Australian Government
Australian Institute of Health and Welfare

Analysis of cancer outcomes and screening behaviour for national cancer screening programs in Australia

AIHW

Australian Government
Australian Institute of Health and Welfare

Cancer Series
Number 111

Analysis of cancer outcomes and screening behaviour for national cancer screening programs in Australia

Australian Institute of Health and Welfare
Canberra
Cat. no. CAN 115

The Australian Institute of Health and Welfare is a major national agency whose purpose is to create authoritative and accessible information and statistics that inform decisions and improve the health and welfare of all Australians.

This publication is part of the Australian Institute of Health and Welfare's Cancer series. A complete list of the Institute's publications is available from the Institute's website www.aihw.gov.au.

ISSN 2205-4855 (PDF)
ISSN 1039-3307 (Print)
ISBN 978-1-76054-412-6 (PDF)
ISBN 978-1-76054-413-3 (Print)

Suggested citation

Australian Institute of Health and Welfare 2018. Analysis of cancer outcomes and screening behaviour for national cancer screening programs in Australia. Cancer series no. 111. Cat. no. CAN 115. Canberra: AIHW.

Any enquiries relating to copyright or comments on this publication should be directed to:
Australian Institute of Health and Welfare
GPO Box 570
Canberra ACT 2601
Tel: (02) 6244 1000
Email: info@aihw.gov.au

Published by the Australian Institute of Health and Welfare

This publication is printed in accordance with ISO 14001 (Environmental Management Systems) and ISO 9001 (Quality Management Systems). The paper is sourced from sustainably managed certified forests.

Please note that there is the potential for minor revisions of data in this report. Please check the online version at www.aihw.gov.au for any amendments.

Contents

Acknowledgments

This report was prepared by Dr Alison Budd, Ms Natasha Bartlett, Dr Christopher Rompotis and Mr David Meere of the AIHW Screening Analysis and Monitoring Unit.

The linkage of the data was carried out by Andrew Powierski, Kirk Hampel and Sadie Law of the AIHW Data Linkage Unit.

Expert advice was kindly provided by Associate Professor Marion Saville, Victorian Cytology Service Foundation; Associate Professor Julia Brotherton, Victorian Cytology Service Foundation; Dr Stephen Morrell, School of Public Health and Community Medicine, University of NSW; and the Australian Breast Screening Technical Reference Group.

This report would not have been possible without the generous provision of data from the state and territory BreastScreen programs and the state and territory cervical screening programs, and thanks are extended to program managers and data managers from all eight states and territories who kindly provided all BreastScreen and cervical screening data.

Thanks are also extended to the Department of Health who kindly approved the provision of data from the National Bowel Cancer Screening Program Register and the National HPV Vaccination Program Register, and to the Department of Human Services and the Victorian Cytology Service Foundation who kindly provided data from these registers.

Thanks are also extended to the state and territory cancer registries, for their provision of cancer incidence data through the Australian Cancer Database.

Data for the National Death Index are provided to the Australian Institute of Health and Welfare by the state and territory registries of births, deaths and marriages and the National Coronial Information System (managed by the Victorian Department of Justice) and include cause of death coded by the Australian Bureau of Statistics.

This report was funded by the Department of Health.

Abbreviations

ABS	Australian Bureau of Statistics
ACD	Australian Cancer Database
AIHW	Australian Institute of Health and Welfare
APHDPC	Australian Population Health Development Principal Committee
CI	confidence interval
GP	general practitioner
HPV	human papillomavirus
HR	hazard ratio
IARC	International Agency for Research on Cancer
ICD-10	International Statistical Classification of Diseases and Related Health Problems, Tenth Revision
ICD-O-3	International Classification of Diseases for Oncology, Third Edition
iFOBT	Immunochemical Faecal Occult Blood Test
NBCSP	National Bowel Cancer Screening Program
NCSP	National Cervical Screening Program
NHVPR	National HPV Vaccination Program Register
PPV	positive predictive value
SIR	standardised incidence ratio
VCS	Victorian Cytology Service Foundation
WHO	World Health Organization

Symbols

χ^2	chi-square statistic
—	nil or rounded to zero
. .	not applicable
<	less than
>	greater than
≤	less than or equal to
%	per cent
p	The probability that the observed difference or association could have occurred by chance alone. If that probability is less than 5% (0.05), it is conventionally held that the observed difference is unlikely enough to be due to chance that it is evidence of a true difference or association.

Summary

This report presents the first results from an Australian-first project, combining data from BreastScreen Australia, the National Cervical Screening Program, the National Bowel Cancer Screening Program, the Australian Cancer Database, the National Death Index, and the National HPV (human papillomavirus) Vaccination Program Register.

Breast cancers detected through BreastScreen Australia were less likely to cause death

This report compared survival outcomes of breast cancers detected through BreastScreen Australia with breast cancers diagnosed in women who had never screened.

Of the breast cancers diagnosed in women aged 50–69 in 2002–2012:

- 31,968 were detected through BreastScreen Australia
- 20,245 were diagnosed in women who had never screened.

Women diagnosed through BreastScreen Australia had a 69% lower risk of dying from breast cancer before 31 December 2015 than those who had never screened.

Even after correcting for lead-time bias (where an earlier diagnosis may not affect date of death, yet give a seemingly longer survival time) and screening selection bias (where women who choose to participate in screening may be at a lower risk of death, which would result in an increase in survival that may not be real), the risk of dying from breast cancer was still 42% lower for women diagnosed through BreastScreen Australia than for women who had never screened through BreastScreen Australia.

Cervical cancers detected through cervical screening were less likely to cause death

Cervical cancer outcomes need to be considered within the context of cervical screening that aims to detect and treat precancerous disease, thereby preventing cervical cancers. This is reflected in these data, since the majority of cervical cancers occurred in women who had either never screened or who were lapsed screeners (had not screened for some time).

This report compared survival outcomes of cervical cancers detected through cervical screening with cervical cancers diagnosed in women who had never had a Pap test.

Of the cervical cancers diagnosed in women aged 20–69 in 2002–2012:

- 354 were detected through cervical screening
- 1,222 were diagnosed in women who had never had a Pap test.

Women diagnosed through cervical screening had an 87% lower risk of dying from cervical cancer before 31 December 2015 than women who had never had a Pap test.

Bowel cancers detected through the National Bowel Cancer Screening Program were less likely to cause death

This report compares survival outcomes of bowel cancers detected through the National Bowel Cancer Screening Program with bowel cancers diagnosed in people who had never been invited to screen.

Of the bowel cancers diagnosed in people aged 50–69 in 2006–2012:

- 3,316 were detected through the National Bowel Cancer Screening Program
- 20,217 were diagnosed in people who had never been invited to screen.

People diagnosed through the National Bowel Cancer Screening Program had a 59% lower risk of dying from bowel cancer before 31 December 2015 than people who had never been invited to screen.

Even after correcting for lead-time bias (where an earlier diagnosis may not affect date of death, yet give a seemingly longer survival time), the risk of dying from bowel cancer was still 40% lower for people diagnosed through the National Bowel Cancer Screening Program than for people who had never been invited to screen.

Screening behaviour

This project also used the combined data to understand screening behaviour of women across the 3 national cancer screening programs. Key findings are summarised below.

- A high proportion (69%) of screened women participated in all the cancer screening programs for which they were eligible, indicating overall good screening behaviour in women who were already engaged in screening. As these data excluded women who did not screen in any program, this is an overestimate of the true proportion of eligible women who screened.

This may mean that if the barriers to screening can be broken in non-screeners, thereby engaging them to participate in at least one screening program, it might lead to participation in other cancer screening programs as well, and greater overall participation, leading to more cancers detected through screening, which have a lower risk of death, as this study shows.

- A positive screening test result that resulted in diagnostic testing in one program resulted in women being more likely to screen in another program, and to do so sooner.

These results indicate that women may be more aware of the need to screen across programs following a screening event that required diagnostic follow-up.

Women vaccinated against HPV are more likely to participate in cervical screening than unvaccinated women

Comparing cervical screening participation rates:

- In women aged 20–24, participation was 45.5% in HPV-vaccinated women and 33.1% in unvaccinated women
- In women aged 25–29, participation was 56.5% in HPV-vaccinated women and 44.3% in unvaccinated women.

This indicates that women who are vaccinated against HPV are either more aware of the need to participate in cervical screening, or are more likely to take part in healthy behaviours generally.

1 Introduction

1.1 Cancer screening programs in Australia

Disease screening is the use of a test in an asymptomatic population to identify individuals who are more likely to have a given disease and therefore require further diagnostic testing to determine if they have the disease. Because the screening test is used on individuals without overt signs or symptoms of the disease, screening is able to detect disease at an earlier stage, which can lead to better outcomes than if the disease was detected at a later stage.

Screening for a given disease should progress only if it meets the World Health Organization (WHO) principles of screening (Wilson & Jungner 1968). These screening principles are:

- the condition should be an important health problem
- there should be a recognisable latent or early symptomatic stage
- the natural history of the condition, including development from latent to declared disease, should be adequately understood
- there should be an accepted treatment for patients with recognised disease
- there should be a suitable test or examination that has a high level of accuracy
- the test should be acceptable to the population
- there should be an agreed policy on whom to treat as patients
- facilities for diagnosis and treatment should be available
- the cost of screening (including diagnosis and treatment of patients diagnosed) should be economically balanced in relation to possible expenditure on medical care as a whole
- screening should be a continuing process and not a 'once and for all' project.

Australia has built upon these WHO criteria for population screening in developing the Australian Population Based Screening Framework, which additionally takes into account:

- the need for a strong evidence base in making a decision about the introduction of a screening program including evidence of the safety, reproducibility and accuracy of the screening test and efficacy of treatment
- the requirement that a screening program offers more benefit than harm to the target population (APHDPC 2008).

Australia currently has 3 population-based cancer screening programs that meet both the WHO principles and the additional considerations under the Australian criteria for the assessment of population screening (APHDPC 2008). These are BreastScreen Australia for breast cancer, the National Cervical Screening Program (NCSP) for cervical cancer, and the National Bowel Cancer Screening Program (NBCSP) for bowel cancer. These programs all aim to reduce mortality from their respective cancer. The National Cervical Screening Program and the National Bowel Cancer Screening Program also aim to reduce the incidence of cervical and bowel cancer, respectively, through identifying and treating their precursors.

The cancer screening programs are implemented to reflect best practice based on the latest available evidence; they can (and do) evolve over time when new evidence comes to light. For example, it is now known that many abnormalities detected through cervical screening will regress without treatment, and so are managed more conservatively than they were previously, which has led to less morbidity. Breast cancer requires further research to allow

a similar change, since it is recognised that some breast cancers identified through screening would not have gone on to cause morbidity, because the cancer would have been slow-growing and never become clinically apparent in a woman's lifetime. However, it is currently not possible to identify which cancers would have progressed and which would not (although it is considered that the majority of breast cancers identified through screening would progress to become symptomatic within a woman's lifetime if left untreated). Molecular and genomic research may in future develop the means of identifying cancers that are unlikely to progress, which would see a change in best practice to allow these breast cancers to be managed more conservatively (Cancer Australia 2017).

These examples highlight that there is the potential for some people to be harmed as a result of participation in cancer screening. Most frequently, this will be due to the screening test result being either a false negative—which can lead to missed cancers and delayed diagnosis and treatment—or a false positive—which can lead to anxiety, costs, and unnecessary procedures. These potential harms are often unavoidable, but should be minimised. It is also important that the benefits of a cancer screening program are clearly demonstrated and sufficiently great to outweigh the potential harms.

1.2 Cancer screening programs reduce mortality

The principles of cancer screening include the requirement for evidence that a screening program is effective in reducing mortality from cancer (Cancer Council Australia 2017). This relates to the requirement for the benefits of screening to outweigh the potential harms. Studies are required to assess mortality benefits due to screening, since assessing mortality trend data alone does not distinguish between reductions in mortality due to screening and reductions due to treatment advancements that have occurred over the same time period.

In considering the available evidence of the benefits of cancer screening, several studies have looked specifically at the Australian setting when considering whether participation in cancer screening programs reduces mortality from breast, cervical and bowel cancers.

Decreases in breast cancer mortality have occurred since BreastScreen Australia commenced, but advancements in treatment for breast cancer have contributed significantly to this decrease, along with any decreases due to the early detection of breast cancer through screening mammography. The latter has been shown to be a contributing factor—several jurisdictional and national Australian studies have demonstrated a reduction in mortality in breast cancer screening participants (Taylor et al. 2004; Roder et al. 2008; Department of Health and Ageing 2009; Morrell et al. 2012; Nickson et al. 2012).

Estimates from these Australian studies align with those based on international data; in 2015 the International Agency for Research on Cancer (IARC) conducted a full review of available high quality observational studies to ensure that evidence compiled in 2002, which showed a reduction in mortality as a result of screening mammography (IARC 2002), was still relevant today. They determined that women aged 50–69 who attended breast cancer screening using screening mammography had about a 40% reduction in the risk of death from breast cancer (Lauby-Secretan et al. 2015), which is similar to Australian estimates.

Cervical cancer mortality rates are much lower in more developed countries, including Australia, attributed to the reduction in cervical cancers due to organised cervical screening programs. It has been recognised internationally for some time that screening for precancerous lesions can greatly reduce both the incidence of and mortality due to cervical cancer (Ferlay et al. 2010).

The ability of cervical screening to lower the incidence of cervical cancer (which then leads to lower mortality) has been demonstrated in annual statistical reports of the Victorian Cytology

Service (VCS) Foundation. Linkage between the Victorian Cervical Cytology Register and the Victorian Cancer Register has shown that underscreeners/lapsed screeners and non-participants in screening programs are much more likely to develop cervical cancer than women who are adequately screened (Victorian Cytology Service 2017).

Further to this, an Australian study of New South Wales women also demonstrated a greatly decreased risk of developing cervical cancer (and hence cervical cancer mortality) in women who participated in either regular or irregular cervical screening (Yang et al. 2008).

There is also evidence for bowel screening. A 2014 study (AIHW 2014; AIHW & DoH 2016), repeated in 2018 (AIHW 2018b), using data from the National Bowel Cancer Screening Program Register linked to cancer and death data, found that (even after adjusting for lead-time bias) invitees (particularly those who participated) had a lower risk of dying from bowel cancer, and were more likely to have less-advanced bowel cancers when diagnosed, than non-invitees. These findings are supported by modelling that predicts that the National Bowel Cancer Screening Program will prevent 92,200 cancers and 59,000 deaths over the period 2015–2040 with the current participation rate of 40%, and the prevention of even greater numbers of cancers and deaths predicted with higher levels of participation (Lew et al. 2017).

1.3 Participation in cancer screening programs

Given the evidence that participation in Australia's cancer screening programs is beneficial, it is of great interest to better understand the screening behaviour of Australians, to learn who benefits most from screening, and what may influence an individual's decision to screen or not to screen.

The AIHW reports on participation in Australia's 3 national cancer screening programs, so there are readily available data on the population groups that participate well, and those that are underscreened. These data are shown in Table 1.3.1, and summarised in Box 1.3.1.

Box 1.3.1: Summary of participation across population groups

- Across **remoteness areas**, participation is highest in *Inner regional* and *Outer regional* areas for both BreastScreen and bowel screening, whereas it is highest in *Major cities* and *Inner regional* areas for cervical screening.
- Across **socioeconomic groups**, participation is lowest in the most disadvantaged socioeconomic group for all 3 cancer screening programs, but thereafter the trend differs; participation increases with decreasing disadvantage for both cervical and bowel (although the trend is stronger for cervical with 12 percentage points between most and least disadvantaged), whereas there is no clear trend for BreastScreen.
- The largest difference in participation is by **Indigenous status**, with participation far lower for Indigenous Australians for BreastScreen and bowel screening (estimated). While there are no national data for cervical screening, there is state-level evidence that participation is also far lower for Indigenous Australians (Whop et al. 2016).
- Participation is also lower for participants who report speaking a **language other than English** at home for BreastScreen and bowel screening, used as a proxy to identify individuals from a culturally and linguistically diverse (CALD) background. There are no national data for cervical screening.

Table 1.3.1: Participation in BreastScreen Australia, the National Cervical Screening Program, and the National Bowel Cancer Screening Program for available population groups

Population group	BreastScreen Australia	National Cervical Screening Program	National Bowel Cancer Screening Program
State or territory			
New South Wales	51.2	55.7	38.2
Victoria	53.8	57.8	41.9
Queensland	56.8	53.6	40.4
Western Australia	54.6	56.2	42.9
South Australia	58.5	57.7	47.0
Tasmania	57.4	56.0	46.4
Australian Capital Territory	55.4	56.2	43.6
Northern Territory	37.7	51.8	28.4
Remoteness area			
Major cities	52.6	56.4	39.9
Inner regional	56.7	56.6	44.3
Outer regional	58.0	54.2	42.0
Remote	53.3	52.1	37.0
Very remote	47.0	46.3	28.0
Socioeconomic group			
1 (lowest)	51.7	50.4	38.8
2	54.9	53.6	41.0
3	54.1	54.8	40.5
4	54.6	57.1	41.7
5 (highest)	54.0	62.1	42.7
Indigenous status			
Indigenous	37.5	. .	19.5 (est.)
Non-Indigenous	54.0	. .	42.7 (est.)
Language spoken at home			
English only	54.3	. .	42.6–46.1
Language other than English	50.5	. .	23.8–32.8
Australia	**54.5**	**55.4**	**40.9**

Note: Participation data shown are for ages 50–69 in 2014–2015 for breast, ages 20–69 in 2015–2016 for cervical, and ages 50–74 in 2015–2016 for bowel. Rates shown are age-standardised except for Australia, for which crude rates are shown. 'est.' indicates the data are estimates.

Source: AIHW analysis of state and territory BreastScreen register data, state and territory cervical screening register data, and National Bowel Cancer Screening Program Register data.

While these data provide insights into patterns of participation *within* each cancer screening program, these do not allow assessment of screening behaviour *across* the 3 cancer screening programs. This would require individual screening histories across the 3 programs, which is not possible without linking the data sets underpinning them.

The desire to better understand an individual's decision to screen (or not to screen), as well as the recognised need for an assessment of breast, cervical and bowel cancers by screen-detected status to provide key data on screening benefits, led to the development of a project to use data linkage to better understand screening outcomes and behaviour.

2 Objectives

2.1 Premise of this data linkage project

On examining the available research related to Australia's 3 cancer screening programs, while there have been a number of rich and high-quality studies, we identified the potential to make a significant additional contribution to these. By building on previous studies, identifying and filling data gaps, and performing novel studies, we aim to provide answers to key questions and a greater understanding of screening outcomes and behaviour across all 3 cancer screening programs in Australia. The opportunity was also taken to investigate the effects and effectiveness of the human papillomavirus (HPV) vaccine in Australia. This is possible due to the role of HPV in the development of cervical abnormalities (and ultimately cervical cancers), data for which were held on state and territory cervical screening registers.

To allow us to investigate the outcomes and screening behaviour of cancer screening programs in Australia, this major data linkage project was undertaken to link data from:

- the 8 state and territory BreastScreen registers
- the 8 state and territory cervical screening registers
- the National Bowel Cancer Screening Program Register
- the Australian Cancer Database
- the National Death Index
- the National HPV Vaccination Program Register.

These data sources are detailed more fully in the 'Data and methods' chapter.

2.2 Objectives of this data linkage project

The data linkage project has 3 objectives.

Objective 1 Determine key cancer outcomes in screening and non-screening individuals to determine whether screen-detected cancers are less likely to result in death than cancers detected outside screening programs.

Objective 2 Gain an understanding of the screening behaviour of participants, such as who screens, in which programs, and whether this is influenced by any common factors such as socioeconomic status, history of positive test results, or other events.

Objective 3 Use the linked data to enhance currently available screening data, such as analysis of linked cervical screening and human papillomavirus (HPV) vaccination data to look at the effect of HPV vaccination on cervical abnormalities, cancers and participation in cervical screening.

The objectives for this data linkage project extend beyond this report. Rather, several published AIHW reports and other published products will be used to present the findings from this important project to optimise their communication to a range of audiences.

3 Data and methods

3.1 Data sources

This data linkage project included data from 6 data sources, with a total of 20 individual data sets combined to form the master linked data set. These are listed in Table 3.1.1 below.

Table 3.1.1: Data sources

Data source	Data set	Data provider
BreastScreen Australia	BreastScreen NSW register data	Cancer Institute NSW
	BreastScreen Victoria register data	BreastScreen Victoria
	BreastScreen Qld register data	Queensland Health
	BreastScreen WA register data	WA Department of Health
	BreastScreen SA register data	SA Department for Health and Ageing
	BreastScreen Tasmania data	Department of Health Tasmania
	BreastScreen ACT data	ACT Health
	BreastScreen NT	NT Department of Health
National Cervical Screening Program	NSW Pap test register data	Cancer Institute NSW
	Victorian cervical cytology register data	Victorian Cytology Service Foundation
	Queensland Health Pap smear register data	Queensland Health
	WA cervical cytology register data	WA Department of Health
	SA cervix screening register data	Victorian Cytology Service Foundation
	Tasmanian cervical screening register data	Department of Health Tasmania
	ACT cervical screening register	ACT Health
	NT Pap smear register data	NT Department of Health
National Bowel Cancer Screening Program	National Bowel Cancer Screening Program Register data	Department of Human Services
Australian Cancer Database	Australian Cancer Database	Australian Institute of Health and Welfare
National Death Index	National Death Index	Australian Institute of Health and Welfare
National HPV Vaccination Program	National HPV Vaccination Program Register data	Victorian Cytology Service Foundation

Further details about each of the 6 data sources follow.

BreastScreen Australia data

BreastScreen Australia is Australia's national breast cancer screening program, operational since 1991. BreastScreen services are delivered at the state and territory level. Eligibility is determined by age: women 40 and over can attend free 2-yearly mammograms, although only women in the target age group are actively targeted. From 1991, the target age group of BreastScreen Australia was women aged 50–69, widened to 50–74 from 1 July 2013.

To attend, a woman contacts BreastScreen in her state or territory to book a screening visit. At the time of her screening visit, a woman is able to self-report clinical details such as the presence and type of symptoms, as well as personal and family history of breast cancer.

Data for women who participate in BreastScreen Australia are collected and maintained on state and territory BreastScreen registers.

BreastScreen Australia data in this project are a subset of variables from each of the 8 state and territory BreastScreen registers, for women screened between 1 January 2000 and 31 December 2014. The target group used for these data was women aged 50–69.

National Cervical Screening Program data

The National Cervical Screening Program is Australia's national cervical screening program, and began operating in 1991. There were significant changes to the cervical screening program on 1 December 2017, including a change in screening test, screening interval and target age group. However, this project includes only data collected under the previous program, and so only the National Cervical Screening Program as it existed from 1991 to 30 November 2017 is described here and considered throughout this project.

Under the previous program, women were recommended to have 2-yearly Pap tests commencing between the ages of 18 and 20, or 1 or 2 years after first having sexual intercourse, whichever was later. Data for women who participated in the previous program were collected and maintained on state and territory cervical screening registers.

National Cervical Screening Program data in this project are a subset of variables from each of the 8 state and territory cervical screening registers that operated under the previous program, for women screened between 1 January 2000 and 31 December 2014. The target group used for these data was women aged 20–69.

National Bowel Cancer Screening Program data

The National Bowel Cancer Screening Program is Australia's national bowel screening program, and has operated since 1 August 2006. Eligibility to participate in this program is determined by age, with individuals who are registered as an Australian citizen or migrant in the Medicare enrolment file, or registered with a Department of Veterans' Affairs gold card, invited to screen when they reach one of the target ages. Invitees are sent an invitation pack containing an iFOBT kit (an immunochemical faecal occult blood test, the screening test of the National Bowel Cancer Screening Program) and can then choose to participate by completing the screening test at home and returning it to be processed in a pathology laboratory, or not to participate.

The target ages initially invited to screen in 2006 were people turning 55 and 65, with 50-year-olds added from July 2008. Since then, additional ages have been progressively invited to participate in the program, and from 2019, the National Bowel Cancer Screening Program will offer all Australians aged 50–74 bowel screening every 2 years.

Data on people who are eligible to be invited to participate in bowel screening appears on the National Bowel Cancer Screening Program Register. This national register is maintained by the Department of Human Services (formerly Medicare Australia) on behalf of the Department of Health. Bowel screening that occurs outside the National Bowel Cancer Screening Program is not included in the national register, and therefore this project.

National Bowel Cancer Screening Program data in this project are a subset of variables from the National Bowel Cancer Screening Program Register, for individuals invited from 1 August 2006 to 31 December 2014. As the target ages have changed over this period, invitations were used to determine screening eligibility. The target group used for these data was people aged 50–69.

Australian Cancer Database data

The Australian Cancer Database contains information on all Australians diagnosed with cancer (excluding basal cell and squamous cell carcinomas of the skin) since 1982. Data are collected by state and territory cancer registries from a number of sources and are supplied annually to the AIHW. The AIHW compiles and maintains the Australian Cancer Database, in partnership with the Australasian Association of Cancer Registries, which includes representatives from each state and territory cancer registry.

The 2013 Australian Cancer Database was the latest version available at the time of data linkage for this project. Although this included cancer data to 2013 for almost all states and territories, it included New South Wales cancer data only to 2012; therefore for this project cancer incidence data from 1 January 1982 to 31 December 2012 were used.

Breast, cervical and bowel cancers were identified using International Statistical Classification of Disease and Related Health Problems, Tenth Revision (ICD-10) codes. Female breast cancers were defined as cancers coded in the ICD-10 as C50 where sex was female, cervical cancers were defined as cancers coded in the ICD-10 as C53 where sex was female, and bowel cancers were defined as cancers coded in the ICD-10 as C18–C20. All cancers were defined as cancers coded in the ICD-10 as C00–C97, D45, D46, D47.1 and D47.3–D47.5.

National Death Index data

The National Death Index contains information on all deaths in Australia since 1980. It is maintained by the AIHW for the purpose of data linkage. The state and territory registrars of births, deaths and marriages supply these data monthly. While fact-of-death information is generally up to date in the National Death Index, underlying-cause-of-death information is usually some years behind. At the time of data linkage for this project, underlying-cause-of-death data contained in the National Death Index were available to 31 December 2015.

Deaths were considered to be from breast cancer if the ICD-10 code was C50; from cervical cancer if the ICD-10 code was C53, and bowel cancer if the ICD-10 code was C18–C20 or C26 (Malignant neoplasm of the intestinal tract, part unspecified, which many bowel cancer deaths are coded as in Australia—ABS 2016). All-cause deaths were any deaths recorded, regardless of the underlying cause.

National HPV Vaccination Program data

The National HPV Vaccination Program was introduced on 1 April 2007 to immunise girls (and extended in 2013 to also immunise boys) against HPV types 16, 18, 6 and 11 (with an HPV vaccine against 9 HPV types introduced from 2018). In addition to the ongoing school-based program introduced in 2007 for girls aged 12–13 and in 2013 for boys aged 12–13, there was a catch-up program for girls aged 14–26 in 2007–2009, and for boys aged 14–15 in 2013–2014.

HPV vaccination records are sent to the National HPV Vaccination Program Register by school or community providers, state or territory departments of health, and general practitioners, depending on whether the vaccine was administered through school or by a general practitioner. The National HPV Vaccination Program Register is operated and maintained by the VCS on behalf of the Department of Health.

National HPV Vaccination Program data in this project are a subset of variables from the National HPV Vaccination Program Register, for females vaccinated from 1 April 2007 to 31 December 2014.

3.2 Methods

Data flow

The AIHW Data Linkage Unit performed all the data linkage for this project. To ensure privacy and confidentiality of participants, data suppliers sent 2 sets of data to the AIHW: the Data Linkage Unit was provided with identified data only, while the Cancer and Screening Unit was provided with deidentified analysis variables only. This ensured that no one person had access to identified and analysis variables. Identification numbers common to both data supplies then allowed the Data Linkage Unit to inform the Cancer and Screening Unit which individuals were common across the data sets. This data flow is illustrated in Figure 3.2.1.

Data linkage

The AIHW Data Linkage Unit performed probabilistic data linkage based on the method developed by Fellegi and Sunter (Fellegi & Sunter 1969).

Briefly, data linkage across the data sets was carried out in a step-wise fashion using the identifying variables names, sex, date of birth and postcode. In the first step, links in which the identifying variables matched exactly were accepted. In the second step, the identifying variables were allowed to vary, with all potential pairs given a weight based on the amount of variation between records and the discriminatory ability of the variable. A sample-based clerical review determined a cut-off weight to accept a link, and all potential pairs above this cut-off were accepted as true links. In the final step, all remaining potential pairs were checked manually to determine if they were likely to be a link.

While this is a robust method of data linkage, it is important to note that, due to the nature of probabilistic data linkage, there may be some unavoidable inaccuracy in the data linkages.

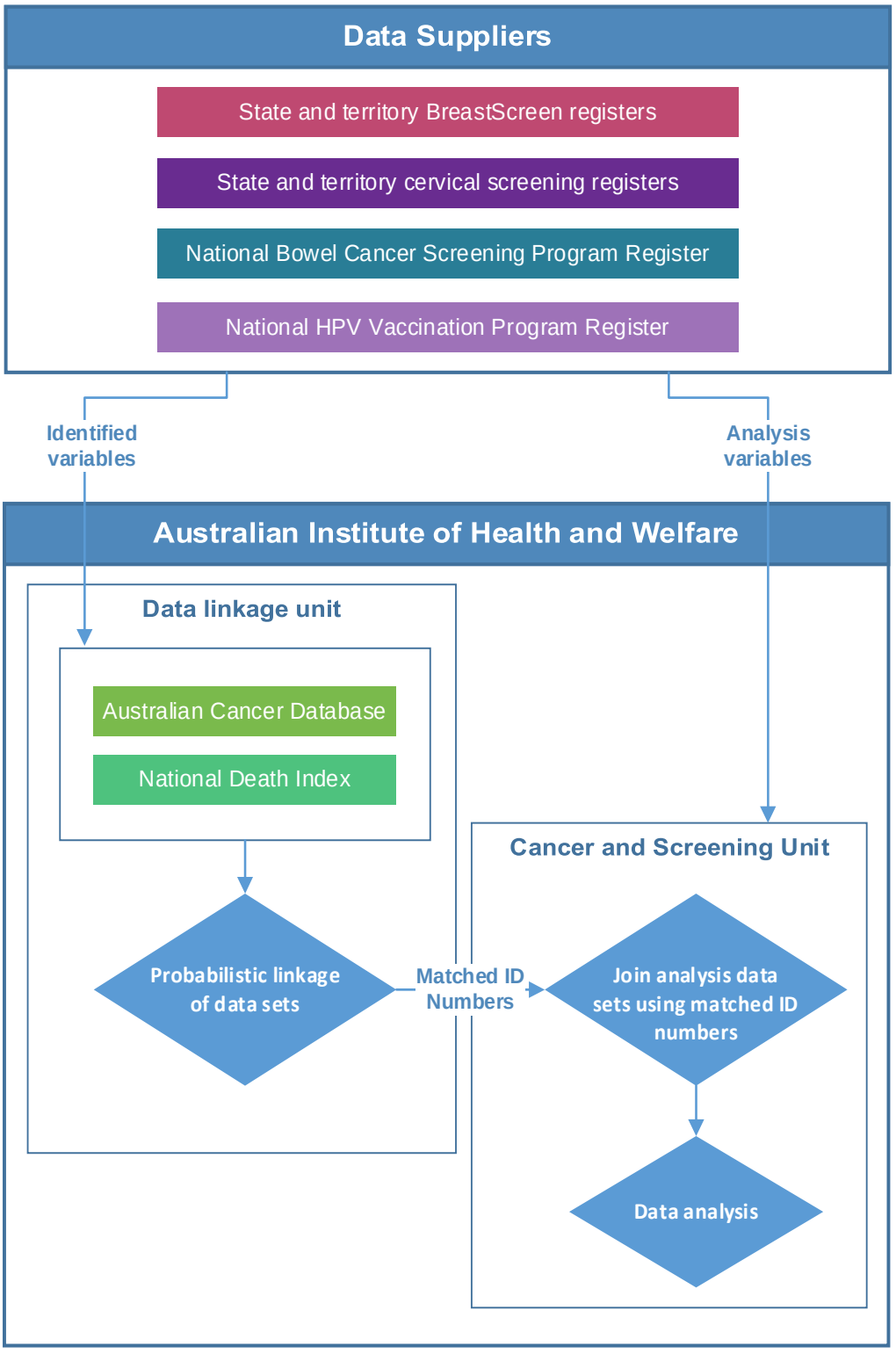


Figure 3.2.1: Data flow for the data linkage project

Statistical analyses

Retrospective cohort studies were undertaken for breast, cervical and bowel cancer to assess survival for screen-detected compared with non-screen-detected cancers.

Breast cancer survival by screening status

Breast cancers were identified on the Australian Cancer Database (coded in the ICD-10 as C50) with date of diagnosis between 1 January 2002 and 31 December 2012 inclusive, for women aged 50–69 at diagnosis. These were linked with available data from BreastScreen registers (from 1 January 2000), and the screening history prior to each cancer used to assign a screening status to each breast cancer. These were:

- **screen-detected cancers**—breast cancers diagnosed in 2002–2012 in women aged 50–69 who had a screening mammogram through BreastScreen Australia *and* the cancer was identified as screen-detected by BreastScreen
- **non-screen-detected cancers in screened women**—breast cancers diagnosed in 2002–2012 in women aged 50–69 who had a screening mammogram through BreastScreen *and* the cancer was not identified as screen-detected or interval
- **interval cancers**—breast cancers diagnosed in 2002–2012 in women aged 50–69 who had a screening mammogram through BreastScreen *and* the cancer was identified as an interval cancer by BreastScreen and/or the cancer met the BreastScreen definition of an interval cancer using the available variables
- **non-screen-detected cancers in never-screened women**—breast cancers diagnosed in 2002–2012 in women aged 50–69 who did not have a screening mammogram through BreastScreen prior to the cancer diagnosis.

These individuals were then linked with data from the National Death Index to ascertain date of death and cause of death for those who died by 31 December 2015.

Cervical cancer survival by screening status

Cervical cancers were identified on the Australian Cancer Database (coded in the ICD-10 as C53) with date of diagnosis between 1 January 2002 and 31 December 2012 inclusive, in women aged 20–69 at diagnosis. These were linked with available data from cervical screening registers (from 1 January 2000), and the screening history prior to each cancer used to assign a screening status to each cervical cancer. These were:

- **screen-detected cancers**—cervical cancers diagnosed in 2002–2012 in women aged 20–69 who had a Pap test with a cytology result of *high-grade or worse* 6 months to 2.5 years prior to the cancer diagnosis
- **non-screen-detected cancers in screened women**—cervical cancers diagnosed in 2002–2012 in women aged 20–69 who had a Pap test with a cytology result that was not *negative* or *high-grade or worse* 6 months to 2.5 years prior to the cancer diagnosis, or who had a Pap test with any cytology result more than 2.5 years prior to the cancer diagnosis
- **interval cancers**—cervical cancers diagnosed in 2002–2012 in women aged 20–69 who had a Pap test with a *negative* cytology result 6 months to 2.5 years prior to the cancer diagnosis
- **non-screen-detected cancers after a diagnostic test**—cervical cancers diagnosed in 2002–2012 in women aged 20–69 whose only Pap test was in the 6 months prior to the cancer diagnosis, and is therefore considered to be part of the diagnostic process and not a screening Pap test that led to the diagnosis of cancer

- **non-screen-detected cancers in never-screened women**—cervical cancers diagnosed in 2002–2012 in women aged 20–69 who did not have a Pap test prior to the cancer diagnosis (either because they did not appear on a cervical screening register or because their first Pap test was after their cancer diagnosis).

These individuals were then linked with data from the National Death Index to ascertain date of death and cause of death for those who died by 31 December 2015.

Bowel cancer survival by screening status

Bowel cancers were identified on the Australian Cancer Database (coded in the ICD-10 as C18–C20) with date of diagnosis between 1 August 2006 and 31 December 2012 inclusive, for people aged 50–69 at diagnosis. These were linked with available data from the National Bowel Cancer Screening Program Register (from 1 August 2006), and the screening history prior to each cancer used to assign a screening status to each bowel cancer. These were:

- **screen-detected cancers**—bowel cancers diagnosed in August 2006–2012 in individuals aged 50–69 who were invited to participate in the National Bowel Cancer Screening Program *and* participated *and* had a positive screening iFOBT at any time prior to the cancer diagnosis
- **interval cancers**—bowel cancers diagnosed in August 2006–2012 in individuals aged 50–69 who were invited to participate in the National Bowel Cancer Screening Program *and* participated *and* had a negative or inconclusive iFOBT screening result in the 2 years prior to the cancer diagnosis
- **non-responder cancers**—bowel cancers diagnosed in August 2006–2012 in individuals aged 50–69 who were invited to participate in the National Bowel Cancer Screening Program but did not participate prior to the cancer diagnosis
- **never-invited cancers**—bowel cancers diagnosed in August 2006–2012 in individuals aged 50–69 who were not invited to participate in the National Bowel Cancer Screening Program.

These individuals were then linked with data from the National Death Index to ascertain date of death and cause of death for those who had died by 31 December 2015.

Cohort design

For the cohort studies, individuals entered the cohort on the date of their cancer diagnosis and were followed to 31 December 2015. For analyses that used death from the cancer of interest as the event, individuals were censored if they died from a cause other than the cancer of interest, or at 31 December 2015 if they did not die during the study period. Person time at risk was calculated in days from the date of cancer diagnosis to either the date of event (for those who died from the cancer of interest) or to date of censor (for those who did not die, or died from another cause).

Statistical tests

The χ^2 test was used to analyse differences across categorical variables.

Kaplan-Meier survival curves were generated and log-rank used to assess differences in survival across groups.

Cox proportional hazards models were used to produce a hazard ratio with 95% confidence intervals, which were used to determine any reduction in risk of death associated with a cancer being screen-detected compared with non-screen-detected. Analyses were adjusted for confounding by sex (for bowel cancer analyses only), age at diagnosis, year of diagnosis,

remoteness area, and socioeconomic disadvantage, as well as the clinical characteristics relevant to each cancer (breast cancer histological types and breast cancer size for breast cancer analyses, and cervical cancer histological types for cervical cancer analyses).

Adjusting for potential biases

There are 2 possible biases that require consideration in these types of analyses: lead-time bias and screening selection bias.

'Lead time' is the length of time between when a cancer is detected by screening, and when the cancer would have been detected due to the development of clinical signs or symptoms if screening had not occurred. Detecting a cancer early by screening can improve survival through effective treatment and management, delaying the time until death. However, a diagnosis of cancer can also be made earlier without affecting the date on which the individual would have died, but the additional lead-time in the screened individuals makes it look as though time until death is longer. This results in an increase in survival in screened individuals that may not be 'real', and is known as '**lead-time bias**' (Duffy et al. 2008).

'**Screening selection bias**' in breast cancer screening exists in countries or regions in which the women who choose to participate in breast cancer screening are at a lower risk of death than those who do not participate, which would lead to an increase in survival in screened individuals that may not be real (Paap et al. 2011). This can differ between regions and countries, however, and may not occur in Australia (Roder et al. 2008).

Cox proportional hazards models for bowel cancer were corrected for lead-time bias using the estimated values used previously in a similar project specific to bowel cancer outcomes (AIHW 2018b). Further details are provided in Appendix D.

There are many estimated lead times for breast cancer, most of which are between 2 and 4 years. A lead-time bias adjustment of 40 months was used in this project, which has received a level of consensus (Duffy & Parmar 2013) (and would produce an estimate of any survival increases due to screening on the conservative side), using methods previously described (Duffy et al. 2008; Brenner et al. 2011). Further details are provided in Appendix D.

To adjust for screening selection bias, hazard ratios were adjusted for the estimated decrease in risk of death that is due to women who choose to screen being less likely to die than women who choose not to screen, even in the absence of a cancer diagnosis. This used a screening selection correction factor of 1.36 using methods previously described (Duffy & Cuzick 2002). In recognition of the fact that this correction factor is probably too high for the Australian setting, a screening selection correction factor of 1.17 was also used, as per Morrell and others (Morrel et al. 2017). Further details are provided in Appendix D.

Ethics approvals

To access the data required for this data linkage project, ethics approvals were obtained from the AIHW Ethics Committee (EO 2014-4-130)—also used by the Department of Health for ethics approval to access National Bowel Cancer Screening Program Register data and National HPV Vaccination Program Register data—and state and territory human research ethics committees to access state and territory cancer register data (through the Australian Cancer Database), BreastScreen register data, and cervical screening register data.

4 Preliminary findings

4.1 Assessment of the success of the data linkage

The overall success of the project, as ascertained by its ability to meet the 3 objectives, was dependent on the data linkage process being able to achieve 5 targets, since these were integral to the data sets that would be generated by data linkage for analysis.

The 5 data linkage targets of the project are listed in Box 4.1.1.

Box 4.1.1: Data linkage targets

1. to provide proof of concept that such data linkage is possible
2. to form a national BreastScreen data set and a national cervical screening data set
3. to form a national cancer screening data set with individual screening histories
4. to link the national cancer screening data set to the Australian Cancer Database and the National Death Index
5. to link the data set created at Target 4 to the National HPV Vaccination Program Register, and to assess the feasibility (and any resulting benefits to the linkage) of first linking this HPV vaccination register to Medicare data to update identifying fields.

All 5 data linkage targets were met, with progress against each detailed below.

Target 1: to provide proof of concept that this data linkage is possible.

This encompassed the phase of the project from the initial process of seeking approval from ethics committees and data custodians through to the ability of the AIHW Data Linkage Unit to receive data in a form that would allow linkage. This was an important target, as it was not known at the commencement of this project whether it was possible, since it was dependent on agreements, approvals, and support from many individuals, spanning 20 individual data sets, and for a project that had never before been attempted and using data sets that had never before been used in this way.

Each step in the process could have seen this project progress or fail. However, each step was successful, with all ethics committees providing their approval, all data custodians providing their approval, and all data provided with common identifying fields to maximise the accuracy of the data linkage process, and in time for the data to be included at each step.

The AIHW Data Linkage Unit was able to progress with the data linkage phase of the project in October 2016.

The data linkage phase was equally successful, with data linkage of all 20 data sets, additionally incorporating the Medicare Enrolment File, completed by the AIHW Data Linkage Unit in June 2017. The data linkage phase was further broken down into Targets 2 to 5.

Target 2: to form a national BreastScreen data set and a national cervical screening data set.

BreastScreen and cervical screening data exist in state and territory registers, and it was not known what degree of duplication might exist across these registers.

The successful linkage of data from all state and territory BreastScreen registers and data from all state and territory cervical screening registers were the first 2 steps in the data linkage process, as illustrated by the top half of Figure 4.1.1.

National identification numbers provided by the AIHW Data Linkage Unit (that received only identified variables) to the AIHW Cancer and Screening Unit (that received only analytic variables) allowed the formation of a deidentified national BreastScreen data set and a deidentified national cervical screening data set for analysis.

Target 3: to form a national cancer screening data set with individual screening histories.

Data linkage was used to create a National Screening Data Set, by linking the national BreastScreen data set and the national cervical screening data set with the national bowel cancer screening data set (a selection of variables sourced from the National Bowel Cancer Screening Program Register), as illustrated by the bottom half of Figure 4.1.1.

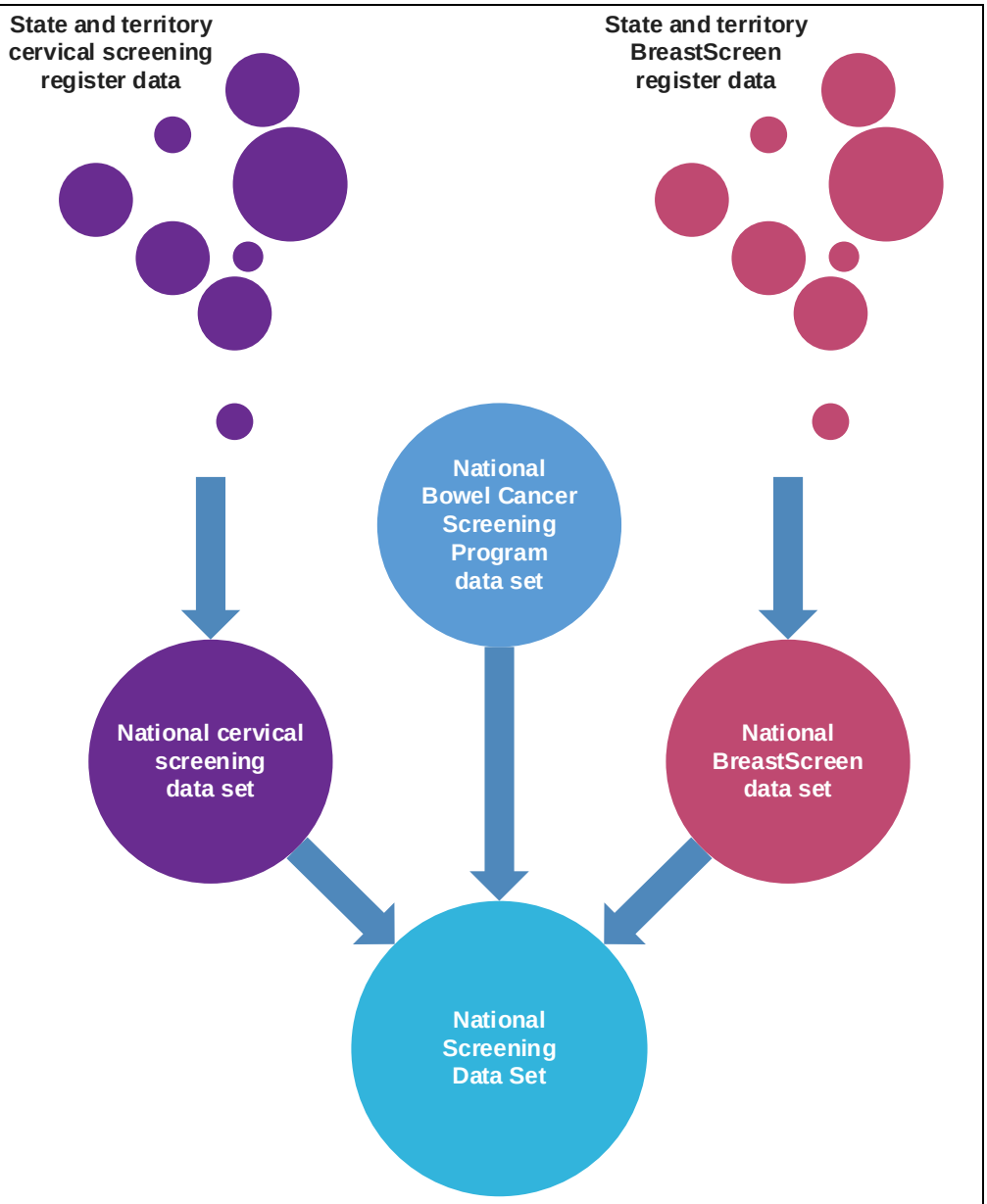


Figure 4.1.1: Data linkage to create a National Screening Data Set

As indicated by the Venn diagram below (Figure 4.1.2), the National Screening Data Set created includes:

- individuals screened through only one of BreastScreen Australia or the National Cervical Screening Program or the National Bowel Cancer Screening Program
- individuals screened through BreastScreen Australia and the National Bowel Cancer Screening Program (but not the National Cervical Screening Program)
- individuals screened through BreastScreen Australia and the National Cervical Screening Program (but not the National Bowel Cancer Screening Program)
- individuals screened through the National Cervical Screening Program and National Bowel Cancer Screening Program (but not BreastScreen Australia)
- individuals screened through BreastScreen Australia, the National Cervical Screening Program, and the National Bowel Cancer Screening Program.

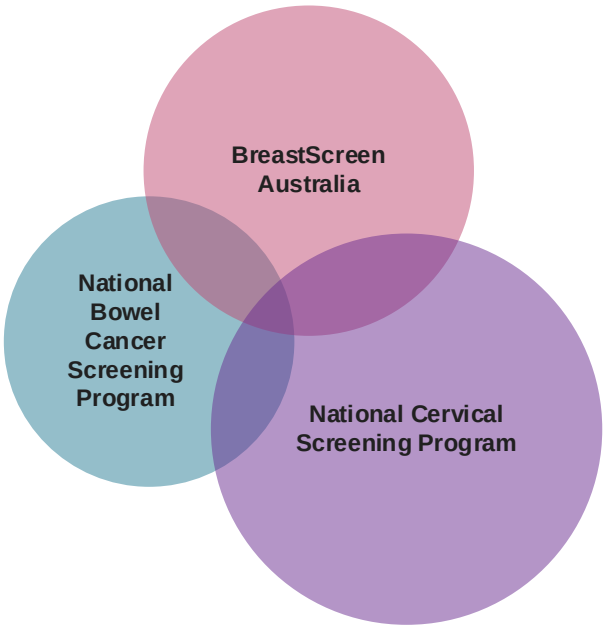


Figure 4.1.2: Participants in the National Screening Data Set

As described at Target 2, national identification numbers provided by the AIHW Data Linkage Unit to the AIHW Cancer and Screening Unit allowed the formation of a deidentified national cancer screening data set for analysis. This National Screening Data Set allows the creation of screening histories for females across the 3 cancer screening programs (as males are able to screen only in the National Bowel Cancer Screening Program, it is not possible to create screening histories across the 3 national cancer screening programs for males).

Target 4: to link the national cancer screening data set to the Australian Cancer Database and the National Death Index.

The Australian Cancer Database was linked to the National Screening Data Set using an *outer join*, meaning that all data from both data sets were retained in the final data set, which then comprised all screened individuals irrespective of whether they were diagnosed with a cancer, and all individuals diagnosed with a cancer irrespective of whether they were screened. This was important to ensure that breast, cervical and bowel cancers that were not detected through screening could contribute to the analyses, and that screening behaviour related to prior cancer diagnosis of any cancer type could be assessed.

Linkage with the National Death Index was the last step in the data linkage process, and was linked to the final data set created from the National Screening Data Set and the Australian Cancer Database (and the National HPV Vaccination Program Register data—see Target 5) using an *outer join*, which also kept deaths in individuals not on any other data set. In practice, however, only death information for individuals who were on one of these data sets were kept. Death information for individuals not in any of the previously linked data sets were discarded, as it was only necessary to know about mortality outcomes for individuals who appear in these linked data sets.

These linkages are illustrated in the Venn diagram below (Figure 4.1.3).

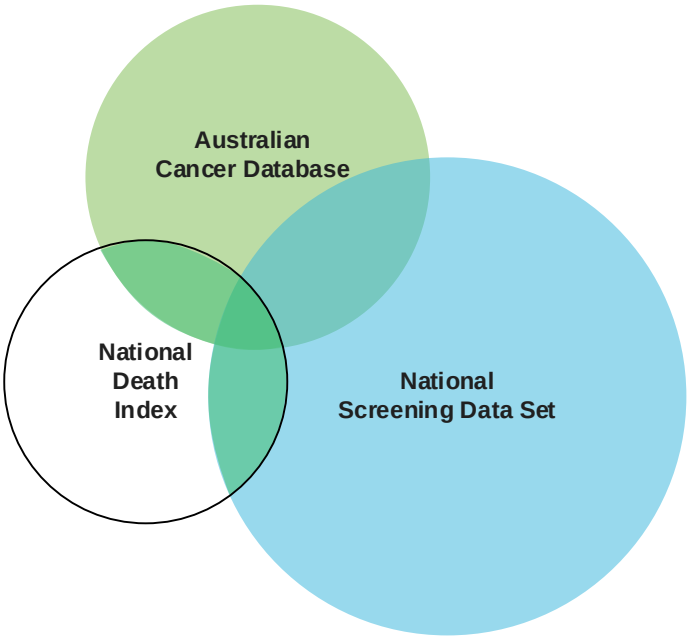


Figure 4.1.3: Linkage between the National Screening Data Set, the Australian Cancer Database and the National Death Index

Target 5: to link the data set created at Target 4 to the National HPV Vaccination Program Register, and to assess the feasibility (and any resulting benefits to the linkage) of first linking this HPV vaccination register to Medicare data to update identifying fields.

Following the linkage to the National Death Index, data from the National HPV Vaccination Program Register were linked using an *outer join* to the data set created at Target 3. This enabled assessment of cervical screening and cervical cancer outcomes in the National Screening Data Set and Australian Cancer Database by HPV vaccination status, as well as the calculation of participation in cervical screening by HPV vaccination status (which requires the number of all screened and unscreened HPV-vaccinated and unvaccinated women to be known in order to calculate these rates).

Included in Target 5 was to assess whether or not these data could first be linked to Medicare enrolment data to allow the identifying details of women who had been vaccinated to be updated prior to linkage. This is because it is not uncommon for surname, for example, to change between when a woman is vaccinated (usually at the age of 12–13) and when she commences cervical screening (usually around age 20), and so by updating details between these 2 events, it was hoped that the linkage could be improved (since the probabilistic linkages are based on name, date of birth, sex, and postcode).

This target was also achieved. Prior to the data linkage for this project, the AIHW Data Linkage Unit acquired Medicare Enrolment File data, covering the period from 1 October 1993 to 30 June 2015. These data were approved for release and used in data linkage operations by the Department of Health (this approval is documented in a Public Interest Certificate and a Schedule between the AIHW and the Department of Health). These Medicare enrolments file data were therefore able to be used to update data on the National HPV Vaccination Program Register data prior to these being linked to the other data sets.

4.2 Assessment of overlap between linked data sets

With all 5 targets relating to the data linkage phase of the project met, the results of the linkage are presented in this section, which provides important contextual information on the degree of overlap across the data sources linked.

Table 4.2.1 shows the number of records that were linked from each data source. The 'event type' relates to screening, cancer, death or vaccination event.

Table 4.2.1: Total number of records for each data source included in the data linkage

Data source	Years	Event type	Number of records	% of records
BreastScreen register data	2000–2014	Screening mammogram at BreastScreen	3,486,621	14.2
Cervical screening register data	2000–2014	Cervical cytology, histology or HPV test	8,270,928	33.7
Bowel screening register data	2006–2014	Invitation to complete an iFOBT	5,909,366	24.1
Australian Cancer Database	1982–2013[(a)]	Cancer diagnosis	2,408,222	9.8
National Death Index	1982–2015	Death	2,297,822	9.4
HPV vaccination register data	2007–2014	HPV vaccine dose	2,182,234	8.9
Total	. .	. .	24,555,193	100.0

(a) NSW data were available only to 2012.

After linkage, there were 15,238,666 unique individuals in the project. The majority (61.7%) of individuals in the data linkage project had only one type of event (that is, appeared in only one of the data sources), while 24.6% experienced 2 event types, and 12.4% experienced 3 event types. Far fewer individuals experienced 4 or 5 event types (1.2% and 1.0%, respectively). Only 3 individuals experienced all 6 event types in the project, meaning that 3 individuals had a screening mammogram through BreastScreen, had a cervical cytology, histology or HPV test, were invited to the bowel screening program, were diagnosed with cancer, received at least 1 dose of HPV vaccine, and had died (Table 4.2.2).

Table 4.2.2: Distribution of the number of different event types an individual experienced

Count of event types	Number of records	% of records
1	9,405,277	61.7
2	3,749,291	24.6
3	1,884,029	12.4
4	186,521	1.2
5	13,545	1.0
6	3	—

It is not possible to illustrate data linkage across this number of data sets in a Venn diagram, but there is value in assessing the degree of overlap of individuals between each cancer

screening data set and the Australian Cancer Database and the National Death Index to ensure that this is adequate to allow the analysis of breast, cervical and bowel cancer outcomes by screen detection status.

Figure 4.2.1 illustrates this overlap for the 3 cancer screening programs. The values shown are for only those individuals who experienced the event types of each screening program and a cancer diagnosis, and each screening program and a cancer diagnosis and death. These are underestimates of the true values as they do not include individuals who experienced these event types *and* additional event types (for example, people who are in the group 'HPV & Cervical screening & Cancer' do not contribute to the overlap figure shown for 'National Cervical Screening Program' and 'Australian Cancer Database') as indicated by the '>' symbol.

Assessment of the degree of overlap between the 3 cancer screening programs is also important to ensure that this is adequate to allow the analysis of screening behavior across the 3 programs. There were 1,524,384 individuals who experienced all 3 screening event types, indicating that more than 1.5 million individuals participated in all 3 cancer screening programs.

A complete list of all variations of event types across the data sets is shown in Table 4.2.3.

Table 4.2.3: Number of individuals who experienced event type combinations

Combinations of event types	Number of records	% of records
Death	1,153,060	7.6
Cancer	917,097	6.0
Cancer & Death	649,646	4.3
Bowel screening	2,901,059	19.0
Bowel screening & Death	70,099	0.5
Bowel screening & Cancer	232,421	1.5
Bowel screening & Cancer & Death	51,259	0.3
BreastScreen	312,000	2.1
BreastScreen & Death	89,766	0.6
BreastScreen & Cancer	43,285	0.3
BreastScreen & Cancer & Death	53,801	0.4
BreastScreen & Bowel screening	323,405	2.1
BreastScreen & Bowel screening & Death	5,962	0.0
BreastScreen & Bowel screening & Cancer	31,127	0.2
BreastScreen & Bowel screening & Cancer & Death	5,387	0.0
Cervical screening	2,991,767	19.6
Cervical screening & Death	44,595	0.3
Cervical screening & Cancer	68,235	0.5
Cervical screening & Cancer & Death	44,946	0.3
Cervical screening & Bowel screening	546,297	3.6
Cervical screening & Bowel screening & Death	6,344	0.0
Cervical screening & Bowel screening & Cancer	55,960	0.4
Cervical screening & Bowel screening & Cancer & Death	8,014	0.1
Cervical screening & BreastScreen	652,169	4.3

(continued)

Table 4.2.3 (continued): Number of individuals who experienced event type combinations

Cervical screening & BreastScreen & Death	40,060	0.3
Cervical screening & BreastScreen & Cancer	62,904	0.4
Cervical screening & BreastScreen & Cancer & Death	40,908	0.3
Cervical screening & BreastScreen & Bowel screening	1,524,384	10.0
Cervical screening & BreastScreen & Bowel screening & Death	11,981	0.1
Cervical screening & BreastScreen & Bowel screening & Cancer	119,434	0.8
Cervical screening & BreastScreen & Bowel screening & Cancer & Death	13,519	0.1
HPV	1,130,294	7.4
HPV & Death	1,153	0.0
HPV & Cancer	2,179	0.0
HPV & Cancer & Death	161	0.0
HPV & Bowel screening	34	0.0
HPV & Bowel screening & Cancer	1	0.0
HPV & BreastScreen	27	0.0
HPV & BreastScreen & Cancer	3	0.0
HPV & BreastScreen & Bowel screening	22	0.0
HPV & BreastScreen & Bowel screening & Cancer	3	0.0
HPV & BreastScreen & Bowel screening & Cancer & Death	1	0.0
HPV & Cervical screening	1,025,980	6.7
HPV & Cervical screening & Death	1,285	0.0
HPV & Cervical screening & Cancer	4,924	0.0
HPV & Cervical screening & Cancer & Death	252	0.0
HPV & Cervical screening & Bowel screening	264	0.0
HPV & Cervical screening & Bowel screening & Death	2	0.0
HPV & Cervical screening & Bowel screening & Cancer	25	0.0
HPV & Cervical screening & Bowel screening & Cancer & Death	3	0.0
HPV & Cervical screening & BreastScreen	622	0.0
HPV & Cervical screening & BreastScreen & Death	4	0.0
HPV & Cervical screening & BreastScreen & Cancer	23	0.0
HPV & Cervical screening & BreastScreen & Cancer & Death	1	0.0
HPV & Cervical screening & BreastScreen & Bowel screening	488	0.0
HPV & Cervical screening & BreastScreen & Bowel screening & Death	1	0.0
HPV & Cervical screening & BreastScreen & Bowel screening & Cancer	20	0.0
HPV & Cervical screening & BreastScreen & Bowel screening & Cancer & Death	3	0.0

Note: 'Death' indicates an individual is on the National Death Index, 'Cancer' indicates an individual is on the Australian Cancer Database, 'BreastScreen' indicates an individual is on a state or territory BreastScreen register, 'Cervical screening' indicates an individual is on a state or territory cervical screening register, 'Bowel screening' indicates an individual is on the National Bowel Cancer Screening Program Register, 'HPV' indicates an individual is on the National HPV Vaccination Program Register.

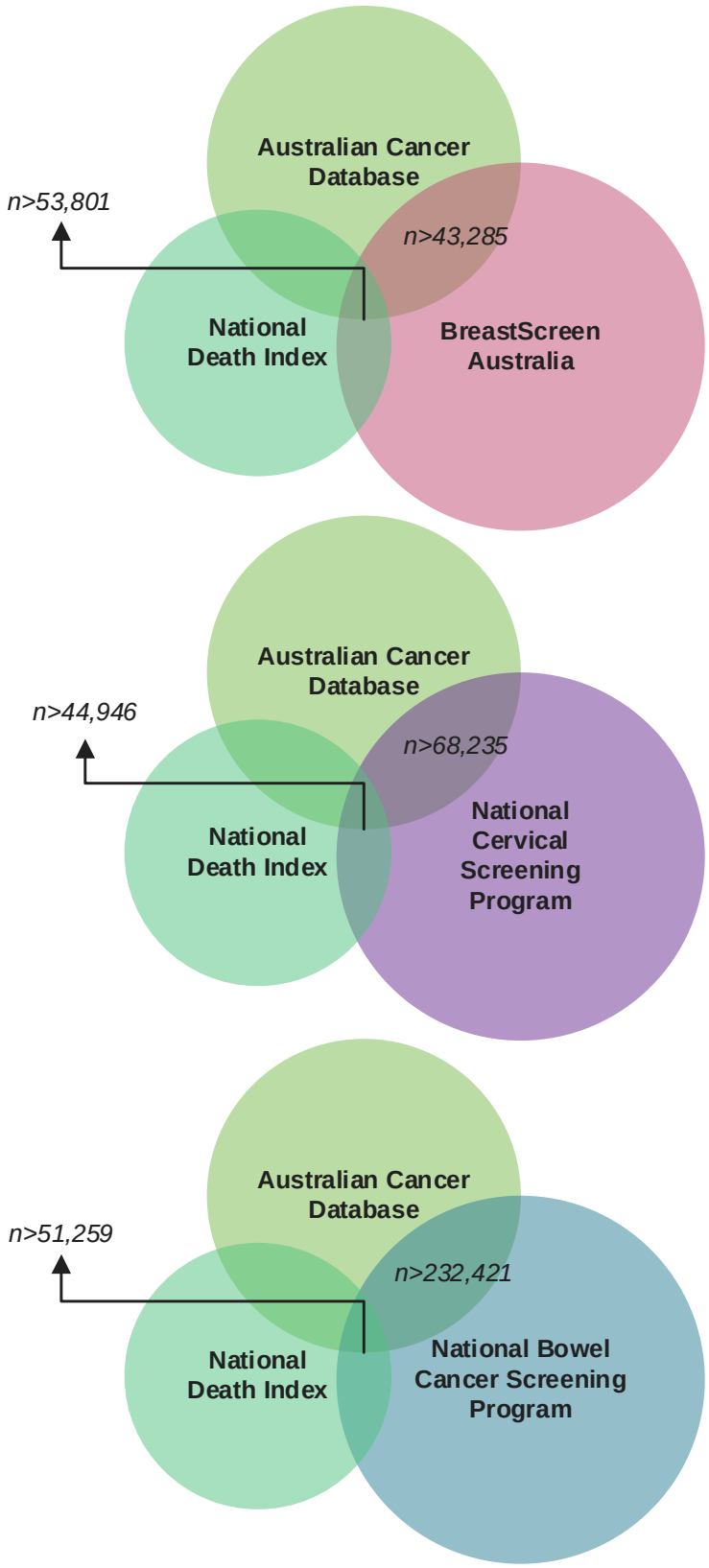


Figure 4.2.1: Overlap between screening, cancer and death data sets

5 What are the benefits of screening?

5.1 Addition of screening history to cancers

Data linkage between individuals who participated in 1 of the 3 cancer screening programs and the Australian Cancer Database allowed the addition of screening history to all breast, cervical and bowel cancers diagnosed (Figure 5.1.1).

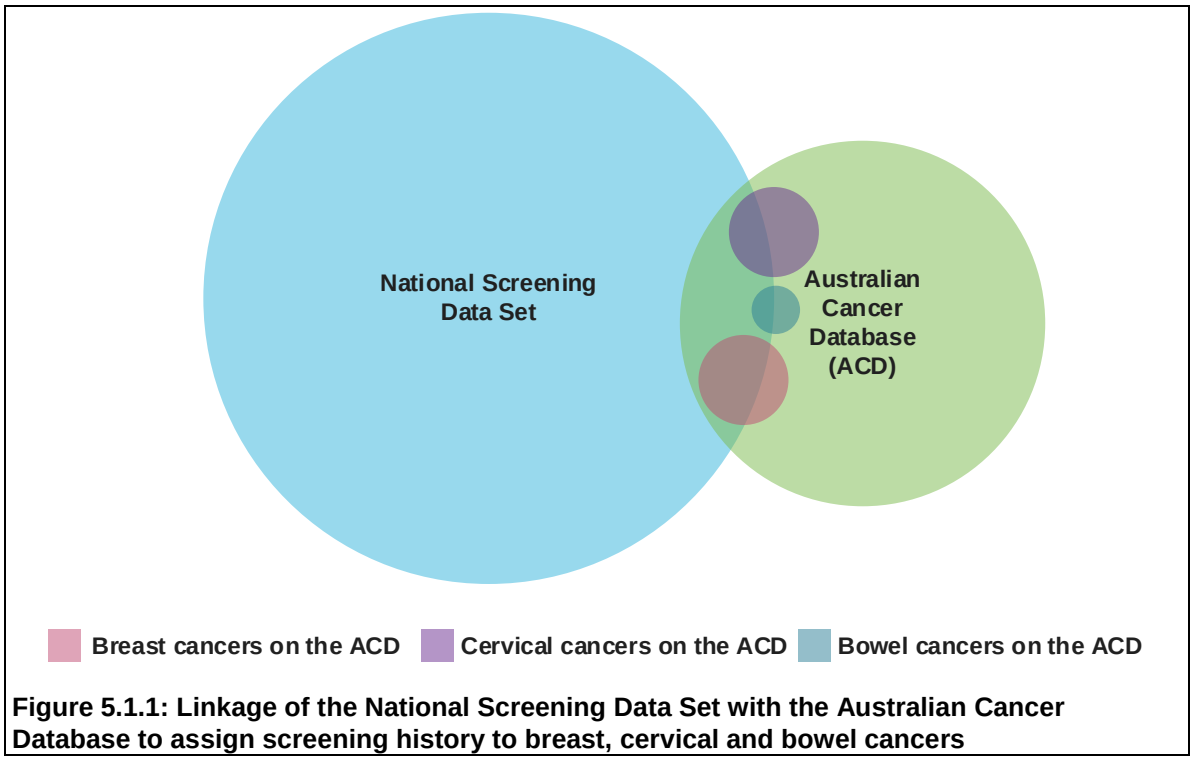


Figure 5.1.1: Linkage of the National Screening Data Set with the Australian Cancer Database to assign screening history to breast, cervical and bowel cancers

Addition of screening history allowed breast, cervical and bowel cancers to be defined as screen-detected, non-screen-detected, or one of the other categories defined.

Linkage of the individuals diagnosed with these breast, cervical and bowel cancers to the National Death Index provided information on which individuals died, and whether the cancer was the cause of death. This information is required to investigate survival outcomes.

Sections 5.2, 5.3 and 5.4 investigate the differences in survival outcomes separately for breast, cervical and bowel cancers, respectively. Section 5.5 allocates breast and cervical cancers to a screening behaviour status, and investigates differences in survival outcomes.

A summary of the 3 cancers and their death outcomes are shown in tables 5.1.1, 5.1.2 and 5.1.3, with cancer-specific and all-cause mortality rates illustrated in Figure 5.1.2.

Breast cancer definitions

Breast cancers were those diagnosed in women aged 50–69 in the years 2002 to 2012.

Breast cancers were categorised as:

- **screen-detected cancers:** breast cancers diagnosed in women with a positive screening result through BreastScreen Australia, where the cancers were identified as screen-detected by BreastScreen Australia
- **interval cancers:** breast cancers diagnosed in women with a negative screening test result through BreastScreen Australia and diagnosed outside BreastScreen Australia in the 2 years following their negative screening result (or in 1 year following if their previous screening recommendation was to rescreen in 12 months), or who were diagnosed within BreastScreen Australia in the 2 years following their negative screening result (or in the 1 year following if their previous screening recommendation was to rescreen in 12 months) either at early recall if the breast cancer was diagnosed more than 6 months after their previous negative screening result, or at early rescreen if they presented with a breast lump and/or clear or blood-stained nipple discharge
- **non-screen-detected cancers in screened women:** breast cancers diagnosed in women who had previously screened through BreastScreen Australia, but not identified as screen-detected cancers or interval cancers
- **non-screen-detected cancers in never-screened women:** breast cancers diagnosed in women who were not screened through BreastScreen Australia prior to diagnosis.

Breast cancer summary

There were 73,440 breast cancers diagnosed in the cohort selected for survival analyses (women aged 50–69 diagnosed 1 January 2002 to 31 December 2012) (Table 5.1.1).

Of these women diagnosed with breast cancer, 11,244 (15.3%) died before the end of 2015; 7,612 women died from breast cancer in this time. Breast cancer deaths occurred in 10.4% of the women diagnosed with breast cancer, and comprised 67.7% of all deaths in these women. In other words, while 15% of women diagnosed with breast cancer died, around two thirds of those that did, died from breast cancer (Figure 5.1.2).

Of the diagnosed breast cancers, 31,968 (43.5%) were screen-detected, with a further 28.9% occurring in women who had previously screened (either interval cancers or non-screen-detected cancers in women who had screened through BreastScreen Australia).

Women diagnosed with screen-detected breast cancers were less likely to die, and those who did die were less likely to die from breast cancer than women whose breast cancer was not screen-detected, with 50.5% of deaths in women with screen-detected breast cancer due to breast cancer, compared with 74.2% in never-screened women.

Cervical cancer definitions

Cervical cancer definitions need to be considered within the context of **cervical screening**, that aims to detect and treat precancerous disease, thereby preventing cervical cancers.

Cervical cancers were those diagnosed in women aged 20–69 in the years 2002 to 2012.

Cervical cancers were categorised as:

- **screen-detected cancers:** cervical cancers diagnosed in women who had a positive screening result (defined as a possible or definite high-grade abnormality or cervical cancer) 6 months to 2.5 years prior their cancer diagnosis. The period 6 months to 2.5 years prior to diagnosis was used as the window in which a positive Pap test was the reason why a cervical cancer was diagnosed. Outside this window, the screening test was considered to be either outside the period in which it could have led to the diagnosis, or within the period of diagnostic testing prior to cervical cancer diagnosis
- **interval cancers:** cervical cancers diagnosed in women who had a negative screening result (defined as a result in which no abnormalities were detected) in the 6 months to 2.5 years prior to their cancer diagnosis
- **non-screen-detected cancers in screened women:** cervical cancers diagnosed in women who had a screening result other than negative or positive 6 months to 2.5 years prior to their cancer diagnosis, and cervical cancers diagnosed in women whose last screen (any screening result) was more than 2.5 years prior to their cancer diagnosis. These cervical cancers were diagnosed in women who had screened, but the screening test prior to diagnosis was not considered to have led to the cervical cancer diagnosis
- **non-screen-detected cancers after a diagnostic test:** cervical cancers diagnosed in women whose only Pap test was in the 6 months prior to their cancer diagnosis. These cervical cancers are considered to be diagnosed only by diagnostic tests, and not as a result of screening
- **non-screen-detected cancers in never-screened women:** cervical cancers diagnosed in women who had no screening test recorded on a cervical screening register, or in women on a cervical screening register but with no screening test prior to diagnosis.

Cervical cancer summary

There were 6,897 cervical cancers diagnosed in the cohort selected for survival analyses (women aged 20–69 diagnosed 1 January 2002 to 31 December 2012) (Table 5.1.2).

Of these women diagnosed with cervical cancer, 1,760 (25.5%) died before the end of 2015, with 1,334 women dying from cervical cancer in this time. Cervical cancer deaths occurred in 19.3% of the women diagnosed with cervical cancer, and comprised 75.8% of all deaths in these women. In other words, a quarter of women diagnosed with cervical cancer died, and three quarters of those that did, died from cervical cancer (Figure 5.1.2).

Of the diagnosed cervical cancers, 354 (5.1%) were screen-detected. This low proportion is likely to be due to cervical screening detecting cervical cancer precursors, thereby preventing any progression to cervical cancer. This means that the majority of cervical cancers are diagnosed in women who either do not screen, or who are lapsed screeners.

Women diagnosed with screen-detected cervical cancers were less likely to die, and those who did die were less likely to die from cervical cancer than women whose cervical cancer was not screen-detected, with 67.7% of deaths in women with screen-detected cervical cancer due to cervical cancer, compared with 78.7% in never-screened women.

Bowel cancer definitions

Bowel cancers were those diagnosed in people aged 50–69 in the years August 2006 to 2012.

Bowel cancers were categorised as:

- **screen-detected cancers:** bowel cancers diagnosed in individuals who were invited and participated in the National Bowel Cancer Screening Program, and who had a positive screening result. Any bowel cancer diagnosed after a positive screening result, regardless of the time between screen and diagnosis, was considered screen-detected
- **interval cancers:** bowel cancers diagnosed in individuals who were invited and participated in the National Bowel Cancer Screening Program, and who had a negative or inconclusive screening result, and were diagnosed with bowel cancer in the 2 years following their negative or inconclusive screening result
- **non-responder cancers:** bowel cancers diagnosed in individuals who were invited to participate in the National Bowel Cancer Screening Program who did not participate. Any bowel cancer diagnosis after an invitation with no response, regardless of time between invitation and diagnosis, was considered a non-responder cancer
- **never-invited cancers:** bowel cancers diagnosed in individuals who were not invited to participate in the National Bowel Cancer Screening Program as they did not have a target-age birthday in the period examined, but were within the target age group.

Bowel cancer summary

There were 31,427 bowel cancers diagnosed in the cohort selected for survival analyses (people aged 50–69 diagnosed 1 August 2006 to 31 December 2012) (Table 5.1.3).

Of these people diagnosed with bowel cancer, 9,765 (31.1%) died before the end of 2015, with 7,566 people dying from bowel cancer in this time. Bowel cancer deaths occurred in 24.1% of the people diagnosed with bowel cancer, and comprised 77.5% of all deaths in these people. In other words, while just under a third of people diagnosed with bowel cancer died, around three quarters of those that did, died from bowel cancer (Figure 5.1.2).

Of the diagnosed bowel cancers, 3,316 (10.6%) were screen-detected. The relatively low proportion is likely to be due to the need to be invited to have a bowel cancer detected through the screening program that previously invited people to screen only when they turned 50, 55 or 65. The proportion of bowel cancers that are screen-detected is expected to increase with the introduction of biennial screening for all Australians aged 50–74 from the year 2019.

People diagnosed with screen-detected bowel cancers were less likely to die, and those who did die were less likely to die from bowel cancer than people whose bowel cancer was not screen-detected, with 65.8% of deaths in people diagnosed with a screen-detected bowel cancer due to bowel cancer, compared with 78.1% in people never-invited to screen.

Table 5.1.1: Deaths in women diagnosed with breast cancer by screen detection status

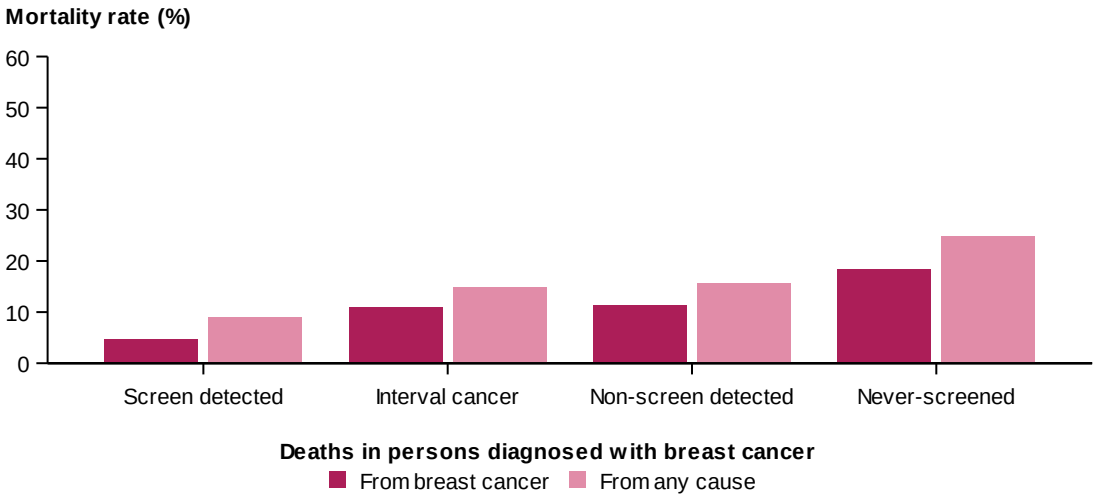
	Screen-detected	Interval cancer	Non-screen-detected	Never-screened
Number diagnosed with breast cancer	31,968	1,202	20,025	20,245
Number died from breast cancer	1,455	131	2,292	3,734
Rate of death from breast cancer (%)	4.6	10.9	11.4	18.4
Number died from any cause	2,883	179	3,150	5,032
Rate of death from any cause (%)	9.0	14.9	15.7	24.9
Mean age at diagnosis *Minimum–Maximum*	*60.4 (±5.6)* *50.0–70.0*	*58.9 (±5.6)* *50.0–69.9*	*59.6 (±5.5)* *50.0–70.0*	*59.1 (±5.9)* *50.0–70.0*
Median age at diagnosis	*60.6*	*58.4*	*59.5*	*58.8*
Mean age at death *Minimum–Maximum*	*67.2(±6.5)* *50.3–82.7*	*63.5(±6.1)* *51.2–79.5*	*64.7(±6.3)* *50.4–81.9*	*63.8(±6.6)* *50.3–82.5*
Median age at death	*67.5*	*63.4*	*64.6*	*63.8*

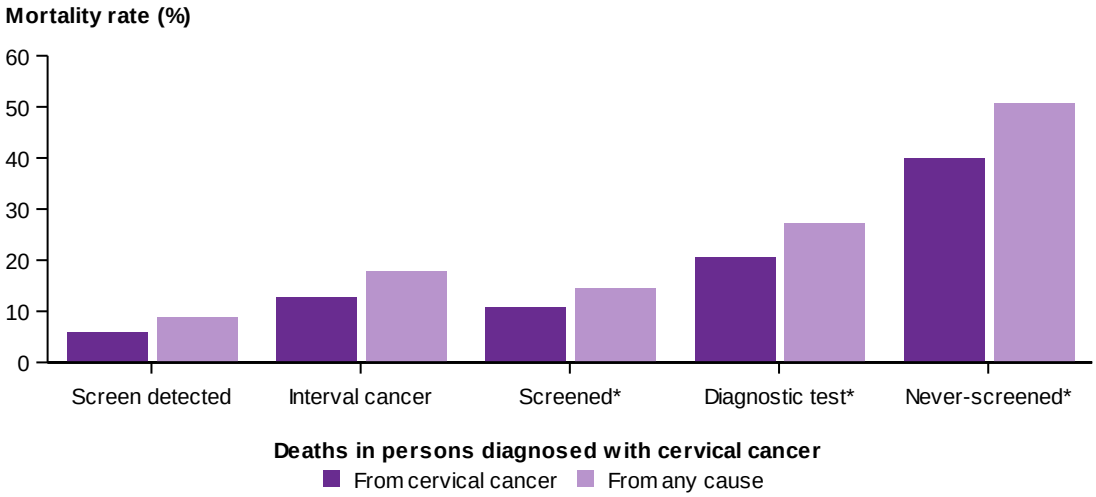
Table 5.1.2: Deaths in women diagnosed with cervical cancer by screen detection status

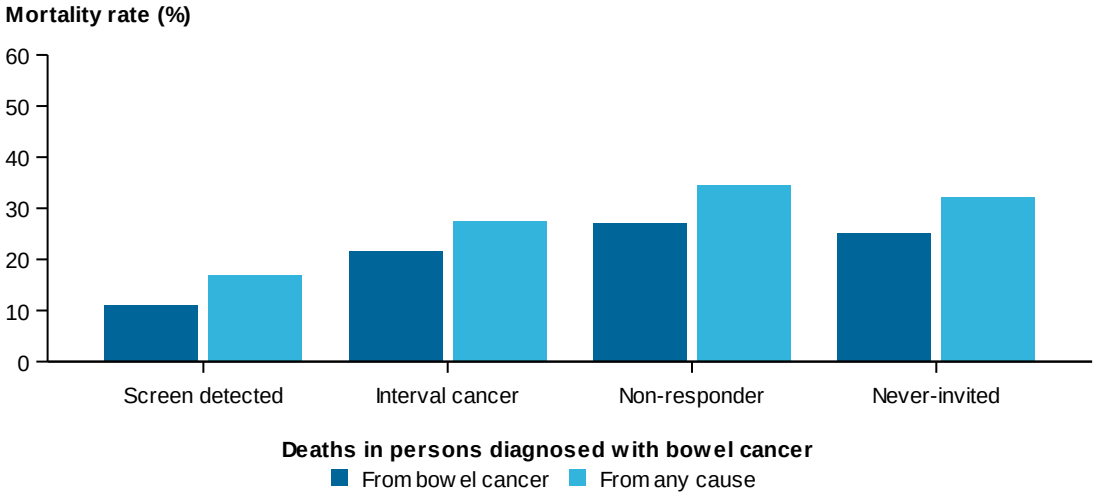
	Screen-detected	Interval cancer	Non-screen-detected in screened	Non-screen-detected after diagnostic test	Non-screen-detected in never-screened
Number diagnosed with cervical cancer	354	1,312	1,720	2,289	1,222
Number died from cervical cancer	21	168	186	471	488
Rate of death from cervical cancer (%)	5.9	12.8	10.8	20.6	39.9
Number died from any cause	31	235	249	625	620
Rate of death from any cause (%)	8.8	17.9	14.5	27.3	50.7
Mean age at diagnosis *Minimum–Maximum*	*41.8 (±11.3)* *21.9–69.5*	*44.1 (±11.8)* *20.6–69.8*	*41.0 (±11.4)* *20.6–70.0*	*47.0 (±11.5)* *20.0–70.0*	*50.9 (±11.5)* *20.6–70.0*
Median age at diagnosis	*38.9*	*42.9*	*38.9*	*46.2*	*51.5*
Mean age at death *Minimum–Maximum*	*54.5 (±13.7)* *28.5–81.5*	*53.9 (±13.0)* *24.8–79.9*	*48.0 (±12.2)* *24.0–76.5*	*54.7 (±11.2)* *22.8–80.6*	*55.0 (±11.5)* *21.4–77.9*
Median age at death	*55.2*	*55.2*	*47.6*	*55.2*	*56.7*

Table 5.1.3: Deaths in persons diagnosed with bowel cancer by screen detection status

	Screen-detected	Interval cancer	Non-responder	Never-invited
Number diagnosed with bowel cancer	3,316	557	7,337	20,217
Number died from bowel cancer	368	121	1,983	5,094
Rate of death from bowel cancer (%)	11.1	21.7	27.0	25.2
Number died from any cause	559	153	2,534	6,519
Rate of death from any cause (%)	16.9	27.5	34.5	32.2
Mean age at diagnosis *Minimum–Maximum*	*61.3 (±5.8)* *50.1–70.0*	*62.6 (±5.6)* *50.1–69.7*	*61.8 (±5.9)* *50.1–70.0*	*61.9 (±5.1)* *50.0–70.0*
Median age at diagnosis	*65.5*	*66.1*	*64.0*	*62.1*
Mean age at death *Minimum–Maximum*	*65.4 (±5.7)* *51.6–76.9*	*65.6 (±5.3)* *51.3–74.3*	*64.3 (±5.9)* *50.6–75.5*	*64.5 (±5.5)* *50.1–78.7*
Median age at death	*67.6*	*67.4*	*66.5*	*64.4*







* Screened = Non-screen detected in screened
Diagnostic test = Non-screen detected after diagnostic test
Never-screened = Non-screen detected in never-screened

Figure 5.1.2: Cancer-specific and all-cause mortality rates by screen detection status

5.2 Survival of women with screen-detected versus non-screen-detected breast cancers

The following section examines breast cancer diagnoses in women aged 50–69 in the period 1 January 2002 to 31 December 2012, who were followed up until 31 December 2015. The age group 50–69 was selected, as this was the target age group of BreastScreen Australia until 1 July 2013.

Although BreastScreen data were available from 2000, which would have allowed the inclusion of breast cancers from that year, it has been postulated (Nickson et al. 2012) that the inclusion of data too soon after the introduction of the screening program may reduce the effect of screening on mortality, since women screening for the first time when the program commenced had less opportunity to benefit from screening. By selecting only cancers diagnosed from 2002 onwards, it is considered that sufficient time would have passed since the introduction of the program for any mortality benefits to be evident (Nickson et al. 2012).

Descriptive statistics

From 1 January 2002 to 31 December 2012, 73,440 women aged 50–69 were diagnosed with breast cancer. Of these cancers, 20,245 (27.6%) were diagnosed in women who had never been screened through BreastScreen (**never-screened cancers**). The remaining breast cancers occurred in women who had previously been screened—**non-screen-detected cancers** were breast cancers diagnosed in women who had previously screened through BreastScreen, but were not screen-detected—20,025 breast cancers (27.3%); **interval cancers** were breast cancers diagnosed after a negative screen through BreastScreen in the interval between screens—1,202 breast cancers (1.6%); and **screen-detected cancers** were those diagnosed in women as a result of their screen—31,968 breast cancers (43.5%).

Descriptive statistics tables allow assessment of similarities and differences between the individuals diagnosed with these different categories of breast cancer by key factors such as age group at diagnosis, remoteness area of residence and socioeconomic group of residence, as well as cancer features that were available on the Australian Cancer Database.

Characteristics of women diagnosed with breast cancers in each of these 4 categories of screen detection status are shown in Table 5.2.1. Key features from this table include:

- a lower proportion of screen-detected breast cancers were diagnosed in women aged 50–54, and a higher proportion in women aged 60–64 and 65–69 compared with breast cancers diagnosed in never-screened women
- a greater proportion of breast cancers were diagnosed in *Inner regional* and *Outer regional* areas when the breast cancer was screen-detected compared with breast cancers diagnosed in never-screened women
- some differences existed in the histological types of breast cancers across the screen detection status categories, most notably a proportionately lower number of *Other—specified* and *Unspecified* breast cancers that were screen-detected compared with those diagnosed in never-screened women
- screen-detected breast cancers were more likely to be small (≤15 mm) than interval breast cancers, non-screen-detected breast cancers in screened women, and breast cancers in never-screened women. Never-screened women also had proportionately more cancers for which the size was unknown (or not applicable).

Table 5.2.1: Characteristics of women diagnosed with breast cancer by screen detection status, women aged 50–69, 2002–2012

		Screen-detected		Interval cancer		Non-screen-detected		Never-screened	
		Count	%	Count	%	Count	%	Count	%
Age group	50–54	6,826	21.4	375	31.2	5,104	25.5	6,334	31.3
	55–59	8,020	25.1	343	28.5	5,479	27.4	4,988	24.6
	60–64	9,044	28.3	265	22.0	5,310	26.5	4,736	23.4
	65–69	8,078	25.3	219	18.2	4,132	20.6	4,187	20.7
Year of diagnosis	2002–2007	15,492	48.5	518	43.1	9,848	49.2	10,785	53.3
	2008–2012	16,476	51.5	684	56.9	10,177	50.8	9,460	46.7
Remoteness area	Major cities	21,739	68.0	784	65.2	12,922	64.5	14,748	72.8
	Inner regional	6,847	21.4	218	18.1	4,493	22.4	3,607	17.8
	Outer regional	2,985	9.3	174	14.5	2,195	11.0	1,590	7.9
	Remote	278	0.9	15	1.2	289	1.4	185	0.9
	Very remote	110	0.3	9	0.7	106	0.5	82	0.4
Socioeconomic group	1 (most disadvantage)	6,336	19.8	169	14.1	4,030	20.1	3,778	18.7
	2	6,730	21.1	234	19.5	3,951	19.7	3,897	19.2
	3	6,327	19.8	271	22.5	3,924	19.6	3,781	18.7
	4	6,069	19.0	228	19.0	3,888	19.4	3,840	19.0
	5 (least disadvantage)	6,486	20.3	297	24.7	4,204	21.0	4,906	24.2

(continued)

Table 5.2.1 (continued): Characteristics of women diagnosed with breast cancer by screen detection status, women aged 50–69, 2002–2012

		Screen-detected		Interval cancer		Non-screen-detected		Never-screened	
		Count	%	Count	%	Count	%	Count	%
Histological type	Invasive ductal carcinoma	25,871	80.9	927	77.1	15,766	78.7	15,847	78.3
	Invasive lobular carcinoma	3,601	11.3	155	12.9	2,613	13.0	2,294	11.3
	Medullar carcinoma & atypical medullary carcinoma	102	0.3	5	0.4	97	0.5	71	0.4
	Tubular carcinoma & invasive cribriform carcinoma	1,015	3.2	16	1.3	293	1.5	286	1.4
	Mucinous carcinoma	497	1.6	16	1.3	256	1.3	256	1.3
	Invasive papillary carcinoma	312	1.0	14	1.2	174	0.9	208	1.0
	Inflammatory carcinoma	16	0.1	4	0.3	49	0.2	48	0.2
	Mesenchymal	11	0.0	1	0.1	11	0.1	30	0.1
	Other—specified	238	0.7	32	2.7	365	1.8	467	2.3
	Unspecified	305	1.0	32	2.7	401	2.0	738	3.6
Tumour size	Small	17,679	55.3	405	33.7	6,814	34.0	5,592	27.6
	Non-small	10,883	34.0	633	52.7	10,170	50.8	9,997	49.4
	Unknown/Not applicable	3,406	10.7	164	13.6	3,041	15.2	4,656	23.0

Results

Breast cancer mortality

The number of women diagnosed with screen-detected, interval, non-screen-detected and never-screened breast cancers, and what number and proportion of these died from breast cancer, are shown in Table 5.1.1 and Figure 5.1.2 in the previous section. The rate of death from screen-detected breast cancer was lowest at 4.6%, followed by interval breast cancer and non-screen-detected breast cancer at 10.9% and 11.4%, respectively. Rate of death from breast cancer was highest for never-screened breast cancers at 18.4%.

Survival analyses were undertaken to explore more thoroughly these apparent differences in death from breast cancer according to their detection status.

In Table 5.2.2, the number and proportion of women diagnosed with breast cancer who died from breast cancer within 1 year, between 1 and 2 years, between 2 and 3 years, and by 31 December 2015 (the end of follow-up) by screen-detection status are shown.

These data reveal that, at every time point, the proportion of women who died from breast cancer was lowest for screen-detected breast cancers, at 0.2% within 1 year, 0.5% between 1 and 2 years, 0.7% between 2 and 3 years, and 4.6% at the end of follow-up (that is, by 31 December 2015). Breast cancer deaths were relatively similar across the screen detection categories of interval and non-screen-detected breast cancers for the different time points. Never-screened breast cancers had the highest mortality at all time points, at 3.3% within 1 year, 3.4% between 1 and 2 years, 3.1% between 2 and 3 years, and 18.4% at the end of follow-up (Table 5.2.2).

Consistent with this finding, the general log rank test statistic of $\chi^2 = 2313.41$ with 3 degrees of freedom ($p < 0.0001$) showed a strong effect of screen detection status (never-screened versus non-screen-detected in screened women versus interval versus screen-detected) on breast cancer mortality.

Table 5.2.2: Breast cancer deaths in women diagnosed with breast cancer by screen detection status

			Deaths from breast cancer			
			Years since diagnosis			
Screen detection status		2002–2012 diagnoses	≤1	1–2	2–3	At 31/12/2015
Screen-detected	Number	31,968	72	149	215	1,455
	Proportion (%)		0.2	0.5	0.7	4.6
Non-screen-detected	Number	20,025	244	403	373	2,292
	Proportion (%)		1.2	2.0	1.9	11.4
Interval	Number	1,202	18	17	30	131
	Proportion (%)		1.5	1.4	2.5	10.9
Never-screened	Number	20,245	678	683	620	3,734
	Proportion (%)		3.3	3.4	3.1	18.4

The survival curves show that women with screen-detected breast cancers had the lowest risk of breast cancer mortality, and that women diagnosed with breast cancer who had never screened through BreastScreen had the highest risk of breast cancer mortality. Women who had previously been screened through BreastScreen but whose breast cancer was not screen-detected, and women with an interval breast cancer, had similar levels of risk (Figure 5.2.1).

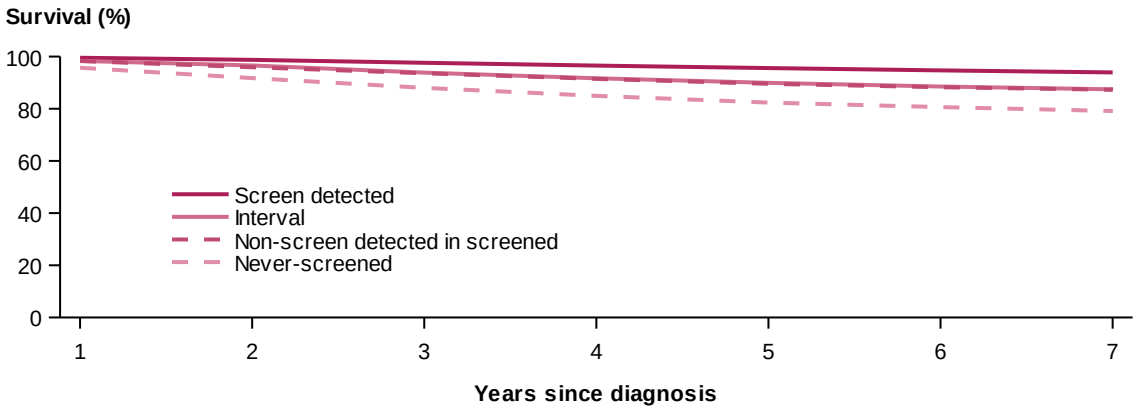


Figure 5.2.1: Crude survival for breast cancer mortality following a diagnosis of breast cancer by screen detection status

Breast cancer mortality survival analyses

The Cox proportional hazards regression model was used to quantify the relationship between survival and a set of explanatory variables for those diagnosed with breast cancer.

Univariate Cox proportional hazards models were fitted to each of the variables: screen detection status, age group at diagnosis, period of diagnosis, remoteness area, socioeconomic group, histological type and tumour size. The crude hazard ratios for each are presented in Table 5.2.3.

The crude hazard ratios showed that, compared with never-screened women, the risk of death from breast cancer for women with screen-detected breast cancers was significantly lower as indicated by a hazard ratio of 0.23 (0.21–0.24).

Statistically significant differences in unadjusted breast cancer mortality hazard ratios were also found across period of diagnosis, remoteness area, socioeconomic group, histological type and tumour size.

In summary, risk of death from breast cancer was lower in 2008–2012 than in 2002–2007, increased with increasing remoteness, and increased with increasing disadvantage.

Breast cancer mortality outcomes also differed by histological type. Compared with *Invasive ductal carcinoma*: *Invasive lobular carcinoma* and *Medullar carcinoma & atypical medullary carcinoma* had a slightly lower risk and no significant difference, respectively; *Tubular carcinoma & invasive cribriform carcinoma*, *Mucinous carcinoma*, and *Invasive papillary carcinoma* had a significantly lower risk; and *Inflammatory carcinoma*, *Mesenchymal* breast cancers, and *Other specified* and *Unspecified* breast cancers had a statistically significantly higher risk of breast cancer mortality.

Tumour size was also a statistically significant predictor of breast cancer mortality, with breast cancers greater than 15 mm or those with an unknown size (or for which tumour size was not applicable) shown to have a statistically significantly higher risk of breast cancer mortality compared with small breast cancers (tumour size ≤15 mm) (Table 5.2.3).

Table 5.2.3: Crude breast cancer mortality hazard ratios for women diagnosed with breast cancer

Variable	HR	95% CI	*P* value
Screen detection status			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.59	0.50–0.70	<.0001
Non-screen-detected	0.59	0.56–0.63	<.0001
Screen-detected	0.23	0.21–0.24	<.0001
Age group at diagnosis			
50–54	1.0	. .	. .
55–59	1.14	1.07–1.21	<.0001
60–64	1.12	1.05–1.19	0.0006
65–69	1.18	1.11–1.26	<.0001
Period of diagnosis			
2002–2007	1.0	. .	. .
2008–2012	0.89	0.84–0.93	<.0001
Remoteness area			
Major cities	1.0	. .	. .
Inner regional	1.11	1.04–1.17	0.0006
Outer regional	1.20	1.11–1.29	<.0001
Remote	1.33	1.08–1.62	0.0061
Very remote	1.67	1.26–2.22	0.0004
Socioeconomic group			
1 (most disadvantage)	1.0	. .	. .
2	0.91	0.85–0.98	0.0091
3	0.89	0.83–0.96	0.0012
4	0.80	0.74–0.85	<.0001
5 (least disadvantage)	0.67	0.62–0.72	<.0001

(continued)

Table 5.2.3 (continued): Crude breast cancer mortality hazard ratios for women diagnosed with breast cancer

Variable	HR	95% CI	*P* value
Histological type			
Invasive ductal carcinoma	1.0	. .	. .
Invasive lobular carcinoma	0.98	0.91–1.05	0.5038
Medullar carcinoma & atypical medullary carcinoma	0.78	0.52–1.16	0.2243
Tubular carcinoma & invasive cribriform carcinoma	0.11	0.07–0.18	<.0001
Mucinous carcinoma	0.35	0.25–0.49	<.0001
Invasive papillary carcinoma	0.52	0.37–0.71	<.0001
Inflammatory carcinoma	5.26	4.02–6.90	<.0001
Mesenchymal	3.37	2.09–5.42	<.0001
Other—specified	2.40	2.13–2.72	<.0001
Unspecified	2.96	2.68–3.26	<.0001
Tumour size			
Small (≤15 mm)	1.0	. .	. .
Non-small (>15 mm)	3.50	3.25–3.76	<.0001
Unknown/not applicable	7.43	6.89–8.01	<.0001

A multivariate Cox proportional hazards model was then generated, the results of which are shown in Table 5.2.4. After adjusting for age group at diagnosis, period of diagnosis, remoteness area, socioeconomic group, histological type and tumour size, the risk of death from breast cancer was significantly lower in screen-detected breast cancers compared with breast cancers diagnosed in women who had never screened through BreastScreen, with a hazard ratio of 0.31 (0.29–0.33).

Methods to correct for lead time (Duffy et al. 2008; Brenner et al. 2011) were applied, using mean lead-time estimates previously published (Duffy & Parmar 2013). When using these to correct for potential lead time in screen-detected cancers, the risk of death from breast cancer was still statistically significantly lower for screen-detected cancers than for breast cancers diagnosed in those never screened, with a hazard ratio of 0.43 (0.41–0.46).

Methods were also applied to correct for screening selection bias, as previously described (Duffy & Cuzick 2002) using a conservative correction factor of 1.36. Correcting for screening selection bias alone increased the adjusted hazard ratio to 0.59 (0.36–0.96).

After correcting for lead-time bias and screening selection bias using a conservative correction factor of 1.36, the risk of death from breast cancer was no longer significantly lower for screen-detected breast cancers than for breast cancers diagnosed in women who had never screened through BreastScreen Australia, with a hazard ratio of 0.81 (0.50–1.33) (Table 5.2.4).

The conservative correction factor of 1.36 is based on the pooled results of 5 randomised control trials (Duffy & Cuzick 2002). It has, however, been recognised that screening selection bias can differ between countries, which means that the data on which this correction factor was based may not be relevant to Australian data. There is also evidence

that screening selection bias may not apply at all to Australian data, based on the findings from a survey of South Australian women (Roder et al. 2008).

To investigate this, a less conservative correction factor of 1.17 was also used, which was the correction factor used in an evaluation of service screening mammography on breast cancer mortality in New Zealand (Morrell et al. 2017). The correction factor of 1.17 chosen for this evaluation was based on Swedish screening service studies (Swedish Organised Service Screening Evaluation Group 2006), as the Swedish screening service environment is considered similar to that of New Zealand (Morrell et al. 2017).

Using the same methods to correct for screening selection bias (Duffy & Cuzick 2002) and a more realistic correction factor for Australia of 1.17, correcting for screening selection bias alone increased the adjusted hazard ratio from 0.31 (0.29–0.33) to 0.42 (0.35–0.49).

After correcting for lead-time bias and screening selection bias using the more realistic correction factor for Australia of 1.17, and in contrast to when the conservative correction factor of 1.36 was used, the risk of death from breast cancer was statistically significantly lower for screen-detected breast cancers than for breast cancers diagnosed in women who had never screened through BreastScreen Australia, with a hazard ratio of 0.58 (0.49–0.68) (Table 5.2.4).

These results demonstrate the effect of the screening selection correction factor used, and the importance of using the appropriate correction factor for the data in order to correctly determine breast cancer survival outcomes in screened compared with unscreened women. Further studies will explore screening selection bias in breast cancer survival in more detail, including examining whether an Australian-specific screening selection correction factor can be derived from these linked data to enable appropriate correction for this potential bias.

Table 5.2.4: Unadjusted and adjusted hazard ratios for breast cancer mortality for women diagnosed with breast cancer

Screen detection status	HR	95% CI	*P* value
Breast cancer mortality, unadjusted			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.59	0.50–0.70	<.0001
Non-screen-detected	0.59	0.56–0.63	<.0001
Screen-detected	0.23	0.21–0.24	<.0001
Breast cancer mortality, adjusted			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.65	0.54–0.77	<.0001
Non-screen-detected	0.65	0.62–0.68	<.0001
Screen-detected	0.31	0.29–0.33	<.0001
Breast cancer mortality, adjusted, corrected for lead-time bias only			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.64	0.54–0.77	<.0001
Non-screen-detected	0.65	0.62–0.69	<.0001
Screen-detected	0.43	0.41–0.46	<.0001
Breast cancer mortality, adjusted, corrected for screening selection bias only (correction factor 1.36)			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	1.23	0.73–2.06	. .
Non-screen-detected	1.23	0.75–2.01	. .
Screen-detected	0.59	0.36–0.96	. .
Breast cancer mortality, adjusted, corrected for lead-time bias and screening selection bias (correction factor 1.36)			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	1.21	0.72–2.03	. .
Non-screen-detected	1.23	0.75–2.01	. .
Screen-detected	0.81	0.50–1.33	. .
Breast cancer mortality, adjusted, corrected for screening selection bias only (correction factor 1.17)			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.88	0.70–1.10	. .
Non-screen-detected	0.88	0.74–1.03	. .
Screen-detected	0.42	0.35–0.49	. .
Breast cancer mortality, adjusted, corrected for lead-time bias and screening selection bias (correction factor 1.17)			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.86	0.69–1.08	. .
Non-screen-detected	0.88	0.74–1.03	. .
Screen-detected	0.58	0.49–0.68	. .

All-cause mortality survival analyses

Analyses were repeated for all-cause mortality. The crude hazard ratios showed that, compared with never-screened women, the risk of death from all causes for women with screen-detected breast cancers was significantly lower, as indicated by a hazard ratio of 0.33 (0.32–0.35).

A multivariate Cox proportional hazards model adjusted for age group at diagnosis, period of diagnosis, remoteness area, socioeconomic group, histological type and tumour size found that the risk of death from all causes was significantly lower in screen-detected breast cancers compared with breast cancers diagnosed in women who were never screened through BreastScreen, with a hazard ratio of 0.41 (0.39–0.43) (Table 5.2.5).

Correcting for lead-time bias or screening selection bias using a conservative correction factor of 1.36 resulted in hazard ratios of 0.62 (0.59–0.65) and 0.78 (0.47–1.27), respectively. These results indicate that, while the risk of death from all causes was still significantly lower for screen-detected breast cancers than for breast cancers diagnosed in women who had never screened through BreastScreen after correcting for lead-time bias, this was not the case after correcting for screening selection bias (as indicated by confidence intervals that include 1). Correcting for both lead-time bias and screening selection bias using a conservative correction factor of 1.36 also demonstrated no difference in the risk of death from all causes between screen-detected breast cancers and breast cancers diagnosed in women who had never screened through BreastScreen—hazard ratio 1.17 (0.72–1.92) (Table 5.2.5).

Both screening selection bias corrections were repeated using the more realistic correction factor for Australia of 1.17 (as for breast cancer specific mortality survival analyses).

Correction for screening selection bias alone using the correction factor of 1.17 increased the adjusted hazard ratio from 0.41 (0.39–0.43) to 0.55 (0.47–0.65). This indicates that, when this less conservative correction factor is applied, and in contrast to when the conservative correction factor of 1.36 was used, the risk of death from any cause was found to be significantly lower for screen-detected breast cancers than for breast cancers diagnosed in women who had never screened through BreastScreen.

After correcting for both lead-time bias and screening selection bias using the more realistic correction factor for Australia of 1.17, and in contrast to when the conservative correction factor of 1.36 was used, the risk of death from any cause was statistically significantly lower for screen-detected breast cancers than for breast cancers diagnosed in women who had never screened through BreastScreen Australia, with a hazard ratio of 0.84 (0.71–0.98) (Table 5.2.5).

Again, these results demonstrate the effect of the screening selection correction factor used, and the importance of using the appropriate correction factor for the data in order to correctly determine breast cancer survival outcomes in screened compared with unscreened women.

Table 5.2.5: Unadjusted and adjusted hazard ratios for all-cause mortality for women diagnosed with breast cancer

Screen detection status	HR	95% CI	*P* value
All-cause mortality, unadjusted			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.61	0.53–0.71	<.0001
Non-screen-detected	0.61	0.58–0.64	<.0001
Screen-detected	0.33	0.32–0.35	<.0001
All-cause mortality, adjusted			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.66	0.57–0.77	<.0001
Non-screen-detected	0.64	0.62–0.67	<.0001
Screen-detected	0.41	0.39–0.43	<.0001
All-cause mortality, adjusted, corrected for lead-time bias only			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.66	0.57–0.77	<.0001
Non-screen-detected	0.64	0.62–0.67	<.0001
Screen-detected	0.62	0.59–0.65	<.0001
All-cause mortality, adjusted, corrected for screening selection bias only (correction factor 1.36)			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	1.25	0.75–2.08	. .
Non-screen-detected	1.21	0.74–1.98	. .
Screen-detected	0.78	0.47–1.27	. .
All-cause mortality, adjusted, corrected for lead-time bias and screening selection bias (correction factor 1.36)			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	1.25	0.75–2.08	. .
Non-screen-detected	1.21	0.74–1.98	. .
Screen-detected	1.17	0.72–1.92	. .
All-cause mortality, adjusted, corrected for screening selection bias only (correction factor 1.17)			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.89	0.72–1.10	. .
Non-screen-detected	0.86	0.73–1.01	. .
Screen-detected	0.55	0.47–0.65	. .
All-cause mortality, adjusted, corrected for lead-time bias and screening selection bias (correction factor 1.17)			
Never-screened	1.0	. .	. .
Screening women			
Interval cancers	0.89	0.72–1.10	. .
Non-screen-detected	0.86	0.73–1.01	. .
Screen-detected	0.84	0.71–0.98	. .

5.3 Survival of women with screen-detected versus non-screen-detected cervical cancers

The following section examines cervical cancer diagnoses in women aged 20–69 from 1 January 2002 to 31 December 2012, who were followed up until 31 December 2015. The age group 20–69 was selected as this was the target age group for the National Cervical Screening Program until 1 December 2017.

While cervical screening data were available from 2000, cervical cancers were included only from 2002 to allow at least 2 years of cervical screening history prior to diagnosis to be included in the data used to define screen detection status in the earlier years of the period.

Descriptive statistics

From 1 January 2002 to 31 December 2012, 6,897 women aged 20–69 were diagnosed with cervical cancer.

Of these 6,897 cervical cancers, 3,511 were diagnosed in women who had never been screened, comprising 1,222 (17.7%) cervical cancers in women who were not on a cervical screening register (**never-screened**), and 2,289 (33.2%) in women who were on a cervical screening register but only due to diagnostic tests (that is, testing in the 6 months prior to diagnosis), with no screening tests prior to the diagnosis (**non-screen-detected after diagnostic test**). The remaining cervical cancers occurred in women who had previously been screened—**interval cancers** (1,312 cervical cancers—19.0%), non-screen-detected cancers in women who had previously been screened (**non-screen-detected in screened**) (1,720 cervical cancers (24.9%)), and **screen-detected cancers** (making up the lowest proportion at 354 cervical cancers—5.1%). The low number of screen-detected cervical cancers is likely to be a consequence of cervical screening detecting precursors to cervical cancer, thereby preventing the cancers from developing.

Characteristics of women diagnosed with cervical cancers in each of these 5 categories of screen detection status are shown in Table 5.3.1. Key features from this table include:

- proportionately more screen-detected cervical cancers were diagnosed in the younger age groups 20–34 and 35–44, compared with cervical cancers in never-screened women, which were more likely to be diagnosed at ages 45–54 and 55–69
- proportionately more cervical cancers diagnosed in never-screened women were cervical cancers other than the cervical carcinomas.

Table 5.3.1: Characteristics of women diagnosed with cervical cancer by screen detection status, women aged 20–69, 2002–2012

		Screen-detected		Interval cancer		Non-screen-detected in screened		Non-screen-detected after diagnostic test		Never-screened	
		Count	%	Count	%	Count	%	Count	%	Count	%
Age group	20–34	107	30.2	362	27.6	625	36.3	374	16.3	119	9.7
	35–44	127	35.9	370	28.2	521	30.3	693	30.3	256	21.0
	45–54	68	19.2	309	23.6	337	19.6	625	27.3	352	28.8
	55–69	52	14.7	271	20.7	237	13.8	597	26.1	495	40.5
Period of diagnosis	2002–2007	151	42.7	685	52.2	635	36.9	1,399	61.1	668	54.7
	2008–2012	203	57.3	627	47.8	1,085	63.1	890	38.9	554	45.3
Remoteness area	Major cities	234	66.1	889	67.8	1,119	65.1	1,496	65.4	779	63.8
	Inner regional	58	16.4	238	18.1	330	19.2	427	18.7	226	18.5
	Outer regional	41	11.6	135	10.3	197	11.5	259	11.3	155	12.7
	Remote and very remote	20	5.7	43	3.3	71	4.1	105	4.6	49	4.0
Socioeconomic group	1 (most disadvantage)	82	23.2	254	19.4	342	19.9	543	23.7	325	26.6
	2	78	22.0	247	18.8	375	21.8	508	22.2	307	25.1
	3	52	14.7	235	17.9	351	20.4	461	20.1	220	18.0
	4	77	21.8	280	21.3	356	20.7	406	17.7	189	15.5
	5 (least disadvantage)	63	17.8	289	22.0	293	17.0	368	16.1	168	13.8
Histological type	Squamous carcinomas	268	75.7	602	45.9	1,078	62.7	1,741	76.1	870	71.2
	Other carcinomas	84	23.7	656	50.0	600	34.9	532	23.2	312	25.5
	Other cancer	2	0.6	54	4.1	42	2.4	16	0.7	40	3.3

Results

Cervical cancer mortality

The number of women diagnosed with screen-detected, interval, non-screen-detected and never-screened cervical cancers, and what number and proportion of these died from cervical cancer, are shown in Table 5.1.2 and Figure 5.1.2 in an earlier chapter. The rate of death from screen-detected cervical cancer was lowest at 5.9%, followed by non-screen-detected cervical cancers in screened individuals and interval cervical cancers at 10.8% and 12.8%, respectively. Rate of death from cervical cancer was higher for diagnostic (20.6%) and never-screened (39.9%) cervical cancers.

Survival analyses were undertaken to explore more thoroughly these apparent differences in death from cervical cancer according to their detection status.

In Table 5.3.2, the number and proportion of women diagnosed with cervical cancer who died from cervical cancer within 1 year, between 1 and 2 years, between 2 and 3 years, and by 31 December 2015 (the end of follow-up) by screen-detection status are shown.

These data reveal that, at every time point, the proportion of women who died from cervical cancer was lowest for screen-detected cervical cancers, at 1.7% within 1 year, 1.4% between 1 and 2 years, 1.1% between 2 and 3 years, and 5.9% at the end of follow-up (that is, by 31 December 2015). Cervical cancer deaths were relatively similar across the non-screen-detected in screened women and interval cervical cancers for the different time points. Never-screened cervical cancers had the highest mortality at almost all time points, at 19.7% within 1 year, 11.5% between 1 and 2 years, 3.6% between 2 and 3 years, and 39.9% at the end of follow-up (Table 5.3.2).

Table 5.3.2: Cervical cancer deaths in women diagnosed with cervical cancer by screen detection status

			Deaths from cervical cancer			
			Years since diagnosis			
Screen detection status		2002–2012 diagnoses	≤1	1–2	2–3	At 31/12/2015
Screen-detected	Number	354	6	5	4	21
	Proportion (%)		1.7	1.4	1.1	5.9
Non-screen-detected in screened	Number	1,720	67	50	30	186
	Proportion (%)		3.9	2.9	1.7	10.8
Interval	Number	1,312	50	40	30	168
	Proportion (%)		3.8	3.0	2.3	12.8
Non-screen-detected after diagnostic test	Number	2,289	130	139	84	471
	Proportion (%)		5.7	6.1	3.7	20.6
Never-screened	Number	1,222	241	141	44	488
	Proportion (%)		19.7	11.5	3.6	39.9

Consistent with this finding, the general log rank test statistic of $\chi^2 = 620.67$ with 4 degrees of freedom (p <0.001) showed a strong effect of screen detection status (never-screened versus diagnostic versus interval versus non-screen-detected in screened women versus screen-detected).

The survival curves show that women with screen-detected cervical cancers had the lowest risk of cervical cancer mortality followed by screened women with interval cervical cancers. Never-screened women diagnosed with cervical cancer had the highest risk of cervical cancer mortality (Figure 5.3.1).

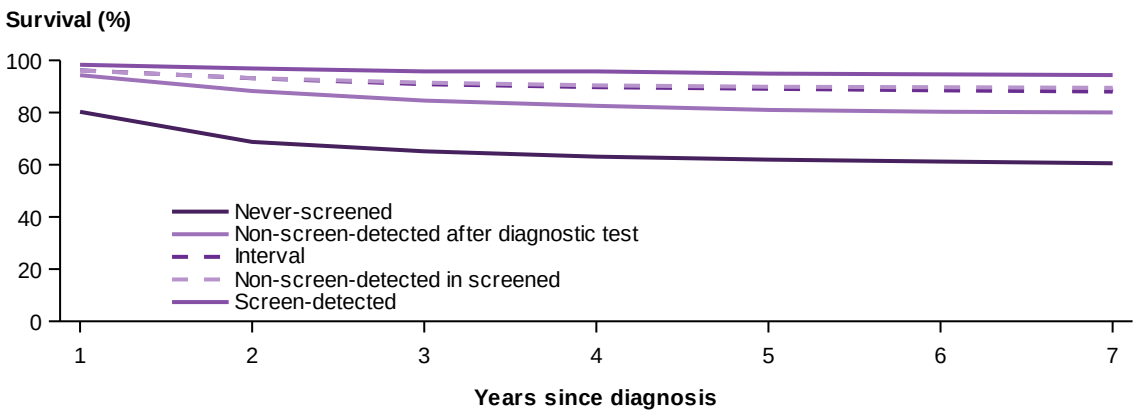


Figure 5.3.1: Crude survival for cervical mortality following a diagnosis of cervical cancer by screen detection status

Cervical cancer mortality survival analyses

The Cox proportional hazards regression model was used to quantify the relationship between survival and a set of explanatory variables for those diagnosed with cervical cancer.

Univariate Cox proportional hazards models were fitted to each of the variables: screen detection status, age group at diagnosis, period of diagnosis, remoteness area, socioeconomic group, and histological type. The crude hazard ratios are presented in Table 5.3.3.

The crude hazard ratios showed that, compared with never-screened women, the risk of death from cervical cancer for women in all screening categories was significantly lower; this effect was strongest for those with screen-detected cancers, with a hazard ratio of 0.11 (0.07–0.17).

Statistically significant differences in unadjusted cervical cancer mortality hazard ratios were also found across age group at diagnosis and socioeconomic group.

In summary, risk of death from cervical cancer increased with increasing age, increased with increasing remoteness, and increased with increasing disadvantage.

Table 5.3.3: Crude cervical mortality hazard ratios for women diagnosed with cervical cancer

Variable	HR	95% CI	*P* value
Screen detection status			
Never-screened	1.0	. .	. .
Non-screen-detected after diagnostic test	0.40	0.35–0.46	<0.001
Screening women			
Interval	0.24	0.20–0.29	<0.001
Non-screen-detected in screened	0.21	0.18–0.25	<0.001
Screen-detected	0.11	0.07–0.17	<0.001
Age group at diagnosis			
20–34	1.0	. .	. .
35–44	1.54	1.27–1.87	<0.001
45–54	2.46	2.04–2.96	<0.001
55–69	3.66	3.05–4.36	<0.001
Period of diagnosis			
2002–2007	1.00	. .	. .
2008–2012	1.02	0.91–1.13	0.072
Remoteness area			
Major cities	1.0	. .	. .
Inner regional	1.00	0.87–1.16	0.958
Outer regional	1.44	1.23–1.68	<0.001
Remote and very remote areas	1.39	1.09–1.77	0.008
Socioeconomic group			
1 (most disadvantage)	1.0	. .	. .
2	0.94	0.81–1.09	0.377
3	0.73	0.62–0.86	<0.001
4	0.69	0.58–0.81	<0.001
5 (least disadvantage)	0.57	0.47–0.68	<0.001
Histological type			
Squamous carcinoma	1.0	. .	. .
Other carcinoma	0.89	0.79–1.09	0.053
Other invasive cancer	0.77	0.50–1.18	0.228

A multivariate Cox proportional hazards model was then generated, the results of which are shown in Table 5.3.4. After adjusting for age group at diagnosis, remoteness area, socioeconomic group, and histological type, the risk of death from cervical cancer was significantly lower in screen-detected cervical cancers compared with cervical cancers diagnosed in never-screened women, with a hazard ratio of 0.13 (0.09–0.21).

Table 5.3.4: Unadjusted and adjusted hazard ratios for cervical cancer mortality for women diagnosed with cervical cancer

Screen detection status	HR	95% CI	*P* value
Cervical cancer mortality, unadjusted			
Never-screened	1.0	. .	. .
Non-screen-detected after diagnostic test	0.40	0.35–0.46	<0.001
Screening women			
Interval	0.24	0.20–0.29	<0.001
Non-screen-detected in screened	0.21	0.18–0.25	<0.001
Screen-detected	0.11	0.07–0.17	<0.001
Cervical cancer mortality, adjusted			
Never-screened	1.0	. .	. .
Non-screen-detected after diagnostic test	0.44	0.39–0.50	<0.001
Screening women			
Interval	0.29	0.24–0.34	<0.001
Non-screen-detected in screened	0.26	0.22–0.32	<0.001
Screen-detected	0.13	0.09–0.21	<0.001

All-cause mortality survival analyses

Analyses were repeated for all-cause cancer mortality. A multivariate Cox proportional hazards model adjusted for age group at diagnosis, remoteness area, socioeconomic group, and histological type found that the risk of death from all causes was significantly lower with screen-detected cervical cancers than with cervical cancers diagnosed in women who had never screened, with a hazard ratio of 0.17 (0.12–0.24) (Table 5.3.5).

Table 5.3.5: Unadjusted and adjusted hazard ratios for all-cause mortality for women diagnosed with cervical cancer

Screen detection status	HR	95% CI	*P* value
All-cause mortality, unadjusted			
Never-screened	1.0	. .	. .
Non-screen-detected after diagnostic test	0.41	0.37–0.46	<0.001
Screening women			
Interval	0.27	0.23–0.31	<0.001
Non-screen-detected in screened	0.22	0.19–0.26	<0.001
Screen-detected	0.13	0.09–0.18	<0.001
All-cause mortality, adjusted			
Never-screened	1.0	. .	. .
Non-screen-detected after diagnostic test	0.47	0.42–0.53	<0.001
Screening women			
Interval	0.32	0.27–0.37	<0.001
Non-screen-detected in screened	0.30	0.26–0.35	<0.001
Screen-detected	0.17	0.12–0.24	<0.001

5.4 Survival of people with screen-detected versus non-screen-detected bowel cancers

In May 2018, the AIHW published the results of a data linkage project specific to the National Bowel Cancer Screening Program (AIHW 2018b), a repeat of a 2014 project (AIHW 2014; AIHW & DoH 2016) that similarly analysed bowel cancer outcomes for the National Bowel Cancer Screening Program. A major difference between that project and this one was the source of cancer data—rather than using the Australian Cancer Database, that project sourced data directly from state and territory cancer registries, which held more up-to-date data, with many jurisdictions also holding bowel cancer staging data, which enriched the analyses of that project. A second difference was the age group used (50–74 compared with 50–69 in this project). Other differences between the two approaches are relatively minor, and are not expected to result in different outcomes, but allow the 3 cancers to be analysed consistently, and according to the objectives of this project, which differed from the objectives of the bowel cancer-specific project and resulting report.

Rather than repeating all the analyses performed for that project, selected analyses were repeated to confirm that similar conclusions were reached. Following this confirmation, the tables, figures and statistics selected for this report were those that were appropriate to the objectives of this project, and to the chosen emphasis of this report.

The following section examines bowel cancer diagnoses in persons aged 50–69 in the period 1 August 2006 to 31 December 2012, who were followed up until 31 December 2015. The age group 50–69 was selected as this included the ages of 50, 55 and 65, which were the focus of invitations for the range of data used in this project.

Descriptive statistics

In the period 1 August 2006 to 31 December 2012, 31,427 people aged 50–69 were diagnosed with bowel cancer. Of these cancers, 20,217 (64.3%) were diagnosed in persons who were not invited to participate in the screening program (**never-invited cancers**). The remaining bowel cancers occurred in persons who had been invited to participate in the screening program (known as invitees). Bowel cancers diagnosed in invitees were further categorised into **screen-detected cancers**, **interval cancers**, and **non-responder cancers**.

Characteristics of persons diagnosed with bowel cancers in each of these 4 categories of screen detection status are shown in Table 5.4.1. Key features from this table include:

- more males than females were diagnosed with bowel cancer in all cancer detection status categories except interval cancers, for which females just outnumbered males
- age group at diagnosis for bowel cancer is affected by the National Bowel Screening Program, which, for the years of data included, invited people aged 50, 55 and 65 to screen. For this reason, there are very few screen-detected cancers diagnosed in the age group 60–64, and a relatively large proportion in the never-invited cancers. Excluding this age group, proportionally more bowel cancers were diagnosed in the age groups of 55–59 and 65–69 in invitees compared with never-invited.

Table 5.4.1: Characteristics of individuals diagnosed with bowel cancer by screen detection status, persons aged 50–69, August 2006–2012

		Screen-detected		Interval cancer		Non-responder		Never-invited	
		Count	%	Count	%	Count	%	Count	%
Sex	Male	2,023	61.0	271	48.7	4,472	61.0	12,001	59.4
	Female	1,293	39.0	286	51.4	2,865	39.1	8,216	40.6
Age group	50–54	377	11.4	54	9.7	902	12.3	2,840	14.1
	55–59	1,006	30.3	147	26.4	2,467	33.6	3,511	17.4
	60–64	47	1.4	6	1.1	316	4.3	8,644	42.8
	65–69	1,886	56.9	350	62.8	3,652	49.8	5,222	25.8
Diagnosis year	August 2006–2007	644	19.4	28	5.1	370	5.0	5762	28.5
	2008	732	22.1	93	16.7	799	10.9	3,539	17.5
	2009	439	13.2	139	25.0	1,132	15.4	3,231	16.0
	2010	874	26.4	96	17.2	1,554	21.2	3,074	15.2
	2011	487	14.7	118	21.2	1,794	24.5	2,308	11.4
	2012	140	4.2	83	14.9	1,688	23.0	2,303	11.4
Remoteness area	Major cities	1,863	56.2	325	58.4	4,404	60.0	11,988	59.3
	Inner regional	830	25.0	144	25.9	1,605	21.9	4,786	23.7
	Outer regional	503	15.2	74	13.3	1,002	13.7	2,674	13.2
	Remote and very remote	120	3.6	14	2.5	318	4.3	740	3.7
Socioeconomic group	1 (most disadvantage)	727	21.4	110	19.8	1,710	23.3	4,560	22.6
	2	741	22.5	127	22.8	1,677	22.9	4,436	21.9
	3	695	21.1	100	18.0	1,519	20.7	4,047	20.0
	4	580	17.9	104	18.7	1,264	17.2	3,607	17.8
	5 (least disadvantage)	571	17.1	115	20.7	1,158	15.6	3,526	17.4

Results

Bowel cancer mortality

The number of people diagnosed with screen-detected, interval, non-responder and never-invited bowel cancers, and what number and proportion of these died from bowel cancer, are shown in Table 5.1.3 and Figure 5.1.2 in an earlier section. The rate of death from screen-detected bowel cancer was lowest at 11.1%, followed by interval bowel cancer and never-invited bowel cancer at 21.7% and 25.2%, respectively. Rate of death from bowel cancer was highest for non-responder bowel cancers at 27.0%.

Survival analyses were undertaken to explore more thoroughly these apparent differences in death from bowel cancer according to their detection status.

In Table 5.4.2, the number and proportion of people diagnosed with bowel cancer who died from bowel cancer within 1 year, between 1 and 2 years, between 2 and 3 years, and by 31 December 2015 (the end of follow-up) by screen-detection status are shown.

These data reveal that, at every time point, the proportion of people who died from bowel cancer was lowest for screen-detected bowel cancers, at 2.1% within 1 year, 2.4% between 1 and 2 years, 2.2% between 2 and 3 years, and 11.1% at the end of follow-up (that is, by 31 December 2015). Bowel cancer deaths were relatively similar across the other screen detection categories of never-invited, non-responder and interval bowel cancers for the different time points. The notable exception to this was bowel cancers diagnosed in non-responders who died within 1 year of diagnosis, which was much higher than all other screen detection categories of bowel cancer at 9.9% (Table 5.4.2). Rapid death in people with these bowel cancers may offer a clue to why non-responders (or at least a proportion of them) did not participate in the National Bowel Cancer Screening Program when invited.

Table 5.4.2: Bowel cancer deaths in persons diagnosed with bowel cancer by screen detection status

			Deaths from bowel cancer			
			Years since diagnosis			
Screen detection status		2006–2012 diagnoses	≤1	1–2	2–3	At 31/12/2015
Screen-detected	Number	3,316	68	78	74	368
	Proportion (%)		2.1	2.4	2.2	11.1
Interval	Number	557	36	33	23	121
	Proportion (%)		6.5	5.9	4.1	21.7
Non-responder	Number	7,337	728	480	348	1,983
	Proportion (%)		9.9	6.5	4.7	27.0
Never-invited	Number	20,217	1,752	1,320	841	5,094
	Proportion (%)		8.7	6.5	4.2	25.2

Consistent with this finding, the general log rank test statistic of $\chi 2 = 412.17$ with 3 degrees of freedom ($p < 0.001$) showed the strong effect of screen detection status (never-invited versus non-responder versus interval versus screen-detected) on bowel cancer mortality.

The survival curves show that people with screen-detected bowel cancers had the lowest risk of bowel cancer mortality, and that non-responders diagnosed with bowel cancer had the highest risk of bowel cancer mortality. People who were never invited to screen who were diagnosed with bowel cancer and people who were diagnosed with an interval bowel cancer had similar levels of risk (Figure 5.4.1).

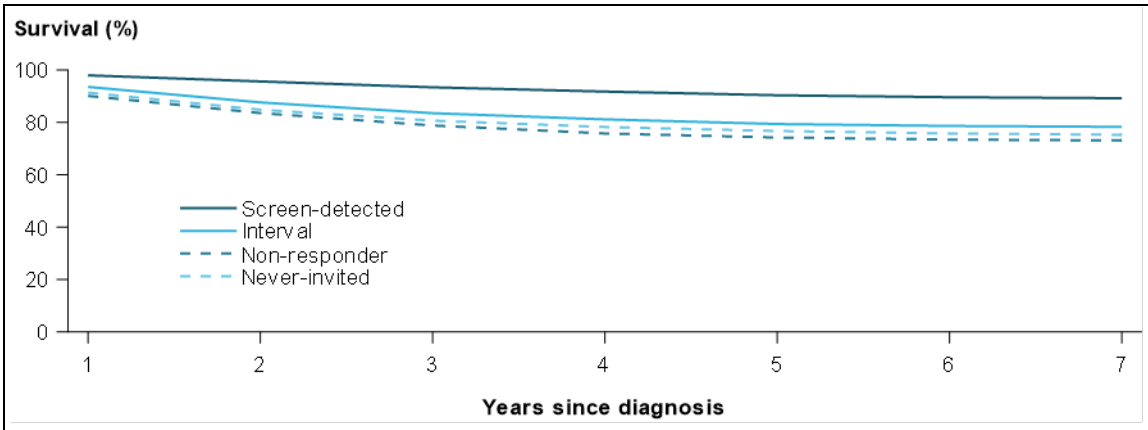


Figure 5.4.1: Crude survival for bowel cancer mortality following a diagnosis of bowel cancer by screen detection status

Bowel cancer mortality survival analyses

The Cox proportional hazards regression model was used to quantify the relationship between survival and a set of explanatory variables for those diagnosed with bowel cancer.

Univariate Cox proportional hazards models were fitted to each of the variables: screen detection status, sex, age group at diagnosis, year of diagnosis, remoteness area, and socioeconomic group. The crude hazard ratios for each are presented in Table 5.4.3.

The crude hazard ratios showed that, compared with never-invited people, the risk of death from bowel cancer for individuals with screen-detected bowel cancers was significantly lower, as indicated by a hazard ratio of 0.39 (0.35–0.43).

Statistically significant differences in unadjusted bowel cancer mortality hazard ratios were also found across sex, age group at diagnosis, year of diagnosis, remoteness area, and socioeconomic group.

In summary, risk of death from bowel cancer was lower in women than in men, highest in people aged 60–64, increased with increasing remoteness, and increased with increasing disadvantage (Table 5.4.3).

Table 5.4.3: Crude bowel cancer mortality hazard ratios for persons diagnosed with bowel cancer

Variable	HR	95% CI	*P* value
Screen detection status			
Never-invited	1.0	. .	. .
Invitees			
Non-responder	1.18	1.12–1.24	<0.001
Interval	0.87	0.72–1.04	0.118
Screen-detected	0.39	0.35–0.43	<0.001
Sex			
Males	1.0	. .	. .
Females	0.89	0.85–0.93	<0.001
Age group at diagnosis			
50–54	1.0	. .	. .
55–59	1.09	1.00–1.18	0.042
60–64	1.22	1.13–1.32	<0.001
65–69	1.10	1.02–1.18	0.014
Year of diagnosis			
2006	1.0	. .	. .
2007	0.92	0.83–1.01	0.085
2008	0.86	0.78–0.95	0.003
2009	0.94	0.85–1.04	0.251
2010	0.77	0.69–0.85	<0.001
2011	0.81	0.73–0.90	<0.001
2012	0.87	0.78–0.98	0.017
Remoteness area			
Major cities	1.0	. .	. .
Inner regional	1.05	0.99–1.11	0.102
Outer regional	1.11	1.04–1.19	0.002
Remote and very remote areas	1.23	1.10–1.37	<0.001
Socioeconomic group			
1 (most disadvantage)	1.0	. .	. .
2	0.98	0.92–1.05	0.520
3	0.90	0.84–0.97	0.004
4	0.87	0.81–0.93	<0.001
5 (least disadvantage)	0.81	0.75–0.87	<0.001

A multivariate Cox proportional hazards model was then generated, the results of which are shown in Table 5.4.4. After adjusting for sex, age group at diagnosis, year of diagnosis, remoteness area and socioeconomic group, the risk of death from bowel cancer was significantly lower in screen-detected bowel cancers compared with bowel cancers diagnosed in people never invited to participate in the screening program, with a hazard ratio of 0.41 (0.37–0.46).

Lead-time bias due to earlier diagnosis (but not necessarily a change in date of death) is generally considered a factor when investigating screening outcomes (Day & Walter 1984). Therefore, methods to correct for lead time (Duffy et al. 2008; Brenner et al. 2011) were applied. When using these to correct for potential lead time in screen-detected cancers, the risk of death from bowel cancer was still significantly lower for screen-detected cancers, with a hazard ratio of 0.60 (0.53–0.67) (Table 5.4.4).

Table 5.4.4: Unadjusted and adjusted hazard ratios for bowel cancer mortality for persons diagnosed with bowel cancer

Screen detection status	HR	95% CI	*P* value
Bowel cancer mortality, unadjusted			
Never-invited	1.0	. .	. .
Invitees			
Non-responder	1.18	1.12–1.24	<0.001
Interval	0.87	0.72–1.04	0.118
Screen-detected	0.39	0.35–0.43	<0.001
Bowel cancer mortality, adjusted			
]Never-invited	1.0	. .	. .
Invitees			
Non-responder	1.31	1.23–1.39	<0.001
Interval	0.96	0.80–1.16	0.680
Screen-detected	0.41	0.37–0.46	<0.001
Bowel cancer mortality, adjusted, corrected for lead-time bias			
Never-invited	1.0	. .	. .
Invitees			
Non-responder	1.30	1.22–1.38	<0.001
Interval	0.96	0.80–1.15	0.648
Screen-detected	0.60	0.53–0.67	<0.001

All-cause mortality survival analyses

Analyses were repeated for all-cause mortality. A multivariate Cox proportional hazards model adjusted for sex, age group at diagnosis, year of diagnosis, remoteness area and socioeconomic group found that the risk of death from all causes was significantly lower for screen-detected bowel cancers than for bowel cancers diagnosed in persons never invited to participate in the screening program, with a hazard ratio of 0.47 (0.43–0.51).

After correcting for lead-time bias, the risk of dying from all causes was still significantly lower for screen-detected bowel cancers compared with bowel cancers diagnosed in people who had never been invited to screen, with a hazard ratio of 0.72 (0.66–0.79) (Table 5.4.5).

Additional analyses of bowel cancer survival in invitees and non-responders of the National Bowel Cancer Screening Program can be found in the previously released AIHW report specific to bowel cancer (AIHW 2018b), which also includes ‘intention to screen’ analyses, as well as bowel cancer site and stage information and how these differ in invitees and in people never invited to participate in the National Bowel Cancer Screening Program.

Table 5.4.5: Unadjusted and adjusted hazard ratios for all-cause mortality for persons diagnosed with bowel cancer

Screen detection status	HR	95% CI	*P* value
All-cause mortality, unadjusted			
Never-invited	1.0	. .	. .
Invitees			
Non-responder	1.20	1.15–1.26	<0.001
Interval	0.87	0.74–1.02	0.093
Screen-detected	0.46	0.42–0.50	<0.001
All-cause mortality, adjusted			
Never-invited	1.0	. .	. .
Invitees			
Non-responder	1.28	1.21–1.35	<0.001
Interval	0.92	0.78–1.08	0.287
Screen-detected	0.47	0.43–0.51	<0.001
All-cause mortality, adjusted, corrected for lead-time bias			
Never-invited	1.0	. .	. .
Invitees			
Non-responder	1.27	1.20–1.34	<0.001
Interval	0.91	0.77–1.07	0.266
Screen-detected	0.72	0.66–0.79	<0.001

5.5 Effect of screening behaviour on breast cancer and cervical cancer outcomes

With 14 years of screening history available, and with the same women targeted across this period, we are able to look more closely at the effect of screening behaviour on breast cancer and cervical cancer outcomes.

The previous sections of this report showed that breast and cervical cancers were less likely to lead to death if they were screen-detected. This section examines breast and cervical cancer survival for women with different screening behaviour.

Breast cancer survival by screening behaviour

In this section, breast cancers are categorised not by whether they were screen-detected, but whether they were diagnosed in women with varying screening behaviours within BreastScreen—either **regular screeners**, **irregular screeners**, or **non-screeners**.

Regular screeners were those who screened at least 3 times with a mean screening interval of 30 months or less, as previously described (Roder et al. 2008), while irregular screeners were those who had screened, but did not conform to this definition.

Descriptive statistics

Between 1 January 2000 and 31 December 2014, 3,327,850 women screened through BreastScreen. Of these women, 1,707,565 (51.3%) were considered regular screeners, and 1,620,285 (48.7%) were considered irregular screeners (Table 5.5.1).

Of the breast cancers diagnosed in the period January 2002 to 31 December 2012 in women aged 50–69, 36.8% were diagnosed in regular screeners, 35.6% were diagnosed in irregular screeners, and 27.6% were diagnosed in women who had never screened through BreastScreen (Table 5.5.1).

Table 5.5.1: Number of women diagnosed with breast cancer according to their screening behaviour in BreastScreen Australia

Screening group	Number of women	Proportion of women	Number of breast cancers	Proportion of breast cancers
Regular screener	1,707,565	51.3	27,037	36.8
Irregular screener	1,620,285	48.7	26,158	35.6
Non-screener	. .	. .	20,245	27.6

Breast cancers diagnosed in women in each of the screening behaviours were further categorised according to their histological type (Table 5.5.2). Women who never screened had a higher proportion of *Other specified* and *Unspecified* breast cancers than women who were regular or irregular screeners. *Other specified* and *Unspecified* breast cancers are associated with a higher risk of mortality (see Table 5.2.3 for crude hazard ratios by histological type).

Table 5.5.2: Histological type of breast cancers diagnosed in women according to their screening behaviour in BreastScreen Australia

	Screening history					
	Regular screener		Irregular screener		Non-screener	
	Count	%	Count	%	Count	%
Invasive ductal carcinoma	21,574	79.8	20,990	80.2	15,847	78.3
Invasive lobular carcinoma	3,278	12.1	3,091	11.8	2,294	11.3
Medullar carcinoma & atypical medullary carcinoma	103	0.4	101	0.4	71	0.4
Tubular carcinoma & invasive cribriform carcinoma	646	2.4	678	2.6	286	1.4
Mucinous carcinoma	439	1.6	330	1.3	256	1.3
Invasive papillary carcinoma	274	1.0	226	0.9	208	1.0
Inflammatory carcinoma	26	0.1	43	0.2	48	0.2
Mesenchymal	12	0.0	11	0.0	30	0.1
Other—specified	323	1.2	312	1.2	467	2.3
Unspecified	362	1.3	376	1.4	738	3.6

Results

Breast cancer mortality

At the end of 2015, 18.4% of women who were diagnosed with breast cancer and had never screened through BreastScreen had died from breast cancer (Table 5.5.3). In contrast, 8.9% of women diagnosed with breast cancer who were irregular screeners had died, and 5.8% of women who were diagnosed with a breast cancer who were regular screeners had died from breast cancer (Table 5.5.3).

Table 5.5.3: Breast cancer deaths in women diagnosed with breast cancer, by screening behaviour status

			Deaths			
			Years since diagnosis			
Screened group		2002–2012 diagnoses	≤1	1–2	2–3	At 31/12/2015
Regular screener	Number	27,037	141	237	246	1,561
	Proportion (%)		0.5	0.9	0.9	5.8
Irregular screener	Number	26,158	193	332	372	2,317
	Proportion (%)		0.7	1.3	1.4	8.9
Non-screener	Number	20,245	678	683	620	3,734
	Proportion (%)		3.3	3.4	3.1	18.4

Crude survival suggested lower breast cancer mortality in women who were regular or irregular screeners than in non-screeners (Figure 5.5.1).

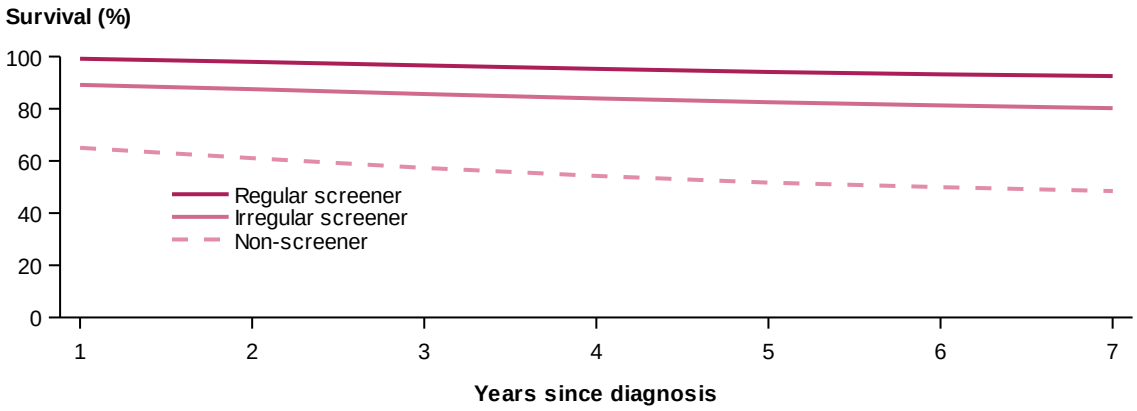


Figure 5.5.1: Crude survival for breast cancer mortality following a diagnosis of breast cancer by screening behaviour

Breast cancer mortality survival analyses

A multivariate Cox proportional hazards model adjusted for age group at diagnosis, remoteness area, socioeconomic group, histological type and tumour size found that, compared with women who did not screen through BreastScreen, women who were regular or irregular screeners had a significantly lower risk of death from breast cancer.

Compared with non-screeners, risk of death from breast cancer was lowest in regular screeners with a hazard ratio of 0.43 (0.41–0.46), but also relatively low in irregular screeners with a hazard ratio of 0.49 (0.47–0.52) (Table 5.5.4).

Methods to correct for lead-time (Duffy et al. 2008; Brenner et al. 2011) were applied to these analyses also, using mean lead-time estimates previously published (Duffy & Parmar 2013). When using these to correct for potential lead time in cancers diagnosed in regular and irregular screeners, the risk of death from breast cancer was still statistically significantly lower for breast cancers diagnosed in regular screeners—hazard ratio 0.52 (0.49–0.55) and irregular screeners—hazard ratio 0.57 (0.54–0.60) compared with breast cancers diagnosed in non-screeners (Table 5.5.4).

Methods were also applied to correct for screening selection bias in these analyses, as previously described (Duffy & Cuzick 2002), using a conservative correction factor of 1.36. Correcting for screening selection bias alone increased the adjusted hazard ratio to 0.81 (0.50–1.33) for regular screeners and to 0.93 (0.57–1.52) for irregular screeners (Table 5.5.4).

Similarly, after correcting for both lead-time bias and screening selection bias using a conservative correction factor of 1.36, the risk of death from breast cancer was no longer significantly lower for breast cancers diagnosed in regular screeners—hazard ratio 0.98 (0.60–1.61) or irregular screeners—hazard ratio 1.08 (0.66–1.76) compared with breast cancers diagnosed in non-screeners (Table 5.5.4).

Because the conservative correction factor of 1.36 is based on the pooled results of 5 randomised control trials (Duffy & Cuzick 2002) that may not be relevant to Australian data, both screening selection bias corrections were repeated using a correction factor of 1.17 that may be more realistic for Australian data than the correction factor of 1.36. Correcting for screening selection bias alone using the correction factor of 1.17 increased the adjusted hazard ratio for regular screeners from 0.43 (0.41–0.46) to 0.58 (0.49–0.68) and increased the adjusted hazard ratio for irregular screeners from 0.49 (0.47–0.52) to 0.66 (0.56–0.78)

(Table 5.5.4). This indicates that, when this less conservative correction factor is applied, and in contrast to when the conservative correction factor of 1.36 was used, the risk of death from breast cancer was found to be significantly lower for breast cancers diagnosed in regular screeners and irregular screeners than for breast cancers diagnosed in non-screeners.

After correcting for lead-time bias and screening selection bias using the correction factor of 1.17, and in contrast to when the conservative correction factor of 1.36 was used, the risk of death from breast cancer was also found to be significantly lower for breast cancers diagnosed in regular screeners—hazard ratio 0.70 (0.59–0.83) and irregular screeners—hazard ratio 0.77 (0.65–0.90) than for breast cancers diagnosed in non-screeners (Table 5.5.4).

As noted earlier, these results demonstrate the effect of the screening selection correction factor, and the importance of using the appropriate correction factor for the data to correctly determine breast cancer survival outcomes in screened compared with unscreened women.

Table 5.5.4: Unadjusted and adjusted hazard ratios for breast cancer mortality in women diagnosed with breast cancer, by screening behaviour

Screening behaviour	HR	95% CI	*P* value
Breast cancer mortality, unadjusted			
Non-screener	1.0	. .	. .
Irregular screener	0.43	0.41–0.45	<.0001
Regular screener	0.31	0.29–0.33	<.0001
Breast cancer mortality, adjusted			
Non-screener	1.0	. .	. .
Irregular screener	0.49	0.47–0.52	<.0001
Regular screener	0.43	0.41–0.46	<.0001
Breast cancer mortality, adjusted, corrected for lead-time bias			
Non-screener	1.0	. .	. .
Irregular screener	0.57	0.54–0.60	<.0001
Regular screener	0.52	0.49–0.55	<.0001
Breast cancer mortality, adjusted, corrected for screening selection bias (correction factor 1.36)			
Non-screener	1.0	. .	. .
Irregular screener	0.93	0.57–1.52	. .
Regular screener	0.81	0.50–1.33	. .
Breast cancer mortality, adjusted, corrected for lead-time bias and screening selection bias (correction factor 1.36)			
Non-screener	1.0	. .	. .
Irregular screener	1.08	0.66–1.76	. .
Regular screener	0.98	0.60–1.61	. .
Breast cancer mortality, adjusted, corrected for screening selection bias (correction factor 1.17)			
Non-screener	1.0	. .	. .
Irregular screener	0.66	0.56–0.78	. .
Regular screener	0.58	0.49–0.68	. .
Breast cancer mortality, adjusted, corrected for lead-time bias and screening selection bias (correction factor 1.17)			
Non-screener	1.0	. .	. .
Irregular screener	0.77	0.65–0.90	. .
Regular screener	0.70	0.59–0.83	. .

Cervical cancer survival by screening behaviour

In this section, cervical cancers are categorised not by whether they were screen-detected, but whether they were diagnosed in women with varying screening behaviours—either **regular screeners**, **irregular screeners**, or **non-screeners**.

These were defined as in the BreastScreen definitions, with the exception of Pap tests that occurred within 6 months of cervical cancer diagnosis; these were excluded prior to the definitions being applied to prevent these 'diagnostic' Pap tests being treated as screening Pap tests. After this omission, regular screeners were defined as those who screened at least 3 times with a mean screening interval of 30 months or less, while irregular screeners were those who had screened, but did not conform to this definition.

Descriptive statistics

Between 1 January 2000 and 31 December 2014, 6,904,190 women had at least one screening Pap test recorded on a cervical screening register. Of these women, 3,188,110 (46.2%) were considered regular screeners, and 3,716,080 (53.8%) were considered irregular screeners (Table 5.5.5).

Of the cervical cancers diagnosed in the period 1 January 2002 to 31 December 2012 in women aged 20–69, 18.7% were diagnosed in regular screeners, 29.8% were diagnosed in irregular screeners, and 51.5% were diagnosed in women who had never screened.

Table 5.5.5: Number of women diagnosed with cervical cancer according to their screening behaviour in the National Cervical Screening Program

Screening group	Number of women	Proportion of women	Number of cervical cancers	Proportion of cervical cancers
Regular screener	3,188,110	46.2	1,289	18.7
Irregular screener	3,716,080	53.8	2,053	29.8
Non-screener	. .	. .	3,555	51.5

Cervical cancers diagnosed in women in each of the screening behaviours were further categorised according to their histological type (Table 5.5.6).

The histological type of cervical cancers diagnosed in regular screeners aligned with effect of cervical screening, which is to detect precancerous disease thereby preventing cervical cancers from developing. Cervical cancers diagnosed in regular screeners were least likely to be *Squamous cell carcinoma* (51.7% of cervical cancers diagnosed), followed by irregular screeners (60.8%), with non-screeners most likely to be diagnosed with *Squamous cell carcinoma* (74.3%).

Squamous cell carcinomas are the most common cervical cancer diagnosed (around 66% of all cervical cancers in this cohort, which aligns well with a previous finding of 67% using only 2014 data (AIHW 2018c)). Cervical screening is most effective at preventing this type of cervical cancer through the detection of high-grade squamous abnormalities, which are readily identified by repeated Pap tests (Blomfield & Saville 2008). As a result, *Squamous cell carcinomas* now comprise 67% of cervical cancers, much reduced from their historical proportion of 95% (Blomfield & Saville 2008).

With many *Squamous cell carcinomas* prevented in screened women, the cervical cancers that were diagnosed in regular screeners were more likely to be *Other invasive carcinoma*, that includes *Adenocarcinoma*, *Adenosquamous carcinoma*, and *Other and unspecified carcinomas*. This proportion was highest in regular screeners (45.7% of cervical cancers

diagnosed), followed by irregular screeners (36.7%), with non-screeners having the lowest proportion (24.3%) of *Other invasive carcinoma*. Pap tests are less effective at identifying glandular abnormalities (Blomfield & Saville 2008), which explains why these occur in greater proportions in regularly screened women, a trend also noted in annual statistical reports of the VCS (Victorian Cytology Service 2017).

Table 5.5.6: Histological type of cervical cancers diagnosed in women according to their screening behaviour in the National Cervical Screening Program

Histological type of cervical cancer	Screening behaviour					
	Regular screener		Irregular screener		Non-screener	
	Count	%	Count	%	Count	%
Carcinoma						
Micro-invasive squamous cell carcinoma	189	14.7	374	18.2	357	10.0
Invasive squamous cell carcinoma	478	37.1	875	42.6	2,285	64.3
Total squamous cell carcinoma	*667*	*51.7*	*1,249*	*60.8*	*2,642*	*74.3*
Other invasive carcinoma	589	45.7	754	36.7	865	24.3
Other specified malignant neoplasm	13	1.0	18	0.9	35	1.0
Unspecified malignant neoplasm	20	1.6	32	1.6	13	0.4

For comparison, the histological types of cervical cancers diagnosed were also disaggregated according to the screening history of women immediately prior to the cervical cancer diagnosis, using the definitions in the annual statistical reports produced by the VCS (Victorian Cytology Service 2017) (Table 5.5.7).

Briefly, women with cervical cancer were defined as **recently screened** (if their last Pap test prior to diagnosis was within 6 months and 2.5 years of their cancer diagnosis), **lapsed** (if their last Pap test prior to diagnosis was more than 2.5 years prior to diagnosis) and **never-screened**. To provide more detail, lapsed was further broken down in lapsed (2.5–3.5 years), lapsed (3.5–5.5 years), and lapsed (5.5+ years).

These data show that the majority (72%) of cervical cancers occurred in women who were either never screened or were lapsed screeners.

After breaking cancers into their different histological types, it is clear that these data tell a very similar story to that for screening behaviour, with recently screened and lapsed screeners (up to 5.5 years prior to cancer diagnosis) having lower proportions of *Squamous cells carcinomas* than never screened women.

Also clear in Table 5.5.7 is the trend in the diagnosis of *Micro-invasive squamous cell carcinoma*. The proportion of cervical cancers diagnosed that were micro-invasive decreased with a greater degree of lapsed screening history, being highest in adequately screened and lapsed (2.5–3.5 years) screeners at 17.4% and 18.4% of cervical cancers diagnosed, respectively, followed by 16.6% in lapsed (3.5–5.5 years) and 13.6% in lapsed (5.5+ years). This was lowest in never-screened women, with *Micro-invasive squamous cell carcinomas* comprising just 9.8% of cervical cancers diagnosed (Table 5.5.7).

Table 5.5.7: Histological type of cervical cancers diagnosed in women according to their screening history in the National Cervical Screening Program

	Screening history									
	Recently screened		Lapsed (2.5–3.5 years)		Lapsed (3.5–5.5 years)		Lapsed (5.5+ years)		Never-screened	
	Count	%	Count	%	Count	%	Count	%	Count	%
Carcinoma										
Micro-invasive squamous cell carcinoma	*341*	*17.4*	*96*	*18.4*	*74*	*16.6*	*62*	*13.6*	*343*	*9.8*
Squamous cell carcinoma	1,061	54.0	297	56.8	276	62.0	309	67.9	2,607	74.3
Adenocarcinoma	665	33.9	160	30.6	119	26.7	107	23.5	561	16
Adenosquamous carcinoma	67	3.4	23	4.4	20	4.5	18	4.0	132	3.8
Other or unspecified carcinomas	105	5.3	28	5.4	18	4.0	15	3.3	155	4.4
Other specified malignant neoplasm	55	2.8	10	1.9	12	2.7	6	1.3	48	1.4
Unspecified malignant neoplasm	10	0.5	5	1.0	0	0.0	0	0.0	8	0.2

Note: ‘Squamous cell carcinoma’ includes ‘Micro-invasive squamous cell carcinoma’.

Results

Cervical cancer mortality

At the end of 2015, 27.0% of non-screeners who were diagnosed with a cervical cancer had died from cervical cancer (Table 5.5.8). In contrast, 10.4% of regular screeners and 11.6% of irregular screeners had died from cervical cancer.

Table 5.5.8: Cervical cancer deaths in women diagnosed with cervical cancer by screening behaviour status

			Deaths			
			Years since diagnosis			
Screened group		2002–2012 diagnoses	≤1	1–2	2–3	At 31/12/2015
Regular screener	Number	1,289	45	37	23	134
	Proportion (%)		3.5	2.9	1.8	10.4
Irregular screener	Number	2,053	77	58	40	239
	Proportion (%)		3.8	2.8	1.9	11.6
Non-screener	Number	3,555	372	280	129	961
	Proportion (%)		10.5	7.9	3.6	27.0

Crude survival suggested lower cervical cancer mortality in women who were regular screeners compared with never-screened (Figure 5.5.2).

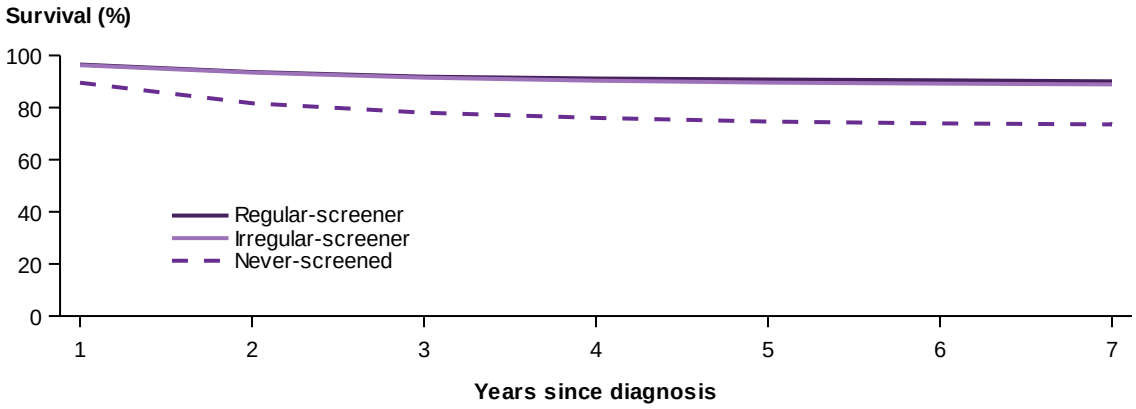


Figure 5.5.2: Crude survival for cervical cancer mortality following a diagnosis of cervical cancer by screening behaviour

Cervical cancer mortality survival analyses

A multivariate Cox proportional hazards model adjusted for age group at diagnosis, remoteness area, socioeconomic group, and histological type found that, compared with non-screeners, women who were regular or irregular screeners had a significantly lower risk of death.

Risk of death was lowest in regular screeners with a hazard ratio of 0.39 (0.33–0.47), but still relatively low in irregular screeners with a hazard ratio of 0.46 (0.40–0.53) (Table 5.5.9).

Table 5.5.9: Adjusted hazard ratios for cervical cancer mortality in women diagnosed with cervical cancer, by screening behaviour

Screening behaviour	HR	95% CI	*P* value
Cervical mortality, adjusted			
Non-screener	1.0	. .	. .
Irregular screener	0.46	0.40–0.53	<0.001
Regular screener	0.39	0.33–0.47	<0.001

6 Who screens and what affects this?

Analyses in Chapter 5 demonstrated that participation in screening has survival benefits.

This leads us into screening behaviour, and our desire to better understand who screens, who doesn't, and the factors that may contribute to the decision to screen or not to screen. The linked National Screening Data Set provides us with a unique opportunity to delve deeper into screening behaviour across all 3 cancer screening programs that has previously not been possible using data from each national cancer screening program separately.

Analyses of screening behaviour are restricted to:

- **women**, as only women are eligible to screen in BreastScreen Australia, the National Cervical Screening Program and the National Bowel Cancer Screening Program
- **those who have screened**, as only women who appear on at least one cancer screening program register are visible (importantly, this means that women who have never screened are invisible and unable to be included in these analyses).

6.1 Patterns in participation across the 3 cancer screening programs

Screening behaviour according to eligibility to screen

These analyses seek to understand cancer screening behaviour, with a focus on women who are known to screen, but do not screen in all the cancer screening programs for which they are eligible.

Analysis design

Linked data from BreastScreen Australia, the National Cervical Screening Program and the National Bowel Screening Program were used in these analyses.

Women were considered eligible to participate in the 3 screening programs if they were:

- aged 50–69 between 1 January 2000 and 31 December 2014 (BreastScreen)
- aged 20–69 between 1 January 2000 and 31 December 2014 (cervical screening)
- aged 50–69 between 1 July 2008 and 31 December 2014 and were sent an invitation and screening kit in the mail following their 50th, 55th or 65th birthday (bowel screening).

Similarly, women were considered to have participated in at least one screening program if they were:

- aged 50–69 between 1 January 2000 and 31 December 2014, and had at least one screening mammogram recorded on a BreastScreen register
- aged 20–69 between 1 January 2000 and 31 December 2014 and had at least one Pap test recorded on a cervical screening register
- aged 50–69 between 1 July 2008 and 31 December 2014, were sent an invitation and screening kit in the mail following their 50th, 55th or 65th birthday, and returned a completed kit to the National Bowel Cancer Screening Program.

Analysis limitations

A major limitation with these analyses is that only women who appear on at least one cancer screening program register—and so by definition are 'screened women'—are included in these analyses. And while much can be learned about screening behaviour from these women, the group of most concern are women who have never screened in any cancer screening program, who are also the very group of women who are unable to be included in these analyses.

A second limitation is specific to women who participate in cervical screening. Unlike the other 2 cancer screening programs, for which it is clear when a screening test has been performed, the screening test for the National Cervical Screening Program is also used for diagnostic purposes. Therefore, a woman who has a Pap test may not be participating in the program, but may be having a diagnostic Pap test with no prior screening history. However, from these data, it is not possible to know the reason for a woman's Pap test, so in these analyses, *all occurrences of Pap tests are interpreted as participation in cervical screening*, thereby inflating estimates of participation in this program.

Analysis results

After the eligibility criteria were applied, almost all women in the study population (91.7%) were eligible to participate in at least 1 of the 3 screening programs, with 26.7% eligible to participate in all 3 (Table 6.1.1).

Of the women who were eligible for at least 1 program, 69.1% participated in all screening programs for which they were eligible (Table 6.1.2).

Table 6.1.1: Eligibility rates for screening participation

	Number of women	% of women
Ineligible for all programs	737,350	8.3%
Eligible for cervical only	4,320,256	48.6%
Eligible for cervical and breast only	1,458,633	16.4%
Eligible for all programs	2,377,648	26.7%

Table 6.1.2: Participation rates for screening behaviours

	Number of women	% of women
Eligible for at least one program and did not participate	391,125	4.8%
Eligible for multiple programs but did not participate in all	2,125,423	26.1%
Participated in all eligible programs	5,639,989	69.1%

While the proportion of screened women taking part in screening programs across Australia is encouraging, 26.1% did not participate in all programs for which they were eligible.

This group of women were investigated further, to learn which programs were favoured over others in screened women who did not participate in all programs for which they were eligible. This information is shown in Table 6.1.3.

The first column includes screened women who were eligible for only BreastScreen and cervical screening, and participated only in one or the other. It was found that, of the 636,981 women who were eligible to participate only in BreastScreen and cervical screening but participated in only one of these programs, 66.0% participated in BreastScreen only, whereas 34.0% participated in cervical screening only. This indicates that, for this subset of women, the majority preferred BreastScreen over cervical screening.

The second columns includes screened women who were eligible for all 3 programs, but participated only in 1 or 2. It was found that, of the 1,488,442 women who were eligible for all 3 programs but did not participate in all 3, 24.4% participated in cervical only, 10.5% participated in BreastScreen only, and 2.6% participated in bowel screening only. Additionally, 45.0% participated in BreastScreen and cervical screening, 8.3% participated in bowel screening and cervical screening, and 9.2% participated in bowel screening and BreastScreen. This indicates that, for this subset of women, the majority participated in both BreastScreen and cervical screening, and a large proportion participated only in cervical screening (although a proportion of these will have had diagnostic Pap tests only and therefore not represent true participation in cervical screening).

Table 6.1.3: Participation rates for women who were eligible for multiple screening programs but did not participate in all programs for which they were eligible

	Eligible for cervical and breast only	Eligible for all programs
Participated in cervical only	216,819 (34.0%)	363,870 (24.4%)
Participated in breast only	420,162 (66.0%)	155,716 (10.5%)
Participated in bowel only	. .	39,269 (2.6%)
Participated in cervical and breast only	. .	669,139 (45.0%)
Participated in cervical and bowel only	. .	123,484 (8.3%)
Participated in breast and bowel only	. .	136,964 (9.2%)
Total	**636,981 (100%)**	**1,488,442 (100%)**

These 2 subsets of screened women were explored further, in an attempt to better understand why they chose (or did not choose) to participate in the cancer screening programs that they did.

Women who fell into these 2 categories were broken down into remoteness area and socioeconomic groups to determine if differences existed that might have contributed to their non-participation in all screening programs for which they were eligible. As a comparison, women who were eligible for BreastScreen and cervical screening only and participated in both, and women who were eligible for participation in all 3 programs and participated in all, are also included (shaded in the tables) (tables 6.1.4 and 6.1.5).

Women who were eligible for BreastScreen and cervical screening only

Compared with women who participated in both BreastScreen and cervical screening:

- women who participated only in BreastScreen were
  - more likely to live in areas of most disadvantage and less likely to live in areas of least disadvantage
- women who participated only in cervical screening were
  - more likely to live in *Major cities* and less likely to live in *Inner* and *Outer regional* areas
  - more likely to live in areas of least disadvantage.

Women who were eligible for all 3 cancer screening programs

Compared with women who participated in all 3 cancer screening programs:

- women who *did not* participate in BreastScreen were:
  - more likely to live in *Major cities* and less likely to live in *Inner* and *Outer regional* areas
  - of a similar socioeconomic profile to those who screened in all 3
- women who *did not* participate in cervical screening were:
  - more likely to live in *Inner* and *Outer regional* areas and less likely to live in *Major cities*
  - more likely to be most disadvantaged and less likely to be least disadvantaged
- women who *did not* participate in bowel screening were difficult to profile due to the opposing trends of women who participated in BreastScreen and women who participated in cervical screening, although these women were notably more likely to live in *Remote* and *Very remote* areas.

Table 6.1.4: Remoteness area of women who did not screen in all programs for which they were eligible

	Remoteness area									
	Major cities		Inner regional		Outer regional		Remote		Very remote	
	Number	%	Number	%	Number	%	Number	%	Number	%
Eligible for cervical and breast screen and participated in cervical only	162,335	75.1	34,030	15.7	15,673.0	7.3	2,250	1.0	1,838	0.9
Eligible for cervical and breast screen and participated in breast only	224,643	66.4	77,602	22.9	31,521.0	9.3	3,236	1.0	1,301	0.4
Eligible for cervical and breast screen and participated in both	433,538	67.7	135,464	21.2	61,756.0	9.6	6,446	1.0	3,269	0.5
Eligible for all programs and participated in cervical only	264,199	72.6	65,906	18.1	28,069.0	7.7	3,567	1.0	1,983	0.5
Eligible for all programs and participated in breast only	101,196	65.0	34,820	22.4	16,742.0	10.8	2,033	1.3	851	0.5
Eligible for all programs and participated in bowel screen only	28,185	71.8	7,335	18.7	3,308.0	8.4	310	0.8	103	0.3
Eligible for all programs and participated in cervical and breast only	464,641	69.5	128,424	19.2	62,776.0	9.4	8,369	1.3	4,690	0.7
Eligible for all programs and participated in cervical and bowel only	89,584	72.6	23,263	18.8	9,290.0	7.5	965	0.8	337	0.3
Eligible for all programs and participated in breast and bowel only	84,752	61.9	34,332	25.1	15,806.0	11.5	1,512	1.1	518	0.4
Eligible for all programs and participated in all	459,425	67.0	148,582	21.7	67,536.0	9.9	7,362	1.1	2,447	0.4

Table 6.1.5: Socioeconomic group of women who did not screen in all programs for which they were eligible

	Socioeconomic group									
	1 (most disadvantage)		2		3		4		5 (least disadvantage)	
	Number	%	Number	%	Number	%	Number	%	Number	%
Eligible for cervical and breast screen and participated in cervical only	43,013	20.0	39,719	18.5	39,214	18.2	40,718	18.9	52,355	24.3
Eligible for cervical and breast screen and participated in breast only	85,187	25.2	76,273	22.6	61,543	18.2	56,326	16.7	58,490	17.3
Eligible for cervical and breast screen and participated in both	136,146	21.3	130,650	20.4	119,699	18.7	121,257	19.0	131,632	20.6
Eligible for all programs and participated in cervical only	72,135	20.0	68,841	19.1	70,156	19.5	69,960	19.4	78,686	21.9
Eligible for all programs and participated in breast only	37,038	24.0	35,386	22.9	31,349	20.3	27,127	17.6	23,391	15.2
Eligible for all programs and participated in bowel screen only	8,207	21.1	8,033	20.7	7,716	19.8	7,391	19.0	7,531	19.4
Eligible for all programs and participated in cervical and breast only	128,186	19.4	130,143	19.6	132,335	20.0	133,003	20.1	138,641	20.9
Eligible for all programs and participated in cervical and bowel only	21,441	17.6	22,312	18.3	23,008	18.8	24,395	20.0	30,925	25.3
Eligible for all programs and participated in breast and bowel only	30,957	22.8	31,388	23.1	27,171	20.0	24,248	17.9	21,909	16.1
Eligible for all programs and participated in all	123,974	18.3	134,438	19.8	131,908	19.4	138,300	20.4	150,160	22.1

Screening behaviour after a positive screening result

These analyses seek to learn the effect of a positive screening result in one cancer screening program on participation in another cancer screening program.

Analysis design

Linked data from BreastScreen Australia and the National Cervical Screening Program were used in these analyses.

- A cohort of women who participated in cervical screening in a single calendar year were selected, with the result of their first Pap test in that year recorded, and then followed for 5 years to determine the length of time between their Pap test and their next screening mammogram through BreastScreen.
- A cohort of women who participated in BreastScreen in a single calendar year were selected, with the recommendation of their screening visit recorded, and then followed for 5 years to determine the length of time between their screening mammogram and their next Pap test.

The calendar year 2009 was used for both cohorts to allow for 5 years of follow-up (to 31 December 2014), and women aged 50–64 selected to ensure women were in the target age group for both programs to the end of the 5 years of follow-up.

Analysis limitations

A limitation with these analyses is specific to women who participated in cervical screening. Unlike the other 2 cancer screening programs, for which it is clear when a screening test has been performed, the screening test for the National Cervical Screening Program is also used for diagnostic purposes. Therefore, a woman who had a Pap test may not have participated in cervical screening, but may have had a diagnostic Pap test instead. However, from these data, it is not possible to know the reason for a woman's Pap test, so in these analyses, *all occurrences of Pap tests are interpreted as participation in cervical screening*, thereby inflating estimates of participation in this program.

Analysis results

Screening mammogram after a Pap test

In the cervical screening cohort, 492,557 women aged 50–64 had a Pap test in 2009. Of these women, 10,010 had an unsatisfactory Pap test, 473,842 had a negative result, 6,876 had a low-grade result, and 1,829 had a Pap test result of high-grade or cervical cancer.

Amongst the women who had a screening mammogram through BreastScreen after a Pap test, those who had a Pap test result of high-grade or cervical cancer (who would have been likely to have had a colposcopy and biopsy) were more likely to visit BreastScreen for a screening mammogram than women who had a negative or unsatisfactory Pap test. Women who had a low-grade Pap test result were also more likely to visit BreastScreen than those with a negative or unsatisfactory Pap test, although not as likely as women who had a Pap test result of high-grade or cervical cancer (Table 6.1.6).

Table 6.1.6: Occurrence of screening mammogram after a Pap test

	Occurrence of next screening mammogram			
Pap test result	**Mammogram after Pap test**	**Mammogram before Pap test only**	**Never had a mammogram**	**Mammogram on same day as Pap test**
Unsatisfactory	908	7,459	1,637	6
%	9.1%	74.5%	16.4%	0.1%
Mean number of days	*685.9*	. .	. .	. .
Negative	45,373	356,104	72,027	338
%	9.6%	75.2%	15.2%	0.1%
Mean number of days	*645.6*	. .	. .	. .
Low-grade	831	4,838	1,201	6
%	12.1%	70.4%	17.5%	0.1%
Mean number of days	*624.2*	. .	. .	. .
High-grade/cancer	279	1166	383	1
%	15.3%	63.8%	20.9%	0.1%
Mean number of days	*621.7*	. .	. .	. .

Further, women who did visit BreastScreen after a Pap test tended to do so sooner after a Pap test result of low-grade or high-grade/cervical cancer than after a negative or unsatisfactory Pap test, and a higher proportion of women who had previously screened through BreastScreen but did not have a screening mammogram after a Pap test had an unsatisfactory or negative Pap test, compared with those who had a Pap test result of high-grade or cervical cancer.

These results are consistent with a tendency for women to be more aware of the need to screen across programs following a cervical screening event that would have been likely to include an invasive procedure such as a colposcopy or biopsy.

Pap test after a screening mammogram

In the BreastScreen cohort, 444,016 women aged 50–64 had a screening mammogram in 2009. Of these women, 426,100 were returned to routine screening, and 17,916 were recalled to assessment for diagnostic testing (Table 6.1.7).

Similarly to the previous cohort, amongst the women who had a Pap test after a screening mammogram through BreastScreen those who were recalled to assessment (who would have had diagnostic procedures up to and including a biopsy) were slightly more likely to have a Pap test than women who were returned to routine screening.

Despite this small difference, there was a large difference in the mean number of days between the screening mammogram and Pap test, with women who were recalled to assessment tending to have a Pap test sooner than women who were not recalled.

Table 6.1.7: Occurrence of Pap test after a screening mammogram

	Occurrence of next screening mammogram			
Screening recommendation	**Pap test after mammogram**	**Pap test before mammogram only**	**Never had a Pap test**	**Pap test on same day as mammogram**
Routine rescreen	7,917	418,115	1	67
%	1.9%	98.1%	0.0%	0.0%
Mean number of days	*815.0*	*. .*	*. .*	*. .*
Recall to assessment	401	17,512	0	3
%	2.2%	97.7%		0.0%
Mean number of days	*686.5*	*. .*	*. .*	*. .*

In summary, these data indicate that a screening test result that leads to diagnostic testing in one screening program results in women being more likely to screen in the other screening program, and to do so sooner.

A further exploratory analysis looked at the number of women who had a Pap test and a screening mammogram through BreastScreen on the same day. Linking all Pap tests and screening mammograms showed 72,165 occurrences of the same Pap test and screening mammogram date, with a proportion of these occurrences found to be the same woman having her Pap tests and screening mammograms on the same date over many screening rounds.

This was an unexpected finding, and suggests that it may have been more convenient for women to have both tests on the same date and/or may make it easier to remember to have both tests.

6.2 Effect of a cancer diagnosis on screening behaviour

Screening behaviour after a cancer diagnosis

These analyses seek to learn the effect of cancer diagnosis on screening behaviour. They consider cancers diagnosed before and after the commencement of screening.

Analysis design

Linked data from BreastScreen Australia, the National Cervical Screening Program, the National Bowel Screening Program, and the Australian Cancer Database were used in these analyses.

All cancers diagnosed in participants were included—not just breast, cervical and bowel cancers—with date of diagnosis used to determine if the cancer was diagnosed before or after a woman's first screen.

Eligibility to participate in the cancer screening programs and participation definitions were as described for 'Screening behaviour according to eligibility'.

Analysis limitations

Participation in cancer screening programs will be affected by a prior cancer diagnosis where the cancer is breast, cervical or bowel. This means that there is a limit to the conclusions that can be drawn in terms of screening behaviour of women with a prior diagnosis of breast, bowel or cervical cancer.

To illustrate, a diagnosis of breast cancer will affect a woman's ability to participate in BreastScreen—women are excluded from BreastScreen either for 5 years after their cancer diagnosis, or for life (depending on the state or territory). The effect of this is an apparently lower participation in BreastScreen after a breast cancer diagnosis, but to interpret this as a screening behaviour would lead to incorrect assumptions.

Analysis results

Of the 8,156,537 eligible women, 620,053 women (7.6%) were diagnosed with a cancer of any type.

Screening behaviour was found to differ between women who had been diagnosed with a cancer and those who had not—for example, the proportion of women who participated in all programs for which they were eligible was higher in women who were not diagnosed with a cancer (72.0%) than in women who were diagnosed with a cancer (34.8%) (Table 6.2.1).

As explained in 'Analysis limitations', part of this trend can be explained by women who have been diagnosed with breast, cervical or bowel cancer not being eligible to participate in that screening program for a period of time after diagnosis (or at all, in some cases).

Table 6.2.1: Participation rates for screening behaviours by cancer diagnosis

	Diagnosed with cancer		Not diagnosed with cancer	
	Number of women	%	Number of women	%
Eligible for at least one program and did not screen	163,353	26.3	227,772	3.0
Eligible for multiple programs but did not participate in all	241,127	38.9	1,884,296	25.0
Participated in all eligible programs	215,573	34.8	5,424,416	72.0

To investigate further, women who were diagnosed with cancer prior to their earliest screen were compared with women diagnosed with cancer after the date of their first screen.

Women who were diagnosed with cancer prior to their earliest screen were less likely to participate in all screening programs for which they were eligible than women who had their first screen prior to their cancer diagnosis (36.4% compared with 51.6%) (Table 6.2.2).

Table 6.2.2: Participation rates for screening behaviours by cancer diagnosis in relation to first screen

	Diagnosed with cancer prior to first screen		Diagnosed with cancer post first screen	
	Number of women	%	Number of women	%
Eligible for multiple programs but did not participate in all	89,238	63.6	150,750	48.4
Participated in all eligible programs	51,084	36.4	160,977	51.6

These differences were partly attributable to the initial cancer diagnosis.

For example, 52.6% of women who were diagnosed with a thyroid cancer prior to their first screen participated in all screening programs for which they were eligible. In comparison, 19.2% of women diagnosed with breast cancer prior to their first screen participated in all eligible screening programs.

Similarly, participation rates in screening programs were low for women diagnosed with bowel or cervical cancer prior to their first screen compared with non-screening-related cancers (for example, head and neck cancer and melanoma of the skin) (Table 6.2.3).

Again, this is illustrative of the effect of a diagnosis of breast, cervical or bowel cancer making women ineligible for screening for a period of time after diagnosis, although higher participation for women diagnosed after their first screen compared with women diagnosed prior to their first screen, even for these 3 cancers, is a notable trend (Table 6.2.3).

These results suggest that, irrespective of the eligibility of women to screen within a cancer screening program after a cancer diagnosis, women were more inclined to screen if the cancer was found after they had commenced screening than if the cancer was diagnosed prior to their commencing screening.

For women who were diagnosed with a cancer, the likelihood of being diagnosed with a new primary breast, cervical or bowel cancer is explored in the following section.

Table 6.2.3: Participation rates for women who participated in all eligible programs by cancer type

	Diagnosed prior to first screen		Diagnosed post first screen	
Cancer Diagnosis	Number of women	Participation (%)	Number of women	Participation (%)
Head and neck cancer (C00–C14, C30–C32)	1,372	43.7	2,946	51.6
Bowel (C18–C20)	4,743	39.7	15,389	46.7
Lung (C33–C34)	647	35.1	8,271	43.3
Melanoma of the skin (C43)	15,247	51.5	20,380	59.7
Breast (C50)	9,270	19.2	54,441	49.5
Cervix (C53)	2,414	33.3	4,607	67.6
Ovary (C56)	922	27.9	4,322	52.3
Thyroid cancer (C73)	3,601	52.6	7,378	63.7

Second primary breast, cervical and bowel cancers

These analyses seek to determine the occurrence of a second primary breast, cervical or bowel cancer.

Analysis design

Linked data from BreastScreen Australia, the National Cervical Screening Program, the National Bowel Screening Program, and the Australian Cancer Database were used in these analyses, with the Australian Cancer Database linked to itself to identify second primary breast, cervical and bowel cancers.

All diagnosed cancers were included as first primary cancers.

Only breast, cervical and bowel cancers were included as second primary cancers.

A ‘second’ breast, bowel or cervical cancer refers to the occurrence of a new primary breast, bowel or cervical cancer in a person who was diagnosed with a primary cancer (referred to as a ‘first cancer’) in the past. Second cancers can occur months or years after the first cancer was diagnosed and treated, and can occur at the same site (as a different histological type) or elsewhere in the body. Second cancers do not include recurrences of a previous cancer (where the first cancer returns after a period of remission), or progressive disease.

Analyses followed the methodology used in the AIHW report *Cancer in adolescents and young adults in Australia* (AIHW 2018a). Briefly, to assess the risk of developing a breast, cervical or bowel cancer as a second primary cancer, the standardised incidence ratio (SIR) was calculated for each first cancer site. The SIR is an estimate of the occurrence of second cancers in survivors of a first cancer, relative to what would be expected based on the cancer-specific rates observed in the general population, stratified by sex, age and year.

Analysis results

In 1982–2014, 12,851 women were diagnosed with a second cancer that was breast cancer, 12,398 were diagnosed with a second cancer that was bowel cancer, and 795 were diagnosed with a second cancer that was cervical cancer.

Second cancers that were breast cancers most often followed melanoma of the skin (3,046 cases), bowel cancer (2,792) and uterine cancer (1,247). Second cancers that were cervical cancers most often followed breast cancer (311 cases), bowel cancer (121) and

melanoma of the skin (109). Second cancers that were bowel cancers most often followed breast cancer (4,785 cases), melanoma of the skin (1,702) and bowel cancer (1,150).

While a relatively large number of second cancers that were breast cancer (16% of all second cancers in women) and second cancers that were bowel cancer (16%) were diagnosed in women, the overall risk of a second cancer that was breast cancer (SIR: 0.67, 95% CI: 0.66–0.67) following all first cancers combined was less than expected compared with the risk of breast cancer experienced by the general population. In contrast, the risk of a second cancer that was bowel cancer following all first cancers combined was similar to the risk of bowel cancer experienced by the general population (SIR: 1.00, 95% CI: 0.98–1.02). However, specific first cancers increased the risk of a second cancer that was breast, bowel or cervical cancer.

Second cancers that were breast cancer

The risk of a second cancer that was breast cancer was increased after the following first cancers:

- Thyroid cancer (592 cases; SIR: 1.27, 95% CI: 1.17–1.38)
- Uterine cancer (1,247; SIR: 1.20, 95% CI: 1.13–1.27)
- Ovarian cancer (466; SIR: 1.19, 95% CI: 1.08–1.30)
- Melanoma of the skin (3,046; SIR: 1.12, 95% CI: 1.08–1.16)
- Bowel cancer (2,792 cases; SIR: 1.09, 95% CI: 1.05–1.13).

A first cervical cancer reduced the risk of a second cancer that was breast cancer (562 cases; SIR: 0.88, 95% CI: 0.81–0.96).

Second cancers that were cervical cancer

No first cancers increased the risk of a second cancer that was cervical cancer.

A first melanoma of the skin cancer reduced the risk of a second cancer that was cervical cancer (109 cases; SIR: 0.75, 95% CI: 0.62–0.91).

Second cancers that were bowel cancers

The risk of a second cancer that was bowel cancer was increased after the following first cancers:

- Uterine cancer (978 cases; SIR: 1.35, 95% CI: 1.27–1.44)
- Ovarian cancer (303; SIR: 1.31, 95% CI: 1.16–1.46)
- Cervical cancer (369; SIR: 1.26, 95% CI: 1.13–1.39)
- Head and neck cancer (392; SIR: 1.22, 95% CI: 1.10–1.34)
- Non-Hodgkin lymphoma (491; SIR: 1.14, 95% CI: 1.05–1.25)
- Melanoma of the skin (1,702; SIR: 1.10, 95% CI: 1.05–1.15)
- Breast cancer (4,785; SIR: 1.07, 95% CI: 1.04–1.10).

A first bowel cancer reduced the risk of a second cancer that was bowel cancer (1,150 cases; SIR: 0.55, 95% CI: 0.52–0.58).

6.3 Effect of HPV vaccination on participation in cervical screening

In 2012, the AIHW and the VCS conducted a project to investigate the effects and effectiveness of the HPV vaccination program using linked Victorian Cervical Cytology Register and National HPV Vaccination Program Register (NHVPR) data.

While the primary finding of this project was that detection rates of high-grade cervical abnormalities were significantly lower for vaccinated women than for unvaccinated women (Gertig et al. 2013; Brotherton et al. 2015), one of the secondary findings was that women who were vaccinated appeared less likely to participate in cervical screening (Budd et al. 2014).

This was a concerning finding, as girls and women who are vaccinated against HPV are advised to participate in cervical screening at the same intervals as non-vaccinated women, to provide the greatest protection against cervical cancer.

Given this concern, it was deemed important to explore this in more detail as part of the analyses on screening behaviour in this current project using linked national cervical screening and NHVPR data. Therefore, analyses performed on Victorian data were repeated nationally to assess if the finding was maintained in these data.

Analysis design

Participation in cervical screening was measured as the proportion of the population that had at least one Pap test over 2 calendar years to align with the 2-year screening interval of the National Cervical Screening Program prior to 1 December 2017. The calendar years 2013 and 2014 were used, as these were the latest available on the linked data set, and would therefore provide the greatest amount of information about women who were vaccinated from 2007 onwards.

Because only women up to the age of 26 were eligible for the catch-up vaccination program (aged around 32 in 2013–2014), women aged 20–24 and 25–29 are the focus of these analyses, since they were eligible for both HPV vaccination through the catch-up vaccination program and cervical screening. Single year of age analyses are also presented to age 32.

Participants were assigned a vaccination status as at the beginning of the 2-year reporting period. The number of women vaccinated at the beginning of the 2-year period was used as the vaccinated population and the remainder used as the unvaccinated population. The population was not adjusted to remove the estimated number of women who had had a hysterectomy because of the very low rates of hysterectomy in women younger than 30.

Analysis results

Participation in cervical screening by HPV vaccination status

In 2013–2014, participation in cervical screening was higher in vaccinated women than in unvaccinated women aged 20–24 and 25–29 (Table 6.3.1). The difference for women aged 20–24 was 12.4 percentage points (45.5% compared with 33.1%) and the difference for women aged 25–29 was 12.2 percentage points (56.5% compared with 44.3%).

The participation rate for 2013–2014 was also calculated for all women using the linked data set for ages 20–24 and 25–29. This was 41.6% and 50.4%, respectively (Table 6.3.1).

Table 6.3.1: Participation in cervical screening by HPV vaccination status

	Australia		Unvaccinated		Vaccinated	
Age group	Number	Participation (%)	Number	Participation (%)	Number	Participation (%)
20–24	338,271	41.6	82,826	33.1	255,445	45.5
25–29	436,982	50.4	194,291	44.3	242,691	56.5

Participation in cervical screening by vaccination status in 2013–2014 was further analysed by number of doses. Women aged 20–24 who received 1, 2 or 3 doses of HPV vaccine had similar levels of participation, at 43.8%, 45.7% and 45.6%, respectively (Figure 6.3.1). Conversely, there was a positive association between number of HPV vaccine doses and participation in cervical screening for women aged 25–29, increasing from 50.3% for women who received 1 dose, to 55.5% for women who received 2 doses, and 58.9% for women who received 3 doses of HPV vaccine (Figure 6.3.1).

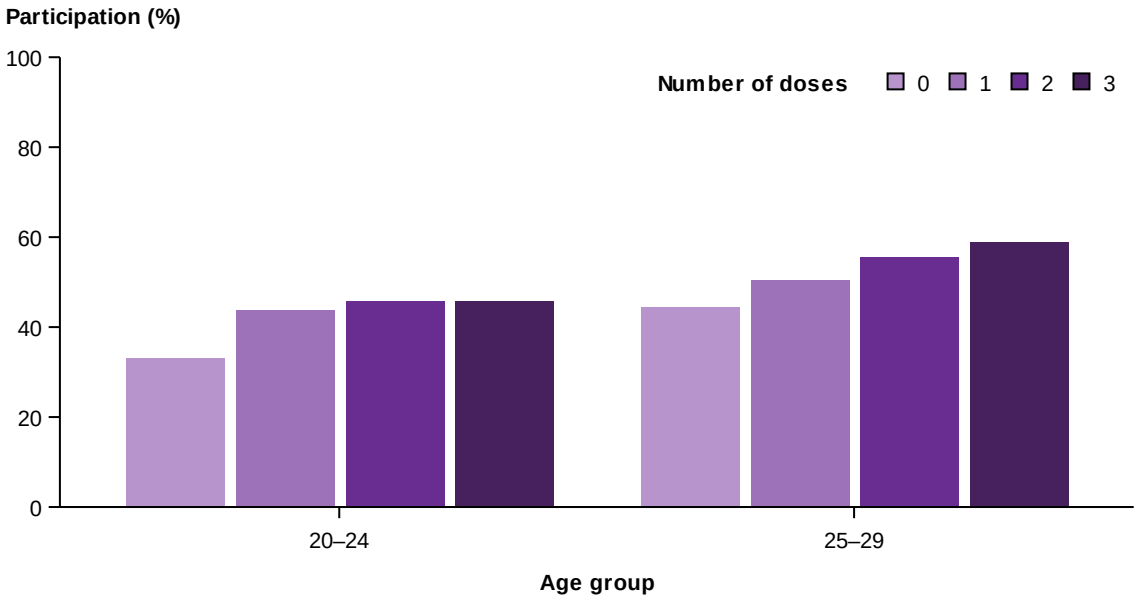


Figure 6.3.1: Participation in cervical screening by number of doses of HPV vaccine received

Participation in cervical screening in 2013–2014 by HPV vaccination status was further examined by single year of age for women aged 20 to 32 (see Table 6.3.2). Participation in cervical screening was higher in vaccinated women than in unvaccinated women for all ages except 32, for which there was only 1 percentage point between vaccinated and unvaccinated women (57.3% compared with 56.0%). Notably, this difference was at or above 10 percentage points for all ages within the 5-year age groups of 20–24 and 25–29 analysed above. Women aged 22, 23, 25 and 26 had the largest differences of around 15 percentage points.

Table 6.3.2: Participation in cervical screening by HPV vaccination status

	Australia		Unvaccinated		Vaccinated		
Age	Number	Participation (%)	Number	Participation (%)	Number	Participation (%)	Difference
20	56,458	36.9	11,082	29.0	45,376	39.5	*10.5*
21	62,731	40.2	12,420	30.8	50,311	43.4	*12.5*
22	68,741	42.5	14,590	32.0	54,151	46.7	*14.7*
23	72,900	43.0	18,599	33.1	54,301	47.9	*14.8*
24	77,441	45.1	26,135	37.3	51,306	50.5	*13.3*
25	80,366	46.9	32,311	39.3	48,055	54.0	*14.7*
26	83,913	48.8	35,863	41.5	48,050	56.2	*14.7*
27	87,900	50.6	39,669	44.7	48,231	56.8	*12.1*
28	91,114	51.9	42,284	46.6	48,830	57.4	*10.8*
29	93,689	53.4	44,164	48.7	49,525	58.4	*9.7*
30	96,359	55.0	46,943	51.2	49,416	59.2	*7.9*
31	95,689	55.6	50,284	53.0	45,405	58.9	*5.9*
32	94,756	56.4	61,968	56.0	32,788	57.3	*1.3*

Examining the number of doses received for women aged between 20 and 32 illustrates trends that are not visible when the different doses are combined into a single vaccinated category (Figure 6.3.2). For instance, while participation was highest for those aged 20, 21 and 22 who received 3 doses, there was very little difference between participation in those who received 2 or 3 doses for women aged 23 and 24. In contrast, women aged 25, 26, 27, 28 and 29 all showed similar patterns of participation by HPV vaccination dose received, which is reflected in the overall participation by vaccination status seen in Figure 6.3.1.

Also of note is that participation of women who received 1 dose was either similar to or lower than that of unvaccinated women aged 30, 31 and 32 (Figure 6.3.2).

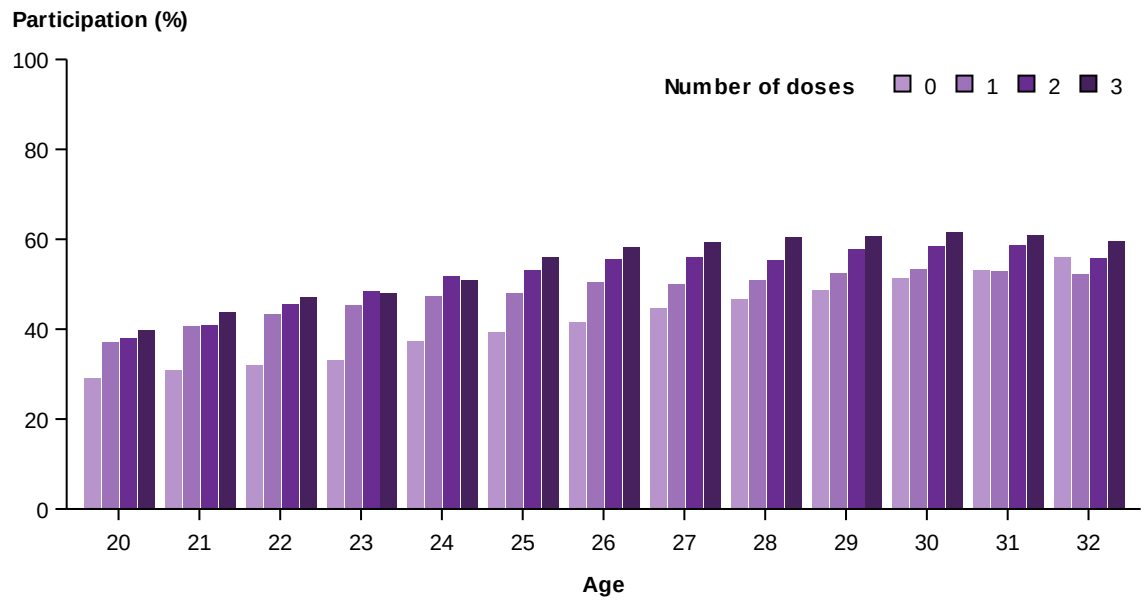


Figure 6.3.2: Participation in cervical screening by number of doses of HPV vaccine received

Opportunistic cervical screening due to HPV vaccination

Opportunistic cervical screening at the time of HPV vaccination was also examined.

Of women aged 18–26 who had their first Pap test on or after 1 April 2007, 8.2% had their first Pap test either on the same day as their first dose of vaccine (2.9%) or between their first and last vaccine doses (5.2%).

Comparison of participation in cervical screening by HPV vaccination status results previously reported

The findings from this project differed from the 2012 AIHW-VCS project, which found that participation was lower in vaccinated women than in unvaccinated women. Further analyses were performed to try to reconcile this difference, with two options considered.

The first option explored was that the difference was due to a shift in participation by vaccination status over time, since the 2012 AIHW-VCS project reported participation for the 2-year period 2010–2011. Data in this study were therefore also analysed for 2010–2011.

It was found that higher participation in cervical screening in vaccinated compared with unvaccinated women was also true in 2010–2011 using the data in this study, indicating that there has been no apparent shift in participation by vaccination status over time. These data are shown in Table 6.3.3 alongside the data from the 2012 AIHW-VCS project.

Table 6.3.3: Participation in cervical screening by HPV vaccination status, 2012 AIHW-VCS project and current project, 2010–2011

	2012 AIHW-VCS project		Current project	
Age-group	Unvaccinated	Vaccinated	Unvaccinated	Vaccinated
20–24	47.7%	37.6%	33.4%	48.1%
25–29	58.7%	45.2%	46.4%	56.4%

The second option explored was that the difference was due to differences between states and territories, since the 2012 AIHW-VCS project included only Victorian women. Data in this study were therefore also analysed for Victoria only for the 2-year period 2010–2011.

It was found that the trends in participation in cervical screening by HPV vaccination status determined using data from the current project for Victoria mirrored those for Australia, indicating that the difference is not unique to Victoria. In comparing the data for Victoria from the 2 projects, it was noted that, while the overall numbers were very similar, the proportion of women identified as vaccinated was larger in the current project than in the 2012 AIHW-VCS project, as demonstrated in Figure 6.3.3.

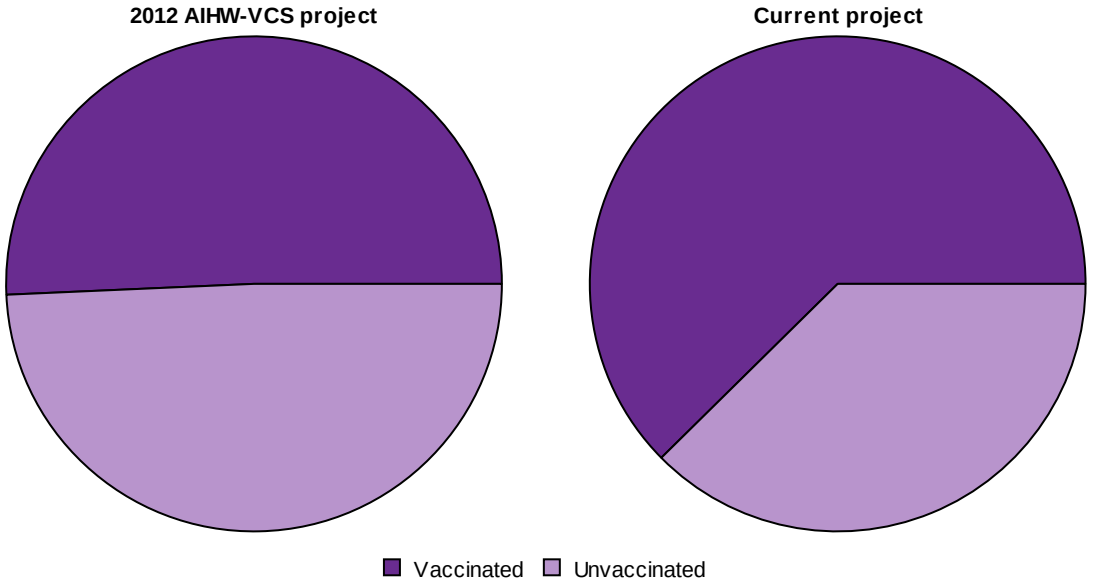


Figure 6.3.3: Proportion of women aged 20–29 participating in cervical screening identified as vaccinated, 2012 AIHW-VCS project and current project, 2010–2011

This means that more women who had participated in cervical screening were classified as vaccinated through being positively linked with records on the NHVPR in the current project than in the 2012 AIHW-VCS project, pointing to a difference in the data linkage process itself being responsible for the greatly different results.

There were two main differences between the data linkage for the 2012 AIHW-VCS project and the current project. The first was that identified data including full names, dates of birth and postcode were used in the current project, which was not possible for the 2012 AIHW-VCS project; the second was that all data were first linked to Medicare data prior to being linked, which allowed personal identifiers to be updated with other information on Medicare, thereby improving the ability of the data linkage process to make positive links. This latter difference is particularly important for this age group, for which changes in surname and postcode are common.

Therefore it appears that the different result is primarily due to a different method of data linkage, one which incorporates Medicare data resulting in a greater number of positive links with the NHVPR.

This is an important finding, as one of the secondary objectives of this project was to determine whether prior linkage of the NHVPR with Medicare data to update the details of girls and women vaccinated against HPV could improve the data linkage between cervical screening and NHVPR.

7 Discussion and conclusions

This is the first of a series of reports to present results from a major data linkage project that linked data from the 8 state and territory BreastScreen registers, the 8 state and territory cervical screening registers, the National Bowel Cancer Screening Program Register, the Australian Cancer Database, the National Death Index, and the National HPV Vaccination Program Register.

The project had 3 main objectives, these being to:

1. determine key cancer outcomes in screening and non-screening individuals to determine whether screen-detected cancers are less likely to result in death than cancers detected outside screening programs
2. gain an understanding of the screening behaviour of participants, such as who screens, in which programs, and whether this is influenced by common factors such as socioeconomic status, history of positive test results, or other events
3. use the linked data to enhance currently available screening data, such as analysis of linked cervical screening and HPV vaccination data to look at the effect of HPV vaccination on cervical abnormalities, cancers and participation in cervical screening.

This report fulfils the first and second objectives, and partly fulfils the third objective.

7.1 Objective 1: Cancer outcomes

This report examined survival outcomes of the 3 cancers for which there is a national, population-based cancer screening program—breast, cervical and bowel—to determine whether there are survival benefits to detecting a cancer as a result of screening.

Breast cancer outcomes by screen detection status

Screening history from state and territory BreastScreen registers was used to categorise breast cancers in the Australian Cancer Database that were diagnosed in women aged 50–69 in the period 2002–2012 according to screen detection status, and data from the National Death Index to the end of 2015 used to determine if death (due to breast cancer, or to any cause) followed these breast cancer diagnoses. Screen detection status groups for breast cancer were ‘screen-detected cancers’, ‘non-screen-detected cancers in screened women’, ‘interval cancers’ and ‘non-screen-detected cancers in never-screened women’.

It was found that women whose breast cancer was detected through BreastScreen Australia had a 69% lower risk of dying from breast cancer than women who had never attended BreastScreen Australia. Interval breast cancers and non-screen-detected breast cancers in screened women were also less likely to result in death from breast cancer, but with a higher level of risk than screen-detected breast cancers (both had a 35% lower risk of breast cancer death). These results indicate that screening through BreastScreen Australia provides benefits, as breast cancers that are detected through BreastScreen are less likely to cause death. Further, even if the breast cancer is not detected as a result of a screening visit, having had a previous screen also lowers the risk of breast cancer death. This may be because cancers can develop only in the time since a woman’s previous screen, so may be more likely to be smaller than breast cancers diagnosed in women who have never been screened. Data from this project support this, since, while the proportion of small (≤15 mm) breast cancers was found to be highest in screen-detected breast cancers at 55.3%, this

proportion in interval cancers and non-screen-detected breast cancers in screened women of around 34% was still higher than for never-screened breast cancers, of which only 27.6% were small (≤15 mm).

Screen-detected breast cancers may be subject to lead-time bias: that is, when a cancer is detected earlier, but leads to no increase in life-span (meaning that an individual lives with cancer for longer, but does not live for longer than they would have had the cancer been diagnosed later). Adjustments were therefore made to account for any lead-time effects, assuming a mean lead time of 40 months (Duffy & Parmar 2013).

After correction for lead-time bias, screen-detected breast cancers still had a 57% lower risk of causing death than breast cancers diagnosed in women who had never screened.

It has further been suggested that screen-detected breast cancers may be subject to screening selection bias, which is when women who choose to screen may have lower breast cancer mortality for non-screening reasons (meaning that women who choose to screen may be more 'well' and therefore may have lived longer after a breast cancer diagnosis than women who choose to not screen, even if the breast cancer had not been screen-detected). Screening selection bias can and does differ between countries, and there is evidence that screening selection bias may not apply to Australian data, based on the findings from a survey of South Australian women (Roder et al. 2008).

Corrections were made to account for any self-selection effects, using both a very conservative correction factor of 1.36 based on the pooled results of 5 randomised control trials (Duffy & Cuzick 2002), and a less conservative correction factor of 1.17 based on Swedish screening service studies (Swedish Organised Service Screening Evaluation Group 2006) that has previously been used to evaluate service screening mammography on breast cancer mortality in New Zealand (Morrell et al. 2017). The data on which the correction factor of 1.36 was based may not be relevant to Australian data, with the correction factor of 1.17 more likely to be realistic for Australian data given its use to correct New Zealand data.

After correcting for screening selection bias, screen-detected breast cancers still had a lower risk of causing death than breast cancers diagnosed in women who had never screened, this being 41% lower using the conservative correction factor of 1.36, and 58% lower using the more realistic correction factor of 1.17.

Correcting for both lead-time bias and screening selection bias gave different results depending on which screening selection correction factor was used.

The conservative correction factor of 1.36 decreased the difference in risk of death from cancers diagnosed in screen-detected and those diagnosed in never-screened women so that they were no longer significantly different. This loss of a difference in risk is likely the result of an over-correction of these Australian data.

In contrast, after correcting for both lead-time bias and screening selection bias using a correction factor of 1.17 that is likely to be more realistic for Australian data, women whose breast cancer was detected through BreastScreen Australia had a 42% lower risk of dying from breast cancer than women who had never attended BreastScreen Australia.

These results demonstrate the importance of using the appropriate correction factor for the analysis data. Further studies will explore screening selection bias in Australia in more detail, including examining whether an Australian-specific screening selection correction factor can be derived from these linked data to enable appropriate correction for this potential bias.

These estimates of lower risk for screen-detected breast cancers align with the findings from a full review of available high quality observational studies undertaken by the International Agency for Research on Cancer that determined that women aged 50–69 who attended

breast cancer screening using screening mammography had about a 40% reduction in the risk of death from breast cancer (Lauby-Secretan et al. 2015). Several jurisdictional and national Australian studies also demonstrated a reduction in mortality in screening participants (Taylor et al. 2004; Roder et al. 2008; Department of Health and Ageing 2009; Morrell et al. 2012; Nickson et al. 2012).

Overall, these findings are consistent with the finding that breast cancers detected through BreastScreen Australia lead to better survival outcomes.

Note that, while it has been recognised that a small number of breast cancers detected by screening mammography would not have become clinically apparent within a woman's lifetime, it is not currently possible to predict which breast cancers will fall into this category. Presence of these cancers cannot be adjusted for in these analyses, but effects have been minimised through the inclusion of only invasive breast cancers (and not ductal carcinoma in situ which may be less likely to progress to be clinically apparent within a woman's lifetime), and appropriate adjustments made to correct for lead-time bias and screening selection bias.

Cervical cancer outcomes by screen detection status

Cervical cancer outcomes need to be considered within the context of cervical screening that aims to detect and treat precancerous disease, thereby preventing cervical cancers from developing. This is supported by these data: over 70% of cervical cancers occurred in women who had either never screened or who were lapsed screeners.

Screening history from state and territory cervical screening registers was used to categorise cervical cancers in the Australian Cancer Database that were diagnosed in women aged 20–69 in the period 2002–2012 according to screen detection status, and data from the National Death Index to the end of 2015 used to determine if death (due to cervical cancer, or to any cause) followed these cervical cancer diagnoses. Screen detection status groups for cervical cancer were 'screen-detected cancers', 'non-screen-detected cancers in screened women', 'interval cancers', 'non-screen-detected cancers after a diagnostic test' and 'non-screen-detected cancers in never-screened women'.

It was found that, compared with women who were never-screened, screen-detected cervical cancers had an 87% lower risk of causing death. This was closely followed by non-screen-detected in screened women and interval cancers, with a 74% and 71% lower risk of cervical cancer death, respectively, and aligns with these women having screened previously. These results indicate that cervical screening, even if not as regular as was recommended under the previous National Cervical Screening Program, is associated with substantially lower risk of death from cervical cancer.

A Swedish study has also shown that screen-detected cervical cancers have a better prognosis, using cervical cancer detected due to symptoms as the comparator, and assessing survival outcomes using 'cure proportions', which are measures of survival that are independent of lead-time bias (Andrae et al. 2012). The study was further able to show that improved cure in screen-detected cervical cancers was largely due to these cancers being detected at an earlier stage.

Although stage data was not available in the Australian Cancer Database, it is reasonable to assume that the Swedish findings would apply for these data, and that down-staging may also play a role in the lower risk of death for screen-detected cervical cancers demonstrated here.

Histological type may also play a role in the worse survival observed for women who have never screened, since these women had a higher proportion of cervical cancers that were

not of epithelial origin, and it has been shown that women with small cell or neuroendocrine carcinomas have poorer survival (Andrae et al. 2012).

Overall, these findings are consistent with cervical cancers being detected through the National Cervical Screening Program leading to better survival outcomes. This aligns with the recognition that cervical screening can greatly reduce both the incidence and mortality of cervical cancer, and that countries with organised cervical screening programs have much lower cervical cancer incidence and mortality rates (Ferlay et al. 2010).

Bowel cancer outcomes by screen detection status

Screening history from the National Bowel Cancer Screening Program Register was used to categorise bowel cancers in the Australian Cancer Database that were diagnosed in men and women aged 50–69 in the period 2006–2012 according to screen detection status, and data from the National Death Index to the end of 2015 used to determine if death (due to bowel cancer, or to any cause) followed these bowel cancer diagnoses. Screen detection status groups for bowel cancer were 'screen-detected cancers', 'interval cancers', 'non-responder cancers' and 'never-invited cancers'.

It was found that, compared with those diagnosed in people who were never invited to screen, screen-detected bowel cancers had a 59% lower risk of death from bowel cancer. In contrast, interval bowel cancers carried a similar risk of death from bowel cancer to never-invited cancers. Non-responder bowel cancers (bowel cancers in people who had been invited to screen but did not do so) had a 31% higher risk of death from bowel cancer.

Screen-detected bowel cancers may be subject to lead-time bias, which is when a cancer is detected earlier, but leads to no increase in life-span (meaning that an individual lives with cancer for longer, but does not live for longer than they would have had the cancer been diagnosed later). Adjustments were therefore made to account for lead-time effects.

Even after adjustment for lead-time bias, people whose bowel cancer was detected through the National Bowel Cancer Screening Program had a 40% lower risk of dying from bowel cancer than individuals whose bowel cancer was diagnosed in the absence of an invitation to screen.

Bowel cancer survival according to screen-detection status has been examined in an earlier AIHW report. While it did not directly compare screen-detected bowel cancers with bowel cancers diagnosed in people never invited, as has been done here, it did compare survival of screen-detected bowel cancers with bowel cancers diagnosed in other invitees, and similarly found that screen-detected bowel cancers had better survival outcomes than interval bowel cancers and bowel cancers diagnosed in non-responders (AIHW 2018b).

These results aligned with the broad findings in this report that indicated that risk of death from bowel cancer was lower if the bowel cancer was screen-detected than if the bowel cancer was an interval bowel cancer, or was diagnosed in people who were invited to participate but did not respond, or in people who had never been invited to participate in the National Bowel Cancer Screening Program.

Better survival outcomes of screen-detected bowel cancers are likely to be due to the cancer being diagnosed at an earlier stage (known as 'down-staging'). Both the AIHW report (AIHW 2018b) and a recent study evaluating the National Bowel Cancer Screening Program in South Australia (Cole et al. 2013) found that screen-detected bowel cancers were more likely to be diagnosed at an earlier stage (as rated by the degree of spread and metastases). An earlier stage at diagnosis has been shown to be associated with better survival outcomes for bowel cancer (National Cancer Intelligence Network 2009).

These findings demonstrate that screen-detected bowel cancers are associated with better survival outcomes, likely to be due to being diagnosed at an earlier stage. While this is evidence that detection of bowel cancers through screening leads to a true increase in length of life for those diagnosed (as opposed to the cancer being detected earlier but not affecting length of life), assessment of survival outcomes has been adjusted for effects of lead-time bias. This means that the adjusted hazard ratios presented are on the conservative side, and true benefits of screening are likely to be greater than those presented.

Overall, these findings are consistent with bowel cancers being detected through the National Bowel Cancer Screening Program having better survival outcomes. This is supported by modelling that predicts that the National Bowel Cancer Screening Program will prevent 92,200 cancers and 59,000 deaths over the period 2015–2040 with the current participation rate of 40%, with the prevention of even greater numbers of cancers and deaths predicted with higher levels of participation (Lew et al. 2017).

Breast cancer and cervical cancer outcomes by screening behaviour

Participants in the National Bowel Cancer Screening Program cannot be classified as regular or irregular screeners with these data, owing to the length of time between invitations (the bowel screening program began only in 2006 with limited invited target ages). Therefore, only participants in BreastScreen Australia and the National Cervical Screening Program were included in the analyses that assessed survival outcomes according to the screening behaviour of participants. Unlike screen detection status, which categorises women based on the screening tests immediately prior to the cancer diagnosis, screening behaviour categorises women based on their overall screening behaviour. The 3 categories used in these analyses are ‘regular screeners’, ‘irregular screeners’, and ‘non-screeners’.

It was found that, compared with women who have never screened, breast cancers diagnosed in regular screeners had a 57% lower risk, and those diagnosed in irregular screeners had a 51% lower risk of death from breast cancer.

This difference was lost when the data were corrected for screening selection bias using a correction factor of 1.36. However, given that the conservative correction factor used has probably resulted in an over-correction of these Australian data, this apparent loss of benefit associated with breast cancer screening may not be real. Indeed, after adjustment for both lead-time bias and screening selection bias using the more realistic correction factor for Australian data of 1.17, the lower risk of breast cancer death in both regular and irregular screeners was maintained. This lower risk of breast cancer death was greatest in regular screeners at 30%, but still 23% lower in irregular screeners than non-screeners.

A New Zealand study by Australian and New Zealand researchers that found that the mortality benefit attributable to regular screening and irregular screening, after adjustment for screening selection bias (using the same lower correction factor of 1.17 considered appropriate for New Zealand), was 39% and 31%, respectively (Morrell et al. 2017). They further showed that breast cancers diagnosed in both regular and irregular screeners had more favourable prognostic factors, including grade, spread, occurrence of multiple tumours, and maximum tumour size.

Results for cervical cancer also showed reduced risk for screened women. It was found that regular screeners diagnosed with cervical cancer had a 61% lower risk, and irregular screeners diagnosed with cervical cancer had a 54% lower risk of cervical cancer death after diagnosis, compared with non-screeners diagnosed with cervical cancer. It has previously been shown that, compared with no cervical screening, irregular and regular cervical

screening reduce the risk of cervical cancer by 85% and 96%, respectively (Yang et al. 2008). The data in this report have further shown that, even if cervical cancer occurs in a woman who is a regular or irregular screener, risk of death is also lower for both groups.

7.2 Objective 2: Screening behaviour

This report used a linked data set including women from the 3 national cancer screening programs to ascertain screening patterns across the 3 programs, which program/s appear to be preferred by women, the effect of a previous cancer diagnosis (as well as investigating whether a previous cancer diagnosis makes women more at risk of developing a breast, cervical or bowel cancer), and whether a positive screening test in one program affects a woman's screening behaviour in another program.

Analyses of screening behaviour across the 3 programs is restricted to women, as only women are eligible to screen in BreastScreen Australia, the National Cervical Screening Program and the National Bowel Cancer Screening Program. Further, by definition, these data include only women who screened in at least one of the programs. This means that these data relate only to women who are by definition 'screeners', at least to some degree, and excludes women who have never participated in any of the 3 programs. This is important to consider when interpreting the results.

There may be an influence of the screening test itself on a woman's decision to screen. The test for each cancer screening program is different, as is the place (and cost) of having the test. BreastScreen Australia uses a screening mammogram to gain views of both breasts in a dedicated BreastScreen service and is free; the cervical screening test under the previous National Cervical Screening Program was the Pap test whereby a health-care provider collected a sample of cells from the cervix, and while the test itself was free, the appointment could incur a cost; the bowel screening test is the iFOBT, that is performed by the participant on a sample of self-collected faeces in the participant's home and is free.

Participation in cancer screening by screened women is overall very good, with 69.1% of screened women participating in all the cancer screening programs for which they were eligible. This means that a large proportion of women consider the screening tests of the 3 cancer screening programs to be acceptable (noting that this figure excludes women who have never screened in any of the 3 national cancer screening programs).

It also may mean that if non-screeners (women who do not screen in any of the programs, who are invisible to us in this project) can be engaged to participate in one screening program, there is a reasonable chance they will become good screeners overall. This suggests that a combined approach to targeting and encouraging screening participation may be warranted.

Women who did not screen in all programs for which they were eligible may hold the key to understanding why eligible people do not screen, in the absence of data on true non-screeners. Screened women who did not screen in all the programs for which they were eligible were examined further to determine which programs are preferred by these women.

For screened women who were eligible to screen only in BreastScreen and cervical screening and screened only in one, 66.0% chose BreastScreen, whereas 34.0% chose cervical screening, which indicates that BreastScreen Australia was the most preferred screening program in which to participate in this subset of women. For screened women who were eligible to screen in all 3 programs but screened only in 1 or 2, 45.0% screened in both BreastScreen and cervical screening. Of the women who screened in only 1 program, 24.4% participated only in cervical screening, and 10.5% participated only in BreastScreen, which is

different from the subset of women who were eligible to screen only in BreastScreen and cervical screening but did not.

Further research was performed on women who participated in BreastScreen and cervical screening, to investigate whether a positive screening result in one program affected their participation in the other program. It was found that a screening test result that would have resulted in diagnostic testing in one program resulted in women being more likely to screen in the other program, and to do so sooner. These results indicate that women may be more aware of the need to screen across programs following a screening event that would have been likely to require diagnostic follow-up. It is encouraging that, rather than turning women away from screening, these events appear to make women more aware of cancer screening and the importance of screening regularly in all cancer screening programs for which they are eligible.

An opportune and unexpected finding during this research was that many women had their screening mammogram through BreastScreen and their Pap test on the same date, which may provide insight into ways in which screening could be made more accessible or more convenient, and possibly increase participation across all cancer screening programs (for instance a 'One Stop' Cancer Screening Shop has been proposed as a way to increase participation (Bobridge et al. 2017)).

Potentially having a greater impact on a woman's decision to screen than diagnostic testing is a diagnosis of cancer. We therefore also investigated screening behaviour following a previous cancer diagnosis. A limitation with a previous diagnosis of breast cancer is that women are then not eligible to screen through BreastScreen either for 5 years or for the rest of their lives, depending on the policy of each state or territory BreastScreen program. The effect of this is to make it appear that participation in BreastScreen after a breast cancer diagnosis is low, but as this is not necessarily a choice that is being made by women, it should not be interpreted as true screening behaviour.

It was found that differences in screening behaviour depended on whether a woman was diagnosed with cancer or not—some of which can be explained by BreastScreen policy described above, as there were differences between women who were diagnosed with a screening cancer (bowel, breast, or cervical cancer) and those diagnosed with a non-screening cancer.

Overall, participation was lower in women who had been diagnosed with a cancer, and higher when the cancer was diagnosed after a woman had already commenced screening than when the cancer was diagnosed prior to screening. Of the women diagnosed with cancer prior to screening, participation was lowest when the cancer was breast cancer, and highest when the cancer was thyroid cancer or melanoma of the skin. These latter 2 cancers have low mortality rates and treatments that are more acceptable than treatments for many other cancers, which may have an impact on subsequent screening behaviour.

7.3 Objective 3: Enhancing screening data

The third objective of this project was to use the linked data to enhance currently available screening data, such as analysis of linked cervical screening and HPV vaccination data to look at the effect of HPV vaccination on cervical abnormalities, cancers and participation in cervical screening. This report partially fulfils this objective by reporting on participation in cervical screening by HPV vaccination status for women aged 20–24 and 25–29 in the latest 2 calendar years.

It was found that, in 2013–2014, participation in cervical screening was higher in vaccinated women than in unvaccinated women aged 20–24 and 25–29. The difference for women aged

20–24 was 12.4 percentage points (45.5% compared with 33.1%) and for women aged 25–29 it was 12.2 percentage points (56.5% compared with 44.3%).

It was further found that participation increased with increasing number of doses, which provides further support to the finding that women vaccinated against HPV are more likely to participate in cervical screening.

This finding aligns with a Swedish study that also found that HPV-vaccinated women were more likely to participate in cervical screening (86% in vaccinated women compared with 75% in unvaccinated women) (Herweijer et al. 2015).

This result indicates that women who are vaccinated against HPV are either more aware of the need to participate in cervical screening, or are more likely to take part in healthy behaviours overall. It will be interesting to follow these women through to breast and bowel cancer screening age to determine whether HPV-vaccinated women participate better in BreastScreen Australia and the National Bowel Cancer Screening Program.

Although the findings here oppose results of a similar study of Victorian data that showed that participation was lower in HPV-vaccinated women than in unvaccinated women (Budd et al. 2014), investigations revealed that the different result was due to the data linkage process, which included first linking HPV vaccination data to Medicare data, allowing personal identifiers to be updated with other information on Medicare, thereby improving the ability of the data linkage process to make positive links.

Therefore it appears that the different result is primarily due to a method of data linkage which incorporates Medicare data resulting in a greater number of positive links with the National HPV Vaccination Program Register. This is an important finding, as one of the secondary objectives of this project was to determine whether prior linkage of the National HPV Vaccination Program Register with Medicare data to update the details of girls and women vaccinated against HPV could improve the data linkage between cervical screening and the National HPV Vaccination Program Register.

7.4 Project limitations and areas for improvement

This project had several limitations and areas where additional or improved data would provide a more enriched outcome data.

- Cancer outcomes and screening behaviour were not explored for Aboriginal and Torres Strait Islander people. This is a major omission, given that it is known that Aboriginal and Torres Strait Islander people have poorer outcomes and lower participation. Indigenous status is available on some of the cancer and cancer screening registers included in this study, and it is a priority to include specific analyses by Indigenous status for this project in future if the opportunity arises.
- The Australian Cancer Database, the source of cancer data in this project, does not currently include data on cancer stage or spread. Staging data would greatly enhance this project, as it would allow the lower mortality of screen-detected cancers to be better understood and explored.
- For screening behaviour analyses, only women who appeared on at least one cancer screening register could be included. Women who have never screened were invisible in these analyses, which limits our understanding of why these women choose not to screen at all.
- In order to appropriately correct breast cancer mortality data for screening selection bias, it would be of benefit if a correction factor specific to Australian data could be derived.

7.5 Where to from here?

This is the first report to present results from this Australian-first data linkage project, and it has fulfilled the first and second objectives, and partly fulfilled the third objective of this project. Future releases and products are planned to enhance the objectives already fulfilled, and to completely fulfil the third objective. At the time of report production, one further AIHW report is planned and another proposed.

The first that is planned is specific to BreastScreen Australia and the need for data for that program, including examining cancer outcomes for women outside the target age group, as well as providing more in-depth analyses of screening behaviour of women who participate in BreastScreen Australia. Importantly, additional analyses will also investigate screening selection bias, and whether this can be better corrected for using Australian data.

The second that is proposed is specific to the previous National Cervical Screening Program, that, in addition to further cancer outcome and screening behaviour analyses, will enable further investigation of the relationship between HPV vaccination and cervical screening and cervical cancer, as well as looking at lessons learned from that program that may be relevant to the current National Cervical Screening Program.

Opportunities to communicate selected outcomes in peer-reviewed journals will also be sought as appropriate, to ensure that these important results reach the desired audience.

These will provide a comprehensive picture of cancer outcomes and screening behaviour across BreastScreen Australia, the National Cervical Screening Program and the National Bowel Cancer Screening Program.

Appendix A: Additional data tables

Table A1: Unadjusted and adjusted hazard ratios for breast cancer mortality

Screen detection status	HR	95% CI	*P* value
Breast cancer mortality, unadjusted			
Screen-detected	1.0	. .	. .
Interval cancers	2.61	2.18–3.12	<.0001
Non-screen-detected	2.63	2.46–2.80	<.0001
Never-screened	4.42	4.16–4.70	<.0001
Breast cancer mortality, adjusted			
Screen-detected	1.0	. .	. .
Interval cancers	2.07	1.73–2.48	<.0001
Non-screen-detected	2.07	1.94–2.21	<.0001
Never-screened	3.00	3.00–3.40	<.0001

Table A2: Unadjusted and adjusted hazard ratios for cervical cancer mortality

Screen detection status	HR	95% CI	*P* value
Cervical cancer mortality, unadjusted			
Screen-detected	1.0	. .	. .
Non-screen-detected in screened	1.92	1.22–3.01	.005
Interval cancer	2.23	1.42–3.51	<0.001
Diagnostic screen	3.70	2.39–5.73	<0.001
Never-screened	9.21	5.95–14.25	<0.001
Cervical cancer mortality, adjusted			
Screen-detected	1.0	. .	. .
Non-screen-detected in screened	1.97	1.08–1.59	0.003
Interval cancer	2.14	1.36–3.37	0.001
Diagnostic screen	3.28	2.12–5.08	<0.001
Never-screened	7.47	4.82–11.58	<0.001

Table A3: Unadjusted and adjusted hazard ratios for bowel cancer mortality

Screen detection status	HR	95% CI	*P* value
Bowel cancer mortality, unadjusted			
Screen-detected	1.0	. .	. .
Interval	2.23	1.82–2.74	<0.001
Non-responder	3.03	2.71–3.38	<0.001
Never-invited	2.57	2.32–2.86	<0.001
Bowel cancer mortality, adjusted			
Screen-detected	1.0	. .	. .
Interval	2.33	1.89–2.86	<0.001
Non-responder	3.17	2.83–3.55	<0.001
Never-invited	2.42	2.17–2.70	<0.001

Appendix B: Positive predictive values of screening tests

The screening tests used in BreastScreen Australia, the National Cervical Screening Program and the National Bowel Cancer Screening Program, like other screening tests, are not intended to be diagnostic, but aim to identify individuals who are more likely to have cancer (or a precursor to cancer), and therefore require further investigation from diagnostic tests. The positive predictive value (PPV) of a screening test is the probability that individuals with a positive screening test have cancer (or a precursor to cancer).

For BreastScreen Australia and the National Bowel Cancer Screening Program, this is calculated as the proportion of positive screening tests that are found to be invasive cancer, whereas for the National Cervical Screening Program, for which the screening test aims to detect precursors to cervical cancer, the PPV is calculated as the proportion of screening tests with a high-grade abnormality result that were found to be a high-grade abnormality or invasive cancer. The differences between the screening tests and the programs within which they are used leads to different PPV values across the screening tests.

The screening test of BreastScreen Australia is the mammogram, with 2 views performed on each breast. The images are reviewed, and if there are features that may be indicative of breast cancer, the woman is recalled to an assessment centre for diagnostic testing. The PPV is the proportion of screening mammograms for which the recommendation is recall to assessment that lead to an invasive breast cancer diagnosis, as previously described (Kavanagh et al. 2000). Since this is a mature screening program, the PPV has been calculated for each year from 2000 to 2014. Further, because both recall to assessment rates and invasive breast cancer detection rates are higher for a woman's first screening round, the PPV has been calculated separately for first and subsequent screening rounds, as well as for all screening rounds combined. These are shown in Table B.1.

The screening test of the National Cervical Screening Program until 1 December 2017 was the Pap test, whereby a sample of cells collected from the cervix was examined and the result determined by a pathology laboratory. The result could range from negative, to a low-grade abnormality, high-grade abnormality or cervical cancer. Because the aim of the screening program was to identify correctly high-grade abnormalities so these could be treated prior to possible progression to cervical cancer, the PPV is the proportion of high-grade abnormalities predicted by cytology that were found on histology (in this case on histology performed within 6 months) to be a high-grade abnormality or cancer.

The PPV has been calculated for each year from 2000 to 2013. Further, because there are differences between squamous abnormalities and endocervical (glandular) abnormalities of the cervix, the PPVs of these are reported separately. These are shown in Table B.2.

The screening test for the National Bowel Cancer Screening Program is the iFOBT, which returns either a negative or positive result based on the absence or presence of blood in a self-collected sample, determined by a pathology laboratory (people with inconclusive tests are asked to retest). The PPV is the proportion of positive iFOBTs that lead to a bowel cancer diagnosis. For the period 1 August 2006 to 31 December 2010 the PPV was 3.3% (Table B.3), meaning the chance of a positive screening test result leading to a diagnosis of bowel cancer was about 1 in 30.

Table B1: Positive predictive value of mammography for women aged 50–69, 2000 to 2014

Year	First screening round PPV (%)	Subsequent screening rounds PPV (%)	All screening rounds PPV (%)
2000	7.5	10.5	9.7
2001	7.3	10.8	9.9
2002	7.0	11.0	10.0
2003	7.6	12.1	11.1
2004	8.1	13.1	11.9
2005	8.0	13.0	11.9
2006	7.0	13.8	12.1
2007	7.3	12.9	11.6
2008	8.1	14.4	12.9
2009	7.5	13.8	12.3
2010	7.7	14.1	12.5
2011	8.4	15.3	13.6
2012	9.3	16.9	14.7
2013	8.0	16.2	13.7
2014	8.1	15.9	13.9

Table B2: Positive predictive value of a high-grade Pap test for women aged 20–69, most serious histology within 6 months of cytology performed in 2000 to 2013

Year	High-grade squamous abnormalities PPV (%)	High-grade endocervical abnormalities PPV (%)
2000	63.8	60.8
2001	65.1	56.3
2002	61.7	59.4
2003	61.3	63.4
2004	65.9	67.2
2005	63.7	68.3
2006	65.1	69.4
2007	64.2	67.1
2008	63.8	69.5
2009	66.0	74.4
2010	65.4	79.8
2011	64.6	76.4
2012	64.9	73.4
2013	64.3	73.4

Table B3: Positive predictive value of iFOBTs for persons aged 50–69, 2006–2010

	Actual cancer outcome		
Positive iFOBT	Cancer diagnosed	Cancer not diagnosed	PPV (%)
85,279	2,775	82,504	**3.3**

Appendix C: Classifications

Classification of population groups

Cancer and screening data were analysed by remoteness area and socioeconomic status. Remoteness area was classified into areas according to the 2011 Australian Bureau of Statistics (ABS) Australian Statistical Geography Standard, while socioeconomic status quintiles were classified using the 2011 ABS Index of Relative Socioeconomic Disadvantage.

Geographical classification

The ability to access and provide a wide range of services is influenced by the distance between clients and providers, be it for the clients to travel to the service providers or for the providers to travel to deliver services close to a person's home. The geographical location of areas is therefore an important concept in planning and analysing the provision of services.

As already stated, geographical location was classified according to the ABS Australian Statistical Geography Standard Remoteness Structure (ABS 2011), which groups geographical areas into 6 remoteness categories, using the Accessibility/Remoteness Index for Australia. This index is a measure of the remoteness of a location from the services provided by large towns or cities. Accessibility is judged purely on distance to one of the metropolitan centres. A higher score on this index denotes a more remote location. Further information is available on the ABS website at http://www.abs.gov.au/websitedbs/D3310114.nsf/home/geography.

Residential address postcodes (at time of screen for BreastScreen and cervical screening participants, at time of invitation for bowel screening invitees, and at time of diagnosis for people never invited for bowel screening) were mapped to the 2011 Remoteness Structure, classified to 5 main areas: *Major cities*, *Inner regional*, *Outer regional*, *Remote* and *Very remote*. The sixth area, *Migratory*, is not used in this project. The category *Major cities* includes Australia's capital cities, except Hobart and Darwin which are classified as *Inner regional*. Participants whose postcodes were not available in the remoteness correspondence were included in an 'Unknown' geographical location grouping.

Socioeconomic classification

Socioeconomic classifications were based on the 2011 ABS Index of Relative Socioeconomic Disadvantage (IRSD) (ABS 2013). The IRSD is one of 4 Socioeconomic Indexes for Areas developed by the ABS and is based on factors such as average household income, education levels and unemployment rates. The IRSD is not a person-based measure; rather, it is an area-based measure of socioeconomic status in which small areas of Australia are classified on a continuum from disadvantaged to affluent. This information is used as a proxy for the socioeconomic status of people living in those areas and may not be correct for each person in that area.

People were assigned to socioeconomic groups (quintiles) according to the IRSD of their residential postcode as per geographical classification. Socioeconomic groups (based on IRSD rankings) were calculated with a 2011 Census postal area correspondence (previously called a concordance) using a population-based method at the Australia-wide level.

The first socioeconomic group (labelled '1') corresponds to geographical areas containing the 20% of the population with the most disadvantage according to the IRSD, and the fifth group (labelled '5') corresponds to the 20% of the population with the least disadvantage.

Classification of cancer groups

Morphology refers to the histological characteristics of tumours, defined by the type of cell they involve. A tumour that involves skin cells, internal organ tissue, or lining cells is called a carcinoma, and a tumour that involves connective or supportive tissue (muscle cells, bone cells) is called a sarcoma. Each of these broad cellular types can be categorised further by their microscopic properties. The histological type of cancer is associated with different risk factors, natural behaviour history and responsiveness to therapeutic interventions.

Histological types of breast cancer are shown in Table C.1, grouped into 10 higher level groups. In this project, breast cancers were not grouped any further.

Table C1: Breast cancer histology groupings

Breast cancer group	Type of breast cancer (ICD-O-3 codes)
Invasive ductal carcinoma	Pleomorphic carcinoma (8022)
	Carcinoma with osteoclast-like giant cells (8035)
	Basaloid carcinoma (8123)
	Scirrhous adenocarcinoma (8141)
	Carcinoma simplex (8231)
	Infiltrating duct carcinoma, not otherwise specified (8500)
	Duct carcinoma, desmoplastic type (8514)
	Infiltrating ductular carcinoma (8521)
	Infiltrating duct and lobular carcinoma (8522)
	Infiltrating duct mixed with other types of carcinoma (8523)
	Paget disease and infiltrating duct carcinoma of breast (8541)
	Paget disease and intraductal carcinoma of breast (8543)
Invasive lobular carcinoma	Pleomorphic lobular carcinoma, not otherwise specified (8519)
	Lobular carcinoma, not otherwise specified (8520)
	Infiltrating lobular mixed with other types of carcinoma (8524)
Medullary carcinoma and atypical medullary carcinoma	Medullary carcinoma, not otherwise specified (8510)
	Atypical medullary carcinoma (8513)
	Medullary carcinoma with lymphoid stroma (8512)
Tubular carcinoma and invasive cribriform carcinoma	Tubular adenocarcinoma (8211)
	Cribriform carcinoma, not otherwise specified (8201)
Mucinous carcinoma	Mucinous adenocarcinoma (8480)
	Mucin-producing adenocarcinoma (8481)
	Signet ring cell carcinoma (8490)
Invasive papillary carcinoma	Intraductal papillary adenocarcinoma with invasion (8503)
	Papillary adenocarcinoma, not otherwise specified (8260)
	Intracystic (papillary) adenocarcinoma (8504)
	Papillary carcinoma, not otherwise specified (8050)
	Solid papillary carcinoma (8509)
	Invasive micropapillary carcinoma (8507)

(continued)

Table C1 (continued): Breast cancer histology groupings

Breast cancer group	Type of breast cancer (ICD-O-3 codes)
Inflammatory carcinoma	Inflammatory carcinoma (8530)
Mesenchymal	Sarcoma, not otherwise specified (8800)
	Spindle cell sarcoma (8801)
	Giant cell sarcoma (8802)
	Epithelioid sarcoma (8804)
	Undifferentiated sarcoma (8805)
	Fibrosarcoma (8810)
	Fibromyxosarcoma (8811)
	Solitary fibrous tumour, malignant (8815)
	Low grade myofibroblastic sarcoma (8825)
	Malignant fibrous histiocytoma (8830)
	Liposarcoma, not otherwise specified (8850)
	Well differentiated liposarcoma, not otherwise specified (excluding superficial soft tissue) (8851)
	Myxoid liposarcoma (8852)
	Pleomorphic liposarcoma (8854)
	Leiomyosarcoma (8890)
	Angiomyosarcoma (8894)
	Myosarcoma (8895)
	Rhabdomyo sarcoma (8900)
	Alveolar rhabdomyo sarcoma (8920)
	Stromal sarcoma, not otherwise specified (8935)
	Haemangiosarcoma (9120)
	Haemangioendothelioma, malignant (9130)
	Haemangiopericytoma, malignant (9150)
	Lymphangio sarcoma (9170)
	Osteosarcoma, not otherwise specified (9180)
	Chondrosarcoma, not otherwise specified (9220)
Other—specified	Metaplastic carcinoma, not otherwise specified (8575)
	Adenocarcinoma with squamous differentiation (8570)
	Adenocarcinoma with spindle cell metaplasia (8572)
	Squamous cell carcinoma, not otherwise specified (8070)
	Squamous cell carcinoma, keratinising, not otherwise specified (8071)
	Squamous cell carcinoma, large cell nonkeratinising, not otherwise specified (8072)
	Squamous cell carcinoma, spindle cell (8074)
	Spindle cell carcinoma, not otherwise specified (8032)
	Carcinosarcoma, not otherwise specified (8980)
	Adenocarcinoma with cartilaginous and osseous metaplasia (8571)

(continued)

Table C1 (continued): Breast cancer histology groupings

Breast cancer group	Type of breast cancer (ICD-O-3 codes)
	Pseudosarcomatous carcinoma (8033)
	Malignant myoepithelioma (8982)
	Adenocarcinoma, not otherwise specified (8140)
	Phyllodes tumour, malignant (9020)
	Paget disease, mammary (8540)
	Adenocarcinoma with apocrine metaplasia (8573)
	Apocrine adenocarcinoma (8401)
	Neuroendocrine carcinoma, not otherwise specified (8246)
	Small cell carcinoma, not otherwise specified (8041)
	Carcinoma with neuroendocrine differentiation (8574)
	Large cell neuroendocrine carcinoma (8013)
	Carcinoid, not otherwise specified (8240)
	Atypical carcinoid tumour (8249)
	Adenocarcinoma with mixed subtypes (8255)
	Mixed cell adenocarcinoma (8323)
	Secretory carcinoma of breast (C50._)(8502)
	Acinar cell carcinoma (8550)
	Mucoepidermoid carcinoma (8430)
	Lipid-rich carcinoma (C50._)(8314)
	Glycogen-rich carcinoma (8315)
	Clear cell adenocarcinoma, not otherwise specified (8310)
	Sebaceous carcinoma (8410)
	Mixed tumour, malignant (8940)
	Lymphoepithelial carcinoma (8082)
	Basal cell adenocarcinoma (8147)
	Trabecular carcinoma (8190)
	Solid carcinoma, not otherwise specified(8230)
	Adenomyoepithelioma, malignant (8983)
	Adenoid cystic carcinoma (8200)
	Epithelial-myoepithelial carcinoma (8562)
	Peripheral neuroectodermal tumour, not otherwise specified (9364)
	Granular cell tumour, malignant (9580)
	Adenocarcinoma in adenomatous polyp (8210)
	Sweat gland adenocarcinoma (8400)
	Papillary cystadenocarcinoma NOS (8450)
	Adenosquamous carcinoma (8560)
	Comedocarcinoma, not otherwise specified (C50._)(8501)

(continued)

Table C1 (continued): Breast cancer histology groupings

Breast cancer group	Type of breast cancer (ICD-O-3 codes)
Unspecified	Neoplasm, malignant (8000)
	Tumour cells, malignant (8001)
	Malignant tumour, spindle cell type (8004)
	Malignant tumour, clear cell type (8005)
	Carcinoma, not otherwise specified (8010)
	Large cell carcinoma, not otherwise specified (8012)
	Carcinoma, undifferentiated (8020)
	Carcinoma, anaplastic (8021)
	Giant cell and spindle cell carcinoma (8030)
	Giant cell carcinoma (8031)

Notes

1. Breast cancer histology types have been categorised by the Australasian Association of Cancer Registries.
2. Codes were sourced from the International Classification of Diseases for Oncology Third Edition.

Histological types of cervical cancer are shown in Table C.2. In this project, cervical cancers were grouped further to support comparisons—the 3 groups used were *Squamous cell carcinoma*, *Other cervical cancers of epithelial origin* (*Adenocarcinoma*, *Adenosquamous carcinoma*, and *Other specified and unspecified carcinoma*), and cervical cancers not of epithelial origin (*Sarcoma* and *Other and unspecified malignant neoplasm*).

Table C2: Cervical cancer histology groupings

Type of cervical cancer	ICD-O-3 codes
1: Carcinoma	8010–8380, 8382–8576
1.1: Squamous cell carcinoma	8050–8078, 8083–8084
1.2: Adenocarcinoma	8140–8141, 8190–8211, 8230–8231, 8260–8263, 8382–8384, 8440–8490, 8570–8574, 8310, 8380, 8576
1.3: Adenosquamous carcinoma	8560
1.4: Other specified and unspecified carcinoma	ICD-O-3 codes for carcinoma excluding those for squamous cell carcinoma, adenocarcinoma and adenosquamous carcinoma
2: Sarcoma	8800–8811, 8840–8921, 8990–8991, 9040–9044, 9120–9133, 9540–9581, 8830, 9150
3: Other specified and unspecified malignant neoplasm	ICD-O-3 codes for cervical cancer, excluding those for carcinoma and sarcoma

Source: Based on classifications in the Cancer incidence in five continents: vol. IX (Curado et al. 2007).

Histological types of bowel cancer are shown in Table C.3. In this project, bowel cancers were grouped further to support comparisons—bowel cancers classified as *Adenocarcinomas* were compared with all other cancer morphologies recorded.

Table C3: Bowel cancer histology groupings

Type of bowel cancer	ICD-O-3 codes
Carcinomas	
1. Squamous and transitional cell carcinoma	8051–8084, 8120–8131
2. Basal cell carcinomas	8090–8110
3. Adenocarcinomas	8140–8149, 8160–8162, 8190–8221, 8260–8337, 8350–8551, 8570–8576, 8940–8941
4. Other specific carcinomas	8030–8046, 8150–8157, 8170–8180, 8230–8255, 8340–8347, 8560–8562, 8580–8671
5. Unspecified carcinomas (not otherwise specified)	8010–8015, 8020–8022, 8050
Sarcoma and soft tissue tumours	8680–8713, 8800–8921, 8990–8991, 9040–9044, 9120–9125, 9130–9136, 9140–9252, 9370–9373, 9540–9582
Tumours of haematopoietic and lymphoid tissues	9590–9591, 9596, 9650–9667, 9670–9719, 9727–9729, 9731–9734, 9740–9742, 9750–9758, 9760–9769, 9800–9801, 9805, 9820, 9823–9837, 9840, 9860–9931, 9940, 9945–9946, 9948, 9950, 9960–9964, 9970, 9975, 9980–9987, 9989
Other specified types of cancer	8720–8790, 8930–8936, 8950–8983, 9000–9030, 9060–9110, 9260–9365, 9380–9539
Unspecified types of cancer	8000–8005

Note: All cases included in each of the groups were coded by state and territory cancer registries as primary site invasive bowel cancers.

Source: IARC 2004.

Appendix D: Additional statistical methods

Correction for lead-time bias

The following method from Duffy and others (2008) was used to correct for estimated lead-time bias for breast and bowel cancers. For those with a breast/bowel cancer diagnosis who are known to be alive at time *t*:

$$E(s) = \frac{1 - e^{-\lambda t}}{\lambda}$$

For those with a breast/bowel cancer diagnosis and a breast/bowel cancer death at time *t*:

$$E(s) = \frac{1 - e^{-\lambda t} - \lambda t e^{-\lambda t}}{\lambda(1 - e^{-\lambda t})}$$

where:

- $E(s)$ equals the estimated sojourn time (lead time)—the period during which the breast/bowel cancer is asymptomatic but screen-detectable
- t equals the time from screen-detected breast/bowel cancer diagnosis to breast/bowel cancer death (or loss to follow-up); that is, the uncorrected 'survival' time
- λ equals the rate of transition from asymptomatic but screen-detectable to symptomatic breast/bowel cancer.

The transition rate λ used for breast cancer was 0.3, based on a mean lead time of 40 months, which has received a level of consensus (Duffy & Parmar 2013).

The transition rates from Brenner and others (2011) were used for λ for bowel cancer.

Table D1: Asymptomatic to symptomatic transition rates for bowel cancer

Sex	Age group at diagnosis	Transition rate (λ) per 100 diagnoses, per year
Men	50–59	18.1
	60–64	19.2
	65–69	21.3
	70–74	20.6
Women	50–59	21.3
	60–64	22.5
	65–69	21.9
	70–74	20.8

This simple method relies on strong assumptions and generalisations but provides a way to take lead-time into account in the mortality estimates of Objective 1. See the relevant papers for further information on correction for lead-time bias.

Correction for screening selection bias

The following method from Duffy & Cuzick (2002) was used to correct for estimated screening selection bias for breast cancers. The correction was applied to the hazard ratios following any other relevant corrections.

$$RR_{corrected} = \frac{P \times RR_1 \times D_r}{1 - (1 - P) \times D_r}$$

where:

- RR_1 equals the original hazard ratio before correction for self-selection bias
- P equals the participation rate in breast cancer screening
- D_r equals the correction factor.

A participation rate of 56.2% was used, which is the mean (and median) participation rate for women aged 50–69 in BreastScreen Australia over the years used in this study.

Two correction factors were used. A correction factor of 1.36 was used, as published by Duffy & Cuzick (2002). This correction factor was the most conservative option from several in the literature, and is likely to be an over-estimate for Australian data. A correction factor of 1.17 was also used, as published by the Swedish Organised Service Screening Evaluation Group (2006), and as used by Morrell and others (Morrell et al. 2017).

Glossary

Aboriginal or Torres Strait Islander: A person of Aboriginal and/or Torres Strait Islander descent who identifies as an Aboriginal and/or Torres Strait Islander. See also **Indigenous**.

adenocarcinoma: The malignant progression of a benign **adenoma**.

asymptomatic: Describes the situation where a person has a particular disease but experiences no symptoms of it.

Australian Statistical Geography Standard (ASGS): Common framework defined by the Australian Bureau of Statistics for collection and dissemination of geographically classified statistics. The ASGS replaced the Australian Standard Geographical Classification (ASGC) in July 2011.

benign: Not malignant.

biopsy: Small sample of tissue that is taken to obtain a definitive diagnosis of an abnormality.

bowel cancer: Comprises cancer of the **colon** and cancer of the rectum, collectively known as colorectal cancer.

breast cancer: Cancer most commonly originating in the ducts of the breast (which carry milk from the lobules to the nipple) but can also originate in the lobules (small lobes of the breast that produce milk), or more rarely in the connective tissue of the breast.

BreastScreen assessment: Further investigation of a mammographic abnormality or symptom reported at screening at a BreastScreen service.

cancer: Cancer, also called malignancy, is a term for diseases in which abnormal cells divide without control and can invade nearby tissues. Cancer cells can also spread to other parts of the body through the blood and lymph systems.

cervical cancer: Cancer affecting the cells of the uterine cervix, which is the lower part (or 'neck') of the uterus where it joins the upper end of the vagina.

cervical cytology test: Cytology means 'study of cells' and, in the context of cervical screening, refers to cells from the cervix that are collected and examined for abnormalities. Cervical cytology using the Pap test was the primary screening tool of the National Cervical Screening Program prior to 1 December 2017.

cervical histology test: Examination of tissue from the cervix through a microscope, collected by a biopsy, which was the primary screening tool of the National Cervical Screening Program prior to 1 December 2017.

cervical HPV test: Assessment of the presence of oncogenic HPV types in a sample, which was used as part of 'test of cure' under the National Cervical Screening Program prior to 1 December 2017, although was also used by some practitioners where it was not indicated.

cervix: The uterine cervix is the 'neck' of the uterus, connecting the vagina to the uterus.

colon: (also called large intestine). Lower part of the digestive system that reabsorbs water, salt and some nutrients from digested food, forming faeces that are later passed out of the body. In this report, the bowel consists of the colon and rectum.

confidence interval: A range determined by variability in data, within which there is a specified (usually 95%) chance that the true value of a calculated parameter lies.

ductal carcinoma in situ (DCIS): A non-invasive tumour of the mammary gland (breast) arising from cells lining the ducts.

eligible population: People who are eligible to participate in a cancer screening programs—for bowel this comprises people registered as an Australian citizen or migrant in the Medicare enrolment file, or registered with a Department of Veterans' Affairs gold card, who reach one of the target ages; for BreastScreen Australia this comprises Australian women aged 40 and above; for cervical screening this comprises sexually active women with an intact cervix.

endocervical: Glandular.

false negative: A test that has incorrectly indicated that the disease is not present.

false positive: A test that has incorrectly indicated that the disease is present.

hazard ratio: Generated from Cox proportional hazards regression, which is used for person-time multivariable modelling, a hazard ratio is essentially the same as a rate ratio. A hazard ratio indicates how many times as high the probability of an event is in one group of people with a particular characteristic as in another group of people without that characteristic, after adjusting for other factors in the model.

HPV: Human papillomavirus, a virus that affects both males and females. There are around 100 types of HPV, with around 40 types known as 'genital HPV', which are contracted through sexual contact. Persistent infection with oncogenic HPV types can lead to cervical cancer, whereas infection with non-oncogenic types of HPV can cause genital warts.

iFOBT: Immunochemical faecal occult blood test—specific type of FOBT test that requires no dietary or medicinal changes before the test. FOBTs are used to detect tiny traces of blood in a person's faeces that may be a sign of **bowel cancer**. The immunochemical FOBT is a central part of Australia's National Bowel Cancer Screening Program.

iFOBT result: The iFOBT results are classified by pathologists as:

positive (blood is detected in at least 1 of 2 samples);

negative (blood is not detected)

inconclusive (the participant is asked to complete another kit).

incidence: The number of new cases (of an illness or event, and so on) occurring during a given period.

Indigenous: A person of Aboriginal and/or Torres Strait Islander descent who identifies as an Aboriginal and/or Torres Strait Islander. See also **Aboriginal or Torres Strait Islander**.

in situ: A Latin term meaning 'in place or position'; undisturbed.

interval cancer: Defined in this report as a cancer diagnosed after a negative screening test. Refer to Methods for definitions for breast, cervical and bowel cancers used in this report.

invasive cancer: A **tumour** whose cells have spread locally and have the potential to spread to nearby healthy or normal tissue or to more distant parts of the body.

invitee: A person who has been invited to participate in the National Bowel Cancer Screening Program.

lead-time bias: Involves the amount of time a diagnosis of **asymptomatic** cancer is brought forward by screening. A concern with some cancers diagnosed earlier through screening is that this earlier diagnosis may make no difference to the outcome of the disease (that is, the date of death). The earlier diagnosis could therefore artificially increase (bias) survival time from that if the cancer were detected symptomatically later.

malignant: Abnormal changes consistent with **cancer**.

mammogram: A radiographic depiction of the breast.

metastasis: The process by which cancerous cells are transferred from one part of the body to another to form a secondary cancer; for example, via the lymphatic system or the bloodstream.

morbidity: Illness.

mortality: The number of deaths occurring during a given period.

National HPV Vaccination Program: This program was first introduced on 1 April 2007 as a program for females. At its inception, it comprised an ongoing vaccination program for females aged 12–13, administered through schools, and a catch-up program for females aged 13–26 between 2007 and 2009, with females aged 13–17 vaccinated through schools and females aged 18–26 vaccinated through the community. From February 2013, the current school-based program for females aged 12–13 was extended to males aged 12–13, with a catch-up program in 2013 and 2014 for males aged 14–15.

negative cytology: A satisfactory cervical cytology test in which no abnormal cells are found.

neoplasm: An abnormal ('neo', new) growth of tissue. Can be benign (not a **cancer**) or malignant (a cancer). Same as **tumour**.

non-responder: A person who was sent an invitation from the National Bowel Cancer Screening Program but did not return their screening kit for analysis.

oncogenic: Cancer-causing.

Pap test: Papanicolaou smear, a procedure to detect cancer and precancerous conditions of the female genital tract, which was the screening test of the National Cervical Screening Program until 1 December 2017. During a Pap test, cells are collected from the transformation zone of the cervix, the area of the cervix where the squamous cells from the outer opening of the cervix and glandular cells from the endocervical canal meet. This is the site where most cervical abnormalities and cancers are detected. For conventional cytology, these cells are transferred onto a slide, and sent to a pathology laboratory for assessment. Collected cells are then examined under a microscope to look for abnormalities.

participant: A person who participated in 1 of the 3 national cancer screening programs.

positive predictive value: The probability that individuals with a positive screening test have cancer (or a precursor to cancer).

positive screening test: In this project defined as a screening test that triggers diagnostic assessment—for bowel screening this is the presence of blood (even microscopic amounts) in a completed screening kit, for BreastScreen this is the identification of a suspicious area on a screening mammogram, for cervical screening this is a Pap test results of possible or definite high-grade abnormality or cervical cancer.

screen-detected cancer: Defined in this report as a cancer diagnosed as a result of a **positive screening test**. Refer to Methods for definitions for breast, cervical and bowel cancers used in this report.

screening: The application of a test to a population which has no overt signs or symptoms of the disease in question, to detect disease at a stage when treatment is more effective. The screening test is used to identify people who require further investigation to determine the presence or absence of disease, and is not primarily a diagnostic test.

sensitivity: A measure of how good a screening test is in identifying people with **cancer**.

socioeconomic status: A measure of socioeconomic status in which small areas of Australia are classified on a continuum from disadvantaged to affluent. See Appendix C for details.

specificity: A measure of how good a screening test is in correctly identifying those who do not have **cancer**.

tumour: See **neoplasm**.

underlying cause of death: The disease or injury that initiated the train of events leading directly to death, or the circumstances of the accident or violence that produced the fatal injury.

References

ABS (Australian Bureau of Statistics) 2011. Australian Standard Geographical Classification 2011. ABS cat. no. 1216.0. Canberra: ABS.

ABS 2013. Census of Population and Housing: Socio-Economic Indexes for Areas 2011. ABS cat. no. 2033.0.5.5.001. Canberra: ABS.

ABS 2016. Causes of death, Australia, 2015: complexities in the measurement of bowel cancer in Australia. ABS cat. no. 3303.0. Canberra: ABS.

AIHW (Australian Institute of Health and Welfare) 2014. Analysis of bowel cancer outcomes for the National Bowel Cancer Screening Program. Cat. no. CAN 87. Canberra: AIHW.

AIHW 2018a. Cancer in adolescents and young adults in Australia. Cat. no. CAN 110. Canberra: AIHW.

AIHW 2018b. Analysis of bowel cancer outcomes for the National Bowel Cancer Screening Program: 2018. Cat. no. CAN 113. Canberra: AIHW.

AIHW 2018c. Cervical screening in Australia. Cat. no. CAN 111. Canberra: AIHW.

AIHW & DoH (Department of Health) 2016. Analysis of colorectal cancer outcomes for the Australian National Bowel Cancer Screening Program. Asia-Pacific Journal of Clinical Oncology 12:22–32.

Andrae B, Andersson TML, Lambert PC, Kemetli L, Silfverdal L, Strander B et al. 2012. Screening and cervical cancer cure: population based cohort study. British Medical Journal 344.

APHDPC (Australian Population Health Development Principal Committee) 2008. Population based screening framework.

Blomfield P & Saville M 2008. Outstanding problems—glandular lesions. Cancer Forum 32(2).

Bobridge A, Price K, Gill TK & Taylor AW 2017. Influencing cancer screening participation rates—providing a combined cancer screening program (a 'One Stop' Shop) could be a potential answer. Frontiers in Oncology 7:308.

Brenner H, Altenhofen L, Katalinic A, Lansdorp-Vogelaar I & Hoffmeister M 2011. Sojourn time of preclinical colorectal cancer by sex and age: estimates from the German national screening colonoscopy database. American Journal of Epidemiology 174:1140–1146.

Brotherton J, Malloy M, Budd A, Saville M, Drennan K & Gertig D 2015. Effectiveness of less than three doses of quadrivalent human papillomavirus vaccine against cervical intraepithelial neoplasia when administered using a standard dose spacing schedule: observational cohort of young women in Australia. Papillomavirus Research 1:59–73.

Budd AC, Brotherton JM, Gertig DM, Chau T, Drennan KT & Saville M 2014. Cervical screening rates for women vaccinated against human papillomavirus. Medical Journal of Australia 201:279–282.

Cancer Australia 2017. Overdiagnosis from mammographic screening. Viewed 14 December 2017, https://canceraustralia.gov.au/publications-and-resources/position-statements/overdiagnosis-mammographic-screening.

Cancer Council Australia 2017. Cancer Control Policy: principles of screening. Viewed 12 December 2017, https://wiki.cancer.org.au/policy/Principles_of_screening.

Cole SR, Tucker GR, Osborne JM, Byrne SE, Bampton PA, Fraser RJ et al. 2013. Shift to earlier stage at diagnosis as a consequence of the National Bowel Cancer Screening Program. Medical Journal of Australia 198:327–330.

Curado M, Edwards B, Shin H, Storm H, Ferlay J, Heanue M et al. 2007. Cancer incidence in five continents: vol. IX. IARC Scientific Publications no. 160. Lyon, France: International Agency for Research on Cancer.

Day N & Walter S 1984. Simplified model of screening for chronic disease: estimation procedures from mass screening programmes. Biometrics 40:1–14.

Department of Health and Ageing 2009. BreastScreen Australia Evaluation. Screening Monograph no. 4/2009. Investigating team: Taylor R, Morell S, Roder D. Mortality (ecological) study. May, 2009.

Duffy S & Cuzick J 2002. Correcting for non-compliance bias in case-control studies to evaluate cancer screening programmes. Applied Statistics 51:235–243.

Duffy S, Nagtegaal I, Wallis M, Cafferty F, Houssami N, Warwick J et al. 2008. Correcting for lead time and length bias in estimating the effect of screen detection on cancer survival. American Journal of Epidemiology 168:98–104.

Duffy S & Parmar D 2013. Overdiagnosis in breast cancer screening: the importance of length of observation period and lead time. Breast Cancer Research 15:R41.

Fellegi IP & Sunter AB 1969. A theory for record linkage. Journal of the American Statistical Association 64:1183–1210.

Ferlay J, Shin HR, Bray F, Forman D, Mathers C & Parkin DM 2010. Estimates of worldwide burden of cancer in 2008: GLOBOCAN 2008. International Journal of Cancer 127:2893–2917.

Gertig DM, Brotherton JM, Budd AC, Drennan K, Chappell G & Saville AM 2013. Impact of a population-based HPV vaccination program on cervical abnormalities: a data linkage study. BioMed Central Medicine 11:227.

Herweijer E, Feldman AL, Ploner A, Arnheim-Dahlstrom L, Uhnoo I, Netterlid E et al. 2015. The participation of HPV-vaccinated women in a National Cervical Screening Program: population-based cohort study. Public Library of Science One 10:e0134185.

IARC (International Agency for Research on Cancer) 2002. IARC handbooks of cancer prevention vol. 7. Breast cancer screening. Lyon, France: IARC Press.

IARC 2004. International rules for multiple primary cancers (ICD-O Third Edition). Lyon: IARC. Viewed 4 February 2014, http://www.iacr.com.fr/MPrules_july2004.pdf.

Kavanagh AM, Giles GG, Mitchell H & Cawson JN 2000. The sensitivity, specificity, and positive predictive value of screening mammography and symptomatic status. Journal of Medical Screening 7:105–110.

Lauby-Secretan B, Scoccianti C, Loomis D, Benbrahim-Tallaa L, Bouvard V, Bianchini F et al. 2015. Breast-cancer screening—viewpoint of the IARC Working Group. New England Journal of Medicine 372:2353–2358.

Lew JB, St John DJB, Xu XM, Greuter MJE, Caruana M, Cenin DR et al. 2017. Long-term evaluation of benefits, harms, and cost-effectiveness of the National Bowel Cancer Screening Program in Australia: a modelling study. Lancet Public Health 2:e331–e340.

Morrell S, Taylor R, Roder D & Dobson A 2012. Mammography screening and breast cancer mortality in Australia: an aggregate cohort study. Journal of Medical Screening 19:26–34.

Morrell S, Taylor R, Roder D, Robson B, Gregory M & Craig K 2017. Mammography service screening and breast cancer mortality in New Zealand: a national cohort study 1999–2011. British Journal of Cancer 116:828.

National Cancer Intelligence Network 2009. Colorectal cancer survival by stage—NCIN data debriefing. June 2009. Viewed 29 June 2018, http://www.ncin.org.uk/publications/data_briefings/colorectal_cancer_survival_by_stage.aspx.

Nickson C, Mason KE, English DR & Kavanagh AM 2012. Mammographic screening and breast cancer mortality: a case-control study and meta-analysis. Cancer Epidemiology, Biomarkers & Prevention 21:1479–1488.

Paap E, Verbeek A, Puliti D, Broeders M & Paci E 2011. Minor influence of self-selection bias on the effectiveness of breast cancer screening in case-control studies in the Netherlands. Journal of Medical Screening 18:142–146.

Roder D, Houssami N, Farshid G, Gill G, Luke C, Downey P et al. 2008. Population screening and intensity of screening are associated with reduced breast cancer mortality: evidence of efficacy of mammography screening in Australia. Breast Cancer Research and Treatment 108:409–416.

Swedish Organised Service Screening Evaluation Group 2006. Reduction in breast cancer mortality from organized service screening with mammography: 1. further confirmation with extended data. Cancer Epidemiology, Biomarkers & Prevention 15: 45–51.

Taylor R, Morrell S, Estoesta J & Brassil A 2004. Mammography screening and breast cancer mortality in New South Wales, Australia. Cancer Causes Control 15:543–550.

Victorian Cytology Service 2017. Victorian Cervical Cytology Registry annual statistical report 2015. Carlton South, Victoria: Victorian Cytology Service.

Whop L, Garvey G, Baade P, Cunningham J, Lokuge K, Brotherton J et al. 2016. The first comprehensive report on Indigenous Australian women's inequalities in cervical screening: a retrospective registry cohort study in Queensland, Australia (2000–2011). Cancer 122:1560–1569.

Wilson J & Jungner G 1968. Principles and practices of screening for disease. Public Health Papers no. 34.

Yang B, Morrell S, Zuo Y, Roder D, Tracey E & Jelfs P 2008. A case-control study of the protective benefit of cervical screening against invasive cervical cancer in NSW women. Cancer Causes Control 19:569–576.

List of tables

List of figures

List of boxes

Related publications

The following AIHW publications provide further information and data from the National Bowel Cancer Screening Program, BreastScreen Australia and the National Cervical Screening Program, as well as cancers diagnosed in Australia, and may be of interest:

- AIHW 2018. Analysis of bowel cancer outcomes for the National Bowel Cancer Screening Program: 2018. Cat. no. CAN 113. Canberra: AIHW.
- AIHW 2018. National Bowel Cancer Screening Program: monitoring report 2018. Cat. no. CAN 112. Canberra: AIHW.
- AIHW 2018. Cervical screening in Australia 2018. Cat. no. CAN 111. Canberra: AIHW.
- AIHW 2017. BreastScreen Australia monitoring report 2014–2015. Cancer series no. 106. Cat. no. CAN 105. Canberra: AIHW.
- AIHW 2017. Cancer in Australia 2017. Cancer series no. 101. Cat. no. CAN 100. Canberra: AIHW.
- AIHW 2017. Australian Cancer Incidence and Mortality (ACIM) books: cervical cancer. Canberra: AIHW. Viewed 11 December 2017, http://www.aihw.gov.au/acim-books.
- AIHW 2014. Analysis of bowel cancer outcomes for the National Bowel Cancer Screening Program. Cat. no. CAN 87. Canberra: AIHW.

This is the first report from an Australian-first project combining data from the National Bowel Cancer Screening Program, BreastScreen Australia, and the National Cervical Screening Program. It was found that screen-detected breast, cervical and bowel cancers were less likely to cause death than non-screen-detected cancers, with analyses also revealing novel patterns in screening behaviour.

aihw.gov.au

AIHW

Stronger evidence,
better decisions,
improved health and welfare