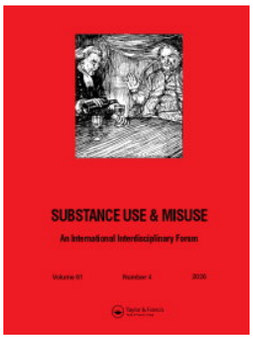

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ORIGINAL ARTICLE

Epidemiology of Smoking During Pregnancy by Women's Country of Birth and Indigenous Status in Victoria, Australia: A Comparative Trend Analysis

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ABSTRACT

Background: Despite its harmful effects, smoking during pregnancy among Australian overseas-born women remains under-researched. This study examined smoking during pregnancy among women who gave birth in Victoria from 2011 to 2020, categorized by birthplace and Indigenous status.

Methods: We analyzed data from the Victorian Perinatal Data Collection, encompassing 777,068 women who gave birth in Victoria, Australia, between 2011 and 2020. Women were classified into four groups based on birthplace and Indigenous status. Smoking during pregnancy was assessed through self-reported data based on the number of cigarettes smoked daily.

Results: Overall, smoking proportion during the first 20 weeks of pregnancy was 9.2% (95% CI: 9.1–9.3), with a 30.7% reduction from 11.7% (95% CI: 11.4–11.9) in 2011 to 8.1% (95% CI: 7.9–8.2) in 2020. The overall proportion of smoking at high intensity (smoking >10 cigarettes/day) at ≥20 weeks of pregnancy declined by 41.3%, from 19.1% (95% CI: 17.9–20.4) in 2011 to 11.2% (95% CI: 10.2–12.3) in 2020. Indigenous Australian women comprised the largest proportion of smokers during pregnancy at 41.2%. Women aged ≤20 years compared to >35 years, single women compared to married, women living in the most disadvantaged areas compared to the least disadvantaged areas, and grand multigravida women compared to primigravida had higher rates of smoking during pregnancy.

Conclusions: Despite the overall declining trend in smoking during pregnancy, smoking rates in certain groups remain high. Targeted smoking cessation interventions, in addition to strengthened national and state-level smoking control strategies, are needed to further reduce smoking rates during pregnancy.

Abbreviations: AfBW: African-born women; AIHW: Australian Institute of Health and Welfare; IAuW: Indigenous Australian women; IRSD: Index of Relative Socioeconomic Disadvantage; LMICs: low-and-middle-income countries; NIAuBW: non-Indigenous Australian-born women; OOSBW: other overseas-born women; RR: rate ratio; SACC: Standard Australian Classification of Countries; SEIFA: Socio-Economic Indexes for Areas; VPDC: Victorian Perinatal Data Collection

KEYWORDS
Epidemiology; smoking; pregnancy; indigenous; overseas-born; Africa; Australia

Introduction

Cigarette smoking remains a significant public health concern, accounting for over 7 million deaths annually (World Health Organization [WHO], 2017). Despite remarkable reductions in smoking, in 2018, tobacco use was responsible for 13% of mortalities in the general Australian population (Australian Institute of Health and Welfare [AIHW], 2021). In recognition of the harmful effects of smoking, the WHO adopted the Framework Convention on Tobacco Control, aiming to combat rising smoking rates (WHO, 2003). Controlling smoking during pregnancy has also been a key focus to improve perinatal health outcomes (Liu et al., 2025).

It was forecasted that there would be around 1.1 billion smokers globally in 2025, with varying rates across countries (Bilano et al., 2015). In 2015, the global prevalence of smoking during pregnancy was 1.7%, ranging from 0.8% in Africa to 8.1% in Europe (Lange et al., 2018). Similarly, evidence from the AIHW has shown that 8.3% of Australian women who gave birth in 2021 reported smoking in the first 20 weeks of pregnancy (AIHW, 2023).

Smoking during pregnancy poses risks to both maternal and child health (Liu et al., 2025). Engaging in smoking during pregnancy correlates with adverse perinatal health outcomes, including fetal growth restriction, stillbirth, preterm birth, sudden infant death syndrome, and birth defects (Cnattingius, 2004; Wang et al., 2024). It has also been associated with increased risks of spontaneous abortion, ectopic pregnancy, and placental abruption (Armstrong et al., 1992). Therefore, prevention of smoking during pregnancy is recognized as an important strategy for reducing the risk of pregnancy complications and adverse perinatal outcomes (Tarasi et al., 2022; Wang et al., 2024).

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Smoking at high intensity (>10 cigarettes/day) further compounds the risk of adverse birth outcomes (Kondracki, 2019). Although no level of smoking during pregnancy is safe, high smoking intensity is documented to pose greater harm to the pregnancy than low smoking intensity (Ko et al., 2014; Kondracki, 2019). Thus, evidence about the intensity of smoking is essential to monitor women at greatest risk of poor pregnancy outcomes (Kondracki, 2019; Lange et al., 2018). However, literature about the rates of smoking during pregnancy and smoking intensity status is limited for overseas-born women living in Australia.

Migration may increase the risk of smoking in a new country, as substances may be used as coping mechanisms to adapt to stressors (Hertner et al., 2023). This can elevate the likelihood of smoking during pregnancy among overseas-born women in host countries. Assimilation into the culture and lifestyle of receiving countries is also linked to an increased risk of smoking (Klöfvermark et al., 2019). Furthermore, the prevalence of smoking during pregnancy varies among migrants, with women from high-income countries being more likely to smoke compared to those from low- and middle-income countries (LMICs) (Klöfvermark et al., 2019; Lange et al., 2018). For example, evidence has shown that 23.2% of women who migrated from other Nordic countries to Sweden smoked, compared to just 1.3% of women who migrated from Asian countries to Sweden (Urquia et al., 2021). Therefore, international migration adds additional challenges for receiving countries in controlling domestic tobacco use, as immigrants may require culturally tailored interventions to reduce smoking rates (Piñeiro et al., 2018).

Given its multicultural population, evidence on smoking during pregnancy by country of birth is crucial in Australia (Menozzi, 2021). According to recent data from the Australian Bureau of Statistics (ABS) in 2023, of the 26.6 million people living in Australia, ~8.2 million were born overseas (ABS, 2023). Although migrants from England, India, China, New Zealand, and the Philippines represent over a third of overseas-born people (ABS, 2017), the proportion of African migrants has also been growing rapidly in Australia (William, 2022).

Despite the high rates of migration to Australia (ABS, 2023), smoking during pregnancy among overseas-born women remains under-researched. Given that migration increases the risk of smoking (Hertner et al., 2023), it is essential to investigate the prevalence of smoking during pregnancy among overseas-born women living in Australia. Migrant populations are heterogeneous (Belihu et al., 2016), and African-born women are less likely to smoke in their home countries compared to women from other regions (Lange et al., 2018). The number of migrant African communities living in Victoria has increased rapidly in recent years (Department of Premier and Cabinet, 2018). African-born women in Australia are more likely to experience adverse perinatal outcomes than other women due to the poor access to maternity care (Belihu et al., 2016). Smoking during pregnancy may increase the risk of adverse birth outcomes among these vulnerable women. This underscores the importance of comparing smoking during pregnancy among African-born women and other overseas-born women in Australia. Furthermore, it is well-documented that smoking rates are higher among Indigenous Australian women than non-Indigenous Australian-born women (AIHW, 2023). This justifies the need to investigate and compare the prevalence of smoking during pregnancy based on women's Indigenous status. The aim of this study was to examine and compare smoking during pregnancy among women who gave birth in Victoria, Australia, from 2011 to 2020, categorized by birthplace and Indigenous status.

Methods

Data source

A retrospective cohort design, analyzing data from the Victorian Perinatal Data Collection (VPDC), a population-based surveillance dataset, was undertaken. The VPDC collects comprehensive information on mothers and babies for every birth occurring in Victoria (VPDC, 2014). Since the VPDC collects anonymized birth records from hospitals, consent is not required, and the study received ethics exemption from the Deakin University Human Research Ethics Committee.

Study participants

This study used data from all women who gave birth in Victoria, Australia, from 2011 to 2020 regardless of birth outcomes. To facilitate comparison of the outcomes across the populations studied, we categorized women into four distinct groups: Non-indigenous Australian-born women (NIAuBW), Indigenous Australian-born women (IAuW), African-born women AfBW, and other overseas-born women (OOSBW). Data for each group were analyzed and presented separately, with comparisons based on their countries of birth and Indigenous status. The IAuW group included women from different countries of birth, as they are likely to live according to the culture of their Indigenous ancestors rather than their country of birth (Victorian Aboriginal Child Care Agency, 2019).

Sample size

Overall, 781,886 births were registered in Victoria from 2011 to 2020. After excluding records where countries of birth codes and residential postcodes could not be identified, data from 777,068 women were included in the analysis. To specifically analyze smoking rates during pregnancy, 10,025 records were excluded where the smoking status was either not stated or inadequately described (see Figure 1).

Measurements

Outcome variables

Smoking during pregnancy was the outcome variable in this study. The VPDC collected women's smoking status based on self-reported smoking during pregnancy. Women

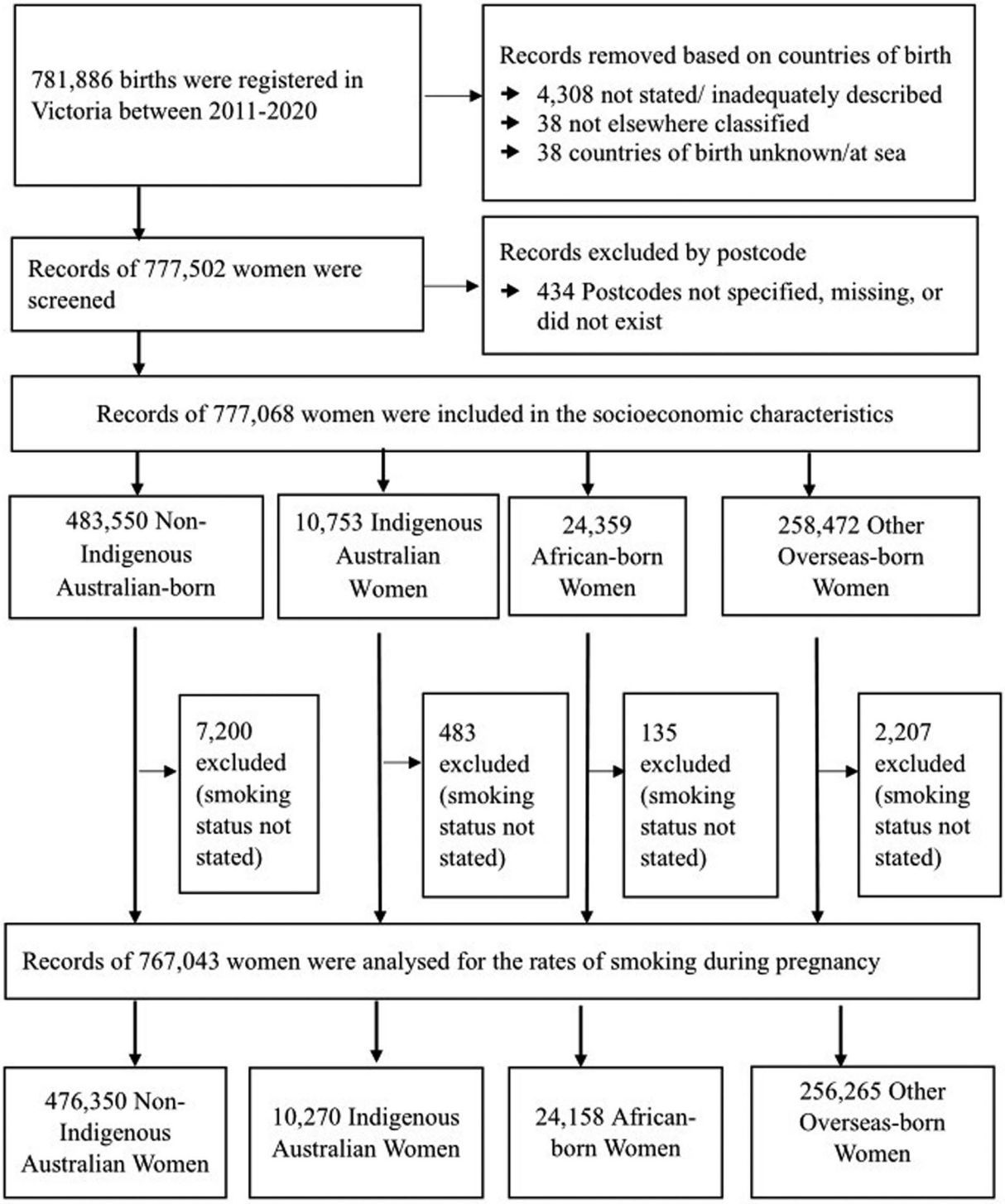


Figure 1. Sampling procedures for the epidemiology of smoking during pregnancy among women who had given birth in Victoria, 2011–2020.

were assessed for smoking during pregnancy at two time points: during the first 20 weeks of pregnancy and at ≥20 weeks of pregnancy. Women who reported any smoking during the first 20 weeks of pregnancy were classified as smokers, and those who did not were considered non-smokers. Women who ceased smoking before 20 weeks of gestation on learning they were pregnant were considered quitters. Additionally, we categorized smoking frequency after 20 weeks of gestation into two intensity groups based on the number of cigarettes smoked per day: low intensity (1–10 cigarettes/day and occasional smokers) or high intensity (>10 cigarettes/day) (Ko et al., 2014).

Explanatory variables

The explanatory variables of interest in this study were women's country of birth and Indigenous status. Although the VPDC used the Standard Australian Classification of Countries (SACC) coding system (ABS, 2016), we adapted this classification to allow for comparison of smoking rates

to women's home countries as well as among NIAuBW and IAuW (AIHW, 2023; Lange et al., 2018). To have a better understanding of smoking rates among African women, we combined northern African countries (which were grouped with the Middle East according to SACC classification) with Sub-Saharan African countries (ABS, 2016).

Potential covariates

All other variables, including maternal age, relationship status, socioeconomic areas, maternal parity, and gravidity, were treated as covariates and controlled for during data analysis. Maternal age was categorized into five groups: ≤20, 21–25, 26–30, 31–35, and >35 years (Lindquist et al., 2015). Relationship status was classified as single, married, or de facto (Lindquist et al., 2015). Socioeconomic position was determined using the Index of Relative Socioeconomic Disadvantage (IRSD), one of the Socio-Economic Indexes for Areas (SEIFA), which summarizes relative disadvantage based on a variety of economic and social conditions (ABS, 2021). Residence areas were grouped into five IRSD quintiles, ranging from the 1st quintile for the most disadvantaged areas to the 5th quintile for the least disadvantaged areas. Missing data were accounted for by creating separate subcategories within each variable and were excluded on a case-by-case basis for subsequent analysis.

Data analyses

The characteristics of women and smoking during pregnancy were analyzed descriptively. For inferential statistics, the outcome variable was dichotomized both for smoking status and intensity (Lange et al., 2018). As we could not link records for women with more than one pregnancy registered during the study period, we treated each pregnancy as an independent event and used a Poisson regression model was used to handle autocorrelation. A Huber-White robust variance estimator to address potential covariance misclassification was applied. We estimated the change in the proportion of smoking during pregnancy from 2011 to 2020 for explanatory variables and covariates. Initially, a univariable Poisson regression analysis was conducted to determine the crude rate ratios (cRR) and their corresponding 95% CIs for potential risk factors for smoking during pregnancy. Based on the results from the unadjusted analysis and insights from preexisting literature, potential confounders were selected using a backward stepwise regression approach. Finally, adjusted rate ratios (aRR) with 95% CIs at a p-value of <0.05 were used to report the magnitude and direction of associations. Data analysis was conducted using Stata version 18.

Findings

Characteristics of the study population

Table 1 presents the characteristics of the study population. Overall, records of 777,068 women who had given birth in Victoria during 2011–2020 were analyzed. Most births (62.2%; 483,550/777,068) were recorded as NIAuBW. The proportion of women aged <20 years was highest among IAuW (15.1%; 1617/10,753), while the proportion of women older than 35 years was highest among AfBW (20.9%; 5073/24,293). The proportion of women living in the most disadvantaged socioeconomic areas was highest among IAuW, followed by AfBW, 31.9%; 3428/10,753 and 16.9%; 4122/24,293, respectively. The proportion of married women was highest within the OOSBW group (85.2%, 220,087/258,472). Additionally, the proportion of grand multigravidity (21.6%, 5249/24,293) and multiparity (33.1%, 8048/24,293) was highest among AfBW.

Proportions of smoking during pregnancy

The overall proportion of smoking during the first 20 weeks of pregnancy was 9.2% (71,406/777,068), the highest rate being among IAuW (39.3%, 4227/10,753) and the lowest among AfBW (2.8%, 677/24,293) (Table 1). The proportion of continuing to smoke until 20 weeks of pregnancy was highest among IAuW (90.6%; 3828/4227). Notably, the proportion of women who ceased smoking within the first 20 weeks of pregnancy was highest among AfBW (34.0%; 230/677).

The overall proportion of smoking at ≥20 weeks of pregnancy was 5.3% (41,303/777,068) (Supplementary File 1). Smoking frequency at ≥20 weeks of pregnancy varied, where the proportions of smoking 21+ cigarettes per day (2.1%) and 16–20 cigarettes per day (5.3%) were highest among IAuW, whereas the proportion of smoking 10–15 cigarettes per day (9.6%) and 6–10 cigarettes per day (33.8%) were highest among NIAuBW. However, the proportion of women who smoked at high intensity at ≥20 weeks of pregnancy was highest among IAuW (15.9%) followed by NIAuBW (15.6%) (see Figure 2).

Proportional changes in smoking during the first 20 weeks of pregnancy, 2011 to 2020

Proportional change analysis indicated that the proportion of smoking during the first 20 weeks of pregnancy declined from 11.7% (95% CI, 11.4–11.9) in 2011 to 8.1% (95% CI, 7.9–8.2) in 2020 across all women included in the sample (Table 2). The largest decline (40.8%) was observed among OOSBW from 4.9% [95% CI, 4.9 (4.5–5.3)] in 2011 to 2.9% (95% CI, 2.6–3.0) in 2020, while IAuW exhibited the smallest decline from 41.4% (95% CI, 40.6–41.9) in 2011 to 41.1% (95% CI, 40.2–41.8) in 2020. Older women exhibited a relatively higher decline in the proportion of smoking during the first 20 weeks of pregnancy than women aged 20 years or less, with a reduction from 7.8% (95% CI, 7.7–7.9) in 2011 to 5.2% (95% CI, 5.1–5.3) in 2020. Although the proportion of smoking during the first 20 weeks of pregnancy was higher among women living in the most disadvantaged areas, the highest decline in smoking rates was apparent for women living in the least disadvantaged areas, dropping from 39.6% in 2011 to 25.7%in 2020.

Table 1. Characteristics of women who had given birth in Victoria, 2011–2020.

Variables	Non-Indigenous Australian born women, *n* (%)	Indigenous Australian women, *n* (%)	African born women, *n* (%)	Other overseas born women, *n* (%)	Overall, *n* (%)
Maternal age (*n* = 777,068)					
20 years and lower	16,377 (3.4)	1617 (15.1)	637 (2.6)	2969 (1.2)	21,600 (2.8)
21–25 years	60,701 (12.5)	3181 (29.6)	3405 (14.0)	25,041 (9.7)	92,328 (11.9)
26–30 years	139,617 (28.9)	2869 (26.7)	7262 (29.9)	79,888 (30.9)	229,636 (29.6)
31–35 years	169,317 (35.1)	2041 (19.0)	7912 (32.6)	98,508 (38.1)	277,778 (35.7)
>35 years	97,368 (20.1)	1045 (9.6)	5073 (20.9)	52,019 (20.1)	155,505 (20.0)
Not stated/missing	170 (0.04)	0 (0)	4 (0.02)	47 (0.02)	221 (0.03)
Relationship status (*n* = 777,068)					
Single[a]	69,142 (14.3)	4595 (42.7)	4244 (17.5)	13,671 (5.3)	91,652 (11.8)
Married	296,090 (61.2)	2463 (22.9)	18,020 (74.2)	220,087 (85.2)	536,660 (69.1)
De facto	111,483 (23.1)	3495 (32.5)	1871 (7.7)	23,049 (8.9)	139,898 (18.0)
Not stated/missing	6835 (1.4)	200 (1.9)	158 (0.6)	1665 (0.6)	8858 (1.1)
Socioeconomic status (*n* = 777,068)					
1st quintile[b]	57,423 (11.9)	3428 (31.9)	4122 (16.9)	40,823 (15.8)	105,796 (13.6)
2nd quintile	60,508 (12.5)	1854 (17.2)	2331 (9.6)	21,468 (8.3)	86,161 (11.1)
3rd quintile	81,187 (16.8)	1572 (14.6)	3325 (13.6)	38,456 (14.9)	124,540 (16.0)
4th quintile	162,687 (33.6)	2848 (26.5)	9599 (39.5)	86,773 (33.6)	261,907 (33.7)
5th quintile	121,745 (25.2)	1051 (9.8)	4916 (20.2)	70,952 (27.4)	198,664 (25.6)
Gravidity (*n* = 777,052)[c]					
Primigravida	155,403 (32.1)	2778 (25.8)	5399 (22.2)	91,204 (35.3)	254,784 (32.8)
Multigravida	284,774 (58.9)	5724 (53.3)	13,645 (56.2)	149,374 (57.8)	453,517 (58.4)
Grand multigravida	43,363 (9.0)	2251 (20.9)	5249 (21.6)	17,888 (6.9)	68,751 (8.8)
Parity (*n* = 777,000)[d]					
Nulliparous	212,277 (43.9)	3904 (36.3)	7214 (29.7)	120,097 (46.4)	343,492 (44.2)
Primiparous	172,157 (35.6)	3066 (28.5)	6950 (28.6)	94,097 (36.4)	276,270 (35.6)
Multiparous	94,931 (19.6)	3258 (30.3)	8048 (33.1)	41,500 (16.1)	147,737 (19.0)
Grand multiparous	4153 (0.9)	525 (4.9)	2076 (8.6)	2747 (1.1)	9501 (1.2)
Smoking before 20 weeks of pregnancy					
Smokers	57,567 (11.9)	4227 (39.3)	677 (2.8)	8935 (3.5)	71,406 (9.2)
Non-smokers	418,783 (86.6)	6043 (56.2)	23,481 (96.7)	247,330 (95.7)	695,637 (89.5)
Not stated/missing	7200 (1.5)	483 (4.5)	135 (0.5)	2207 (0.8)	10,025 (1.3)
Smoking cessation before 20 weeks of pregnancy (*n* = 71,406)					
Continued smoking	45,843 (79.6)	3828 (90.6)	447 (66.0)	6010 (67.3)	56,128 (78.6)
Ceased smoking <20 weeks	11,724 (20.4)	399 (9.4)	230 (34.0)	2925 (32.7)	15,278 (21.4)
Smoking at ≥20 weeks of pregnancy (*n* = 777,068)					
Smokers	33,563 (6.9)	3193 (29.7)	331 (1.4)	4216 (1.6)	41,303 (5.3)
Nonsmokers	414,797 (85.8)	6557 (61.0)	23,403 (96.3)	247,930 (95.9)	692,687 (89.1)
Not stated/missing	35,190 (7.3)	1003 (9.3)	559 (2.3)	6326 (2.5)	43,078 (5.6)
Year of arrival in Australia (for *n* = 282,765 overseas born women only)					
Before 1990	Not applicable	Not applicable	269 (4.2)	4214 (5.7)	4483 (5.6)
1991–2000	Not applicable	Not applicable	696 (10.9)	6212 (8.4)	6908 (8.6)
2001–2010	Not applicable	Not applicable	2796 (43.8)	22,548 (30.3)	25,344 (31.4)
2011–2020	Not applicable	Not applicable	2624 (41.1)	41,326 (55.6)	43,950 (54.5)
Not stated/missing	Not applicable	Not applicable	17,908	184,172	202,080
Overall	483,550 (62.2)	10,753 (1.4)	24,293 (3.1)	258,472 (33.3)	777,068 (100.0)

[a]Single include never married, widowed, divorced, and separated.
[b]1st quartile is the most disadvantaged group while 5th quartile is the least disadvantaged group.
[c]Data of 16 women (10 Non-Indigenous Australian-born women and 6 overseas-born women) whose information about gravidity was not stated/missed were excluded from the analysis.
[d]Data of 68 women (32 Non-Indigenous Australian-born women, 5 African-born women, and 31 other overseas-born women) whose information about parity was not stated/missed were excluded from the analysis.

Trend analysis

Figure 3 presents a trend analysis for smoking during the first 20 weeks of pregnancy for the women. The trend analyses revealed that the overall proportion of smoking during the first 20 weeks of pregnancy declined steadily from 2011 to 2020. The declining trends were also steady among NIAuBW and OOSBW. However, the reduction rate fluctuated among IAuW and AfBW. Overall, smoking rates during the first 20 weeks of pregnancy remained the highest among IAuW than the other groups of women from 2011 to 2020 (see Figure 3 and Supplementary File 2).

Overall, the proportion of smoking at high intensity at ≥20 weeks of pregnancy declined from 19.1% in 2011 to 11.2% in 2020, a 41.3% decline (see Figure 4). NIAuBW exhibited a steady decline in high smoking intensity from 19.8% in 2011 to 11.5% in 2020 (a 42% decline), whereas the rate of decline fluctuated for other groups of women (see Figure 4).

Table 3 shows the differences in smoking among women based on their country of birth, Indigenous status, and women's socioeconomic status using RRs. With other variables held constant in the model, IAuW showed a 2.8 times higher rate of smoking during the first 20 weeks of pregnancy compared to NIAuBW (aRR: 2.80; 95% CI: 2.40–3.10). However, the proportions were significantly lower among AfBW (aRR: 0.21; 95% CI: 0.19–0.23) and OOSBW (aRR: 0.26; 95% CI: 0.24–0.28) compared to NIAuBW. Proportional change of smoking during the first 20 weeks of pregnancy was significantly higher among women ≤20 years (aRR: 5.10; 95% CI: 4.81–5.32) than women older than 35 years, single women than married women (aRR:

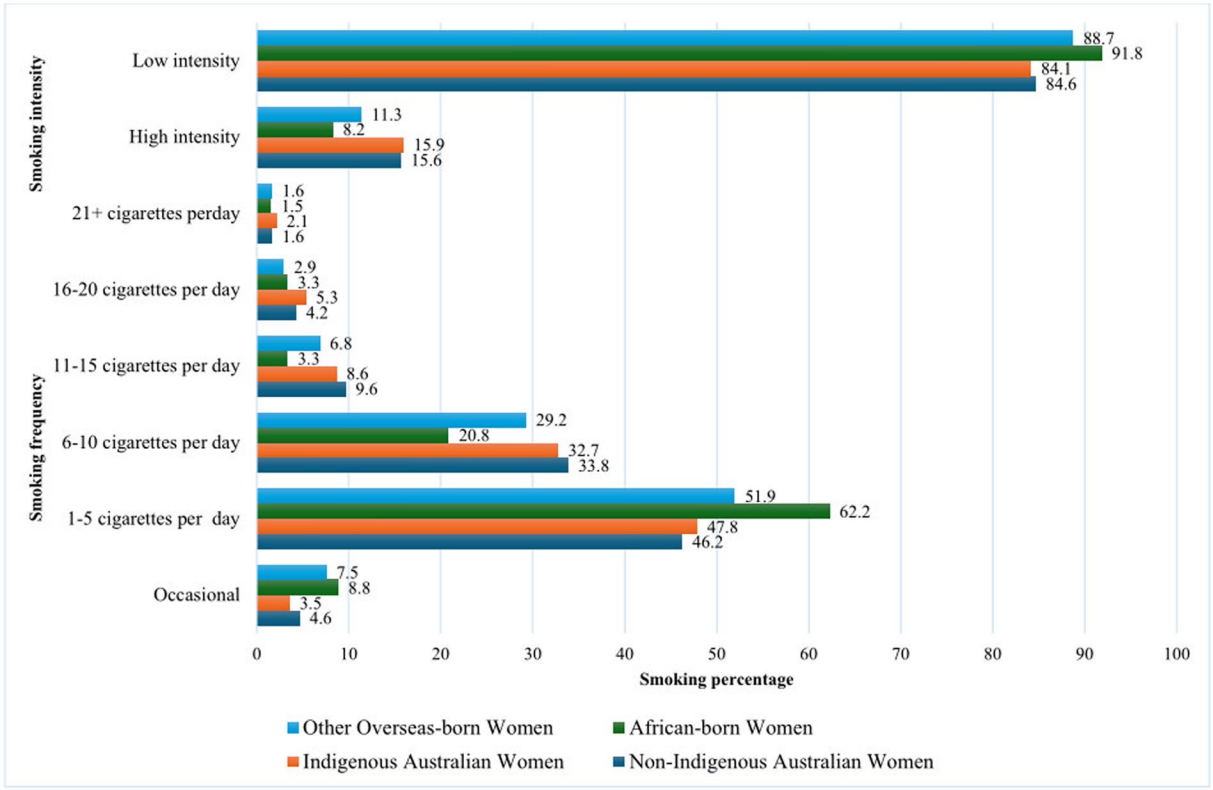
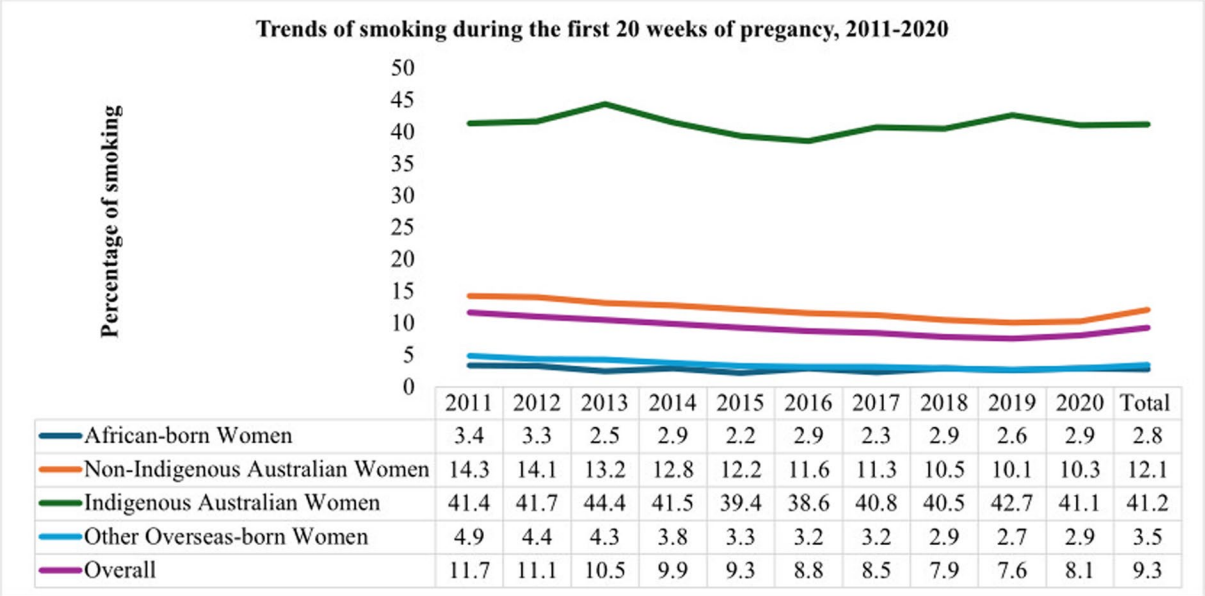


Figure 2. Proportion of pregnant women who smoked during ≥20 weeks of pregnancy, by frequency and intensity among women who had given birth in Victoria, 2011–2020.

Table 2. Changes in the proportions of smoking during the first 20 weeks of pregnancy among women who had given birth in Victoria, 2011 and 2020, stratified by maternal characteristics.

	2011			2020				
Countries of birth	Smokers (*n*)	Total birth (*n*)	Smoking proportion (95% CI)	Smokers (*n*)	Person-time (*n*)	Smoking rate (95% CI)	Proportional change (95% CI)*	Rate ratio (95% CI)
Non-Indigenous Australian-born women	6950	48,582	14.3 (13.9–14.7)	4630	44,850	10.3 (10.1–10.6)	−27.9 (−28.2 to −27.2)	0.72 (0.69–0.75)
Indigenous Australian women	366	884	41.4 (38.1–44.7)	453	1103	41.1 (38.1–44.0)	−0.7 (0.0 to −1.5)	0.99 (0. 86–1.14)
African-born women	72	2112	3.4 (2.7–4.3)	71	2389	2.9 (2.3–3.7)	−14.7 (−14.8 to −13.9)	0.8 (0.62–1.22)
Other overseas born women	1015	20,473	4.9 (4.5–5.3)	818	27,578	2.9 (2.6–3.2)	−40.8 (−41.2 to −38.3)	0.59 (0.54–0.65)
Maternal age								
20 years and less	988	2803	35.2 (33.4–37.1)	428	1325	32.3 (29.7–34.8)	−8.5 (−11.1 to −6.2)	0.91 (0.81–1.02)
20–25 years	2118	9670	21.9 (21.1–22.7)	1376	7613	18.1 (17.2–18.9)	−17.4 (−18.9 to −16.7)	0.83 (0.77–0.88)
26–30 years	2371	21,604	10.9 (10.5–11.4)	1803	21,517	8.4 (8.0–8.8)	−22.9 (−23.8 to −22.7)	0.76 (0.71–0.81)
31–35 years	1808	23,536	7.7 (7.3–8.0)	1518	29,188	5.2 (4.9–5.4)	−32.4 (−32.9 to −32.5)	0.67 (0.63–0.73)
>35 years	1115	14,367	7.8 (7.3–8.2)	847	16,266	5.2 (4.8–5.5)	−33.3 (−34.3 to −32.9)	0.67 (0.61–0.73)
Relationship status								
Single	2986	8627	34.6 (33.6–35.6)	2459	9304	26.4 (25.5–27.3)	−23.7 (−24.1 to −23.3)	0.76 (0.72–0.81)
Married	2552	49,925	5.1 (4.9–5.3)	1278	51,020	2.5 (2.4–2.6)	−50.9 (−51.0 to −50.8)	0.49 (0.45–0.52)
De facto	2660	12,022	22.1 (21.4–22.8)	2142	14,740	14.5 (13.9–15.1)	−34.4 (−35.1 to −33.7)	0.65 (0.62–0.69)
Gravidity								
Primigravida	2277	24,017	9.5 (9.1–9.9)	1459	24,923	5.8 (5.5–6.2)	−37.9 (−39.5 to −37.3)	0.62 (0.57–0.67)
Multigravida	4730	41,674	11.4 (11.1–11.5)	3286	44,421	7.4 (7.1–7.6)	−35.1 (−36.1 to −33.9)	0.65 (0.62–0.68)
Grand multigravida	1396	6349	21.9 (20.9–22.9)	1227	6576	18.7 (17.7–19.6)	−14.6 (−15.3 to −14.4)	0.85 (0.78–0.92)
Parity								
Nulliparous	3525	31,947	11.0 (10.6–11.4)	2463	33,933	7.1 (6.7–7.5)	−35.4 (−36.8 to −34.2	0.66 (0.62–0.69)
Primiparous	2403	24,632	9.8 (9.3–10.1)	1572	27,233	5.8 (5.4–6.1)	−40.8 (−41.9 to −39.6)	0.59 (0.55–0.61)
Multiparous	2281	14,597	15.6 (15.0–16.2)	1746	13,879	12.6 (12.0–13.1)	−19.2 (−20.0 to −19.1)	0.81 (0.75–0.85)
Grand multiparous	192	859	22.4 (19.6–25.3)	190	863	22.0 (19.3–25.0)	−1.3 (−1.5 to −1.1)	0.98 (0.80–1.21)
Socioeconomic status								
1st quintile	1904	10,390	18.3 (17.6–19.2)	1324	9738	13.6 (12.8–14.4)	−25.7 (−26.7 to −25.1)	0.74 (0.69–0.79)
2nd quintile	1393	7982	17.4 (16.6–18.3)	1044	8741	11.9 (11.2–12.6)	−31.6 (−32.5 to −31.1)	0.68 (0.63–0.74)
3rd quintile	1568	11,478	13.7 (13.0–14.3)	1108	12,158	9.1 (8.6–9.6)	−33.5 (−33.9 to −30.7)	0.66 (0.61–0. 72)
4th quintile	2513	22,841	11.0 (10.6–11.4)	1920	27,148	7.1 (6.7–7.4)	−35.4 (−36.8 to −35.0)	0.64 (0.60–0.68)
5th quintile	1025	19,360	5.3 (4.9–5.6)	576	18,135	3.2 (2.9–3.4)	−39.6 (−40.8 to −39.2)	0.60 (0.54–0.66)

*The negative sign in proportional change indicates a reduction in the proportions of smoking during pregnancy from 2011 to 2020.



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
African-born Women	3.4	3.3	2.5	2.9	2.2	2.9	2.3	2.9	2.6	2.9	2.8
Non-Indigenous Australian Women	14.3	14.1	13.2	12.8	12.2	11.6	11.3	10.5	10.1	10.3	12.1
Indigenous Australian Women	41.4	41.7	44.4	41.5	39.4	38.6	40.8	40.5	42.7	41.1	41.2
Other Overseas-born Women	4.9	4.4	4.3	3.8	3.3	3.2	3.2	2.9	2.7	2.9	3.5
Overall	11.7	11.1	10.5	9.9	9.3	8.8	8.5	7.9	7.6	8.1	9.3

Figure 3. Trends of smoking during the first 20 weeks of pregnancy among women who had given birth in Victoria, 2011–2020.

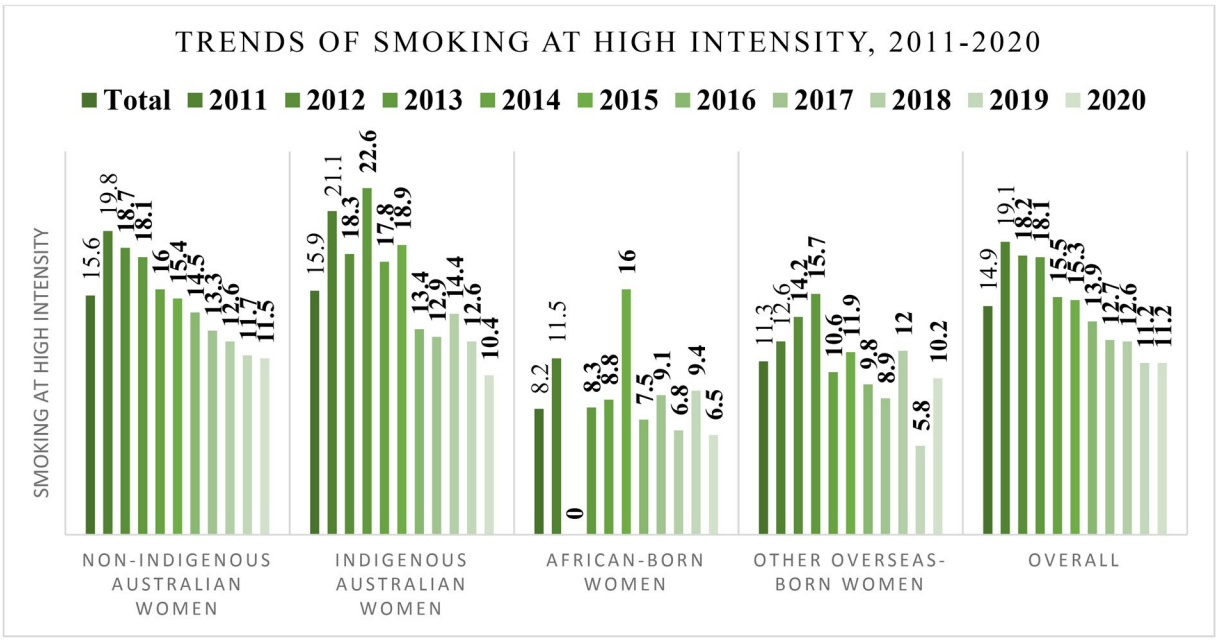


Figure 4. Trends of smoking at high intensity at ≥20 weeks of pregnancy among women who had given birth in Victoria, 2011–2020.

8.42; 95% CI: 8.21–8.65), women living in the most disadvantaged areas than those residing in the least disadvantaged areas (aRR: 3.61; 95% CI: 3.58–3.67), grand multigravida women than primigravida women (aRR: 2.83; 95% CI: 2.81–2.86), grand multiparous women than primiparous women (aRR: 2.36; 95% CI: 2.21–2.47), and women who arrived in Australia before 1990 than those who arrived after 2010 (aRR: 3.64; 95% CI: 3.58–3.72).

Discussion

This study is the first of its kind to examine trends of smoking during pregnancy and compare outcomes by taking women's birthplace and Indigenous status into account. The overall proportion of women who smoked during the first 20 weeks of pregnancy declined by 30.7% over 10 years. The proportion of women who smoked at a high intensity at ≥20 weeks of pregnancy declined by 41.3%. This might indicate the effectiveness of smoking cessation interventions, such as improved public awareness about smoking harms, bans placed on smoking in public spaces, cigarette labels stating the risks, and increased taxes on the costs of cigarettes (Almeida et al., 2022; Jenkins et al., 2023). While NIAuBW exhibited a steady decline in both smoking frequency and intensity, the decline rate fluctuated among other groups of women. This indicates targeted smoking cessation interventions, such as culturally tailored programs (Leinberger-Jabari et al., 2024) and psychological interventions (Chamberlain et al., 2017) are needed.

Table 3. Factors associated with the proportion of smoking during pregnancy among women who had given birth in Victoria, 2011–2020.

	Smoking during 20 weeks of pregnancy					Intensity of smoking during ≥20 weeks of pregnancy				
Variables	Smokers	Non-smokers	Person-time	cRR (95%CI)	aRR (95%CI)	High	Low	Perso-time	cRR (95%CI)	aRR (95%CI)
Countries of birth										
Non-Indigenous Australian-born women	57,567	418,783	476,350	1.00	1.00	5162	28,401	33,563	1.00	1.00
Indigenous Australian women	4227	6043	10,270	3.40 (3.30–3.51)	2.80 (2.40–3.10)	510	2683	3193	1.03 (0.94–1.13)*	1.12 (0.98–1.23)*
African-born women	677	23,481	24,158	0.23 (0.21–0.25)	0.21 (0.19–0.23)	27	304	331	0.53 (0.34–0.77)	0.56 (0.48–0.59)
Other overseas-born women	8935	247,330	256,265	0.29 (0.28–0.30)	0.26 (0.24–0.28)	475	3741	4216	0.73 (0.66–0.80)	0.77 (0.73–0.81)
Maternal age (766,827)[a]						[f]				
≤20 years	7068	13,969	21,037	5.40 (5.24–5.57)	5.10 (4.81–5.32)	506	4059	4565	0.58 (0.52–0.65)	0.52 (0.49–0.56)
21–25 years	17,666	73,323	90,989	3.12 (3.04–3.20)	2.92 (2.71–3.12)	1411	9463	10,874	0.68 (0.62–0.74)	0.64 (0.61–0.66)
26–30 years	20,683	206,507	227,190	1.46 (1.43–1.50)	1.42 (1.39–1.44)	1785	9859	11,644	0.80 (0.74–0.87)	0.77 (0.73–0.80)
31–35 years	16,452	257,875	274,327	0.96 (0.94–0.99)	0.89 (0.86–0.94)	1455	7425	8880	0.87 (0.80–0.94)	0.85 (0.82–0.87)
>35 years	9524	143,760	153,284	1.00	1.00	1016	4319	5335	1.00	1.00
Relationship status (758,384)[b]						[g]				
Married	18,156	512,801	530,957	1.00	1.00	1083	6874	7957	1.00	1.00
Single	27,367	62,090	89,457	8.94 (8.77–9.11)	8.42 (8.21–8.65)	2875	15,173	18,048	1.17 (1.10–1.26)	1.20 (1.18–1.23)
De facto	24,870	113,100	137,970	5.27 (5.17–5.37)	4.92 (4.85–4.98)	2089	12,600	14,689	1.04 (0.97–1.12)*	1.11 (0.98–1.16)*
Socioeconomic status										
1st quintile	16,454	87,841	104,295	4.00 (3.89–4.11)	3.61 (3.58–3.67)	1762	9054	10,816	1.25 (1.12–1.40)	1.23 (1.09–1.37)
2nd quintile	12,122	72,832	84,954	3.62 (3.52–3.73)	3.24 (3.10–3.39)	1281	6617	7898	1.25 (1.11–1.39)	1.23 (1.08–1.35)
3rd quintile	13,157	109,960	123,117	2.71 (2.63–2.79)	2.50 (2.38–2.76)	1061	6265	7326	1.11 (0.99–1.25)*	1.10 (0.97–1.20)*
4th quintile	21,968	237,048	259,016	2.15 (2.09–2.21)	1.92 (1.75–2.13)	1655	10,409	12,064	1.05 (0.94–1.18)*	1.01 (0.91–1.14)*
5th quintile	7705	187,956	195,661	1.00	1.00	415	2784	3199	1.00	1.00
Gravidity (767,043)[c]										
Primigravida	18,510	233,078	251,588	1.00	1.00	842	7696	8538	1.00	1.00
Multigravida	39,703	408,389	448,092	1.20 (1.18–1.22)	1.30 (1.27–1.41)	3264	19,976	23,240	1.42 (1.32–1.54)	1.51 (1.48–1.57)
Grand multigravida	13,193	54,154	67,347	2.66 (2.60–2.72)	2.83 (2.81–2.86)	2068	7457	9525	2.20 (2.03–2.39)	2.24 (2.12–2.44)
Parity ($n=767,043$)[d]						[h]				
Nulliparous	29,534	309,581	339,115	1.00	1.00	1398	12,546	13,944	1.00	1.00
Primiparous	19,989	253,049	273,038	0.84 (0.82–0.86)	0.76 (0.74–0.78)	1642	10,339	11,981	1.36 (1.27–1.47)	1.42 (1.31–1.54)
Multiparous	19,819	125,762	145,581	1.56 (1.53–1.59)	1.42 (1.38–1.46)	2665	11,039	13,704	1.94 (1.82–2.07)	1.98 (1.93–2.16)
Grand multiparous	2056	7186	9242	2.55 (2.44–2.67)	2.36 (2.21–2.47)	469	1202	1671	2.79 (2.51–3.11)	2.82 (2.73–3.24)
Year of arrival in Australia ($n=80,685$)[e]										
Before 1990	298	4148	4446	3.49 (3.05–3.99)	3.64 (3.58–3.72)	26	130	156	1.64 (0.95–2.78)*	1.84 (1.18–3.12)
1991–2000	469	6370	6839	3.57 (3.18–4.01)	3.71 (3.48–3.84)	18	259	277	0.64 (0.34–1.15)	0.73 (0.44–1.36)*
2001–2010	693	24,478	25,171	1.43 (1.29–1.59)	1.57 (1.52–1.61)	26	325	351	0.73 (0.42–1.24)	0.85 (0.60–1.49)*
2011–2020	839	42,947	43,786	1.00	1.00	37	328	365	1.00	1.00

*Statistically not significant ($p>0.05$).
[a]216 (13 smokers and 203 nonsmokers) where age was not stated/missed were removed.
[b]8659 (1013 smokers and 7646 nonsmokers) where data about relationship status was not stated/missed were removed.
[c]16 nonsmokers where data about gravidity was not stated/missed were removed.
[d]67 records (8 smokers and 59 nonsmokers) whose data about parity were not stated/missed were removed.
[e]443 women whose data about smoking during pregnancy were not stated/missed were removed.
[f]5 (4 smokers at low intensity and 1 smoker at high intensity) where data about maternal age were not stated/missed were removed.
[g]609 (127 smokers at low intensity and 482 smoker at high intensity) where data about relationship status were not stated/missed were removed.
[h]3 smokers at low intensity where data about parity were not stated/missed were removed.

A significant difference was noted in smoking during pregnancy among groups of women by country of birth and Indigenous status. The proportion of smoking during pregnancy was highest among IAuW, followed by NIAuBW, showing that smoking during pregnancy was higher among Australian-born women than overseas-born women. This is

consistent with the findings of a previous study where higher proportions of native women smoked than overseas-born women (Teixeira et al., 2018). However, the frequency and intensity of smoking during pregnancy remain significantly varied among the groups studied. Given that smoking any number of cigarettes per day during pregnancy significantly increases the risk of adverse perinatal outcomes and that smoking at high intensities further elevates these risks (Liu et al., 2025), smoking cessation strategies should target all smokers. Similarly, Australian national data have shown that smoking during pregnancy remains disproportionately higher among IAuW (AIHW, 2023) despite many smoking cessation interventions in this group. This could be explained by existing health inequalities, social norms, and increased stressors experienced by IAuW that continue to pose barriers to the uptake of available smoking cessation strategies (Harris et al., 2019). Given that smoking during pregnancy among IAuW was disproportionately higher than other groups, novel strategies such as educating women *via* peer groups, and co-designing smoking cessation interventions may be beneficial (Flemington et al., 2021).

Compared to the NIAuBW, overseas-born women exhibited lower proportions of smoking during pregnancy. These results are in line with findings of previous studies where overseas-born women smoked at a lower rate than women born in the host country (Klöfvermark et al., 2019; Teixeira et al., 2018). However, other studies show that high proportions of women from high-income countries smoke during pregnancy (Lange et al., 2018) and are likely to continue this behavior following migration. Additionally, migration factors have been shown to increase the risk of smoking (Hertner et al., 2023). Research suggests that assimilation into the culture of the host country is associated with an increased risk of smoking during pregnancy (Urquia et al., 2014), suggesting that the duration women have resided in Australia should be considered when examining risks for smoking during pregnancy.

The prevalence of smoking during pregnancy among AfBW was found to be 2.7%. This finding indicates that AfBW smoked at a higher rate in Australia as compared to their home countries (Lange et al., 2018). For example, a study conducted across 33 sub-Saharan African countries reported a prevalence of smoking during pregnancy at 1.76% (Aychiluhm et al., 2024). Evidence from the analysis of data from the Demographic and Health Surveys from 54 LMICs showed that the lowest prevalence of smoking during pregnancy was observed in the African region at 2.0% (Caleyachetty et al., 2014). Additionally, a recent meta-analysis found that the prevalence of smoking during pregnancy was lowest in the African region at 0.8% (Lange et al., 2018). These discrepancies may be attributable to migration factors, including poor access to existing support services (Hertner et al., 2023) suggesting a need for tailored smoking prevention interventions for this group.

In this study, the proportion of smoking during pregnancy declined from 2011 to 2020, with variability among the four groups. This is consistent with the findings of previous studies (Moussa et al., 2010; Urquia et al., 2021). For example, a time-trend study conducted in Sweden revealed that smoking during pregnancy had declined from 30.3% in 1982 to 11.0% in 2001, with significant differences according to women's country of origin (Moussa et al., 2010). The decline in smoking during pregnancy found in our study might be attributed to the effectiveness of Australian behavioral and pharmacological smoking cessation interventions (Jenkins et al., 2023). Although behavioral interventions appear to be more effective for smoking cessation during pregnancy (Patnode et al., 2021), nearly half of pregnant Australian mothers prefer medical interventions as a strategy to quit smoking (Hoekzema et al., 2014). Evidence has shown that pharmacological interventions have minimal risk of harm during pregnancy (Tran et al., 2020) and may be incorporated as part of multiple smoking cessation strategies to address women's preferences.

Apart from women's country of birth and Indigenous status, several socioeconomic factors heightened the risk of smoking during pregnancy in some groups of women. Higher smoking rates during pregnancy were associated with younger age, being single, living in the most disadvantaged areas, and grand multiparity and gravidity. These findings are in line with the analysis of national data (AIHW, 2023). Younger pregnant women are more likely to smoke than older women (Reitan & Callinan, 2017), suggesting that they may be reluctant to adopt smoking control guidance at the same pace as their older counterparts. Single pregnant women who move to another country may experience loneliness and psychological problems, and thus are more likely to use psychoactive substances (Melchior et al., 2015). Data from the AIHW support our findings that women living in the most disadvantaged areas were more likely to smoke than those in the least disadvantaged areas (AIHW, 2022). Although reduction in smoking during pregnancy could be attributed to costs related to smoking, Cigarettes might be used more frequently in this group to relieve stress related to lack of employment, low-income, a lack of social support, and being economically marginalized (Boucher & Konkle, 2016) Thus, providing financial incentives as a smoking cessation strategy may be beneficial (Flemington et al., 2021).

This study used a longitudinal dataset covering all women who gave birth in Victoria over 10 years, ensuring evidence representativeness. A Poisson regression model was applied because it is suitable to account for autocorrelation for multiple births. The accuracy of the VPDC dataset has been confirmed by prior studies, making the findings robust to inform policy and practice. Additionally, stepwise exclusion of missing data was employed to enhance the accuracy of results. Despite these strengths, the study has some limitations. The VPDC relies on self-reported data from pregnant women to their service providers, which could introduce reporting biases and data incompleteness. Additionally, each pregnancy was treated as an independent event in the analysis, even though some women may have been pregnant multiple times over the study period, potentially affecting the accuracy of estimated proportions. The dataset also did not include information on women's educational attainment, which could be a significant factor that influences smoking during pregnancy. Furthermore, due to the shortage of similar studies, discussing the findings to draw comparable conclusions was challenging.

Conclusions

Despite a significant reduction in smoking during pregnancy during 2011–2020, the proportion remains high in NIAuBW and IAuW. Given that no smoking level is safe during pregnancy, the implications of these results are concerning in all groups of women. AfBW smoked at a higher rate in Australia as compared to smoking status of women in their home countries. This finding suggests that migration factors may increase the risk of smoking during pregnancy for these women (Hertner et al., 2023).

Providing consistent screening of smoking at every antenatal care visit, as recommended by WHO (2013), designing smoking control interventions tailored to sociocultural expectations, and referral to smoking cessation support services is important. Integration of smoking cessation interventions into routine prenatal care and expanding smoking control strategies to all women of childbearing age could help to reduce smoking rates during pregnancy. Prevention of smoking during pregnancy can be better achieved by strengthening smoking cessation strategies during the preconception period (Dean et al., 2013). Strengthening the implementation of the National Tobacco Strategy (Department of Health and Aged Care, 2023) and the Victorian Public Health and Wellbeing Plan (Department of Health, 2023) which aim to reduce harm from tobacco, is also important for reducing smoking during pregnancy. Overall, the findings of the current study inform policy and practice and highlight new approaches to reduce smoking during pregnancy among overseas-born women in Australia.

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Ethical approval

Please accept this as confirmation that the "Epidemiology of smoking during pregnancy by women's country of birth and Indigenous status in Victoria, Australia: A comparative trend analysis" obtained exemption from ethical approval from the Deakin University Human Research Ethics Committee.

Author agreement

The authors confirm that the article is the authors' original work. The article has not received prior publication and is not under consideration for publication elsewhere. All authors have read the final draft and approved the manuscript being submitted.

Authors contributions

All authors (AGB, VV, TF, and LS) have substantially contributed to the conception and design of the work; the acquisition, analysis, and interpretation of data. AG has drafted the manuscript and VV, TF, and LS revised the article critically, provided substantive feedback, and contributed to the intellectual content of this article. All authors read and approved the final version of the manuscript to be submitted.

Declaration of interest

The authors declare that they have no conflict of interest. The authors alone are responsible for the content and writing of the article.

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Data availability statement

The data analyzed in this study can be accessed from the Victorian Perinatal Data Collection.

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