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Distance to screening site and non-participation in screening for breast cancer: a population-based study

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ABSTRACT

Background In population-based breast cancer screening programmes, the geographical distance to the screening site may influence a woman's propensity to participate. The aim of this study was to analyse the effect driving distance to the screening unit had on women's participation in a breast cancer screening programme.

Methods All women invited to the first round of breast cancer screening in the Central Denmark Region were eligible for inclusion ($n = 149\,234$). Information on participation was collected from a regional administrative database. The shortest road distance between each woman's residence and her affiliated screening site was assessed using Network Analyst, ArcGIS.

Results The unadjusted association between distance and non-participation formed a J-shape curve. Adjustment for socio-demographic characteristics caused the J-shape to disappear, and the probability of non-attendance rose with longer distance to the screening site but flattened after ~45 km. Women without access to a vehicle had a higher risk of non-participation than women with access to a vehicle.

Conclusions A long road distance to the screening site was associated with an increased risk of non-participation. Women without access to a vehicle were at higher risk of non-participation than women who had access to a vehicle.
Keywords: cancer, screening, transport.

Background

Denmark runs a nation-wide breast cancer screening programme in an attempt to reduce mortality from breast cancer.[1] Most Western countries recommend such screening despite on-going controversy over harms and benefits as well as the effectiveness of these programmes.[2–6] Population-based breast cancer screening programmes must enjoy high participation rates to be efficient.[1] To achieve efficiency, health-care professionals and administrators often have to rely on 'best practice' and common sense; yet, we need more knowledge about the critical components for achieving efficiency. The geographical distance could be an important issue because it may influence the target-population's ability and propensity to participate.

The association between travel distance to the screening site and participation rates has been studied internationally, but the results have been inconclusive. A longer distance was associated with a higher risk of non-attendance in some studies,[7–9] but not in all;[10,11] and some studies reported vague associations.[12,13] The methods used to assess the distance vary from using women's self-reports[8,9] to applying various types of geographical software to calculate the distance.[12–14] Distance calculation is based on either women's complete addresses,[14] postal codes,[12,13] a combination of the two[11] or self-reported county of residence.[10] The inconclusiveness of the results in this field may be related to the variety of methods applied.

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Divergence may also be rooted in socioeconomic differences and variables access to transportation, hence adjusting for these variables is important in these studies.

The five regions in Denmark have since 2008 been obligated by law to invite their 50–69 years female citizens to participate biannually in organized breast cancer screening free-of-charge. However, some regions already implemented the programme in the 1990s. The national participation rate in the first screening round has been assessed to 77.4%.[15] Denmark is a small country (app. 5.5 million inhabitants) with only 5 cities with more than 70 000 inhabitants and an estimated 13.3% proportion of the population being rural.[16]

In a previous explorative study, we have found an association between distance and participation using rough categorization of distance.[17] The purpose of the present study was to perform a detailed analysis of the association between distance and non-participation in a Danish breast cancer screening programme applying advanced statistical methods to control for relevant confounders.

Methods

Setting

The design of the study is an observational population-based study. It includes women invited to the first screening round in the Central Denmark Region (1.2 million inhabitants, ∼150 000 women aged 50–70). The first screening round was implemented from 28 February 2008 to 31 December 2009 and included all women aged 50–69 years. Women were offered a pre-booked mammogram appointment at one of the six screening sites scattered across the region in the following cities: Aarhus, Horsens, Viborg, Holstebro, Randers and Kjellerup. Women were able to change the date, time and location of their screening appointment and decline participation altogether. Women who did not attend their appointment received no reminders.

Data collection and variables

Data on all invited women ($n = 149\,234$) were collected from a regional administrative database containing information on participation status, screening site, scheduled screening date and the unique identification number (CRN) possessed by all Danes.[18] The primary exposure variable was 'distance to the screening site', which was calculated in Network Analyst, ArcGIS (version 10.0)[19] using the Danish road network. The distance from each woman's residence to her affiliated screening site was calculated based on the shortest driving route in kilometres. The six screening sites were geocoded in Network Analyst based on complete street addresses. Geographical coordinates obtained from the Civil Registration Registry were used to geocode each invited woman's residence on the date of her scheduled screening examination.

Data on socio-demographic variables were obtained from Statistics Denmark.[20] Included variables were: The '*OECD-adjusted household income*' in the year prior to mammography adjusted for number of persons in the household.[21] Based on tertiles the OECD-adjusted household income was categorized as: low, middle and high income. *Education* was classified according to UNESCO classification as low (≤10 years), middle (11–15 years) and higher education (>15 years). *Marital status* was classified as married, cohabitating or single. *Ethnicity* was categorized as Danish/descendants, immigrants from Western countries and immigrants from non-Western countries. The women's age on the screening date was calculated based on the woman's CRN and categorized as: 50–54, 55–59, 60–64 and 65–69 years. Information on the household's *access to a vehicle* was obtained from the Car Register.[22] Access was defined as someone in the women's household being registered as an owner of a vehicle.

The following women were excluded from the analysis (Fig. 1): women not living in the region on the screening date or who were registered with a general practitioner whose

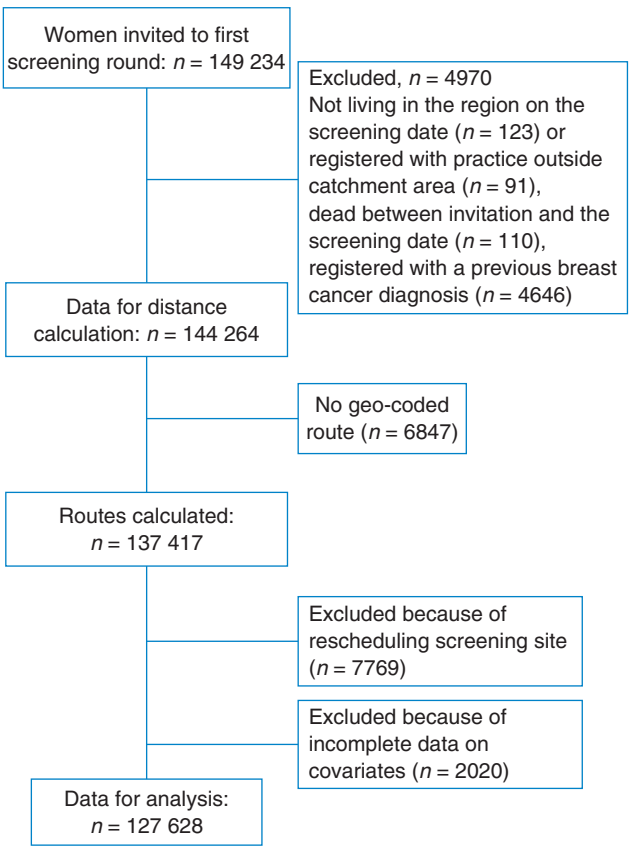

Fig. 1. Flow chart for the study population.

female patients should not be screened in the region; women who had died at the time of the scheduled screening date, or who were registered in the Cancer Registry with a previous breast cancer diagnosis. In addition, women with no calculated route to the screening site and women who had rescheduled their screening site to one of the other screening sites in the region were excluded from the analysis since they directly influenced their distance to the screening site. Women with missing data on variables used in the adjusted models were also excluded. This left 127 628 (85.5%) women for analysis.

According to Danish Legislation and the Central Denmark Region Committees on Biomedical Research Ethics (j.no.: 181/2011), the study was exempt from formal ethical approval because it was based on registry data. The project was approved by the Danish Data Protection Agency (j. no.: 2009-41-3471 and j. no.: 1-16-02-31-11).

Statistical analysis

Risk of non-participation was analysed in a generalized linear model (GLM) from the Bernoulli family. First, an analysis was performed in which the distance to the screening site was categorized as 0–10, >10–15, >15–25, >25–35, >35–45, >45–55, >55–65 and >65 km. This model was applied unadjusted as well as adjusted for age, ethnicity, education, income, marital status and access to vehicle. Additionally, an adjusted analysis stratified for access to a vehicle was conducted.

Secondly, the influence of distance was assessed using three different models applying restricted cubic splines to allow for a smooth non-linear association, which was presented by the method proposed by Orsini and Greenland.[23] Knots were set at 5, 27.5, 50, 72.5 and 95 percentiles as recommended by Harrel,[24] and the reference was set at a distance of 0 km from the women's residence to the screening site. A crude association was illustrated in the first model. The second model was adjusted for age, ethnicity, education, income and marital status; and the third model was adjusted for these five variables as well as access to a vehicle. For all of the above-mentioned analyses we chose a parameterization using a logarithmic link function so that results are given in terms of risk ratios (RRs).

Thirdly, for women with and without access to a vehicle we depicted the overall proportion of non-participation as a function of distance estimated from crude and adjusted spline regression analyses with the aforementioned adjustments and placements of knots. Adjusted proportions were standardized using a standard scale shift moving the origin for each of the correction variables to the population mean. For this part we chose a parameterization using identity link in preference to the logarithmic link, as concavity of the latter would cause the proportion corresponding to a population mean to slightly underestimate the mean proportion.

In all analyses, robust variance estimation was performed to account for clustering of patients in general practices.[25] Calculations were carried out using STATA version 12.

Results

The participation rate in the first screening round was 78.8%. For all women, the median distance to the screening site was 20.3 km with 25 percentiles at 6.6 km and 75 percentiles at 35.7 km. Participants were on average living 1.7 km closer to the screening site than non-participants. Participants and non-participants differed significantly by all socio-demographic variables (chi-square: $P < 0.001$) (Table 1). Women living closer to the screening unit (<10 km) were more often single, were of non-Danish origin, had no access to vehicle, were slightly older, were more often highly educated and had less often middle level income (chi-square: $P \leq 0.001$) (data not shown).

The unadjusted analysis revealed a J-shaped association between distance and non-participation (Table 2 and Fig. 2a). The spline model showed that the risk of non-participation was lowest at ~12 km from the screening site (Fig. 2a). The J-shaped relation disappeared when the data were adjusted for age, ethnicity, education, income and marital status (Fig. 2b). When data were also adjusted for access to a vehicle, the risk of non-participation rose monotonously and almost steadily until ~45 km at which point the curve became less steep (Fig. 2c). Similar results were found in the adjusted analysis when the distance variable was categorized (Table 2). A statistically significantly increased risk of non-participation was observed for women living more than 15 km from the screening site compared with women living 0–10 km from the screening site (Table 2).

A statistically significant difference in the association for women with and without access to a vehicle was observed when an absolute risk scale was used. Women without access to a vehicle were at a higher risk of non-participation at all kilometres than women with access to a vehicle, regardless of the adjustment for socio-demography (Fig. 3a and b). The risk of non-participation increased more per km for women without access to a vehicle than for women with access to a vehicle.

Discussion

Main findings of this study

We found a J-shaped association between the distance to the screening site and non-participation. This association disappeared when the data were adjusted for socio-demography, and the risk of non-participation rose with increasing distance.

Table 1 The distribution of participants ($n = 100\,048$) and non-participants ($n = 27\,580$) in a breast cancer screening programme in relation to women's distance to the screening site and socio-demographic characteristics

	Participants (n = 100 048)	*Non-participants (n = 27 580)*	
Distance in km (numeric)			
Mean (range)	23.2 (0–118.3)	24.9 (0–133.8)	
Median	19.8	22.1	
IQI[a]	6.6–35.0	6.7–38.9	
	n, % (column)	*n*, % (column)	*P*-value (chi-square)
Distance in km (categorical)			
0–10	30 991 (31.0)	8155 (29.7)	<0.001
>10–15	8538 (8.5)	1942 (7.0)	
>15–25	19 850 (19.8)	5091 (18.5)	
>25–35	15 623 (15.6)	4186 (15.2)	
>35–45	10 859 (10.9)	3431 (12.4)	
>45–55	7272 (7.3)	2454 (8.9)	
>55–65	5485 (5.5)	1825 (6.6)	
>65–max	1430 (1.4)	496 (1.8)	
Women's age in years			
50–54	27 000 (27.0)	6699 (24.3)	<0.001
55–59	26 860 (26.9)	6860 (24.8)	
60–64	27 025 (27.0)	7294 (26.5)	
65–70	19 163 (19.1)	6727 (24.4)	
Ethnicity			
Danish	97 099 (96.1)	25 922 (94.0)	<0.001
Western immigrants	1701 (1.7)	731 (2.7)	
Non-Western immigrants	1248 (1.3)	927 (3.4)	
Marital status			
Married	71 518 (71.5)	14 886 (54.0)	<0.001
Cohabiting	6827 (6.8)	2027 (7.4)	
Single	21 703 (21.7)	10 667 (38.7)	
Education			
Low	35 357 (35.3)	11 822 (42.9)	<0.001
Middle	42 154 (42.1)	9935 (36.0)	
High	22 537 (22.5)	5823 (21.1)	
Household income			
Low	29 617 (29.6)	12 901 (46.8)	<0.001
Middle	34 666 (34.7)	8241 (29.9)	
High	35 765 (35.7)	6438 (23.3)	
Access to vehicle			
Yes	88 155 (88.1)	19 683 (71.4)	<0.001
No	11 893 (11.9)	7897 (28.6)	

[a]IQI, interquartile interval: 25 and 75 percentiles of the distribution.

The risk curve was steepest until a distance of ~45 km to the screening site after which the curve flattened. Women with no access to a vehicle were more at risk for non-participation than women with access to a vehicle, and the risk of non-participation increased more per km for women without access to a vehicle.

What is already known on this topic

The results on the association between distance and non-participation are, in general, inconclusive. Studies reporting that a longer distance is associated with a higher level of non-participation have generally studied European populations.[7–9] In these studies, distance was estimated based on the self-reported distance to the screening facility,[9] or the distance was estimated from a map,[7] or the women were simply asked to report reasons for non-participation and mentioned distance.[8] In the two studies reporting vague associations between distance and non-participation, the distance estimates were based on ZIP codes for both the women's addresses and the addresses of the screening facilities.[12,13] ZIP codes give a rather imprecise estimate of distance since all the women living in the same ZIP code area are categorized as having the same starting point. The studies reporting no associations between distance and participation are all from the USA. One of these studies investigated the association by using standardized 'commuting time' based on data from population-based census tracks;[10] the other study reported the odds of non-participation by comparing women who were living more than 3 miles from a screening unit with women living less than 3 miles from a screening unit.[11] These studies testify the differences in methods applied, and the methodological diversity may, in part, explain the different conclusions. An explanation for the inconclusive results could also be culturally determined variations in attitudes towards driving distance influenced by usual proximity to health-care providers and country-wise defined frame of references concerning what is a long distance.

Concerning access to a vehicle, the few previous findings have revealed no clear picture. One previous study from 1990 compared the proportion of participants who had access to a vehicle with the background population and found a higher proportion of access to a vehicle among participants than among the background population.[9] Another study analysed whether women living in areas in which a high proportion had access to a car were more likely to participate than women living in areas in which a low proportion had access to a car, but this study found no association.[10]

Table 2 Crude, adjusted and stratified RRs with 95% confidence intervals for associations between distance in km and screening non-participation

	Unadjusted	*Adjusted*[a]	*Stratified on access to vehicle*[b]	
			Access	*No access*
Distance in km				
0–10	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
>10–15	0.89 (0.83–0.95)	1.04 (0.97–1.11)	1.05 (0.97–1.13)	0.99 (0.91–1.08)
>15–25	0.98 (0.92–1.04)	1.11 (1.05–1.17)	1.09 (1.03–1.16)	1.14 (1.07–1.21)
>25–35	1.01 (0.95–1.08)	1.16 (1.10–1.23)	1.14 (1.07–1.22)	1.23 (1.16–1.31)
>35–45	1.15 (1.06–1.25)	1.30 (1.21–1.40)	1.29 (1.19–1.40)	1.31 (1.21–1.41)
>45–55	1.21 (1.11–1.32)	1.35 (1.25–1.46)	1.35 (1.24–1.47)	1.32 (1.20–1.44)
>55–65	1.20 (1.11–1.30)	1.30 (1.21–1.41)	1.31 (1.20–1.43)	1.27 (1.17–1.38)
>65 max	1.24 (1.10–1.39)	1.36 (1.22–1.52)	1.32 (1.15–1.51)	1.46 (1.27–1.68)

[a]Adjusted for age, ethnicity, education, income, marital status and access to vehicle.

[b]Adjusted for age, ethnicity, education, income and marital status.

What this study adds

In our study, revealing a fairly robust association between distance and screening participation, distance calculations were based on accurate addresses and individual geographical coordinates for every woman. Using individual data from the valid Danish Car Register,[22] we found that women without access to a vehicle were at higher risk of non-participation than women who had access to a vehicle.

Half of the women were living fairly close (20 km or less) to the screening site (see Table 1 for median for participants and non-participants). The adjusted risk of non-participation reached statistical significance at 15 km (Table 2), indicating that more than half of the women had an increased risk of non-participation due to distance. This indicates that the distance to the screening unit played an important role for participation in this breast cancer screening programme. The efficiency and the benefits from centralizing screening for breast cancer must therefore be weighed against the risk of a lower participation rate because of a longer distance to the screening sites for some women. One important factor in this regard was access to a vehicle. Health-care planners could consider how to make the programme more attractive and more accessible for women without access to a vehicle. A possible solution could be to implement mobile screening units or to help organizing transportation or car pool for women with transportation challenges.

Limitations of this study

This population-based study benefitted from a large sample which ensures a high level of statistical precision. The population was identified in complete regional and national registries; and it was possible to link different registers using the CRN.[18] Thus, we were able to include the entire population of women invited to the first screening round in the Central Denmark Region. Furthermore, we could exclude women who had moved out of the region or had died. Information bias was therefore low. However, some limitations must be mentioned.

Women who had rescheduled their screening site were excluded from the study. We did so because this group had influenced their assigned distance to the screening site and any rescheduling would likely be associated with the outcome as reflected in higher participation rate (91.8% of the women who rescheduled participated versus 78.2% participants among non-rescheduling women). Women's social characteristics also differed between the two groups with women who rescheduled being slightly younger, more often single and had more often higher education and income (data not shown). Women might have rescheduled their screening site to another unit further away from home, but closer to their workplace, family, etc. This would increase the distance, but also raise their chances of participation. This scenario could have underestimated the influence of distance on the participation rate. Hence, including this group may have introduced selection bias, although running the regression analysis as a sensitivity analysis where we included women who rescheduled their screening unit yielded almost identical results as when this group was excluded (data not shown).

A route between the residence and screening site could not be calculated for about 5% of the women because of inconsistency between ArcGIS and the geographical coordinates. A similar problem was found in another study which dubbed

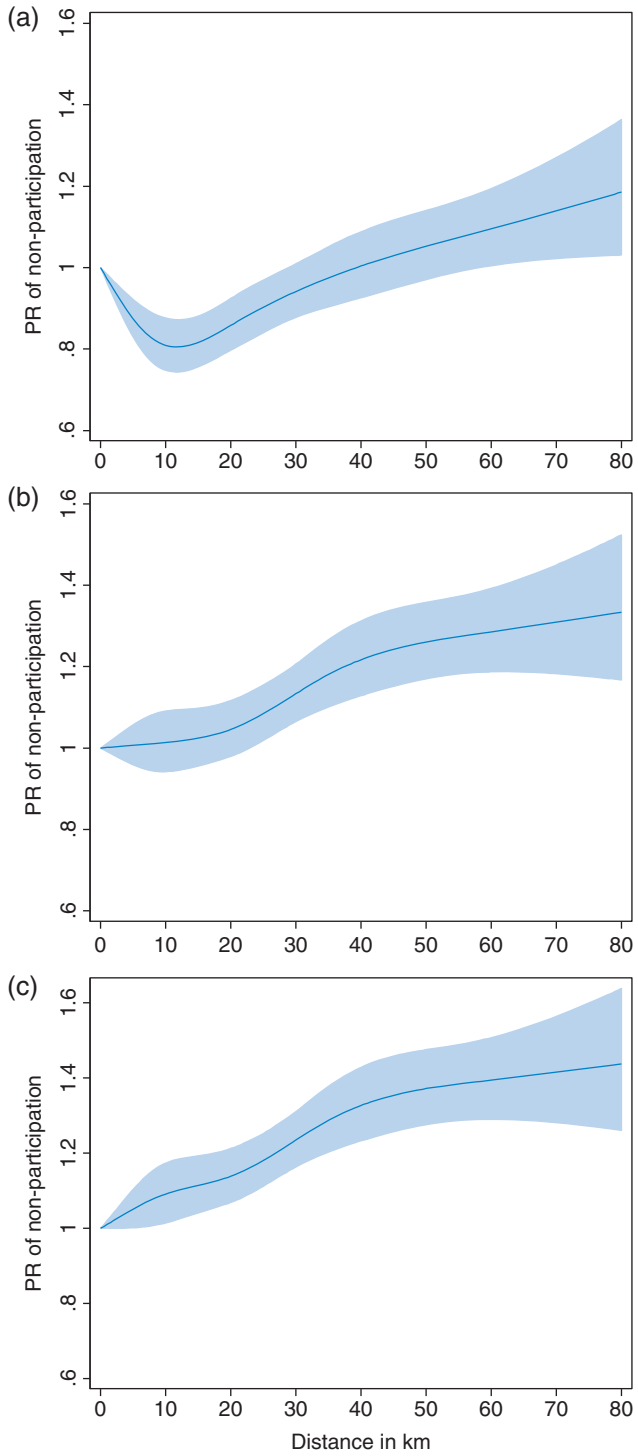

Fig. 2. Association between distance and non-participation as estimated using cubic spline models with four knots (reference 0 km.). (**a**) Unadjusted association between distance and non-participation with corresponding 95% confidence interval (CI). (**b**) Adjusted for age, ethnicity, education, income and marital status with corresponding 95% CI. (**c**) Adjusted for variables in (b) and access to vehicle with corresponding 95% CI.

this type of information bias 'geographical bias'.[26] Analysis showed that women with an uncalculated route did not differ significantly from women with calculated routes in terms of marital status, education and screening participation, but the former were significantly younger, more likely to be immigrants from non-Western countries, more likely not to have access to a vehicle and had higher income than the latter (data not shown). These data indicate that the distribution of missing routes was not equally distributed between all social characteristics. Further, we are unaware of how the missing routes were associated with distance, and selection bias may be present if women with uncalculated routes in general lived closer to or further away from the screening unit. We assess this bias to be less important in this study since it was not associated with the study outcome (e.g. non-participants were not more likely to have uncalculated routes).

Geographical software (Network Analyst, ArcGIS) was used to calculate the road distance to the screening site. This gave precise estimates of the distance between the screening site and the women's residence on the day they were booked for screening (regardless of whether they participated or not). However, some of the participants may have driven to the screening from their workplace rather than from home. We had no data on this.

To our knowledge, no previous studies have used flexible parametrization that allows for a smooth non-linear relationship between distance and non-participation. Previous studies have studied distance using various categorizations of the distance variable,[7,11] or by estimating an effect per 5 or 10 km increase in distance.[12,13] Our study thus draws one of its main strengths from an advanced analysis.

As one of the first studies, we took into account access to a vehicle. However, a limitation of the 'Car Register' is that it does not include leased cars and business cars. Statistics Denmark estimated that in 2007–11, 7% of all newly acquired cars were private leased cars[27] indicating that leasing is not uncommon in Denmark and hence, the prevalence of people having access to a vehicle may therefore be underestimated. We had no information on public transportation in relation to this study. This could have been an interesting variable to take into consideration given the variability in access to public transportation across the region, with areas around the larger cities (e.g. Aarhus) having more fluent and frequent public transportation options than women in the countryside.

Finally, residual confounding cannot be ruled out since not all possible confounders were adjusted for. Other factors of importance could be co-morbidity, family history of breast cancer and neighbourhood-level socio-demography.

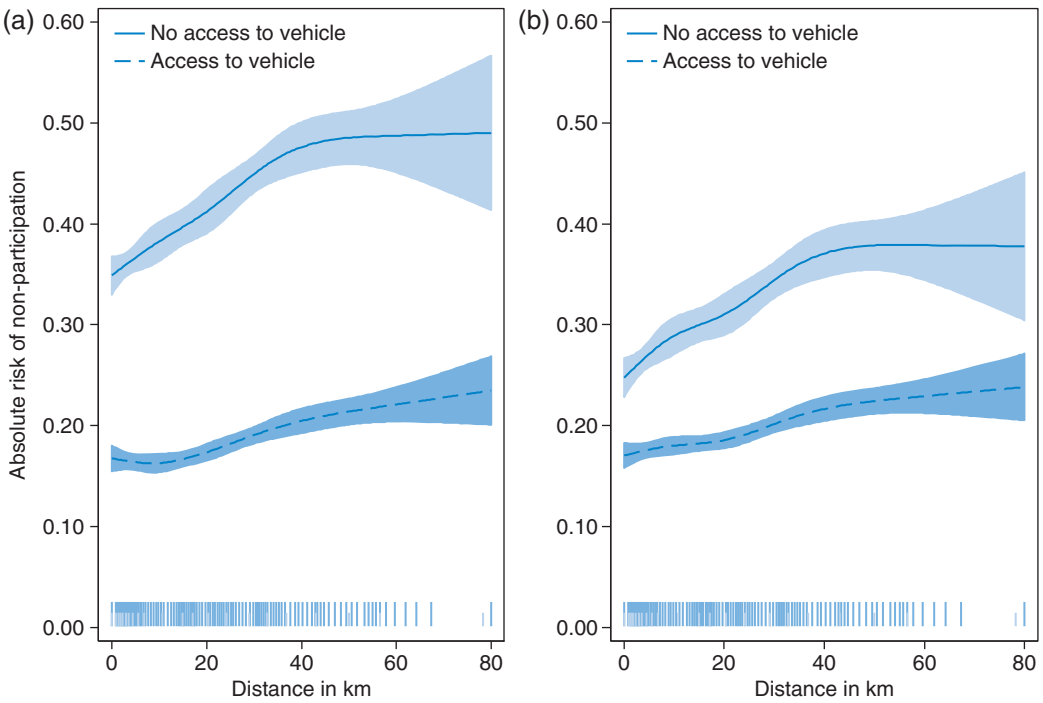

Fig. 3. The unadjusted and adjusted risk for non-participation in relation to distance in km, stratified according to access to a vehicle. (**a**) Unadjusted association between distance and non-participation with corresponding 95% confidence interval (CI) stratified on access to vehicle. (**b**) Adjusted for age, ethnicity, education, income and marital status with corresponding 95% CI stratified on access to vehicle. Spikes per 1000 women illustrate the distance distribution in the population in the bottom of the figure (light blue represent women with access to a vehicle and dark blue women without access to a vehicle).

Conclusions

This study analysed in detail the association between distance to the screening site and non-participation. The risk of non-participation grew with increasing road distance to the screening site when data were adjusted for socio-demography. Women without access to a vehicle were at special risk of non-participation irrespective of their distance to the screening site. This knowledge should be taken into account when planning breast cancer screening programmes.

Authors' contributions

A.F.P., B.A., L.F.J. and P.V. conceived the idea. P.V., A.F.P., M.F.G. and B.A. contributed with input and critical revision of the statistical analyses and the contents of the paper. L.F.J. conducted the distance calculations in ArcGIS and drafted the manuscript. L.F.J. was primarily responsible for the statistical analyses in close collaboration with M.F.G. All authors read and approved the final version of the manuscript.

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Conflict of interest

The authors declare no competing interests.

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