BMC Pregnancy and Childbirth

https://doi.org/10.1186/s12884-026-09000-9

Article in Press

Trends in prenatal alcohol use from 2001 to 2017 in the Northern Territory, Australia: a joinpoint regression analysis

Received: 24 December 2025

Accepted: 23 March 2026

Published online: 25 March 2026

Cite this article as: Derseh B., Dadi A., Phan H. *et al.* Trends in prenatal alcohol use from 2001 to 2017 in the Northern Territory, Australia: a joinpoint regression analysis. *BMC Pregnancy Childbirth* (2026). https://doi.org/10.1186/s12884-026-09000-9

Behailu Derseh, Abel Dadi, Hoang Phan, Holger W Unger, Kiarna Brown, Demeke Mesfin Belay & Steven Guthridge

Trends in prenatal alcohol use from 2001 to 2017 in the Northern Territory, Australia: A joinpoint regression analysis

Behailu Derseh[1,2*], Abel Dadi[1,3], Hoang Phan[1], Holger W Unger[4,5,6,7], Kiarna Brown[7,8], Demeke Mesfin Belay[1,9], Steven Guthridge[1]

[1] Centre for Child Development and Education, Menzies School of Health Research, Charles Darwin University, Darwin, Northern Territory, Australia.

[2] Department of Public Health, Asrat Woldeyes Health Science Campus, Debre Berhan University, Debre Berhan, Ethiopia.

[3] Addis Continental Institute of Public Health, Addis Ababa, Ethiopia

[4] Global and Tropical Health Division, Menzies School of Health Research, Charles Darwin University, Darwin, NT, Australia

[5] Department of Infectious Diseases, University of Melbourne, The Doherty Institute, Melbourne, VIC, Australia

[6] Department of Clinical Sciences, Liverpool School of Tropical Medicine, Liverpool, UK

[7] Department of Obstetrics and Gynaecology, Royal Darwin Hospital, Darwin, NT, Australia

[8] Child and Maternal Health Division, Menzies School of Health Research, Charles Darwin University, Darwin, NT, Australia

[9] College of Health Science, Debre Tabor University, Debre Tabor, Ethiopia

*Correspondence: behailu.derseh@menzies.edu.au

Abstract

Background: Prenatal alcohol use (PAU) is a risk factor for many adverse maternal, fetal, and child health outcomes. In Australia, a range of interventions have been implemented in recent decades to reduce the harms associated with alcohol consumption during pregnancy. While there is evidence of a national decline in the prevalence of PAU, there is limited information on changes in the Northern Territory (NT). This study aims to estimate the trends in PAU among NT Aboriginal and non-Aboriginal women.

Methods: We used de-identified, individual-level linked records from perinatal care, hospital admissions and emergency department (ED) presentations to estimate trends in PAU for all births to NT women between 2001 and 2017. We classified PAU into "No PAU" (a record of no alcohol consumption in pregnancy) and "any PAU" (a record of alcohol consumption in pregnancy). Sub-categories of any PAU included "Early PAU" (a record of alcohol use in early pregnancy only), "Continued PAU" (a record of alcohol use in early and late pregnancy), "Extreme PAU" (a record of hospital admission or ED presentation with an alcohol-related diagnosis during pregnancy), and "Unknown PAU" (insufficient information). We used a joinpoint regression model to estimate the Annual Percentage Change (APC) with 95% confidence intervals (CI).

Result: There were 63,081 births to 39,075 NT mothers (11,723 Aboriginal and 27,352 non-Aboriginal). For all births, from 2001 to 2017, there was a 5% annual decrease in PAU prevalence (APC: -5.2; 95% CI: -6.3, -4.3), with variations in trend by Aboriginal status and PAU category. For births to Aboriginal women, there was no evidence of overall change in annual PAU prevalence (APC: -0.6; 95%CI: -1.8, 0.6), no change in early PAU (APC: 1.1; 95%CI: -0.5, 2.8), a decrease in continued PAU (APC: -4.5; 95%CI: -6.4, -2.7), and an increase in extreme PAU (APC:10.7; 95%CI: 7.7, 15.7). For births to non-Aboriginal women, there was a decline in any PAU prevalence (APC: -10.7; 95%CI: -13.1, -9.1), early PAU (APC: -8.9; 95%CI: -11.4, -7.1) and continued PAU (APC: -13.9; 95%CI: -17.2, -11.84). On average, 17.9% of births had unknown PAU values (23.1% births to Aboriginal and 14.9% births to non-Aboriginal women), with a trend toward improved capture of PAU for births to Aboriginal women only (APC: -1.8; 95%CI: -2.9, -0.9).

Conclusion: This study highlights the prevalence of PAU in the NT is decreasing disproportionately among Aboriginal and non-Aboriginal women. The general decline in PAU among NT non-Aboriginal women is consistent with national trends. However, the mixed results for Aboriginal women, and particularly the marked increase in the extreme PAU category, emphasise the need for a more targeted approach to reduce PAU in this population. Additionally, improvements in recording alcohol use at antenatal care visits can enhance data quality and support more effective interventions.

Keywords: Alcohol, Preconception, Pregnancy, Joinpoint Regression, Smoking, Trends

Introduction

The adverse effects of prenatal alcohol use (PAU) have been widely reported and include multiple health and social problems for both the mother and child [1]. PAU can cause fetal alcohol spectrum disorders (FASD), a diagnostic term that is used to describe the diverse and lifelong developmental effects that exposure to alcohol during pregnancy has on the developing fetus [2–8], as well as other harms such as spontaneous abortion, stillbirth [6, 9–11], preterm birth [10, 11], low birthweight [10, 12], small for gestational age [11–13], congenital anomalies [4], developmental impairment [14], and learning disabilities [6, 15–17]. Globally, an estimated 10% of all pregnancies are exposed to PAU [1]. Understanding the patterns in the annual prevalence of PAU is critical to an effective response to reduce prenatal alcohol exposure.

The Australian Government has been working to reduce harms related to alcohol during pregnancy. In 2001, the National Health and Medical Research Council (NHMRC) guidelines to reduce harms related to alcohol during pregnancy emphasise avoiding intoxication and recommend fewer than seven standard drinks per week, and no more than two standard drinks on any one day [18]. In 2009, Australia revised the national alcohol guidelines, recommending that pregnant women abstain entirely from consuming alcohol [19]. This guideline was designed to reduce PAU and its associated harms by informing women about alcohol associated risks, encouraging abstinence, and guiding healthcare providers to promote safe practices [2, 19, 20]. Notably, the most recent national guidelines (2020) continue to reinforce the message that there is no safe level, time, or type of alcohol consumption during pregnancy [2, 21, 22]. In 2022, Australia introduced mandatory pregnancy warning labels on alcoholic beverages, as required by national food standards [23]. The launching of the “Every Moment Matters” public awareness campaign to increase the understanding of “no alcohol during pregnancy, planning pregnancy, and breastfeeding is the safest option” in 2021 was an additional effort that intended to reduce alcohol-related harms [24]. In the Northern Territory (NT), while there have been no specific interventions to respond to PAU, reducing alcohol-related harm in the general population has been a long-standing public health focus. Beginning with the NT Liquor Act in 1979 and followed by the Living with Alcohol (LWA) program in 1992, there has been a continuing stream

of initiatives designed to reduce alcohol-related harm, which may have contributed to declines in both acute and chronic alcohol-related morbidity and mortality [21, 22, 25], including alcohol-related injury and hospitalisations [26].

In Australia, the annual prevalence of PAU declined from 2001 to 2016. The most significant decline was observed from 2001 to 2010, where PAU dropped from 44% to 20% [27]. After 2010, alcohol use after pregnancy recognition plateaued, while pre-recognition use declined by half from 44.6% in 2010 to 22.9% in 2016 [27]. Between 2020 and 2023, the national annual prevalence of PAU in the first 20 weeks of pregnancy remained low (2.3%–2.6%), while higher rates were reported in the Northern Territory (NT) (3.4%–4.4%) [28]. In a separate study, PAU prevalence for births in the NT, across five years (2013 - 2017), was reported to be 5.7%, with a marked disparity between Aboriginal (13%) and non-Aboriginal women (2.3%) [29]. This estimate was based on alcohol use reported at the first antenatal care visit, at 36 weeks of gestation, and from alcohol-related hospital admissions and emergency department presentations [29].

Previous Australian studies have estimated the annual prevalence of PAU and have reported trends [30, 31]. However, they have a number of limitations. First, they have not provided results for the NT, and only one has provided estimates for Aboriginal and Torres Strait Islander women [32]. There have also been limitations in sample size and coverage [32] and response rate [30, 31]. All previous studies have relied on a single survey or national datasets to estimate PAU prevalence and trends. These limitations have prevented an accurate assessment of PAU trends in the NT, particularly among Aboriginal women, including the assessment of the impact of national and local interventions to reduce PAU. Therefore, this study aims to examine long-term trends in the annual prevalence of PAU, by risk category, for births to NT Aboriginal and non-Aboriginal women.

Methods and materials

Study design and setting

This is a retrospective study using linked, individual-level data from three NT administrative datasets: the NT Perinatal Data Register, the NT Emergency Department Activity dataset, and the NT Hospital Inpatient Activity dataset [33–35].

The data linkage technique linked birth records from 2001 to 2017, with admission and emergency department (ED) records for mothers. We included records from 2001 to 2017 in our trend analysis and excluded earlier birth records because NT hospital admission data began in April 2000 and ED presentation data in July 2000; therefore, 2001 was the first complete year for prevalence calculation (Figure 1).

We obtained the data from a repository developed through a collaboration between the Menzies School of Health Research and NT Government agencies - the Child and Youth Development Research Partnership [36]. The NT Perinatal Data Register, established in 1986, contains detailed records of antenatal care and birth outcomes for all births in the NT (of ≥20 weeks' gestation or birthweight ≥400g). We used NT hospital admission and ED datasets to identify maternal admissions and ED presentations for: alcohol-related, mental health-related and substance misuse-related conditions (including current tobacco use, psychoactive substances, poisoning by noxious substances, medications, and other drugs) (Supplementary Table 1b); and all forms of violence during pregnancy and in the year before pregnancy. Diagnoses were classified in the datasets using the International Classification of Diseases and Related Conditions, 10th Revision, Australian Modification (ICD-10-AM) [37] (Supplementary Table 1a & 1b) [29].

The NT is a sparsely populated, self-governing jurisdiction in the north and central parts of Australia, with a population of 250,700 and a land area of 1,346,200km² [38]. The NT Aboriginal population are approximately 30.8% of the total NT population, of whom 80% live in rural or remote areas [39]. There were five public and one private hospital that provided maternity services during the study period. In addition to healthcare services, including antenatal care, are provided through a network of government and non-government services, including government primary care services, Aboriginal Community Controlled Health Organisations (ACCHOs), and private practitioners [38, 40].

Study variables

Prenatal Alcohol Use (PAU) is the dependent variable, and we show its change over time among births to Aboriginal and non-Aboriginal women. As described previously and presented in Supplementary Table 2 [29], a permutation analysis technique was

used to classify information on alcohol use recorded in early and late pregnancy in the perinatal dataset, and in hospital admission and ED presentation records, into a 36-combination matrix [29]. This matrix was then collapsed into five PAU categories (No PAU, Early PAU, Continued PAU, Extreme PAU, and Unknown PAU). Births to women who had a perinatal record of no alcohol consumption during pregnancy and no admissions or ED presentations with a diagnosis of an alcohol-related condition during pregnancy were categorised as “No PAU”. Births to women with a record of alcohol consumption at the time of their first antenatal care visit only were classified under the “Early PAU” category. Births to women who had a perinatal record of alcohol consumption at 36 weeks of gestation or both the first antenatal visit, and the 36-week antenatal visit) were categorised under the “Continued PAU” category. Births to women with any hospital admission or ED presentation during the specified pregnancy with a diagnosis of an alcohol-related condition were classified under the “Extreme PAU” category. The ICD-10-AM diagnosis codes for alcohol related conditions are alcohol abuse (F10.0, F10.1), alcohol dependence syndrome (F10.2), and alcoholic psychosis (F10.3 – F10.9), as well as alcohol-related diseases such as alcoholic gastritis (K29.2), alcoholic liver disease (K70.0 - K70.4, K70.9), alcohol-induced acute pancreatitis (K85.2), and alcohol poisoning (Y15) [37]. Births to women with insufficient information to categorise into one of the above four categories were classified as “Unknown PAU” (Supplementary Table 2) [29].

The independent variables used in this study were Aboriginal status of the mother (0 for non-Aboriginal women, and 1 for Aboriginal women), mother's age (continuous), number of antenatal care visits (coded as 0 for zero visits, 1 for 1-4 antenatal care visits, 2 for five or more antenatal care visits, and 3 for missing), parity (0, 1, and 2+), smoking (0 for non-smokers, 1 for smokers, and 2 for missing), substance misuse-related hospitalisation (0 for No, and 1 for Yes), mental health-related hospitalisation (0 for No, and 1 for Yes), violence (0 for No, and 1 for Yes), and self-harm (0 for No, and 1 for Yes). Information about age, antenatal care visits, smoking, and Aboriginal status of the mother originated from the NT Perinatal Registry dataset. For consistency, mothers whose Aboriginal status varied across pregnancies were defined using the “ever” Aboriginal classification [41]. Substance misuse-related hospitalisation, mental health-related hospitalisation and hospitalisation for violence and self-harm in the 12 months prior to or during pregnancy were extracted from the

NT hospital admission and ED presentation datasets using the ICD-10-AM diagnosis codes (Supplementary Table 1a & 1b) [29].

Data management and analysis

To understand the patterns of change in PAU, we estimated trends in annual prevalence for the following populations: (I) PAU trends for all births, (II) PAU trends for births to Aboriginal and non-Aboriginal women, and (III) PAU trends for births to Aboriginal and non-Aboriginal women by PAU category.

The prevalence of PAU in each category was calculated for each year between 2001 and 2017. Then, the year, the prevalence of PAU (proportion), and the standard error of the proportion [42], were exported to the Joinpoint Regression Program (version 4.5.0.0) [43]. Joinpoint regression uses the Annual Percentage Change (APC) to quantify changes in annual prevalence at each identified turning point (TP) or joint point. The choice of Joinpoints was based on a Monte Carlo permutation method, which reports both a best-fit line and a test of statistical significance [43–45].

A chi-square test of independence and cross-tabulation were used to evaluate the relationship between categorical variables for births to Aboriginal and non-Aboriginal women [46]. We applied a binary logistic regression model with restricted cubic splines to adjust the trend in PAU, stratified by Aboriginal status [47–49]. Restricted cubic splines are used to model non-linear associations in regression. They divide the range of a variable into intervals and fit smooth curves between the knots (or joinpoints). The number of splines is calculated as *k–1*, where *k* is the number of knots, chosen using the Joinpoint regression model with the Monte Carlo permutation method [48–50]. We used predictive margins and plots to estimate adjusted probabilities. We also used a postestimation command (xblc) in Stata to compute odds ratios and 95% confidence intervals for spline-transformed years, allowing for the interpretation of the non-linear relationship between the year of birth (cubic splines) and changes in PAU prevalence [51]. Multicollinearity [52] was checked using the Variance Inflation Factor (VIF > 10). We used STATA (Stata/MP 17.0 for Windows) software [53] for analysis. The threshold for statistical significance was set at an alpha level of 0.05.

Missing data management

We examined the characteristics of records with Unknown PAU in the datasets and compared them with those of complete PAU records using a frequency distribution table. The distribution of covariates between Unknown PAU and complete PAU records was homogeneous. Thus, this trend analysis, including logistic regression and restricted cubic spline models, and adjusted odds ratio, was a complete case analysis, as the impact of missing data on model coefficients was minimal [54]. A detailed description of the missing variables is presented in a table (Supplementary Table 3).

Results

There were 69,968 birth records in the NT from 2000 to 2017. After excluding 6,101 records, including births to non-NT resident mothers (1,523) and births in 2000 (3,472), the study cohort comprised 63,081 births to 39,075 NT resident mothers (11,723 Aboriginal and 27,352 non-Aboriginal) from 2001–2017 (Figure 1). Most babies (81.6%) were born in one of five public hospitals, while approximately 18% were born in a single private NT hospital. Most births (87.9%) were to women who attended five or more antenatal care visits. The average maternal age at delivery was 27.8 years (±6.3) (Table 1). Among all births, 23,285 (36.9%) were born to Aboriginal mothers. Most pregnancies (98.7%) were singletons. Overall, 27% (95%CI: 26.8, 27.5) of births were to mothers who smoked during pregnancy (Table 1).

Hospital admissions of women related to substance misuse, mental health conditions, experience of violence, and self-harm were documented in 1.4% (95% CI: 1.3–1.5), 1.2% (95% CI: 1.1–1.3), 2.2% (95% CI: 2.1–2.4), and 0.3% (95% CI: 0.2–0.3) of births, respectively (Table 1). The proportion of women with admission with these conditions was higher among Aboriginal women than non-Aboriginal women ($p<0.001$) (Table 1). In analysis, 17.9% of births had Unknown PAU data (22.9% and 14.9% for births to Aboriginal and non-Aboriginal women, respectively), 1.3% missing data on antenatal care visits (2.3% and 0.7% for births to Aboriginal and non-Aboriginal women, respectively), and 9.1% had missing smoking status (13.3% and 6.7% for births to Aboriginal and non-Aboriginal women, respectively) (Table 1).

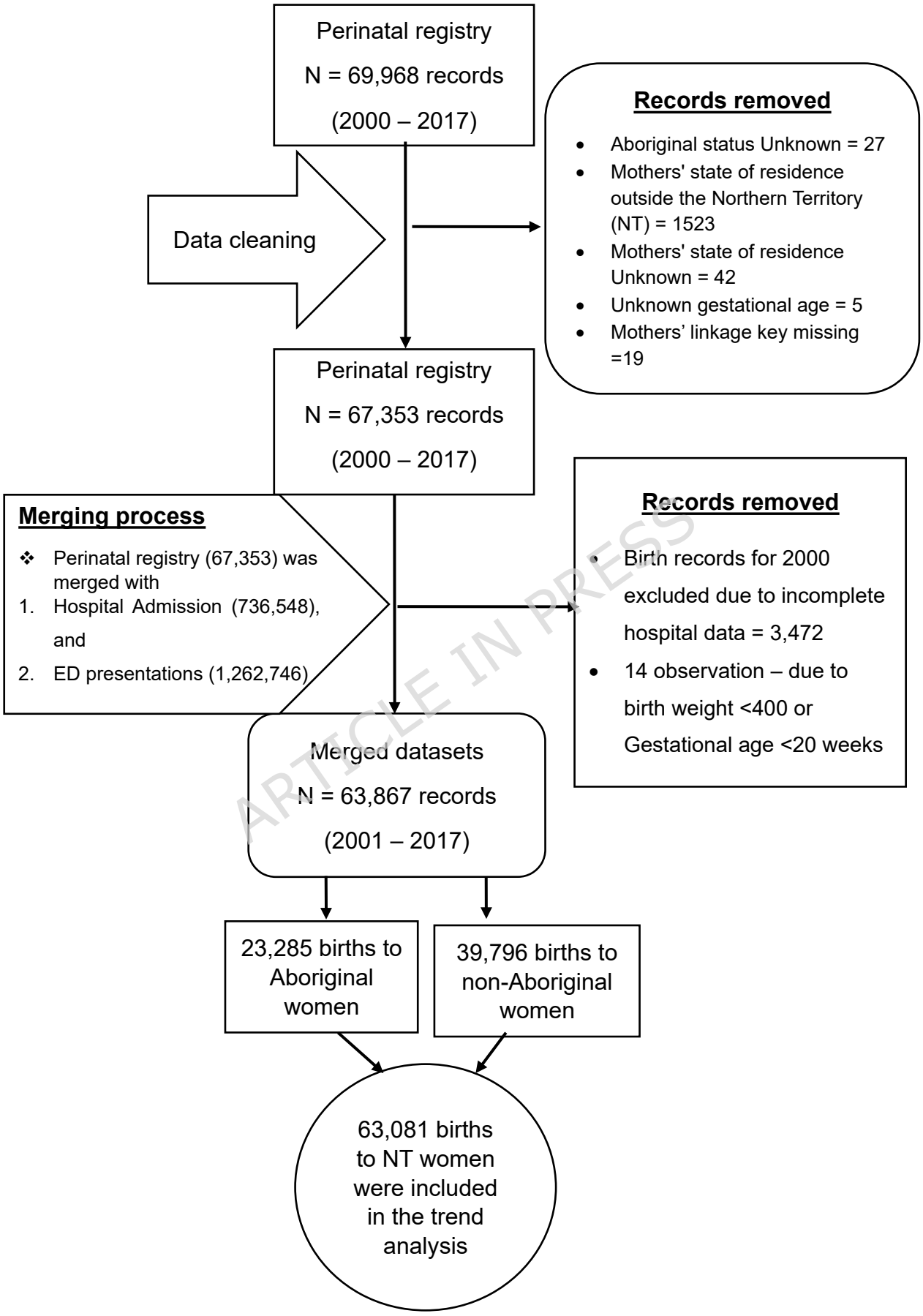


Figure 1: Study cohort selection.

Table 1: Maternal sociodemographic and behavioural characteristics between 2001 – 2017 to NT mothers– (n = 63,081).

Variables	Births to Aboriginal women (N=23,285) N (%)	Births to non-Aboriginal women (N=39,796) N (%)	All births in NT (N=63,081) N (%)
Age of mother at delivery			
Less than 20 Years	5,369 (23.0)	1,283 (3.2)	6,652 (10.6)
20 – 24 years	7,353 (31.6)	5,976 (15.0)	13,329 (21.1)
25 – 29 years	5,509 (23.7)	11,580 (29.1)	17,089 (27.1)
30 – 34 years	3,350 (14.4)	12,900 (32.4)	16,250 (25.8)
35+ years	1,704 (7.3)	8,057 (20.3)	9,761 (15.5)
Antenatal care visits			
Zero visits	478 (2.1)	253 (0.6)	731 (1.2)
1 – 4 visits	4,203 (18.1)	1,873 (4.7)	6,076 (9.6)
5+ visits	18,053 (77.5)	37,407 (94.0)	55,462 (87.9)
Missing	551 (2.3)	261 (0.7)	812 (1.3)
Plurality count			
Singleton	23,035 (98.9)	39,250 (98.6)	62,285 (98.7)
Twins and Triplets	250 (1.1)	546 (1.4)	796 (1.7)
Parity			
0	7,414 (31.8)	17,736 (44.6)	25,150 (39.9)
1	5,901 (25.4)	13,134 (33.0)	19,035 (30.2)
2+	9,970 (42.8)	8,926 (22.4)	18,896 (29.9)
Smoking status of mothers			
Non-smoker	9,954 (42.8)	31,760 (79.8)	41,714 (66.1)
Smoker	10,242 (43.9)	5,366 (13.5)	15,608 (24.8)
Missing	3,089 (13.3)	2,670 (6.7)	5,759 (9.1)
Substance misuse-related hospitalisation			
Yes	705 (3.0)	148 (0.4)	853 (1.4)
No	22,580 (97.0)	39,648 (99.6)	62,228 (98.6)
Mental health-related hospitalisation			
Yes	380 (1.6)	385 (1.0)	765 (1.2)
No	22,905 (98.4)	39,411 (99.0)	62,316 (98.8)
Hospital admission for all forms of violence			
Yes	1,088 (4.7)	322 (0.8)	1,410 (2.2)
No	22,197 (95.3)	49,474 (99.2)	61,671 (97.8)
Hospital admission for self-harm			

Yes	106 (0.5)	58 (0.2)	164 (0.3)
No	23,179 (99.5)	439,738 (99.8)	62,917 (99.7)

Trends in the annual prevalence of prenatal alcohol use (2001 – 2017)

Trend of PAU among all women

For births to all women, there was a decline in any PAU from 10.9% in 2001 to 6.2% in 2017 (AAPC: –5.2; 95%CI: –6.2, –4.2; p < 0.001). (Table 2 and Supplementary Table 4a).

Trends of PAU among Aboriginal women

The trend in the prevalence of any PAU for births to Aboriginal women fluctuated over time — stable from 2001–2003, rising by 3.3% annually from 2003–2009, declining by 6.1% from 2009–2014, and increasing again by 7.5% from 2014–2017 — showing no evidence of an overall change (AAPC: –0.7; 95%CI: –1.8, 0.4; p = 0.19) (Table 2 & Supplementary Figure 2). There was no evidence of annual change in "Early PAU" (APC: 1.1; 95% CI: -0.5, 2.8; p = 0.16) (Table 2 and Supplementary Figure 3). The prevalence of "Continued PAU" decreased from 9.2% in 2001 to 4.2% in 2017, with the annual decrement of 4.7% (APC: -4.5; 95%CI: -6.6, -2.8; p <0.001) and the most significant decline occurring between 2009 and 2013. By contrast, the prevalence of "Extreme PAU" rose from 1% in 2001 to 3.3% in 2017, with the annual increment of 10.6% (APC = 10.6; 95%CI: 7.7, 15.3; p < 0.001) (Table 2, Supplementary Figures 4 and 5). Moreover, during the study period, the proportion of "Unknown PAU" decreased from 27.4% in 2001 to 20.3% in 2017, with the annual decrement of 1.9% among births to Aboriginal women (AAPC = -1.9; 95% CI: -2.9 to -0.9; p < 0.001) (Supplementary Table 4e & Supplementary Figure 6).

Trends of PAU among non-Aboriginal women

The trend in the annual prevalence of any PAU among births to non-Aboriginal women decreased from 8.3% in 2001 to 2.3% in 2017, with an annual decrease of 10.7% (AAPC: -10.7; 95%CI: –12.6, –8.7; p < 0.001). (Table 2, Supplementary Table 4a, and Supplementary Figures 7). There was a marked decline in "Early PAU" from 4.2% in 2001 to 1.6% in 2017, with the annual decrement of 8.9% (APC: -8.9; 95%CI: -10.9, -6.9; p < 0.001). There was also a decline in "Continued PAU" from 4.0% in 2001 to 0.6% in 2017, with the annual decrement of 13.7% (APC: -13.7; 95%CI: -16.2, -11.1;

p < 0.001). The most significant declines in Continued PAU occurred between 2004 and 2011. The number of births classified in the "Extreme PAU" category was too small to reliably estimate the trend (Table 2, Supplementary Figures 8 and 9). During the study period, there was no evidence of change in “Unknown PAU” among non-Aboriginal women (AAPC = 1.2; 95% CI: -0.5 to 2.9; p=0.14) (Supplementary Figure 10).

Table 2: Annual percentage change (APC), from 2001 to 2017, in the prevalence of PAU for births to Northern Territory women, by Aboriginal status and risk category.

Trends of PAU		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	AAPC
All births in the NT	Any PAU (APC)	-1.6%						-7.4%					-9.6%			+4.2%			-5.2%*
Births to Aboriginal women	Any PAU	-8.3%			+3.3%						-6.1%					+7.5%			-0.7%
	Early PAU	+0.9%								+6.6%			-9.2%			+10.7%			+1.1%
	Continued PAU	-7.6%*				+3.9%*					-17.6%*				+2.4%				-4.7%*
	Extreme PAU	-22.6%			+7.7%			+27.6%			+9.0%								+10.6%*
Births to non-Aboriginal women	Any PAU	+8.1%			-6.6%			-19.5%			-9.8%*								-10.7%*
	Early PAU	+11.9%			-5.8%			-18.0%			-7.3%*								-8.9%*
	Continued PAU	+2.7%					-16.0%*						-29.5%			+9.6%			-13.7%*

Note: Table 2 summarises results from 8 joinpoint regression models, stratified by Aboriginal status and PAU levels. Asterisk (*) shows statistical significance at the alpha level of 0.05. AAPC = Average Annual Percentage Change calculated for all years combined. APC = Annual Percentage Change; the + sign shows the increasing trends of PAU, while the - sign shows the decline in the trends of PAU.

Predictive margins, marginal plots, and odds of change in PAU

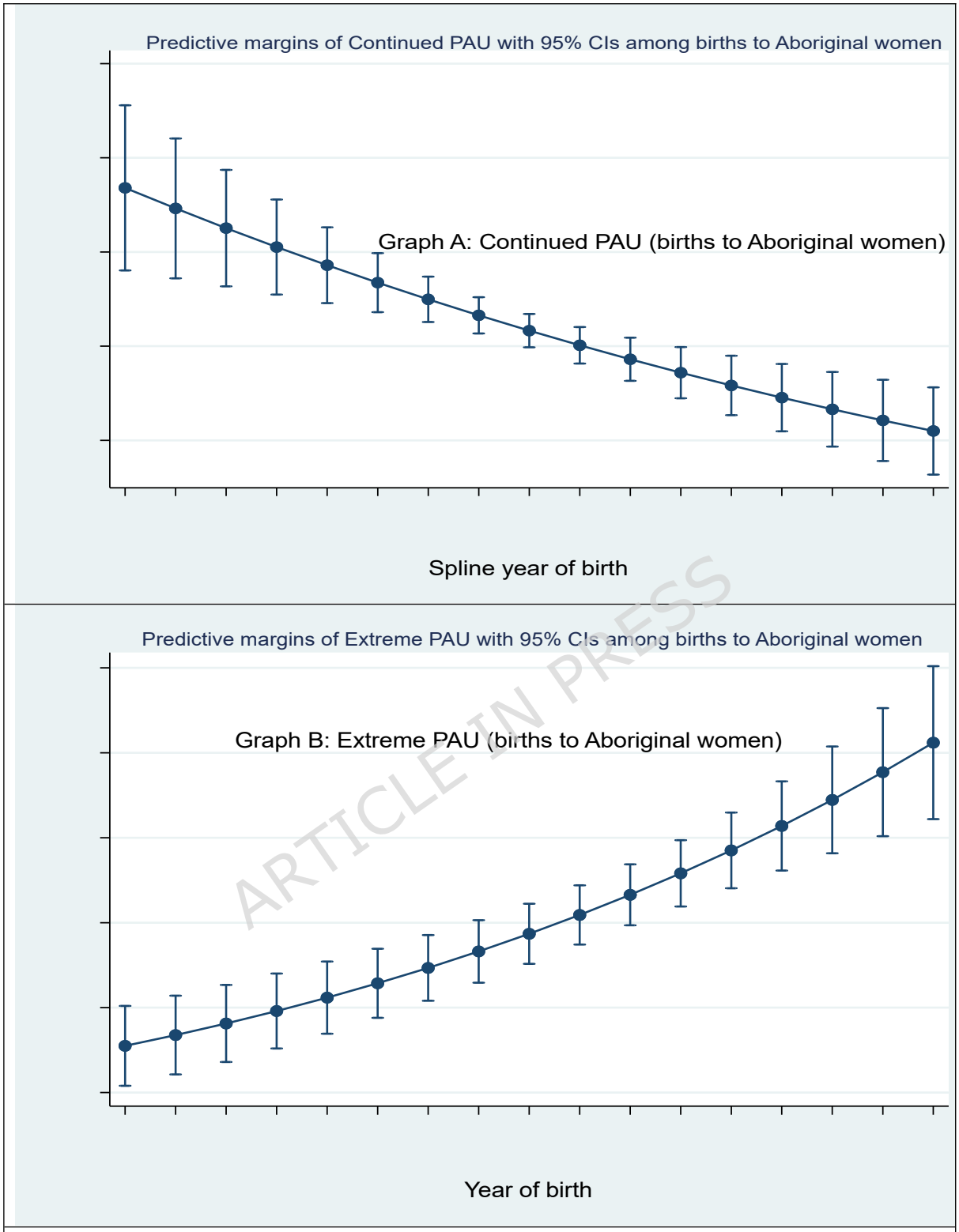
As illustrated in Table 3 and Figure 2A, holding all covariates constant, the adjusted odds ratio of the trend in "Continued PAU" among births to Aboriginal women significantly declined from 2001 to 2017, and included a 16% reduction by 2004 (aOR: 0.84; 95%CI: 0.78, 0.92), 38% by 2009 (aOR: 0.62; 0.51, 0.76), 56% by 2013 (aOR: 0.44; 0.37, 0.53), and 70% by 2017 (aOR: 0.30; 0.24, 0.38). The adjusted odds ratio for the trend in "Extreme PAU" increased, with a two-fold increase by 2009 (aOR: 2.00; 1.57, 2.55), more than three-fold increase by 2014 (aOR: 3.10; 2.09, 4.59), and a four-fold increase by 2017 (aOR: 4.02; 2.48, 6.52), compared to 2001 (Table 3 and Figure 2B).

As illustrated in Table 3 and Figure 2C, among births to non-Aboriginal women, compared to 2001, the trend in "Early PAU" showed a modest decline up to 2006 (aOR: 0.86; 95%CI: 0.71, 1.04), followed by sharper reductions by 35% in 2009 (aOR: 0.65; 0.54, 0.78), by 58% in 2013 (aOR: 0.42; 95% CI: 0.35, 0.51) and reductions by 72% in 2017 (aOR: 0.28; 95% CI: 0.22, 0.34). Similarly, continued PAU also decreased substantially, with a 25% reduction in 2004 (aOR: 0.75; 95%CI: 0.68, 0.84), 61% in 2011 (aOR: 0.39; 95%CI: 0.28, 0.55), 71% in 2014 (aOR: 0.29; 95%CI: 0.19, 0.46), and 78% in 2017 (aOR: 0.22; 95%CI: 0.13, 0.38) (Table 3 and Figure 2D).

Table 3: Odds of change of PAU categories for selected years, compared to the corresponding 2001 PAU among births to Aboriginal and non-Aboriginal women.

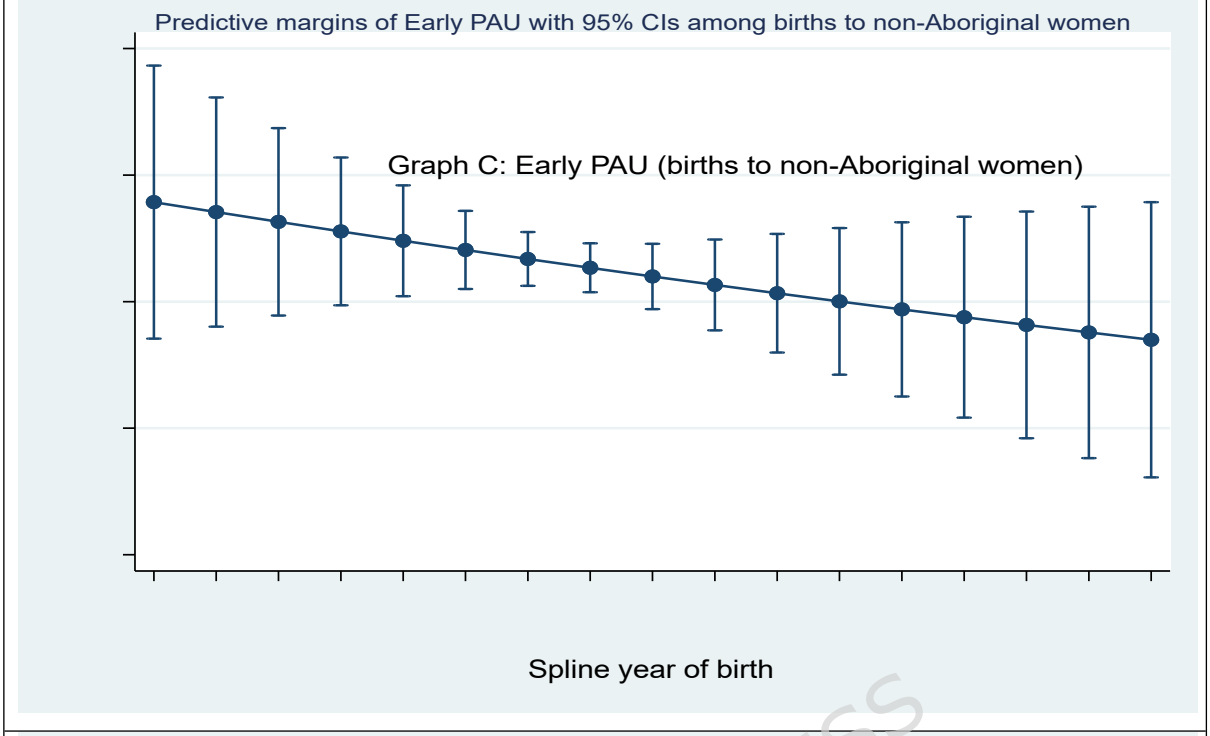
Year	Model – 1 "Continued PAU" among births to Aboriginal women (aOR, 95% CI)	Model – 2 "Extreme PAU" among births to Aboriginal women (aOR, 95% CI)	Model – 3 "Early PAU" among births to non-Aboriginal women (aOR, 95% CI)	Model – 4 "Continued PAU" among births to non-Aboriginal women (aOR, 95% CI)
2001	1	1	1	1
2003	0.89 (0.84 – 0.94) *	1.19 (1.12 – 1.26) *	0.96 (0.87 – 1.05)	0.83 (0.77 – 0.89) *
2004	0.84 (0.78 – 0.92) *	1.30 (1.19 – 1.42) *	0.93 (0.82 – 1.07)	0.75 (0.68 – 0.84) *
2006	0.75 (0.65 – 0.86) *	1.54 (1.33 – 1.80) *	0.86 (0.71 – 1.04)	0.63 (0.53 – 0.74) *
2009	0.62 (0.51 – 0.76) *	2.00 (1.57 – 2.55) *	0.65 (0.54 – 0.78) *	0.47 (0.36 – 0.62) *
2011	0.53 (0.44 – 0.64) *	2.39 (1.76 – 3.23) *	0.52 (0.44 – 0.63) *	0.39 (0.28 – 0.55) *
2013	0.44 (0.37 – 0.53) *	2.84 (1.98 – 4.08) *	0.42 (0.35 – 0.51) *	0.32 (0.21 – 0.49) *
2014	0.40 (0.33 – 0.48) *	3.10 (2.09 – 4.59) *	0.38 (0.31 – 0.46) *	0.29 (0.19 – 0.46) *
2017	0.30 (0.24 – 0.38) *	4.02 (2.48 – 6.52) *	0.28 (0.22 – 0.34) *	0.22 (0.13 – 0.38) *

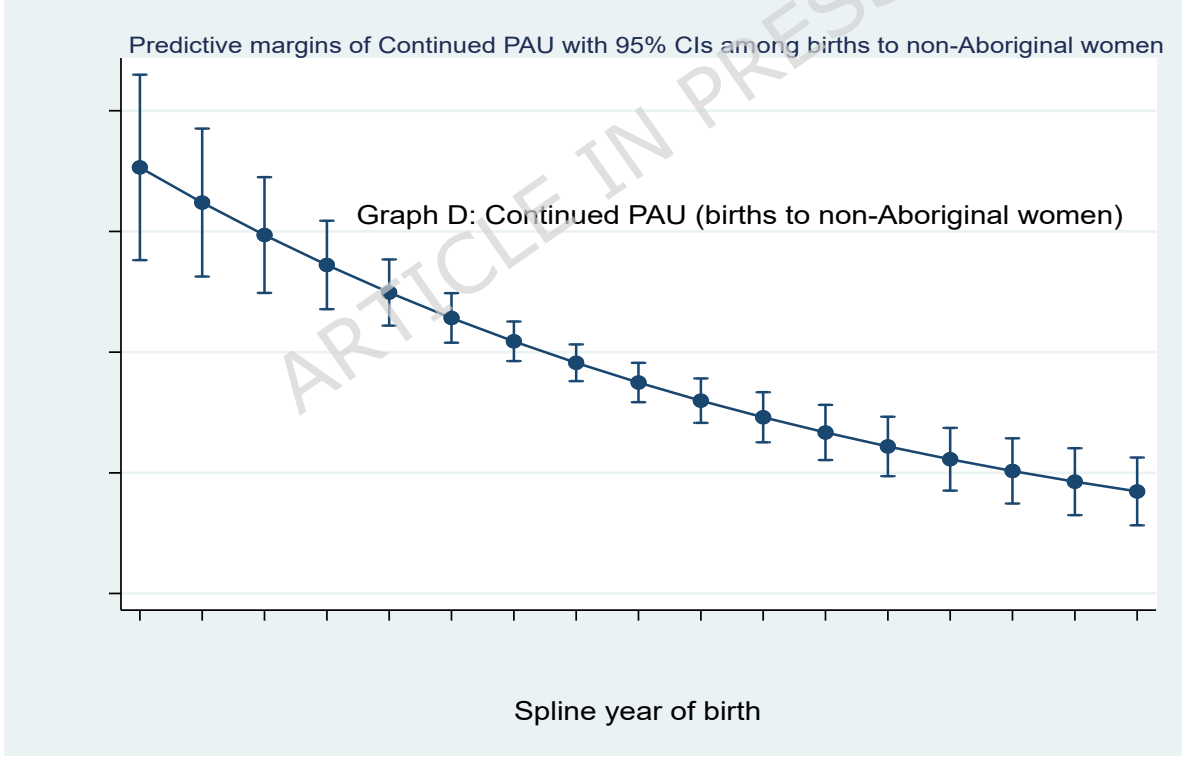
Note: The model has been adjusted for the age of the mother, antenatal care, parity, smoking, mental health-related hospitalisation, substance misuse-related hospitalisation, violence, and self-harm-related hospitalisation. * Shows statistically significant findings at an alpha level of 0.05.



Figures 2A and 2B: Adjusted predictive margins of PAU among births to Aboriginal women, 2001 – 2017.

Note: Graph A shows declining predictive margins for continued PAU over time, holding covariates constant, while Graph B shows increasing predictive margins for extreme PAU among Aboriginal women in the NT.





Figures 2C and 2D: Adjusted predictive margins of PAU among births to non-Aboriginal women, 2001 – 2017.

Note: Graph C shows declining predictive margins for early PAU over time, holding covariates constant, while Graph D shows increasing predictive margins for continued PAU among non-Aboriginal women in the NT.

Discussion

This study investigated the trends in the prevalence of PAU among births to Aboriginal and non-Aboriginal women in the NT. A Joinpoint regression model was fitted to the annual prevalence of PAU from 2001 to 2017. The overall trend in PAU prevalence in the NT showed an average annual decline of 5% from 2001 to 2017. However, analyses examining the separate trends among Aboriginal and non-Aboriginal women revealed different results. For births to Aboriginal women, the overall trend showed fluctuating patterns with no evidence of sustained change in annual prevalence. Conversely, the overall trend among births to non-Aboriginal women showed a marked decline in prevalence between 2001 and 2017, at a rate of 10.7% annually.

Stratified analyses also demonstrated differences in the trends by PAU categories between these two population groups. Among births to Aboriginal women, improvements were limited with no evidence of change in early PAU, an increase in extreme PAU and a reduction in continued PAU during specific periods. Among births to non-Aboriginal women, early and continued PAU declined, and extreme use was almost non-existent.

The combined efforts of governmental and non-governmental organisations may have contributed to the observed declines. In 2001, the National Health and Medical Research Council (NHMRC) guidelines highlighted the risks of alcohol for unborn babies and mothers, and recommended consuming fewer than seven standard drinks per week and no more than two standard drinks per day [18]. While advising against intoxication, the 2001 guideline emphasised that the most significant risk occurs in early pregnancy [2]. At that time, the Australian Government Department of Health and Ageing held a similar position, concluding that there was unclear evidence of harm from low to moderate alcohol intake during pregnancy [18]. In 2006, the Ministerial Council on Drug Strategy (MCDS) noted uncertainty over a safe minimum level and, concluding that no amount of alcohol could be assumed entirely safe, recommended that all pregnant women be asked about alcohol use and informed of its risks [55]. The Australian Medical Association, however, wrote a position statement against occasional small amounts of alcohol during pregnancy, supporting abstinence [18]. In 2009, the revised NHMRC guidelines recommended complete abstinence from alcohol during pregnancy or when planning pregnancy to prevent harm to the unborn

child [2]. The timing of the guidelines for the restriction and later abstinence from the consumption of alcohol in pregnancy is consistent with the decline in annual prevalence of PAU observed in this study.

Supporting this, the Australian National Drug Strategy Household Survey showed an overall decline in the prevalence of PAU between 2001 and 2016 [27], after controlling for the confounding effects of mothers' age and educational level. The implementation of the national clinical guidelines for the management of drug use during pregnancy, birth, and the early development years of the newborn [55] and the clinical practice guidelines for antenatal care module one [56] may also have had an impact on the prevalence of PAU among births to NT women. Moreover, increased public awareness of FASD, consistent health professional advice on the harmful effects of alcohol during pregnancy, public health campaigns with pregnancy-specific messaging, and media campaign involvement may also have contributed to the change in the prevalence of PAU in the NT[57].

Our findings highlight a difference in PAU trends between NT non-Aboriginal and Aboriginal populations. While non-Aboriginal women showed consistent reduction in alcohol use during pregnancy, Aboriginal women experienced mixed trends with some improvement but also ongoing challenges, particularly in "Extreme PAU" and the absence of change in "Early PAU". It is essential to view these patterns through the lens of the social determinants of health [58], which for Aboriginal people encompasses higher levels of social disadvantage and marginalisation, stemming from ongoing colonisation and discrimination. These mixed results are consistent with a need for community-led, culturally safe, and sustained interventions explicitly tailored for pregnant women to address the underlying causes and barriers to reducing PAU. The Marulu Strategy is an example of community-led public health intervention, which is effective in changing policy locally, enhancing awareness of the health impact of alcohol, increasing the diagnosis of FASD, and reducing some harms related to alcohol [59]. Moreover, interventions aimed at reducing the level of smoking, substance misuse-related hospitalisation, mental health-related hospitalisation, and all forms of violence have been reported to contribute to a reduction in PAU among pregnant women [29, 60–62] (Supplementary Tables 5 & 6).

This study also highlights that substance misuse, mental health hospitalisation, self-harm, and violence in the 12 months before pregnancy are associated with increased likelihood of prenatal alcohol exposure. This underscores the importance of preconception care, which encompasses a range of services that optimise health before pregnancy, including reproductive planning, health assessment, nutritional guidance, and mental health support [63]. Preconception care in Australia aims to promote best practices in preconception health and improve access to care through collaboration with health professionals and community engagement. Women who are involved in preconception care are more likely to have better knowledge and show positive health behaviours, including reducing smoking, increasing folic acid intake, and increasing antenatal care [64, 65]. Our study showed smoking was associated with increased PAU, while an increasing number of antenatal care visits was associated with reduced PAU. The Australian National Preventive Health Strategy emphasises that active client participation in the health care delivery process is vital for evidence-based decision-making [66]. Effective interventions also require the integration of modern scientific approaches with Indigenous knowledge and partnerships between the health sector and other relevant agencies [67]. The Strong Women, Strong Babies, Strong Culture Program exemplified the effectiveness of combining Indigenous knowledge with modern medical practices in promoting maternal and child health [68].

Improvements in perinatal data collection, both in quality and quantity, should also be considered. Over the study period, missing values of PAU among births to Aboriginal women showed only a slight decrease, while there was no evidence of change among births to non-Aboriginal women. There is an opportunity to improve both the completeness of the collection of PAU information and to extend the current questions on alcohol consumption to be more frequent and to include a measure of the quantity of alcohol consumed. These changes are consistent with recent changes introduced in the Tasmanian perinatal data collection [69]. A more frequent and comprehensive collection of information on alcohol consumption will not only provide more complete information but will also increase the opportunity for brief interventions during antenatal care.

Strengths and limitations of the study

The study's strengths included the use of linked data from multiple administrative datasets, a population-based approach, and the application of a Joinpoint regression model to illustrate nonlinear trends of PAU. This study also has the following limitations. Missingness in the dataset due to incomplete recording or women not disclosing their alcohol drinking status during antenatal care clinic visits may underestimate the results. However, as presented in Supplementary Table 3, the distributions of covariate characteristics among women with missing PAU records and those with complete PAU records are similar, indicating that the bias created by this missingness is minimal. Moreover, we lacked data from the perinatal dataset on the amount of alcohol consumed and frequency of PAU among mothers, which limited our ability to assess PAU risk profiles in the study population. To address this limitation, we utilised linked data to illustrate women at varying levels of risk. For instance, mothers with "Extreme PAU"—those admitted to hospital or presenting to the ED for alcohol-related conditions—were used to complement this gap. The confidence intervals for some odds ratio estimates are relatively wide due to the small number of cases, limiting the precision of the results. All these limitations should be carefully considered when interpreting the study's findings.

Conclusion

This study highlights that the prevalence of PAU in the NT is decreasing disproportionately among Aboriginal and non-Aboriginal women. The general decline in PAU among NT non-Aboriginal women is consistent with national trends that have followed the introduction of national policies and clinical guidelines to reduce health risks from alcohol in pregnancy. The limited improvements in trends in PAU among Aboriginal women, including the marked increase in the extreme PAU category, emphasise the need for a more targeted approach, which will require an understanding of social and cultural determinants and greater support for Aboriginal women and their service providers. Additionally, improvements in recording alcohol use at antenatal care visits can enhance data quality and support more effective interventions.

Abbreviations

ACCHO: Aboriginal Community Controlled Health Organisations, **ANC**: Antenatal care, **CI**: Confidence Interval, **CYDRP**: Child and Youth Development Research Partnership, **FASD**: Fetal Alcohol Spectrum Disorder, **JP**: Joinpoint, **ICD**: International Classification of Diseases, **PAU**: Prenatal Alcohol Use, **NT**: Northern Territory, **OR**: Odds Ratio, **PSLK**: Project Specific Linkage Key, **TP**: Turning Points.

Supplementary materials

Additional tables and figures are included in the “Supplementary file”.

Authors’ contributions

BD, AD, HP, and SG played a substantial role in the conceptualisation, investigation, methods, funding acquisition, design, data linkage, data analysis, data visualisation, validation, and manuscript writing. DMB, HWU, and KB played essential roles in conceptualisation, investigation, data visualisation, validation, and manuscript editing. All authors edited and reviewed the manuscript. The authors have approved the final version of the manuscript and will handle all aspects of the work.

Funding

This work is sponsored by the Menzies School of Health Research and Charles Darwin University, Australia.

Availability of data

The datasets used and/or analysed in this study are stored on a secure, cloud-based server managed by the Menzies School of Health Research Data Manager and are subject to restricted access. Since the datasets contain sensitive personal information, access requires approval from the ethics committee and data custodians. However, all relevant data supporting the study’s findings are provided in the form of tables, graphs, and supplementary materials.

Declarations

Ethical Approval

This study received ethics approval from the NT Department of Health and Menzies Human Research Ethics Committee (HREC-2024-4852) and Charles Darwin

University HREC (H24069). It adheres to NHMRC guidelines for ethical research involving Aboriginal women. This article adheres to the Ethical principles for medical research involving human subjects, as declared in Helsinki. The First Nation Advisory Group reviewed the project's relevance for Aboriginal and Torres Strait Islander youth. Data confidentiality was maintained in accordance with a Data Security Declaration. This study used large, de-identified administrative datasets with strict controls to prevent re-identification. Because individual consent was not feasible for this large-scale study, the NT Department of Health, the Menzies Human Research Ethics Committee, and Charles Darwin University (HREC-2024-4852) waived the consent requirement.

Consent to participate

Not applicable.

Consent for publication

Not Applicable.

Competing interests

The authors declare that they have no competing interests to disclose.

References

1. Popova S, Lange S, Probst C, Gmel G, Rehm J. Estimation of national, regional, and global prevalence of alcohol use during pregnancy and fetal alcohol syndrome: a systematic review and meta-analysis. Lancet Glob Heal. 2017;5:e290–9.

2. National Health and Medical Research Council. Australian Guidelines to Reduce Health Risks from Drinking Alcohol. Canberra; 2020.

3. Popova S, Lange S, Temple V, Poznyak V, Chudley AE, Burd L, et al. Profile of mothers of children with fetal alcohol spectrum disorder: A population-based study in Canada. Int J Environ Res Public Health. 2020;17:1–15.

4. Popova S, Lange S, Shield K, Mihic A, Chudley AE, Mukherjee RAS, et al. Comorbidity of fetal alcohol spectrum disorder: a systematic review and meta-analysis. Lancet. 2016;387:978–87.

5. Popova S, Rehm J, Shield K. Epidemiology of Alcohol Consumption among Pregnant and Childbearing Age Women and Fetal Alcohol Spectrum Disorder. In: Neurodevelopmental Pediatrics. Cham: Springer International Publishing; 2023. p. 371–8.

6. Dejong K, Olyaei A, Lo JO. Alcohol Use in Pregnancy. Clin Obstet Gynecol. 2019;62:142–55.

7. Cook JL, Green CR, Lilley CM, Anderson SM, Baldwin ME, Chudley AE, et al. Fetal alcohol spectrum disorder: a guideline for diagnosis across the lifespan. CMAJ. 2016;188:191–7.

8. Bower C, Elliott EJ, Zimmet M, Doorey J, Wilkins A, Russell V, et al. Australian guide to the diagnosis of foetal alcohol spectrum disorder: A summary. J Paediatr Child Health. 2017;53:1021–3.

9. Cornman-Homonoff J, Kuehn D, Aros S, Carter TC, Conley MR, Troendle J, et al. Heavy prenatal alcohol exposure and risk of stillbirth and preterm delivery. J Matern Neonatal Med. 2012;25:860–3.

10. Addila AE, Azale T, Gete YK, Yitayal M. The effects of maternal alcohol consumption during pregnancy on adverse fetal outcomes among pregnant women attending antenatal care at public health facilities in Gondar town, Northwest Ethiopia: a prospective cohort study. Subst Abus Treat Prev Policy. 2021;16.

11. Gibberd AJ, Simpson JM, Jones J, Williams R, Stanley F, Eades SJ. A large proportion of poor birth outcomes among Aboriginal Western Australians are attributable to smoking, alcohol and substance misuse, and assault. BMC Pregnancy Childbirth. 2019;19:110.

12. Strandberg-Larsen K, Poulsen G, Bech BH, Chatzi L, Cordier S, Dale MTG, et al. Association of light-to-moderate alcohol drinking in pregnancy with preterm birth and birth weight: elucidating bias by pooling data from nine European cohorts. Eur J Epidemiol. 2017;32:751–64.

13. Sania A, Brittain K, Phillips TK, Zerbe A, Ronan A, Myer L, et al. Effect of alcohol consumption and psychosocial stressors on preterm and small-for-gestational-age

births in HIV-infected women in South Africa: A cohort study. BMJ Open. 2017;7.

14. Marianian A, Darenskaya M, Grebenkina L, Protopopova N, Kolesnikova L. The effect of low alcohol consumption during pregnancy on the metabolic processes of women and their alcohol-exposed babies. Int J Biomed. 2021;11:519–25.

15. Denny CH, Acero CS, Naimi TS, Kim SY. Consumption of Alcohol Beverages and Binge Drinking Among Pregnant Women Aged 18–44 Years — United States, 2015–2017. MMWR Morb Mortal Wkly Rep. 2019;68:365–8.

16. O'leary C, Leonard H, Bourke J, D'antoine H, Bartu A, Bower C. Intellectual disability: population-based estimates of the proportion attributable to maternal alcohol use disorder during pregnancy. Dev Med Child Neurol. 2013;55:271–7.

17. Chu JTW, McCormack J, Marsh S, Wells A, Wilson H, Bullen C. Impact of prenatal alcohol exposure on neurodevelopmental outcomes: a systematic review. Heal Psychol Behav Med. 2022;10:973–1002.

18. O'Leary CM, Heuzenroeder L, Elliott EJ, Bower C. A review of policies on alcohol use during pregnancy in Australia and other English-speaking countries, 2006. Med J Aust. 2007;186:466–71.

19. National Health and Medical Research Council. Australian guidelines to reduce health risks from drinking alcohol. Canberra; 2009.

20. Wolfaardt BM, Brownbill AL, Mahmood MA, Bowden JA. The Australian NHMRC guidelines for alcohol consumption and their portrayal in the print media: a content analysis of Australian newspapers. Aust N Z J Public Health. 2018;42:43–5.

21. Clifford S, Smith JA, Livingston M, Wright CJC, Griffiths KE, Miller PG. A historical overview of legislated alcohol policy in the Northern Territory of Australia: 1979–2021. BMC Public Health. 2021;21:1921.

22. Miller P, Coomber K, Smith J, Livingston M, Stevens M, Guthridge S, et al. Learning from alcohol (policy) reforms in the Northern Territory (LEARNT): protocol for a mixed-methods study examining the impacts of the banned drinker register. BMJ Open. 2022;12:e058614.

23. Food Standards Australia New Zealand (FSANZ). Labelling of alcoholic beverages. 2022. https://www.foodstandards.gov.au/consumer/labelling/Labelling-of-alcoholic-beverages. Accessed 31 Jul 2025.

24. Australian Government Department of Health Disability and Ageing. Every Moment Matters – The National Awareness Campaign for Pregnancy and Breastfeeding Women. 2023. https://www.health.gov.au/our-work/every-moment-matters-the-national-awareness-campaign-for-pregnancy-and-breastfeeding-women.

25. Clifford S, Wright CJC, Miller PG, Coomber K, Griffiths KE, Smith JA, et al. What are the impacts of alcohol supply reduction measures on police-recorded adult domestic and family violence in the Northern Territory of Australia? Int J Drug Policy. 2024;127:104426.

26. Chen JLJ, Zhang X, Draper ADK, Kaur G, Field E, Boffa J, et al. Alcohol-related injury hospitalisations in relation to alcohol policy changes, Northern Territory, Australia, 2007–2022: A joinpoint regression analysis. Drug Alcohol Rev. 2024;44:324–35.

27. Stanesby O, Cook M, Callinan S. Examining trends in alcohol consumption during pregnancy in Australia, 2001-2016. Canberra: Foundation for Alcohol Research and Education., 2018.

28. Australian Institute of Health and Welfare. Australia's mothers and babies. 2025.

29. Derseh B, Dadi A, Phan H, Unger HW, Brown K, Belay DM, et al. Prevalence of prenatal alcohol use among Aboriginal and non-Aboriginal women in the Northern Territory, Australia: estimate from perinatal, emergency, and admission datasets. BMC Pregnancy Childbirth. 2025;25:1110.

30. Callinan S, Ferris J. Trends in alcohol consumption during pregnancy in Australia, 2001–2010. Int J Alcohol Drug Res. 2014;3:17–24.

31. Stanesby O, Cook M, Callinan S. Examining trends in alcohol consumption during pregnancy in Australia, 2001 to 2016. Camberra; 2018.

32. Fitzpatrick JP, Latimer J, Ferreira ML, Carter M, Oscar J, Martiniuk ALC, et al.

Prevalence and patterns of alcohol use in pregnancy in remote Western Australian communities: The Lililwan Project. Drug Alcohol Rev. 2015;34:329–39.

33. Su JY, He VY, Guthridge S, Silburn S. The impact of hearing impairment on the life trajectories of Aboriginal children in remote Australia: Protocol for the hearing loss in Kids project. JMIR Res Protoc. 2020;9:e15464.

34. Dadi AF, He V, Nutton G, Su J-Y, Guthridge S. Predicting child development and school readiness, at age 5, for Aboriginal and non-Aboriginal children in Australia's Northern Territory. PLoS One. 2023;18:e0296051.

35. Guthridge S, Li L, Silburn S, Li SQ, McKenzie J, Lynch J. Impact of perinatal health and socio-demographic factors on school education outcomes: A population study of Indigenous and non-Indigenous children in the Northern Territory. J Paediatr Child Health. 2015;51:778–86.

36. Menzies School of Health Research. Child and Youth Development Research Partnership CYDRP 2017-2024. 2017. https://www.menzies.edu.au/page/Research/Projects/Population_Health_and_Wellbeing/Child_and_Youth_Development_Research_Partnership_CYDRP_2017-2024/Overview/.

37. CDC. Alcohol-Related Disease Impact (ARDI) International Classification of Diseases (ICD) Codes and Alcohol-Attributable Fraction (AAF) Sources. https://www.cdc.gov/alcohol/ardi/alcohol-related-icd-codes.html#.

38. Northern Territory Government Department of Health. NT Health Annual Report 2022-23. Darwin; 2023.

39. Australian Bureau of Statistics. Estimates of Aboriginal and Torres Strait Islander Australians. 2021. https://www.aihw.gov.au/reports/australias-welfare/profile-of-indigenous-australians. Accessed 2 Oct 2025.

40. The Territory. Hospitals in the Northern Territory. Hospitals. 2024. https://jointheterritory.nt.gov.au/live/healthcare/hospitals.

41. Thompson SC, Woods JA, Katzenellenbogen JM. The quality of indigenous

identification in administrative health data in Australia: insights from studies using data linkage. BMC Med Inform Decis Mak. 2012;12:133.

42. Brayer EF. Calculating the Standard Error of a Proportion. Appl Stat. 1957;6:67.

43. National Cancer Institute. Joinpoint Regression Program, Version 5.4.0.0. April, 2025. 2025.

44. National Cancer Institute. Joinpoint Regression Program: Statistical Methodology and Applications Branch, Surveillance Research Program. 2025.

45. Kim H-J, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. Stat Med. 2000;19:335–51.

46. McHugh ML. The Chi-square test of independence. Biochem Medica. 2013;:143–9.

47. Harris JK. Primer on binary logistic regression. Fam Med Community Heal. 2021;9 Suppl 1:e001290.

48. Schuster NA, Rijnhart JJM, Twisk JWR, Heymans MW. Modeling non-linear relationships in epidemiological data: The application and interpretation of spline models. Front Epidemiol. 2022;2.

49. Lusa L, Ahlin Č. Restricted cubic splines for modelling periodic data. PLoS One. 2020;15:e0241364.

50. Orsini N, Greenland S. A Procedure to Tabulate and Plot Results after Flexible Modeling of a Quantitative Covariate. Stata J Promot Commun Stat Stata. 2011;11:1–29.

51. Discacciati A, Palazzolo MG, Park J-G, Melloni GEM, Murphy SA, Bellavia A. Estimating and presenting non-linear associations with restricted cubic splines. Int J Epidemiol. 2025;54.

52. Tsagris M, Pandis N. Multicollinearity. Am J Orthod Dentofac Orthop. 2021;159:695–6.

53. StataCorp LLC. Stata/BE 17.0 for windows. 2023.

54. van Buuren S. Flexible Imputation of Missing Data, Second Edition. Second edi. Second edition. | Boca Raton, Florida : CRC Press, [2019] |: Chapman and Hall/CRC; 2018.

55. Ministerial Council on Drug Strategy. National clinical guidelines for the management of drug use during pregnancy, birth and the early development years of the newborn. 2006.

56. Australian Health Ministers' Advisory Council 2012. Clinical Practice Guidelines: Antenatal Care - Module I. Canberra; 2012.

57. Millians MN. Educational Needs and Care of Children with FASD. Curr Dev Disord Reports. 2015;2:210–8.

58. Marmot M. Social determinants and the health of Indigenous Australians. Med J Aust. 2011;194:512–3.

59. Fitzpatrick JP, Oscar J, Carter M, Elliott EJ, Latimer J, Wright E, et al. The Marulu Strategy 2008–2012: overcoming Fetal Alcohol Spectrum Disorder (FASD) in the Fitzroy Valley. Aust N Z J Public Health. 2017;41:467–73.

60. Piasecki TM, Jahng S, Wood PK, Robertson BM, Epler AJ, Cronk NJ, et al. The subjective effects of alcohol-tobacco co-use: an ecological momentary assessment investigation. J Abnorm Psychol. 2011;120:557–71.

61. Little HJ. Behavioral mechanisms underlying the link between smoking and drinking. Alcohol Res Health. 2000;24:215–24.

62. Popova S, Dozet D, Akhand Laboni S, Brower K, Temple V. Why do women consume alcohol during pregnancy or while breastfeeding? Drug and Alcohol Review. 2022;41:759–77.

63. Withanage NN, Botfield JR, Black KI, Mazza D. Improving the provision of preconception care in Australian general practice through task-sharing with practice nurses. Aust J Prim Health. 2022;29:217–21.

64. Dean S V, Lassi ZS, Imam AM, Bhutta ZA. Preconception care: closing the gap in the continuum of care to accelerate improvements in maternal, newborn and child

health. Reprod Health. 2014;11:S1.

65. Dorney E, Black KI. Preconception care. Aust J Gen Pract. 2018;47:424–9.

66. Department of Health Disability and Aging. National Consumer Engagement Strategy for Health and Wellbeing. 2025.

67. Liberda EN, Zuk AM, Davey R, Edwards-Wheesk R, Tsuji LJS. Two-Eyed Seeing and developmental origins of health and disease studies with indigenous partners. J Dev Orig Health Dis. 2022;13:417–23.

68. Lowell A, Kildea S, Liddle M, Cox B, Paterson B. Supporting aboriginal knowledge and practice in health care: lessons from a qualitative evaluation of the strong women, strong babies, strong culture program. BMC Pregnancy Childbirth. 2015;15:19.

69. Australian Institute of Health and Welfare. Female—alcohol consumption frequency after 20 weeks of pregnancy, code N Data Element Attributes. Hobart; 2023.