



Performance measures among non-immigrants and immigrants attending BreastScreen Norway: a population-based screening programme

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Abstract

Objectives To explore performance measures among non-immigrants and immigrants attending BreastScreen Norway.

Methods We analysed data from 2,951,375 screening examinations among non-immigrants and 153,026 among immigrants from 1996 to 2015. Immigrants were categorised into high- and low-incidence countries according to the incidence of breast cancer in their birth country. Performance measures, including attendance and recall rates, rates of screen-detected cancer (SDC) and interval breast cancer (IBC), positive predictive value (PPV) and histopathological tumour characteristics, were analysed. We used Fisher's exact model and *t* tests for descriptive statistics, and Poisson regression, adjusting for age and screening history, comparing results for non-immigrants versus immigrants.

Results Attendance rates were 78% for non-immigrants and 56% for immigrants ($p < 0.001$). Rates of prevalent screens were 24% for non-immigrants and 32% for immigrants ($p < 0.001$). Immigrants from low-incidence countries were younger at diagnosis than non-immigrants (57 years versus 60 years, $p < 0.001$). Recall rates were 3.1% for non-immigrants and 3.8% for immigrants ($p < 0.001$), while PPVs were 17% and 14% ($p < 0.001$), respectively. IBCs in immigrants from low-incidence countries were more often triple negative (RR_{adj} 1.81, 95% CI 1.11–2.94) than those in non-immigrants. Both SDC and IBC in immigrants from low-incidence countries tended more often to be histological grade 3 than those in non-immigrants.

Conclusion Immigrants had lower attendance rates, higher recall rates and lower PPV than non-immigrants. The optimal age range and screening interval for immigrant women from low-incidence countries need to be further investigated.

Key Points

- Immigrants from countries with a low incidence of breast cancer had their breast cancer diagnosed at a younger age than non-immigrants.
- Interval breast cancers detected in immigrants from countries with a low incidence of breast cancers were more often triple negative than those in non-immigrants.
- The optimal age range and screening interval for immigrant women from low-incidence countries and non-immigrants might differ.

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Keywords Mammography · Early detection of cancer · Breast cancer · Mass screening · Health care utilisation

Abbreviations

DCIS	Ductal carcinoma in situ
ER	Oestrogen receptor
FFDM	Full-field digital mammography
IBC	Interval breast cancer
ICNST	Invasive carcinoma of no special type
IHC	Immunohistochemistry
ILC	Invasive lobular carcinoma
PR	Progesterone receptor
SDC	Screen-detected cancer
SFM	Screen-film mammography

Introduction

Breast cancer incidence and mortality rates differ between countries and continents, with the highest incidence in Northern America, Western Europe and Australia/New Zealand [1]. Studies have shown lower breast cancer incidence, but more advanced disease among groups of immigrants compared to non-immigrant women [2, 3]. Further, groups of immigrants and ethnic minorities are shown to have different clinico-pathological features, such as younger age at diagnosis and a higher rate of triple-negative breast cancer [4, 5].

Recommendations and guidelines for population-based breast cancer screening target women based on age [6], and the aim of screening is to reduce disease-specific mortality among women through early detection [7]. The quality of the performance of screening programmes can be evaluated through performance measures [8], which include attendance and recall rates, rates of screen-detected cancer (SDC) and interval breast cancer (IBC) and histopathological tumour characteristics, among others. Set levels for performance measures should be reached in order to potentially reduce breast cancer mortality in the future.

Despite differences in breast cancer incidence and stage at diagnosis, screening recommendations and performance measures do not differ for non-immigrants and immigrants [6, 9]. Studies have shown lower attendance rates among immigrants than non-immigrants in high-income countries [10]. If non-adherence to screening leads to more advanced disease among immigrants, this might influence their risk of death from breast cancer.

In the nationwide population-based breast cancer screening programme in Norway, BreastScreen Norway, the average attendance rate has been 75% over the past two decades [11]. However, while 86% of non-immigrants have ever attended screening, this proportion has been shown to be only 67% among immigrants [12].

Immigrants account for 14% of the Norwegian population [13]. Net migration to Norway was low/negative until the 1970s. Few children of immigrants have reached the target age for screening, hence non-immigrants eligible to attend BreastScreen Norway consist of a relatively homogenous ethnic group. While we have observed higher attendance among non-immigrants than immigrants in Norway, we lack knowledge about performance measures for these groups of women. With increasing global migration, it is important to generate knowledge and improve the understanding of whether performance measures differ by country of origin.

In this study, we explored performance measures of mammographic screening among non-immigrants and immigrants attending BreastScreen Norway.

Materials and methods

BreastScreen Norway started in four counties in 1996 and became nationwide by 2005 following a gradual expansion [14]. The programme invites all women aged 50–69 to biennial two-view mammography. Full-field digital mammography (FFDM) gradually replaced screen-film mammography (SFM) starting in 2005, and the programme was fully digitalised in 2011. Women receive a letter written in Norwegian with a time and place for examination that can be changed upon request. Some information about breast cancer screening and the screening programme is available in three foreign languages: a language that is understood by many people globally (English); a language targeting Pakistanis, the fifth largest immigrant group and one with a long history in Norway (Urdu); and a language that can be understood by people from several Arabic countries (Arabic) [15]. This information is available online but not promoted by the service providers.

The programme is administered by the Cancer Registry of Norway and run according to the Cancer Registry Regulations (Kreftregisterforskriften) and the Personal Health Data Filing System Act (Helseregisterloven) [16, 17]. All cancer cases must legally be reported to the Cancer Registry of Norway, and data is considered almost 100% complete for solid tumours [18].

This study was approved by the Regional Committees for Medical and Health Research Ethics (REC 2013/795).

Cohort selection

We followed women who attended BreastScreen Norway until emigration, death, breast cancer diagnosis or end of

the study period. Our cohort was population-based and initially consisted of 887,443 women with no history of breast cancer who were invited for screening during the study period, January 1996 to December 2015. Of these women, 815,129 (92%) were non-immigrants, and 72,314 (8.2%) were immigrants. Of all the invited women, 134,767 (15%) did not attend and were excluded from further analyses. Thus, 752,676 (85%) women remained in the study.

Screening examinations were the unit of analysis. The 815,129 non-immigrant women received 3,790,629 invitations (mean 4.7), and the 72,314 immigrant women received 274,593 invitations (mean 3.8) ($p < 0.001$) (Table 1).

Among the non-immigrants invited, 110,820 (14%) did not attend and were excluded. Among the remaining 704,309 women, 2,951,375 screening examinations were performed (mean 4.2). Of the 72,314 immigrants, 23,947 (33%) women did not attend and were excluded. In the

remaining 48,367 attending immigrants, 153,026 screening examinations were performed (mean 3.2) ($p < 0.001$).

Country of birth

We used immigrant status as a proxy for ethnicity, and Statistics Norway's definition to identify immigrants as women born abroad, with two foreign-born parents and four foreign-born grandparents [13]. All other women were defined as non-immigrants. We received information about country of birth from Statistics Norway and divided these countries into high- and low-incidence countries based on local incidence of breast cancer (see Appendix in the Electronic Supplementary Material for details) [19, 20]. If geographical variations in incidence and survival were related to differences in diet, alcohol, reproductive factors, hormonal factors [21] and other biological factors, it is possible that these variations could lead to differences in performance measure outcomes. As high- and low-incidence countries are broad

Table 1 Performance measures among immigrants and non-immigrants attending BreastScreen Norway

	Non-immigrants (<i>n</i> = 815,129)	Immigrants (<i>n</i> = 72,314)	Immigrants from high-incidence countries (<i>n</i> = 28,173)	Immigrants from low-incidence countries (<i>n</i> = 44,141)
Invitations, no.	3,790,629	274,593	114,756	159,837
Screens, no.	2,951,375	153,026	78,756	74,270
Attendance, %	77.9	55.7***	68.6***	46.5***
Prevalent screens, no. (%)	704,309 (23.9)	48,367 (31.6***)	21,429 (27.2***)	26,938 (36.3***)
Subsequent screens, no. (%)	2,247,066 (76.1)	104,659 (68.4***)	57,327 (72.8***)	47,332 (63.7***)
Age at screening, mean (SD)	59.0 (5.8)	57.7*** (5.8)	59.1*** (5.9)	56.2*** (5.3)
Age at diagnosis, mean (SD)	60.3 (5.8)	59.1*** (6.0)	60.6 (6.0)	56.9*** (5.1)
Recall rate, no. (%)				
All screens	91,908 (3.1)	5858 (3.8***)	2783 (3.5***)	3075 (4.1***)
Prevalent screens	38,159 (5.4)	3149 (6.5***)	1259 (5.9***)	1890 (7.0***)
Subsequent screens	53,749 (2.4)	2709 (2.6***)	1524 (2.7***)	1185 (2.5)
PPV, no. (%)				
All screens	15,778 (17.2)	828 (14.1***)	466 (16.7)	362 (11.8***)
Prevalent screens	4310 (11.3)	307 (9.8**)	136 (10.8)	171 (9.1***)
Subsequent screens	11,468 (21.3)	521 (19.2**)	330 (21.7)	191 (16.1***)
Cancer detection rate (DCIS and invasive breast cancer)				
SDC (1996–2015), no. (%)				
All screens	16,129 (0.55)	849 (0.55)	478 (0.61*)	371 (0.50)
Prevalent screens	4438 (0.63)	315 (0.65)	143 (0.67)	172 (0.64)
Subsequent screens	11,691 (0.52)	534 (0.51)	335 (0.58*)	199 (0.42***)
IBC (1996–2013 ^a), no. (%)				
All screens	4319 (0.17)	228 (0.18)	151 (0.22***)	77 (0.13*)
Prevalent screens	1152 (0.18)	59 (0.15)	36 (0.19)	23 (0.11*)
Subsequent screens	3167 (0.17)	169 (0.20*)	115 (0.23***)	54 (0.15)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.005$, with non-immigrants as the reference group

^a Screened 1996–2013, followed for IBC 1996–2015

categories, we present results for smaller geographical regions in the [Appendix](#) in the Electronic Supplementary Material.

Performance measures

We extracted data related to the screening examinations and breast tumours from the Cancer Registry of Norway's databases. These data were merged with data about country of birth from Statistics Norway on an individual level.

The attendance rate was defined as the number of screening examinations divided by the number of invitations for screening within the study period. We defined prevalent screens as the first screening examination within BreastScreen Norway, while subsequent screens refer to a screening examination where prior screening mammograms were available for comparison. The subsequent screen group included regular and irregular attenders, which means that some women had a screening interval of more than 2 years. The recall rate was defined as the number of screening examinations leading to further assessment due to abnormal mammographic findings divided by the total number of screening examinations. SDC was defined as breast cancer diagnosed after a recall, within 6 months after the screening examination. Our definition of breast cancer included ductal carcinoma in situ (DCIS) and invasive cancer. The positive predictive value (PPV) was calculated as the percentage of SDC among recalled women. We defined IBC as breast cancer diagnosed after a negative or false-positive screening result, either before the next scheduled biennial screening examination or within 2 years among women who had reached the upper age limit for screening.

Histopathological type was given as follows: DCIS, invasive carcinoma of no special type (ICNST), invasive lobular carcinoma (ILC) and others. For invasive cancers, we analysed the distribution of maximum tumour diameter, histological grade, lymph node status, molecular tumour subtype (St. Gallen surrogate IHC classification [22]), oestrogen receptor (ER) status and progesterone receptor (PR) status. In the case of multifocal disease, tumour diameter referred to that of the largest focus. Information about multifocality or centrality was not available for this study. Using ER, PR and Her2 status, we divided the tumours into molecular subtypes based on the St. Gallen surrogate IHC classification of molecular subtypes of breast cancer [22]. Information about Her2 status was available from 2005 onward, and we were thus only able to classify 8906 out of 14,098 invasive SDCs and 2802 out of 4315 invasive IBCs.

Statistical analyses

We calculated attendance rates as the percentage of screening examinations among all invitations within the study period, while screening history (prevalent screens and subsequent screens), recall rates, rates of SDC and IBC and the rates of

exams performed with SFM and FFDM were calculated as percentages among all screening examinations. Further, we presented the distribution of histopathological type for all malignancies. For the remaining tumour characteristics (tumour diameter, histological grade, lymph node status, molecular subtype and ER and PR status), we presented descriptive results and regression analyses for invasive cancers. In order to ensure sufficient follow-up time for IBC (24 months), analyses pertaining to IBC were restricted to women screened from 1996 to 2013.

We used Fisher's exact model, comparing each group of immigrants to non-immigrants. We chose Fisher's exact model as we expected that some cells might have low counts. For comparisons of mean age at screening, mean age at diagnosis and mean tumour diameter, we used Student's *t* test to compare each group to non-immigrants. All tests were two-sided, and we considered *p* values of ≤ 0.05 as statistically significant. We used the Poisson regression to calculate the rate ratio (RR) unadjusted and adjusted for age and screening history (RR_{adj}) with 95% confidence interval (CI) comparing recall rates, PPV, cancer detection rates and tumour characteristics between immigrants and non-immigrants.

All statistical analyses were conducted using Stata/MP 15.0 for Windows.

Results

Attendance rates were 78% (2,951,375/3,790,629) for non-immigrants and 56% (153,026/274,593) ($p < 0.001$) for immigrants (Table 1). The rates of prevalent screens were 24% (704,309/2,951,375) for non-immigrants and 32% (48,367/153,026) ($p < 0.001$) for immigrants. While 50% (1,459,752/2,951,375) of the screening examinations of non-immigrants were performed with FFDM, the percentage was 58% (88,035/153,026) ($p < 0.001$) for immigrants.

Recall rates were 3.1% (91,908/2,951,375) for non-immigrants and 3.8% (5858/153,026) ($p < 0.001$) for immigrants for all examinations (Table 1). PPVs were 17% (15,778/91,908) for non-immigrants and 14% (828/5858) ($p < 0.001$) for immigrants. The rate of SDC was 0.55%, for both non-immigrants (16,129/2,951,375) and immigrants (849/153,026) ($p = 0.657$), while the rates of IBC were 0.17% (4319/2,552,154) for non-immigrants and 0.18% (228/125,699) ($p = 0.309$) for immigrants.

The proportions of invasive SDC ≥ 2 cm were 23% (3072/13,200) for non-immigrants and 28% (185/672) ($p = 0.013$) for immigrants, while histological grade 3 accounted for 21% (2745/13,375) of SDC among non-immigrants and 24% (162/689) ($p = 0.060$) among immigrants (Table 2). Twenty-three per cent (3007/13,209) of SDCs among non-immigrants were lymph node positive,

Table 2 Tumour characteristics among immigrants and non-immigrants screened in BreastScreen Norway

	Screen-detected cancers				Interval cancers			
	Non-immigrants	All immigrants	High incidence	Low incidence	Non-immigrants	All immigrants	High incidence	Low incidence
All tumours, no.	16,129	849	478	371	4319	228	151	77
Histopathological type								
DCIS, %	16.9	18.5	18.8	18.1	5.1	5.3	5.3	5.2
IDC, %	67.8	67.6	68.4	66.6	73.6	77.6	78.2	76.6
ILC, %	8.3	7.9	7.7	8.1	12.3	12.3	13.9	9.1
Other, %	7.1	6.0	5.0	7.3	9.1	4.8*	2.7**	9.1
Invasive, no.	13,406	692	388	304	4099	216	143	73
Maximum tumour diameter								
Median, mm	13	13	13	14	19	20	19	21
Mean, mm (SD)	14.8 (9.6)	15.2 (9.0)	15.0 (9.0)	15.5 (9.1)	21.3 (13.6)	21.4 (13.3)	21.1 (14.6)	22.0 (10.5)
≥ 2 cm, %	23.3	27.5*	27.0	28.2	50.1	54.2	52.6	57.1
Not available, no. (%)	206 (1.5)	20 (2.9)	7 (1.8)	13 (4.3)	208 (5.1)	13 (6.0)	10 (7.0)	3 (4.1)
Histological grade								
1, %	32.3	29.3	31.4	26.7*	16.9	12.6	16.8	4.2**
2, %	47.1	47.2	48.7	45.2	44.5	47.4	47.6	47.2
3, %	20.5	23.5	20.0	28.1**	38.6	40.0	35.7	48.6
Not available, no. (%)	31 (0.2)	3 (0.4)	2 (0.5)	1 (0.3)	13 (0.3)	1 (0.5)	0 (0.0)	1 (1.4)
Lymph node status								
Positive, %	22.8	25.6	26.0	25.1	41.4	42.8	44.5	39.4
Not available, no. (%)	197 (1.5)	20 (2.9)	11 (2.8)	9 (3.0)	145 (3.5)	8 (3.7)	6 (4.2)	2 (2.7)
ER								
Positive, %	89.5	90.3	92.1	88.0	77.4	76.3	78.8	71.4
Not available, no. (%)	622 (4.6)	32 (4.6)	19 (4.9)	13 (4.3)	174 (4.2)	9 (4.2)	6 (4.2)	3 (4.1)
PR								
Positive, %	71.3	71.8	70.0	74.2	58.7	56.1	59.3	50.0
Not available, no. (%)	734 (5.5)	35 (5.1)	22 (5.7)	13 (4.3)	216 (5.3)	11 (5.1)	8 (5.6)	3 (4.1)
Molecular tumour subtype								
Luminal A-like, %	66.0	66.5	65.7	67.3	52.7	46.9	46.0	48.2
Luminal B-like (Her2-), %	14.9	14.9	17.7	11.7	15.6	18.9	20.7	16.1
Luminal B-like (Her2+), %	10.0	10.2	9.7	10.8	11.9	11.2	14.9	5.4
Her2+ (non-luminal), %	3.5	3.2	2.4	4.0	7.3	6.3	5.8	7.1
Triple negative, %	5.6	5.3	4.4	6.3	12.4	16.8	12.6	23.2*
Not available, no. (%)	4971 (37.1)	221 (31.9)	140 (36.1)	81 (26.6)	1440 (35.1)	73 (33.8)	56 (39.2)	17 (23.3)

Values that are not available are not included when calculating the percentage of the distributions

* $p < 0.05$; ** $p < 0.005$, with non-immigrants as the reference group

while the rate was 26% (172/672) ($p = 0.090$) among immigrants.

Attendance rates were lower for immigrants from high-incidence countries (69% (78,756/114,756)) and low-incidence countries (47% (74,270/159,837)) than those for non-immigrants (78%) ($p < 0.001$ for both groups relative to non-immigrants) (Table 1). The rates of prevalent screens was 27% (21,429/78,756) for immigrants from high-incidence countries and 36% (26,938/74,270) for immigrants from

low-incidence countries, compared to 24% for non-immigrants ($p < 0.001$ for both groups relative to non-immigrants).

We identified higher recall rates for immigrants from high-incidence countries (3.5% (2783/78,756)) and low-incidence countries (4.1% (3075/74,270)) compared with non-immigrants (3.1%) ($p < 0.001$ for both groups relative to non-immigrants) (Table 1). For immigrants from low-incidence countries, PPV was 12% (362/3075) ($p < 0.001$

relative to 17% for non-immigrants). PPV did not differ statistically significantly between immigrants from high-incidence countries and non-immigrants.

The rates of SDC was 0.61% (478/78,756) among immigrants from high-incidence countries ($p = 0.024$ relative to non-immigrants) and 0.50% (371/74,270) among immigrants from low-incidence countries ($p = 0.086$ relative to non-immigrants). The IBC rate was higher among immigrants from high-incidence countries (0.22% (151/68,302)) ($p = 0.002$ relative to non-immigrants) than among non-immigrants (0.17%) and was lower for immigrants from low-incidence countries (0.13% (77/57,397)) ($p = 0.044$ relative to non-immigrants).

As shown in Table 2, SDCs among women from low-incidence countries were more often histological grade 3 (28% (85/303)) than those among non-immigrants (21%) ($p = 0.002$). No other analyses of tumour characteristics for SDC among immigrants from high- or low-incidence countries compared to non-immigrants reached statistically significant levels.

For IBC, we observed a lower rate of histological grade 1 tumours among immigrants from low-incidence countries compared to non-immigrants (4.2% (3/72) relative to 17% (690/4086), $p < 0.001$, for non-immigrants). Among the tumours that were classified according to molecular subtype (i.e. those diagnosed during 2005 or later), the proportion of triple-negative IBC was higher among immigrants from low-incidence countries (23%, 13/56) compared to that among non-immigrants (12%, 330/2659) ($p = 0.024$) (Table 2). No other descriptive analyses of tumour characteristics for IBC among immigrants from high- or low-incidence countries compared to non-immigrants reached statistically significant levels.

Using non-immigrant women as the reference population, RR_{adj} for recall was 1.13 (95% CI 1.10–1.16) for all immigrant women, 1.10 (95% CI 1.06–1.15) for immigrants from high-incidence countries and 1.15 (95% CI 1.11–1.19) for immigrants from low-incidence countries (Table 3). RR_{adj} for PPV was 0.86 (95% CI 0.78–0.95) for immigrants from low-incidence countries relative to non-immigrants. The difference between immigrants from high-incidence countries and non-immigrants did not reach statistically significant levels. Immigrants from high-incidence countries had borderline higher SDC rates (RR_{adj} 1.09, 95% CI 1.00–1.19) and higher IBC rates (RR_{adj} 1.30, 95% CI 1.11–1.53) than non-immigrants, while immigrants from low-incidence countries had borderline lower IBC rates than non-immigrants (RR_{adj} 0.80, 95% CI 0.63–1.00).

For tumour characteristics, results from regression analyses mostly reflected the results from the descriptive analyses (Table 4). However, SDC in immigrants from high-incidence countries tended more often to be ER positive than in non-immigrants (RR_{adj} 1.03, 95% CI 1.00–1.06). Also,

immigrants from low-incidence countries more often had SDC > 2 cm than non-immigrants, but the difference was no longer statistically significant after adjusting for age and screening history.

Discussion

This study demonstrated important differences in tumour characteristics and other performance measures between non-immigrants and immigrants attending organised mammographic screening in Norway. Immigrants had higher proportions of prevalent screens and higher recall rates than non-immigrants. Immigrants from low-incidence countries had a lower PPV than non-immigrants, meaning that fewer cancers were detected among recalled immigrants from low-incidence countries than among recalled non-immigrants. For immigrants from low-incidence countries, adjusting for age and screening history reduced some of the difference in recall rates and PPV, but the results remained statistically significant from what observed among non-immigrants.

Overall rates of SDC and IBC did not differ statistically significantly between immigrants and non-immigrants. However, immigrants from high- and low-incidence countries had comparable SDC rates to non-immigrants for prevalent screens, while immigrants from high-incidence countries had higher rates of SDC after subsequent screens than non-immigrants, and immigrants from low-incidence countries had lower rates than non-immigrants. Further, we observed additional differences in tumour characteristics, both when comparing results from all immigrants to non-immigrants and when comparing results from immigrants from high- and low-incidence countries to non-immigrants.

Age and screening history can explain some of the differences in recall rates and PPV. Lower attendance rates with potentially irregular attendance among immigrants could be another factor contributing to the differences in recall rates. Other factors complicate the interpretation of how screening history affects PPV and cancer detection rates. PPV for immigrants from high-incidence countries did not differ statistically from non-immigrants, but SDC rates and IBC rates (all screens and subsequent screens) were higher than for non-immigrants. The combination of low attendance rates, a high proportion of prevalent screens and high recall rates among the immigrants could be part of the explanation for higher cancer detection rates despite similar PPV as non-immigrants.

Immigrants from low-incidence countries had lower PPV, lower rates of SDC (subsequent screens) and lower rates of IBC (all screens and prevalent screens) than non-immigrants. The lower PPV persisted after adjusting for age and screening history. These women have emigrated from low-incidence countries, and we can expect cancer detection rates to be lower than those for non-immigrants. However, the SDC rate

Table 3 Relative rates for performance measures among immigrants compared to non-immigrants attending BreastScreen Norway, unadjusted and adjusted for age and screening history (prevalent or subsequent screens)

	Non-immigrants	Immigrants	Immigrants from high-incidence countries	Immigrants from low-incidence countries
Attendance ^a				
Unadjusted	1.00 (ref)	0.72 (0.71–0.72)	0.88 (0.88–0.88)	0.60 (0.59–0.60)
Adjusted	1.00 (ref)	0.72 (0.72–0.72)	0.88 (0.88–0.89)	0.60 (0.60–0.60)
Recall				
Unadjusted	1.00 (ref)	1.23 (1.20–2.26)	1.14 (1.09–1.18)	1.33 (1.28–1.38)
Adjusted	1.00 (ref)	1.13 (1.10–1.16)	1.10 (1.06–1.15)	1.15 (1.11–1.19)
PPV				
Unadjusted	1.00 (ref)	0.82 (0.77–0.88)	0.98 (0.90–1.06)	0.69 (0.62–0.76)
Adjusted	1.00 (ref)	0.93 (0.87–0.99)	0.98 (0.90–1.06)	0.86 (0.78–0.95)
Cancer detection (DCIS and invasive breast cancer)				
SDC (1996–2015)				
Unadjusted	1.00 (ref)	1.02 (0.95–1.09)	1.11 (1.01–1.22)	0.91 (0.82–1.01)
Adjusted	1.00 (ref)	1.04 (0.97–1.12)	1.09 (1.00–1.19)	0.98 (0.89–1.09)
IBC (1996–2013 ^b)				
Unadjusted	1.00 (ref)	1.07 (0.94–1.22)	1.31 (1.11–1.54)	0.79 (0.63–0.99)
Adjusted	1.00 (ref)	1.07 (0.94–1.23)	1.30 (1.11–1.53)	0.80 (0.63–1.00)

^a Adjusted for age only

^b Screened 1996–2013, followed for IBC 1996–2015

remained not significantly different to non-immigrants after adjusting for age and screening history, and IBC rates were only borderline lower.

Women from low-incidence countries were younger at the time of screening and time of diagnosis. The younger age at screening reflects a lower age distribution due to shorter time residing in Norway. Women from low-incidence countries had different distribution levels of tumour characteristics than non-immigrants, which might be related to younger age at diagnosis and, thereby, biological factors. This hypothesis is strengthened by the higher rate of triple-negative IBC, and a trend towards a higher proportion of tumours of histological grade 3 (significant for SDC, borderline for IBC) and > 2 cm (only significant for unadjusted RR for SDC) among immigrants from low-incidence countries than non-immigrants. Similar to our findings, a study showed a higher proportion of tumours that were histopathologic grade 3 and ≥ 2 cm among Moroccan Arab women versus European women, and also differences in molecular subtypes [4]. Studies from the USA have shown a higher proportion of triple-negative breast cancers among African Americans, Hispanics and Asian Indians than among non-Hispanic Whites [23]. Of the molecular subtypes, survival is worst for triple-negative disease and survival is also worse for advanced-stage disease [24]. Our results build on these findings and further contribute to an understanding of ethno-racial differences in breast cancer characteristics.

Immigrants from low-incidence countries had similar SDC rates as non-immigrants after prevalent screens, but lower SDC rates after subsequent screens. These findings, combined with the lower age at diagnosis, could indicate that the prevalence peak is at a younger age for immigrants from low-incidence countries than for other women but could also be a result of a difference in age distribution. However, a recent Norwegian study showed that 54% of breast cancers diagnosed in non-Western immigrants were detected in women younger than 50 years old (age of first screening invitation), while the corresponding proportion was 21% for non-immigrants [3]. Studies from other countries have also shown that groups of immigrant women are younger at diagnosis than non-immigrants [25].

Combining our results with other studies, one could ask whether the target age group and recommended screening interval are optimal for immigrants from low-incidence countries. It is possible that these women should start more frequent screening at a younger age than they do today. With the low PPV and SDC rate after subsequent screens, one could also explore whether there is evidence also for stopping screening at an earlier age for immigrants from low-incidence countries (shifting rather than expanding the age range). A recent study from the USA suggested that race-based screening guidelines should be considered, for instance lowering the screening age for non-White groups in the country [26].

Table 4 Relative rates for tumour characteristics among immigrants compared to non-immigrants attending BreastScreen Norway, unadjusted and adjusted for age and screening history (prevalent or subsequent screen)

	Screen-detected cancers						Interval cancers							
	Non-immigrants			All immigrants			High incidence			Low incidence				
	Non-immigrants	All immigrants	High incidence	High incidence	Low incidence	Non-immigrants	All immigrants	High incidence	High incidence	Low incidence	Non-immigrants	All immigrants	High incidence	Low incidence
All tumours (no.)	16,129	849	478	478	371	4319	228	151	151	77				
Invasive	1.00 (ref)	0.98 (0.95–1.01)	0.98 (0.93–1.02)	0.98 (0.93–1.02)	0.99 (0.94–1.03)	1.00 (ref)	1.00 (0.97–1.03)	1.00 (0.96–1.04)	1.00 (0.96–1.04)	1.00 (0.95–1.05)	1.00 (ref)	1.00 (0.97–1.03)	1.00 (0.96–1.04)	1.00 (0.95–1.05)
Adjusted	1.00 (ref)	0.99 (0.95–1.02)	0.97 (0.93–1.02)	0.97 (0.93–1.02)	1.00 (0.95–1.05)	1.00 (ref)	1.00 (0.97–1.03)	1.00 (0.96–1.04)	1.00 (0.96–1.04)	1.00 (0.95–1.05)	1.00 (ref)	1.00 (0.97–1.03)	1.00 (0.96–1.04)	1.00 (0.95–1.05)
Invasive (no.)	13,406	692	388	388	304	4099	216	143	143	73				
Maximum tumour diameter > 2 cm	1.00 (ref)	1.18 (1.04–1.34)	1.16 (0.98–1.37)	1.16 (0.98–1.37)	1.21 (1.01–1.46)	1.00 (ref)	1.08 (0.95–1.23)	1.05 (0.89–1.24)	1.05 (0.89–1.24)	1.14 (0.93–1.40)	1.00 (ref)	1.08 (0.95–1.23)	1.05 (0.89–1.24)	1.14 (0.93–1.40)
Adjusted	1.00 (ref)	1.15 (1.02–1.31)	1.16 (0.98–1.37)	1.16 (0.98–1.37)	1.14 (0.95–1.38)	1.00 (ref)	1.08 (0.95–1.23)	1.05 (0.89–1.24)	1.05 (0.89–1.24)	1.13 (0.92–1.39)	1.00 (ref)	1.08 (0.95–1.23)	1.05 (0.89–1.24)	1.13 (0.92–1.39)
Histological grade 3	1.00 (ref)	1.15 (1.00–1.32)	0.97 (0.79–1.19)	0.97 (0.79–1.19)	1.37 (1.14–1.64)	1.00 (ref)	1.04 (0.88–1.23)	0.92 (0.74–1.16)	0.92 (0.74–1.16)	1.26 (0.99–1.60)	1.00 (ref)	1.04 (0.88–1.23)	0.92 (0.74–1.16)	1.26 (0.99–1.60)
Adjusted	1.00 (ref)	1.14 (0.99–1.31)	0.98 (0.80–1.20)	0.98 (0.80–1.20)	1.34 (1.11–1.61)	1.00 (ref)	1.03 (0.87–1.22)	0.92 (0.74–1.15)	0.92 (0.74–1.15)	1.24 (0.98–1.58)	1.00 (ref)	1.03 (0.87–1.22)	0.92 (0.74–1.15)	1.24 (0.98–1.58)
Positive lymph node status	1.00 (ref)	1.12 (0.98–1.28)	1.14 (0.96–1.36)	1.14 (0.96–1.36)	1.10 (0.90–1.35)	1.00 (ref)	1.03 (0.88–1.22)	1.08 (0.89–1.30)	1.08 (0.89–1.30)	0.95 (0.71–1.27)	1.00 (ref)	1.03 (0.88–1.22)	1.08 (0.89–1.30)	0.95 (0.71–1.27)
Adjusted	1.00 (ref)	1.08 (0.95–1.24)	1.14 (0.96–1.36)	1.14 (0.96–1.36)	1.01 (0.83–1.23)	1.00 (ref)	1.03 (0.87–1.21)	1.08 (0.89–1.30)	1.08 (0.89–1.30)	0.93 (0.70–1.25)	1.00 (ref)	1.03 (0.87–1.21)	1.08 (0.89–1.30)	0.93 (0.70–1.25)
ER positive	1.00 (ref)	1.01 (0.98–1.04)	1.03 (1.00–1.06)	1.03 (1.00–1.06)	0.98 (0.94–1.03)	1.00 (ref)	0.99 (0.91–1.07)	1.02 (0.93–1.11)	1.02 (0.93–1.11)	0.92 (0.79–1.07)	1.00 (ref)	0.99 (0.91–1.07)	1.02 (0.93–1.11)	0.92 (0.79–1.07)
Adjusted	1.00 (ref)	1.01 (0.98–1.04)	1.03 (1.00–1.06)	1.03 (1.00–1.06)	0.98 (0.94–1.03)	1.00 (ref)	0.99 (0.91–1.07)	1.02 (0.93–1.11)	1.02 (0.93–1.11)	0.93 (0.80–1.08)	1.00 (ref)	0.99 (0.91–1.07)	1.02 (0.93–1.11)	0.93 (0.80–1.08)
PR positive	1.00 (ref)	1.01 (0.96–1.06)	0.98 (0.92–1.05)	0.98 (0.92–1.05)	1.04 (0.97–1.11)	1.00 (ref)	0.96 (0.84–1.08)	1.01 (0.88–1.16)	1.01 (0.88–1.16)	0.85 (0.67–1.08)	1.00 (ref)	0.96 (0.84–1.08)	1.01 (0.88–1.16)	0.85 (0.67–1.08)
Adjusted	1.00 (ref)	1.00 (0.95–1.05)	0.98 (0.92–1.05)	0.98 (0.92–1.05)	1.03 (0.96–1.10)	1.00 (ref)	0.96 (0.85–1.08)	1.01 (0.87–1.16)	1.01 (0.87–1.16)	0.86 (0.68–1.09)	1.00 (ref)	0.96 (0.85–1.08)	1.01 (0.87–1.16)	0.86 (0.68–1.09)
Luminal A-like	1.00 (ref)	1.01 (0.94–1.08)	1.00 (0.91–1.09)	1.00 (0.91–1.09)	1.02 (0.93–1.12)	1.00 (ref)	0.89 (0.74–1.06)	0.87 (0.69–1.10)	0.87 (0.69–1.10)	0.91 (0.70–1.20)	1.00 (ref)	0.89 (0.74–1.06)	0.87 (0.69–1.10)	0.91 (0.70–1.20)
Adjusted	1.00 (ref)	0.99 (0.93–1.06)	0.99 (0.91–1.09)	0.99 (0.91–1.09)	1.00 (0.91–1.10)	1.00 (ref)	0.89 (0.75–1.07)	0.87 (0.69–1.10)	0.87 (0.69–1.10)	0.93 (0.71–1.23)	1.00 (ref)	0.89 (0.75–1.07)	0.87 (0.69–1.10)	0.93 (0.71–1.23)
Luminal B-like (Her2 negative)	1.00 (ref)	0.99 (0.80–1.24)	1.19 (0.90–1.56)	1.19 (0.90–1.56)	0.78 (0.54–1.12)	1.00 (ref)	1.21 (0.85–1.72)	1.33 (0.87–2.02)	1.33 (0.87–2.02)	1.03 (0.56–1.89)	1.00 (ref)	1.21 (0.85–1.72)	1.33 (0.87–2.02)	1.03 (0.56–1.89)
Adjusted	1.00 (ref)	1.04 (0.83–1.30)	1.19 (0.90–1.56)	1.19 (0.90–1.56)	0.85 (0.59–1.23)	1.00 (ref)	1.23 (0.86–1.74)	1.31 (0.86–2.00)	1.31 (0.86–2.00)	1.08 (0.59–1.98)	1.00 (ref)	1.23 (0.86–1.74)	1.31 (0.86–2.00)	1.08 (0.59–1.98)
Luminal B-like (Her2 positive)	1.00 (ref)	1.02 (0.77–1.34)	0.97 (0.66–1.42)	0.97 (0.66–1.42)	1.08 (0.73–1.58)	1.00 (ref)	0.94 (0.58–1.51)	1.25 (0.75–2.09)	1.25 (0.75–2.09)	0.45 (0.15–1.36)	1.00 (ref)	0.94 (0.58–1.51)	1.25 (0.75–2.09)	0.45 (0.15–1.36)
Adjusted	1.00 (ref)	1.00 (0.76–1.32)	0.98 (0.66–1.44)	0.98 (0.66–1.44)	1.03 (0.70–1.51)	1.00 (ref)	0.92 (0.57–1.48)	1.26 (0.76–2.11)	1.26 (0.76–2.11)	0.42 (0.14–1.27)	1.00 (ref)	0.92 (0.57–1.48)	1.26 (0.76–2.11)	0.42 (0.14–1.27)
Her2 positive (non-luminal)	1.00 (ref)	0.92 (0.55–1.53)	0.70 (0.31–1.55)	0.70 (0.31–1.55)	1.16 (0.61–2.23)	1.00 (ref)	0.86 (0.45–1.64)	0.78 (0.33–1.86)	0.78 (0.33–1.86)	0.97 (0.38–2.53)	1.00 (ref)	0.86 (0.45–1.64)	0.78 (0.33–1.86)	0.97 (0.38–2.53)
Adjusted	1.00 (ref)	0.94 (0.56–1.56)	0.72 (0.32–1.59)	0.72 (0.32–1.59)	1.19 (0.62–2.28)	1.00 (ref)	0.85 (0.44–1.62)	0.79 (0.33–1.87)	0.79 (0.33–1.87)	0.94 (0.36–2.43)	1.00 (ref)	0.85 (0.44–1.62)	0.79 (0.33–1.87)	0.94 (0.36–2.43)
Triple negative	1.00 (ref)	0.95 (0.64–1.40)	0.79 (0.44–1.42)	0.79 (0.44–1.42)	1.12 (0.67–1.88)	1.00 (ref)	1.35 (0.93–1.97)	1.02 (0.58–1.79)	1.02 (0.58–1.79)	1.87 (1.15–3.04)	1.00 (ref)	1.35 (0.93–1.97)	1.02 (0.58–1.79)	1.87 (1.15–3.04)
Adjusted	1.00 (ref)	1.00 (0.68–1.48)	0.80 (0.45–1.44)	0.80 (0.45–1.44)	1.24 (0.74–2.08)	1.00 (ref)	1.33 (0.91–1.94)	1.02 (0.58–1.78)	1.02 (0.58–1.78)	1.81 (1.11–2.94)	1.00 (ref)	1.33 (0.91–1.94)	1.02 (0.58–1.78)	1.81 (1.11–2.94)

We used high-quality, individual-level registry data for a large number of women. However, there are some limitations to our study. The dataset is comprehensive, and we have tested a substantial number of outcomes for statistical significance. With a vast number of outcomes and p values < 0.05 considered statistically significant, it is possible that some of our outcomes are falsely positive. With a large study population, it is also likely that we found outcomes that are statistically significant but not clinically relevant. Secondly, we excluded all DCIS from our analyses of tumour characteristics, regardless of whether these were small microcalcifications with low-grade cancer cells or extensive linear intraductal microcalcifications involving large areas with high-grade cancer cells. Further, we did not include screening technique, whether the women were screened with SFM or FFDM, in the analyses. Results from a study using data from the same population showed an increased detection of DCIS during the transition phase [27]. However, the results stabilised after one screening round, when prior FFDM was available for comparison and the assumed learning effect was complete. Further studies are needed to identify possible differences in performance measures in immigrants versus non-immigrants screened with different techniques. Fourthly, we examined the outcome for each screening examination, not taking into account the number of years since the previous examination for subsequent screens. Furthermore, we do not know whether differences in other performance measures would have been attenuated if non-immigrants and immigrants had had similar attendance rates. Finally, less than 1% of screening examinations lead to a cancer diagnosis. This resulted in low numbers when dividing immigrants into subgroups and dividing cancers into SDC and IBC, thereby reducing the statistical power of these analyses.

Conclusion

We observed different results of selected performance measures for non-immigrants versus immigrants who participated in BreastScreen Norway from 1996 to 2015. Two important differences were lower attendance rates and higher proportions of prevalent screens among immigrants, which could explain some of the other variations observed. Efforts aimed at increasing attendance are an important step towards improving the quality of the performance of organised screening for immigrants. IBCs among immigrants from low-incidence countries were more often triple negative than among non-immigrants. Our results indicate that optimal age range and screening interval for immigrant women from low-incidence countries versus non-immigrants might differ and need to be further investigated.

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Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Solveig Hofvind.

Conflict of interest The authors declare that they have no conflict of interest.

Statistics and biometry One of the authors has significant statistical expertise.

Informed consent Written informed consent was waived by the institutional review board (the Regional Ethical Committee approved the use of the data for the study).

Ethical approval Institutional review board approval was obtained. This study has been approved by the Regional Committee for Medical and Health Research Ethics in South-eastern Norway, REC South East (2013/795).

Study subjects or cohorts overlap This cohort is used in several studies from the Cancer Registry of Norway. However, this paper represents an original study which has not been performed previously.

Methodology

- prospective
- Cohort study (historic cohort)
- Performed at one institution

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