Accelerating cervical cancer elimination in Aboriginal and Torres Strait Islander women: a modelling study

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Summary

Background Australia aims to achieve cervical cancer elimination (incidence <4 cases per 100 000 women) nationally by 2035. Incidence in Aboriginal and Torres Strait Islander women is around twice the national rate, driven by long-standing inequity in screening. We aimed to predict when elimination would be achieved among Aboriginal and Torres Strait Islander women, and if increased vaccination or screening coverage could expedite elimination, using a cervical cancer simulation model.

Methods In this modelling study, we adapted Policy1-Cervix—an existing dynamic model of human papillomavirus (HPV) transmission and vaccination, and linked model of HPV natural history, cervical screening, and cancer—to reflect data on Aboriginal and Torres Strait Islander women. We compared the timing of cervical cancer elimination for a scenario where current coverage continues to seven hypothetical scenarios involving improved vaccination and screening coverage in Aboriginal and Torres Strait Islander women: increased HPV vaccination coverage (from 80·9% to 90·0% in 12-year-old females); increased uptake (reducing the proportion of individuals who are never-screened); timeliness (reducing under-screening); and increased follow-up attendance. Cervical cancer elimination timing was defined as the first year from which cervical cancer incidence was consistently lower than 4 per 100 000 women.

Findings Under current vaccination and screening rates in Australia, cervical cancer elimination among Aboriginal and Torres Strait Islander women was projected to occur in 2047, 21 years later than projected for Australian women overall (2026). Improving vaccination coverage (from 80·9% to 90·0%) improved longer-term outcomes but did not accelerate elimination in Aboriginal and Torres Strait Islander women. Increasing screening uptake, on-time attendance, and attendance for follow-up tests to match national rates expedited elimination in Aboriginal and Torres Strait Islander women by 4 years (2043). A one-off large-scale screening initiative that reached every unscreened Aboriginal and Torres Strait Islander women, and sustained efforts thereafter, could achieve elimination by 2036, aligning with national targets and setting a precedent for global efforts.

Interpretation Urgent effective action to improve culturally safe access to screening and follow-up could markedly accelerate cervical cancer elimination among Indigenous women in Australia.

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Introduction

Cervical cancer is highly preventable by vaccination against human papillomavirus (HPV) and cervical screening. WHO called for global action to eliminate cervical cancer as a public health problem. The WHO elimination strategy sets an elimination threshold of fewer than four new cases of cervical cancer per 100 000 women annually, and identifies targets for HPV vaccination, cervical screening, and treatment of identified lesions.[1]

Australia has had a National Cervical Screening Program in place since 1991, transitioning in December, 2017, from cytology every 2 years to HPV screening every 5 years. Cervical cancer incidence reduced by 51% during the first 20 years of the programme.[2] HPV vaccination has been included in the National Immunisation Program since 2007 for girls (with catch-up for those aged ≤26 years), and 2013 for boys. Targets for vaccination, screening, and treatment are close to being met at the national level.[3] In a previous modelled analysis, we predicted that Australia could achieve cervical cancer elimination (incidence consistently <4 cases per 100 000 women) by around 2028.[4] In 2023, Australia published a national strategy to eliminate cervical cancer by 2035, based on the WHO strategy, but tailored to local needs.[5] The priorities identified in the strategy focus strongly on equity because, while the national incidence rate is relatively low (6·3 cases per 100 000 women), incidence and mortality are higher in some groups, such as Aboriginal and Torres Strait Islander people, people living in very remote areas, and people living in lower socioeconomic areas.[3]

The ongoing impacts of colonisation and racism have resulted in the loss of land, languages, cultures, and

Research in context

Evidence before this study

Aboriginal and Torres Strait Islander women, the First Peoples of Australia, have been disproportionately affected by cervical cancer for decades, driven by long-standing systemic inequity, structural racism, and the absence of culturally safe, accessible cervical screening. It has previously been estimated that, nationally, Australia's cervical cancer rates could fall below the WHO threshold for elimination by 2035, but it is not known when this could be achieved among Aboriginal and Torres Strait Islander women. Considering the higher starting point for cervical cancer incidence rates among Aboriginal and Torres Strait Islander women than the general population, it is likely that specific action is needed to accelerate reductions and align with the national target of achieving elimination by 2035. We searched PubMed for studies published between Jan 1, 2015, and Dec 31, 2025, using the search terms: "cervical cancer" AND eliminat* AND model* AND (timeframe OR "time frame" OR timing OR timeline OR expedit* OR accelerat*). We also searched reference lists of identified articles for additional studies. Our search identified 41 studies, 21 of which estimated the timeline to achieve elimination. Implementing human papillomavirus (HPV) vaccination was necessary to achieve elimination. Actions that were found to affect elimination timing in the 19 studies that considered this were improving screening coverage (including introducing screening), switching to HPV screening, and (up to a point) increasing screening frequency or lifetime screens. Improving vaccine coverage, and especially catch-up of adolescents, could accelerate elimination if the baseline timing was sufficiently far in the future, although this had a negligible effect once coverage was high. Three studies considered timing of elimination and actions affecting it in identifiable population subgroups and how this related to the national timeline; one study considered women with HIV in Kwa-Zulu Natal, South Africa, a second considered women in two different regions in Malaysia, and another study done in China considered urban versus rural populations. We identified no studies that considered timing of elimination in Aboriginal and Torres Strait Islander peoples or Indigenous peoples from other countries, nor any that sought to identify how disparities in timing could be reduced.

Added value of this study

We assessed when elimination would be achieved among Aboriginal and Torres Strait Islander women based on existing vaccination and screening coverage, and what actions to scale up prevention measures could expedite it. We found that, in the absence of change, elimination is predicted to occur 21 years later among Aboriginal and Torres Strait Islander women than is predicted for Australia overall (2047 *vs* 2026). Increasing vaccine coverage to 90% made virtually no difference to the timing of elimination. Scaling up screening uptake, re-attendance for routine screening, and attendance for follow-up tests to match national rates led to small improvements (the combined effect of improving all of these accelerated elimination by up to 4 years). Considering the bounds of what was possible, we found that if these aspects of screening were scaled up to 100%, elimination could be achieved in 2036, close to the national target of 2035. Most of this acceleration was due to increasing screening uptake to 100% (ie, ensuring every Aboriginal and Torres Strait Islander woman was screened at least once and appropriately followed up based on clinical guidelines).

Implications of all the available evidence

Consistent with earlier analyses, we found that improving access to screening is crucial to expediting elimination. To overcome decades of failure to provide culturally safe, accessible screening to all Aboriginal and Torres Strait Islander women, more is required than simply matching national rates. A one-off large-scale national outreach campaign to reach the approximately 45 900 Aboriginal and Torres Strait Islander women who have never been screened could make a profound difference towards cervical cancer elimination. This could be achieved through Indigenous community-led approaches that prioritise cultural safety and impact, such as self-collection or point-of-care testing, delivered via community co-designed pathways. It is likely that these broad findings, specifically that reaching never-screened individuals will have the greatest effect on expediting elimination, would also apply to other populations that have also experienced barriers to screening (such as LGBTQ+ populations, multicultural populations, those with a disability, who are intersex, or who live in rural or remote areas) but where there are limited data to support direct modelling.

identity and also manifested in health inequities for Aboriginal and Torres Strait Islander peoples, the First Peoples of the continent now known as Australia.[6] These inequities are exemplified in the case of cervical cancer.[7] Cervical cancer incidence in Aboriginal and Torres Strait Islander women is 11·7 cases per 100 000 women, approximately twice the national rate and substantially higher than national rates in several other high-income countries.[3] Inequities in access to cervical screening seem to have been the main driver of this disparity. Although there are no routinely reported or national data on cervical screening among Aboriginal and Torres Strait Islander women, ad-hoc state-based analyses suggest that participation is around 20–30 percentage points lower than in non-Indigenous women, and that this difference has not reduced over time.[8,9] The universal option to be screened on a self-collected sample (introduced in July, 2022) provides opportunities to increase access to screening. In contrast to screening, HPV vaccination coverage had been similar in Aboriginal and Torres Strait Islander and non-Indigenous girls before diverging after 2022

(coverage of ≥1 dose, 76·7% in Aboriginal and Torres Strait Islander girls and 81·3% in non-Indigenous girls in 2024).[3]

Considering the different starting point for cervical cancer incidence and screening rates in Aboriginal and Torres Strait Islander women compared with national rates, it is likely that elimination among this group could take longer than the timeframe predicted nationally.[7,10] In the current analysis, we aimed to estimate when cervical cancer elimination would be achieved among Aboriginal and Torres Strait Islander women, considering existing rates of vaccine uptake and cervical screening, and explore the extent to which increasing HPV vaccination and cervical screening coverage could expedite elimination.

Methods

Positionality statement

Recognising that research is deeply social and shaped by subjective decisions, we pause to reflect on our own position in relation to this work and the worldviews that shape our realities. We are a team of both Aboriginal and Torres Strait Islander (LJW and GG) and non-Indigenous (MAS, JK, XO, DTNN, LJ, and KC) researchers. We bring collective expertise in areas related to Indigenous health, public health, epidemiology, modelling, and cervical cancer elimination. We share a commitment to addressing racial and social inequities and the unequivocal vision to ensuring the elimination of cervical cancer is both equitable and timely. This work was undertaken to support this vision.[5,10] The authors acknowledge ongoing repercussions and harms of settler-colonialism, and this understanding underpins our research. We acknowledge that data presented in this article are not just numbers—they represent women and matriarchs, families, communities, histories, and futures. We are deeply committed to sharing findings in ways that honour self-determination and advance strengths-based narratives for Aboriginal and Torres Strait Islander peoples; and in turn clearly articulate the effort and responsibilities required by the nation to commit to the health and wellbeing of Aboriginal and Torres Strait Islander peoples.

Governance

The research question, methodological approach, interpretations, and dissemination and engagement plans were refined through discussions with Thiitu Tharrmay Aboriginal and Torres Strait Islander research reference group. We report against the CONSIDER statement in line with best practice (appendix p 24).

Model

The Policy1-Cervix model platform used for this analysis has been validated to several different settings, including Australia, the USA, and at the global level.[11,12] Previous analyses with this model include projecting the timing of cervical cancer elimination in Australia.[4] The model consists of multiple components: (1) a dynamic model of HPV transmission, incorporating sexual behaviour and vaccination; (2) HPV natural history; (3) a cervical screening overlay of diagnosis, management and treatment of pre-cancer lesions and cancer; and (4) cancer survival. Oncogenic HPV types preventable by the nine-valent HPV vaccine (HPV 16, 18, 31, 33, 45, 52, and 58) are modelled individually, and other oncogenic types as a group. The model is described in detail in the appendix (pp 3–22).

See Online for appendix

Patient consent and ethical approval were not required because all data used were de-identified, aggregated published data.

Model parameterisation and calibration

The model parameterisation and calibration remained largely consistent with previous analyses calibrated to Australia.[4] Model parameters were adjusted to fit observed data for Aboriginal and Torres Strait Islander women, where available, including screening participation data from New South Wales and Queensland,[8,9] HPV vaccination coverage, other-cause mortality, and follow-up attendance (appendix pp 5–12). HPV exposure was assumed to be the same since HPV prevalence is broadly similar in Aboriginal and Torres Strait Islander and non-Indigenous women, especially for HPV 16/18 and among younger women.[13]

	Description
Scenario 0: base case (status quo)	Current vaccination and cervical screening rates continue
Scenario 1: improved vaccination coverage	Vaccination coverage in Aboriginal and Torres Strait Islander females is boosted from 80·9% to 90% in girls aged 12 years, consistent with the WHO target
Scenario 2: improved screening initiation	Cervical screening initiation (uptake) rates in Aboriginal and Torres Strait Islander women are increased to match national rates
Scenario 3: improved routine screening	Attendance rates for routine screening in Aboriginal and Torres Strait Islander women are increased to match national rates
Scenario 4: improved follow-up	Attendance rates for a follow-up test in Aboriginal and Torres Strait Islander women are increased to match national rates
Scenario 5: all screening improvements combined	Includes all the screening improvements detailed in scenarios 2, 3, and 4
Scenario 6: perfect screening benchmark	Scale-up of screening uptake, routine screening, and follow-up rates to 100% (including a catch-up in 2024 whereby any previously unscreened Aboriginal and Torres Strait Islander females aged 25–74 years were screened), to reflect the potential of a very large-scale campaign and concerted efforts thereafter, which would provide a benchmark of the potential impact of such a concerted effort and the upper bound of what is possible
Scenario 7: perfect initiation (including catch-up) benchmark; improved routine screening and follow-up (match national rates)	Improved routine screening and follow-up to national rates, as in scenarios 3 and 4, and scale-up of screening uptake to 100% (including a catch-up in 2024 whereby any previously unscreened Aboriginal and Torres Strait Islander females aged 25–74 years were screened); this scenario isolates the impact of reaching previously never-screened women, and the upper bound of if every Aboriginal and Torres Strait Islander woman is screened at least once in their life

All scenarios simulating scaled-up prevention activities (scenarios 1–7) assumed that these higher vaccination, screening, or follow-up rates start from (and were fully achieved in) 2024.

Table 1: **Scenarios simulated in the analysis**

Adjusting screening attendance primarily accounted for the observed difference in cervical cancer incidence between Aboriginal and Torres Strait Island women and the general population. Model-predicted pre-vaccination cervical cancer rates in Aboriginal and Torres Strait Islander women closely aligned with observed data (appendix pp 7–8). Similarly, observed data for cytology results and high-grade histology rates in Aboriginal and Torres Strait Islander women were broadly consistent with Policy1-Cervix model predictions (appendix pp 9–10). This consistency supported our assumption that HPV exposure and natural history are similar, with differences in cancer incidence being attributed to inequalities in access to health care.

Modelled scenarios

All scenarios modelled screening recommendations of cytology screening every 2 years pre-2018, transitioning in 2018 to primary HPV screening every 5 years; vaccination with the quadrivalent vaccine for females from 2007 and boys from 2013 (including catch-up in both cases); and the transition to the nine-valent HPV vaccine in 2018. The base-case scenario incorporated realistic vaccination and cervical screening rates and assumed that these would continue (appendix pp 6–7, 19–20). A base-case national scenario was run for comparison.

Seven additional exploratory scenarios simulated scaling up cervical cancer prevention measures among Aboriginal and Torres Strait Islander women in 2024, to quantify which scenario would be the most effective in bridging the gap between Aboriginal and Torres Strait Islander women and the overall Australian population (table 1).

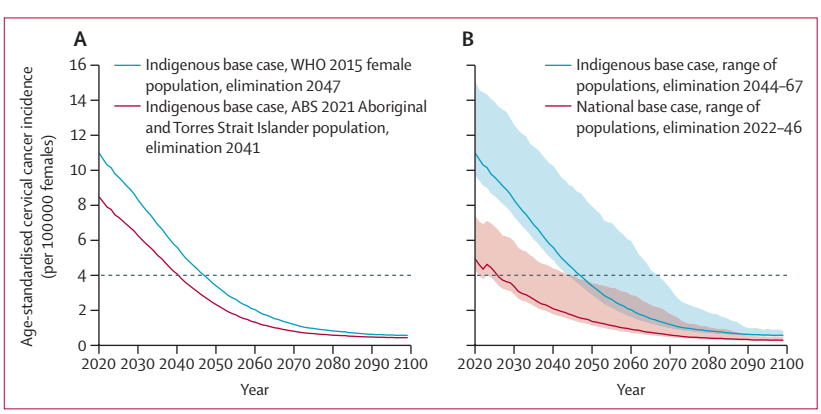

Figure 1: **Predicted cervical cancer incidence (age standardised, per 100 000 females) between 2020 and 2100**
(A) Incidence rates in Aboriginal and Torres Strait Islander females, age-standardised to the WHO 2015 world female population (as per the recommended methodology for elimination)[14] and the ABS 2021 Aboriginal and Torres Strait Islander population.[15] The ABS 2021 Aboriginal and Torres Strait Islander population is relatively younger than the other populations considered, resulting in an earlier elimination time of 2041. The age-structure of the population is itself an indicator of the gap between national and Indigenous health outcomes more broadly and therefore was not used in the comparisons of elimination timing, as it could paradoxically downplay the differences between outcomes. (B) Incidence rates in Aboriginal and Torres Strait Islander women and in Australian women overall, for a range of standard populations. The solid lines represent incidence rates age-standardised to the WHO 2015 world female population aged 0–99 years. The shaded area indicates the range of cancer incidence rates resulting from applying different standard populations during age-standardising. For both the national and Indigenous base-case scenarios, the upper end of the range reflects an unweighted population and the lower end of the range reflects the Segi population.[18] The black dashed lines represent the WHO cervical cancer elimination threshold of four cases per 100 000 women. ABS=Australian Bureau of Statistics.

Outcomes

The primary analysis outcome was the timing of cervical cancer elimination, defined as the first year from which cervical cancer incidence rates were consistently below 4 cases per 100 000 women (age-standardised to the WHO 2015 world female population aged 0–99 years, as per the recommended methodology for elimination and international benchmarking[14]). Based on advice and direction from the Thiitu Tharrmay Aboriginal and Torres Strait Islander reference group, for Aboriginal and Torres Strait Islander rates only, we additionally used the Australian Bureau of Statistics (ABS) 2021 Aboriginal and Torres Strait Islander population,[15] to generate "metrics centred around and reflective of reality for the population of focus, supporting self-determination and Indigenous data sovereignty principles".[16] This population is younger than the overall Australian population (median age 24 years *vs* 38 years), reflecting lower life expectancy and higher birth rates, in turn reflecting many complex factors that are long-standing impacts of colonisation.[6]

Sensitivity analysis

One-way sensitivity analyses used alternative assumptions for benign hysterectomy rates and the population used to age-standardise cervical cancer incidence rates. The alternative standard populations used were the ABS 2001 (standard used in routine Australian statistics),[17] WHO 2000, Segi,[18] and an unweighted rate (representing the mean of all age-specific rates). In the absence of reliable data on hysterectomy rates in Aboriginal and Torres Strait Islander women, the base-case rates were assumed to be the same as for the overall population, with sensitivity analysis exploring a high-end scenario of 20% higher incidence and a low-end scenario of 20% lower incidence than the national hysterectomy rates.

Role of the funding source

The study funders had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Under current vaccination and screening rates in Australia, the achievement of cervical cancer elimination among Aboriginal and Torres Strait Islander women was projected to occur in 2047 (figure 1, table 2). At the national level, elimination was projected to be achieved 21 years earlier, in 2026. Differences in absolute cervical cancer incidence will be reduced as vaccinated cohorts age, however incidence (per 100 000 females) would remain approximately twice as high in Aboriginal and Torres Strait Islander women than rates in the national

	Elimination year (years delayed compared with Australia overall, n)						Years elimination was brought forward *vs* status quo: base case (range)
	WHO 2015 (base case)[14]	ABS 2001[17]	Segi[18]	WHO 2000	Unweighted*	ABS Aboriginal and Torres Strait Islander 2021[15]	
Australia overall	2026	2031	2022	2026	2046	2020	..
Aboriginal and Torres Strait Islander women							
Scenario 0: base case (status quo)	2047 (21)	2053 (22)	2044 (22)	2046 (20)	2067 (21)	2041	..
Scenario 1: improved vaccination	2047 (21)	2052 (21)	2044 (22)	2046 (20)	2067 (21)	2041	0 (0–1)
Scenario 2: improved screening uptake	2045 (19)	2050 (19)	2042 (20)	2043 (17)	2065 (19)	2039	2 (2–3)
Scenario 3: improved routine screening	2047 (21)	2052 (21)	2044 (22)	2045 (19)	2067 (21)	2040	0 (0–1)
Scenario 4: improved follow-up	2046 (20)	2050 (19)	2043 (21)	2045 (19)	2064 (18)	2040	1 (1–3)
Scenario 5: improved screening (uptake, routine, and follow-up	2043 (17)	2047 (16)	2040 (18)	2042 (16)	2063 (17)	2037	4 (4–6)
Scenario 6: perfect screening	2036 (10)	2040 (9)	2032 (10)	2034 (8)	2058 (12)	2028	11 (9–13)
Scenario 7: perfect uptake and catch up	2037 (11)	2042 (11)	2034 (12)	2036 (10)	2061 (15)	2030	10 (6–11)

Table 1 contains a detailed description of the scenarios. ABS=Australian Bureau of Statistics. *Unweighted rate represents the mean of all age-specific rates.

Table 2: **Timing of cervical cancer elimination for all scenarios and all population structures**

population overall (0·60 *vs* 1·21 in 2070, 0·31 *vs* 0·58 in 2099).

The timing of elimination was not altered by increasing vaccination rates (elimination was brought forward up to 1 year depending on the population used; figure 2, table 2). Improvements to screening each had a greater impact than improving vaccination but even when combined the elimination year was much later than projected at the national level. Improving screening uptake and follow-up in Aboriginal and Torres Strait Islander women accelerated elimination by 2 and 1 years to 2045 and 2046, respectively, compared with the base case. Improving re-attendance for routine screening did not bring forward elimination by itself but did contribute to the overall effect when the screening improvements were combined. Improving all three aspects together brought elimination forward by 4 years, to 2043, still representing a 17-year delay for Aboriginal and Torres Strait Islander women. In the benchmarking analysis where screening uptake, routine screening, and follow-up attendance were all set to 100%, elimination was brought forward 11 years to 2036.

We further explored these findings by maintaining perfect initiation of screening and a catch-up screen in 2024 for every previously unscreened Aboriginal or Torres Strait Islander woman aged 25–74 years, but with routine screening and follow-up attendance set to national rates. This brought forward elimination by 10 years to 2037, which was similar to the timing achieved by scaling up all three aspects of screening to 100%. Both scenarios with perfect uptake, including screening catch-up in 2024, resulted in a substantial transient increase in cervical cancer incidence rates in 2024 (as screening identified previously undiagnosed cervical cancers in unscreened women), after which incidence rapidly decreased.

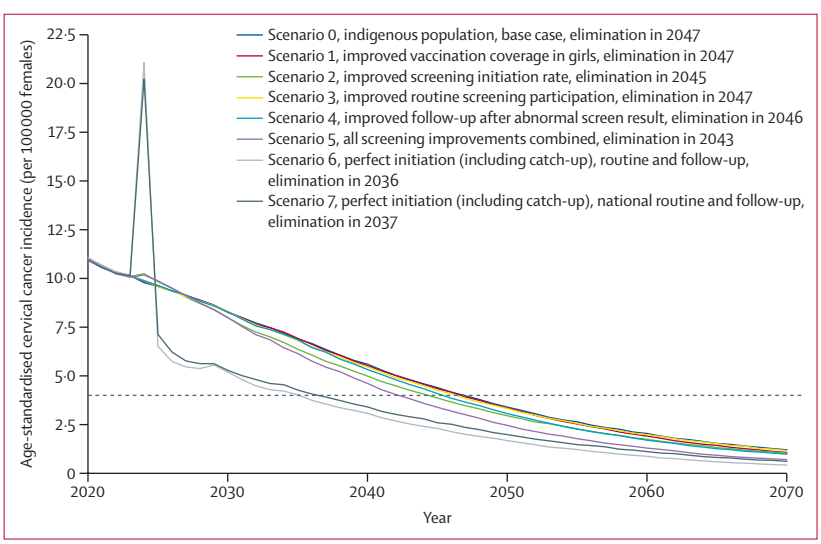

Figure 2: **Predicted cervical cancer incidence (per 100 000) under improved prevention scenarios in Aboriginal and Torres Strait Islander women**

Cervical cancer incidence was age-standardised to the WHO 2015 world female population aged 0–99 years. The figure has been cut off at 2070 to enable easier visualisation of elimination timings of the different scenarios, which occur between 2036 and 2047. All scenarios simulating scaled-up prevention activities (scenarios 1–7) assumed that these higher vaccination, screening, or follow-up rates started from (and were fully achieved in) 2024. Lines showing results for scenarios 0, 1, and 3 largely overlapped (elimination would be achieved in the same year in each case).

In sensitivity analysis, using different standard populations shifted the base-case elimination year substantially both for Aboriginal and Torres Strait Islander women (range 2044–67) and Australian women overall (2022–46); however, the gap between the timing of elimination for Aboriginal and Torres Strait Islander women and Australian women overall was less variable, varying by only 2 years (20-year delay: WHO 2000, 22-year delay: a 20-year delay was observed when

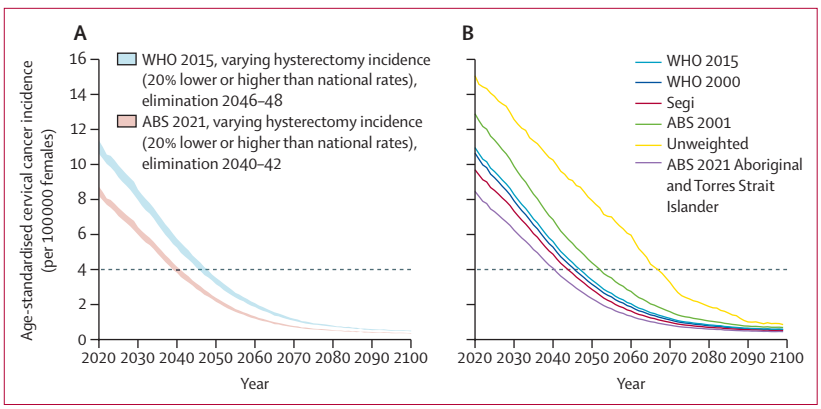

Figure 3: **Cervical cancer incidence in Aboriginal and Torres Strait Islander women (per 100 000 females): sensitivity analysis under varying assumptions**

(A) Cervical cancer incidence under varying hysterectomy incidence (20% lower or higher incidence than the national hysterectomy rates), age-standardised to the WHO 2015 world female population, and the ABS 2021 Aboriginal and Torres Strait Islander population. (B) Cervical cancer incidence standardised to different populations. ABS=Australian Bureau of Statistics.

standardised to the WHO 2000 population, a 21-year delay when standardised to an unweighted population, and a 22-year delay when standardised to the ABS 2001 population or Segi population; table 2, figure 3).

Varying hysterectomy incidence by 20% had relatively little impact on elimination timing, regardless of the standard population used. The high-end hysterectomy incidence scenario brought forward elimination by 1 year, while the low-end hysterectomy incidence scenario delayed elimination by 1 year.

Discussion

Our analysis predicted that, without change, cervical cancer elimination will be 21 years later for Aboriginal and Torres Strait Islander women than for the national population of Australia overall (2047 *vs* 2026, respectively), and 12 years later than Australia's target of achieving equitable elimination by 2035. We found that systematic improvements to make screening more accessible and support timely follow-up that removed the difference in screening participation and follow-up rates could bring elimination forward to 2043, reducing the delay by 4 years. Increasing vaccination coverage to 90% seems unlikely to substantially expedite elimination timing, due to herd effects and one-dose vaccination coverage already being relatively high among Aboriginal and Torres Strait Islander females. However, the importance of high vaccine uptake in long-term cancer reductions should be noted. Since the current analysis was undertaken, more recent vaccine uptake data have been published, showing a decline overall but a more pronounced decline in Aboriginal and Torres Strait Islander than non-Indigenous adolescents.[3] Considering that changes in vaccination coverage take some time to affect cancer incidence, due to the delay between vaccination and cancer prevention, this is unlikely to affect national elimination timing but might delay elimination among Aboriginal and Torres Strait Islander women, further widening the disparity in timing. This further emphasises the need to take rapid action to improve screening, which can affect incidence in the nearer term, while also working to reverse declines in vaccine uptake and maintain high coverage, to ensure longer-term reductions.

Two of the three modelled improvements to screening expedited elimination timing (improved initiation, by 2 years; improved follow-up after an abnormal result, by 1 year). Improved routine participation did not on its own alter elimination timing but did contribute when combined with the other screening improvements, whereby the total effect of these improvements was greater than the sum of the individual effects (ie, expedition of elimination date by 4 years *vs* 3 years). Thus, our analysis suggests that improving access to all aspects of the screening pathway to match rates achieved nationally will have an impact on the timing of elimination but implies a 17-year delay will remain for Aboriginal and Torres Strait Islander women. Our benchmarking analysis that considered scale-up to 100% screening, suggests that elimination could be accelerated by up to 11 years, within 1 year of the national 2035 goal; the key factor is to ensure every eligible Aboriginal and Torres Strait Islander woman is screened at least once. First, these findings suggest that matching the existing national rates should be a minimum, not a target. Second, they suggest that a major investment, now, in realising near-universal screening coverage in Aboriginal and Torres Strait Islander women would result in profound health outcomes within the next decade, achieve elimination as early as 2036, and could be expected to save lives, although quantifying these is beyond the scope of our analysis. Such a campaign would need to reach approximately 45 900 women in the near term. This could be achieved through an Aboriginal and Torres Strait Islander-led approach that prioritises culturally safe and impactful methods, such as self-collection or point-of-care testing delivered via community co-designed pathways.[19] Leadership from Aboriginal Community Controlled Health Organisations, supported by Aboriginal and Torres Strait Islander health workers and practitioners, will be essential to ensure the campaign is trusted, accessible, and responsive to community needs.[5,20] New ways of addressing what has been a known inadequacy of the National Cervical Screening Program are required.

Our finding that improved screening can expedite cervical cancer elimination in comparable settings with screening and HPV vaccination programmes is consistent with previous findings for the USA, Greece, the Netherlands, Norway, and the Canadian province of British Columbia.[21–25] Our findings that improving existing vaccination coverage in adolescents has relatively little impact on the timing of elimination is also consistent with these previous analyses, and our previous

analysis for Australia overall.[4] The Australian analysis found elimination timing was relatively insensitive to whether or not boys were vaccinated (which would indirectly protect unvaccinated females, analogous to directly vaccinating more females). However, the analysis noted that vaccination of boys or increasing coverage in girls would have other benefits in preventing non-cervical HPV-related cancers, and other HPV-related disease.[4] Some studies have found improved vaccination has an impact on elimination timing, generally involving situations where elimination would otherwise occur around 20 or more years after the assumed change in vaccination, providing sufficient lead-time for improved vaccination to have an impact on overall rates.[23,24]

Much is known about inequitable access to cervical screening, and the resulting low screening participation, due to a combination of systemic, cultural, and logistical barriers. These include the absence of culturally safe health-care services, experiences of racism, mistrust of the health system, and limited access in remote areas.[7,9,26] Additionally, many women report feelings of shame, embarrassment, or discomfort during the screening process.[7] Self-collection has been shown to be acceptable and increase screening participation in under-screened populations, including Aboriginal and Torres Strait Islander women.[27–31] Resourcing scale-up of innovative point-of-care testing models that have been successfully piloted, as called for in Australia's national cervical cancer elimination strategy, would benefit communities in more remote areas as they not only improve screening accessibility, but also enable same-day follow-up with colposcopy or triage cytology.[5,19] These approaches could address some current barriers that have resulted in Aboriginal and Torres Strait Islander women being less likely than non-Indigenous women to receive timely colposcopy and precancer treatment, despite having higher detection rates of high-grade abnormalities.[3,32] Other opportunities to improve include systemic reform that positions Aboriginal and Torres Strait Islander health practitioners and workers at the centre of screening and follow-up delivery.[5,20] Embedding their leadership is essential to ensure cultural safety, strengthen trust, and improve engagement. Enhancing the quality and visibility of Indigenous-specific data is crucial to driving accountability and sustaining progress.

In this analysis, we defined cervical cancer elimination as occurring in the first year that cervical cancer incidence decreased to less than 4 cases per 100 000 and thereafter remained below this threshold. This definition is possible in a modelled analysis, but not in real-world assessment. First, because models can simulate large populations to remove year-to-year random variation, but removing random variation is not possible in the real world for smaller populations, which would include Aboriginal and Torres Strait Islander people and also many countries. Second, because in a model simulation it is possible to project incidence rates in future years and thus confirm a reduction below the threshold is consistent, rather than transient, but in the real world incidence rates in future years are unknown. Therefore, for real-world assessment of elimination, it is important for there to be a definition that is not sensitive to year-to-year variations, to prevent cervical cancer elimination being declared prematurely. A more robust approach could be to use a rolling average of cancer incidence over multiple years (noting that this would also mean elimination would likely not be observed until after rates had remained below the threshold for multiple years).

Strengths of this analysis include the use of a well established model, with natural history assumptions validated across a range of settings, and exploring the impact of different standard populations on the relative timing of achieving elimination in Aboriginal and Torres Strait Islander women. We sought advice and direction from the Thiitu Tharrmay Aboriginal and Torres Strait Islander reference group, who provided advice on presenting cervical cancer incidence rates for Aboriginal and Torres Strait Islander women.

Limited data on Aboriginal and Torres Strait Islander women posed a challenge during parameterisation and calibration, in some cases necessitating the use of studies with small sample sizes and broad confidence intervals. The absence of routine national cervical screening data required parameterisation to rely on the available state-specific estimates, which varied by up to 15% and were consistently higher for Queensland than for New South Wales. In this case, the model was parameterised to fall within the range provided by these observed values. It is possible that screening varies in other areas or has changed since; however, screening assumptions affect other outcomes which were found to be consistent with national data or those sourced from other states. No data were available on hysterectomy rates in Aboriginal and Torres Strait Islander women, but elimination timing was relatively unaffected by the wide range of possibilities explored during our sensitivity analysis.

Our modelling focused on the equity disparities between Aboriginal and Torres Strait Islander women and the national population; however, this approach does not capture the heterogeneity within each of these groups, for example between those living in more geographically remote areas, where access to health care is poorer, compared with those living in major cities. This heterogeneity is potentially greater for Aboriginal and Torres Strait Islander women, as a larger proportion live in outer regional or more remote areas than the overall Australian population (34·4% *vs* 10·1%).[15] It is crucial to acknowledge that outcomes vary across Aboriginal and Torres Strait Islander communities and that this needs to also be considered through an equity lens.

To maintain consistency with our previous national elimination analysis,[4] the same assumptions were used in this analysis for national rates of screening uptake,

attendance for routine screening, and follow-up. At the time of this previous analysis, no observed data were available from the primary HPV screening programme, which commenced on Dec 1, 2017. Consequently, these parameters were estimated using data from the cytology screening programme. The introduction of universal self-collection from mid-2022 will further impact screening attendance. Despite the intention to maintain consistency with the previous national elimination analysis, some updates to the model have led to slight changes in predictions. For example, the model was expanded to include eight HPV types and type groups (previously four), requiring updates to the natural history parameterisation and calibration. Additionally, the WHO elimination benchmarking methodology[14] was not known at the time of our previous analysis. Finally, since the modelled intervention year (2024) has passed, elimination timing resulting from scaled-up prevention will likely be delayed; however, this does not alter the projected elimination year in the absence of change nor the relative impact of scaling up vaccination versus screening.

HPV vaccination and screening will in the long term decrease cervical cancer rates in Aboriginal and Torres Strait Islander women sufficiently to achieve cervical cancer elimination; however, without change, this is predicted to occur 21 years later than for other Australians. To achieve Australia's goal of equitable elimination as nearly as possible to the target timeframe of 2035, urgent action is imperative to ensure as many Aboriginal and Torres Strait Islander women as possible are supported to access screening and follow-up, and, in particular, a comprehensive effort to catch up those who have not screened previously.

Contributors

MAS, LJ, KC, and LJW conceptualised the study. JK and DTNN curated the data. JK, XO, and MAS did formal analysis. LJ and MAS acquired funding. MAS, JK, XO, and KC were involved in study methodology. MAS was the project administrator. KC, LJ, and MAS supervised the study. JK and XO validated the study data. MAS and JK wrote the original draft. JK, MAS, and XO had access to and verified the underlying data. All authors contributed to the writing and editing of the report. MAS was responsible for the decision to submit the manuscript.

Declaration of interests

MAS, JK, and KC have received funding through their institution from the Commonwealth Department of Health and Ageing for contracted work relating to the National Cervical Screening Program. KC is co-principal investigator of an investigator-initiated trial of HPV screening in Australia (Compass), which is conducted by the Australian Centre for the Prevention of Cervical Cancer (ACPCC), a government-funded health promotion charity. The ACPCC has previously received equipment and a funding contribution for the Compass trial from the Australian Government, Roche Molecular Systems USA, and Micobix. KC is also co-principal investigator on a major implementation programme—Elimination Partnership for Cervical Cancer in the Indo-Pacific—which receives support from the Australian Government, the Minderoo Foundation, and equipment donations from Cepheid.

Data sharing

Published data sources used to parameterise the model are cited in the technical appendix. The model used for this evaluation, Policy1-Cervix, is a well established model platform spanning multiple software programs and related tools, which has been developed over a period of 20 years. The code for these software programs is proprietary property. These software programs, modules, and tools consist of multiple versions for use in different contexts, and their accurate and appropriate use requires considerable supervised training. For these reasons, the code cannot be provided universally by the authors at this time. We will consider collaborative opportunities harnessing the code, and interested parties are encouraged to contact the authors at cec.coordinating-team@sydney.edu.au.

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