified records. The research team will complete a formal agreement outlining the roles and responsibilities of the research team relating to data access, data extraction, confidentiality, intellectual property, and research dissemination.

Consent for publication.

Not applicable.

Availability of data and materials

Not applicable.

Acknowledgements

We thank the Child and Youth Development Research Partnership (CYDRP) Steering Committee for approving access to the linked administrative datasets. We also express our gratitude to Professor Gary Robinson, Head of the Centre for Child Development and Education at the Menzies School of Health Research, for supporting and guiding us through the development of this project proposal.

Funding

BD's doctoral thesis is the primary focus of this project, for which he receives financial support from the Menzies School of Health Research and Charles Darwin University in the Northern Territory, Australia. We also acknowledge the NT Government's commitment to supporting the CYDRP project.

Author contributions

BTD, AFD, and SG played a substantial role in the study, including contributing to the study design, data request, and analysis plan. They have drafted, revised, and critically reviewed the protocol. The authors have approved the final version of the protocol and accept responsibility for all aspects of the work.

Competing interests

The authors declare they have no competing interests.

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Supplementary materials

Figure 1: Conceptual framework for the effects of prenatal alcohol use on birth, development, and educational outcomes.

Figure 2: Diagrammatic representation of the selection of study cohorts.