

Title: Breast compression across consecutive examinations among women participating in BreastScreen XXX

Running title: Breast compression across consecutive screening examinations

Abstract

Objectives

Breast compression is used in mammography to improve image quality and reduce radiation dose. However, optimal values for compression force are not known, and studies has found large variation in use of compression forces between breast centres and radiographers. We investigated breast compression, including compression force, compression pressure and compressed breast thickness across four consecutive full field digital mammography (FFDM) screening examinations for 25,143 subsequently screened women aged 50-69 years.

Methods

Information from women attending four consecutive screening examinations at two breast centres in BreastScreen XXX during January 2007 - March 2016 was available. We compared the changes in compression force, compression pressure and compressed breast thickness from the first to fourth consecutive screening examination, stratified by craniocaudal (CC) and mediolateral oblique (MLO) view.

Results

Compression force, compression pressure and compressed breast thickness increased relatively by 18.3%, 14.4% and 8.4% respectively, from first to fourth consecutive screening examination in CC view ($p < 0.001$ for all). For MLO view, the values increased relatively by 12.3% for compression force, 9.9% for compression pressure and 6.9% for compressed breast thickness from first to fourth consecutive screening examination ($p < 0.001$ for all).

Conclusions

We observed increasing values of breast compression parameters across consecutive screening examinations. Further research should investigate the effect of this variation on image quality and women's experiences of discomfort and pain.

Advances in Knowledge: Breast compression force, compression pressure and compressed breast thickness increased across consecutive screening examinations, which might be of influence for the women's experiences of discomfort and pain during the examination and for image quality.

Keywords: breast; screening; mammography; compression; radiography

Introduction

Consistent production of high quality mammograms is crucial in mammographic screening to allow optimal visualization of the breast. Breast compression is used during image acquisition to achieve optimal image quality and reduced radiation dose^{1,2}. The radiographer who performs the examination, positions and places the woman's breast on the image detector and compresses the breast to reduce breast thickness³. Compression is measured in force, and the value is visible to the radiographer during the examination. However, optimal values for compression force are not known². National and international guidelines for quality assurance in mammography either have a large range of accepted compression force values³⁻⁶, or they include subjective statements for the compression force². For instance, the European guidelines for quality assurance in breast cancer screening and diagnosis suggest that "the breast should be properly compressed, but no more than is necessary to achieve a good image quality"². Further, the compression force is recommended to be minimum 98.1 Newton (N) (> 10 kp) in Germany⁴, maximum 200 N (or 20 kg) in the UK⁵, between 120-200 N (12-20 daN) in the Netherlands³ and between 108-177 N (11-18 kg) in XXX⁶.

These large ranges in numeric values and subjective descriptions of breast compression may reflect possibilities for individualization, that the radiographer can adjust the compression force to the individual breast and preferences of the women. However, lack of precise and objective recommendations for breast compression might lead to subjective and inconsistent variations in compression force between and within women. Studies have observed large variations between breast imaging centres and among radiographers in the use of compression forces⁷⁻¹¹, also for the individual women^{10, 11}.

Several factors affects compression force application, such as positioning, the woman, and the radiographer. Positioning includes appropriate image receptor height¹², distance between woman and image receptor³, and the positioning and fixating of the breast on the image receptor³. Factors related to the woman, such as breast size and composition¹³, the woman's cooperative ability, whether she is experiencing or tolerating discomfort or pain, and mobility; whether she has any tension or pain in neck or shoulder, may affect both the amount of compression force that is applied and also the positioning. The radiographer performs both the positioning and applies compression force. The practical, communication and social skills of the radiographer is thus of importance.

We assume that breast compression is a key factor for image quality. Varying breast compression for the same woman when attending consecutive screening examinations might result in different image quality between images from different screening examinations. This may represent a challenge for the screen-readers in the reading process as they use prior mammograms for comparison. In this longitudinal retrospective study, we investigated breast compression parameters across four consecutive screening examinations for the individual women. The results of this study might provide insight to whether a change in breast compression practice is required or not.

Materials and methods

The Regional committee for health research ethics approved this study (Reference 2016/938). BreastScreen XXX invites all women aged 50-69 years to biennial mammographic screening. The program is administered by the Cancer Registry of XXX, and is described in detail elsewhere¹⁴.

Information from 108,229 women screened with full field digital mammography (FFDM) using General Electric (GE, Senographe Essential) at two breast centres (Rogaland and Hordaland) as a part of BreastScreen XXX in the period from January 2007 to March 2016 was available. The available information was solely from women who had not refused the Cancer Registry to use data about their screening examination for quality assurance and research, and included both screening positive and negative cases. Both breast centres used flexible compression paddles during the study period and quality assurance of the equipment was performed daily and weekly by the radiographers according to guidelines of the program¹⁵. In addition, calibration of the equipment was performed and approved twice a year by representatives from the vendor. From each examination, the following data were extracted: woman age, breast compression parameters (compression force [Newton, N]; compression pressure [kilopascal, kPa]; compressed breast thickness [mm]), and breast characteristics (breast volume [cm³]; fibroglandular volume [cm³]; and volumetric breast density [VBD, percentage, %]. This information was obtained retrospectively from the Cancer Registry's databases, the Digital Imaging and Communications in Medicine (DICOM)¹⁶ header of the images and by assessing the images in an automated software for mammographic density estimation (VolparaDensity version 4, Matakina, Wellington NZ)¹⁷.

We included solely information from subsequently screened women who had participated in four consecutive screening examinations (less than 2.5 years since the prior screening examination) with four standard views (left and right breast in craniocaudal, CC; and mediolateral oblique, MLO view) (Figure 1). By including only subsequently screened women, we ensured that all women had at least one experience of breast compression before they entered the study population. Our final study population included 25,143 women with four consecutive screening examinations (100,572 examinations and 402,288 images in total), performed during the study period. In this paper ‘first screening examination’ reflects the first screening examination for the women in the study period. The second, third and fourth consecutive screening examinations reflected the consecutive screening examinations 2, 4 and 6 years later, respectively.

Statistical analysis

To meet assumptions of independency between observations, all analyses were performed for left breast only. We calculated mean and 95% confidence interval (95% CI) of age, breast volume, fibroglandular volume and volumetric breast density for the study population by consecutive screening examinations (first to fourth). Further, mean and 95% CI of compression force, compression pressure and compressed breast thickness were calculated by consecutive screening examinations and view (CC, MLO). Analysis of variance (ANOVA), Tukey’s Honestly significant different (HSD) pairwise comparisons, and t-tests was used to test for differences in mean values for the covariates. Percentage difference from first to fourth consecutive screening examination was calculated for compression force, compression pressure and compressed breast thickness.

We used Generalized Estimating Equation (GEE) to investigate whether breast compression parameters changed between consecutive screening examinations. GEE is an appropriate statistical method to account for within-group dependency between the variables¹⁸. Using GEE, we performed a linear regression with robust standard errors with each of the breast compression parameters as the outcome variable and consecutive screening examinations as the explanatory variable, adjusting for breast volume, fibroglandular volume, the woman's age, breast centre and calendar year, stratified by view. Breast volume was excluded from the model with compression pressure due to collinearity¹⁹. To simplify the interpretation of the intercept term in the linear regression model we standardized all covariates in the model. We modelled both the additive and the multiplicative change in breast compression parameters. The estimated coefficients represents the change in breast compression parameters between consecutive screening examinations.

All statistical analyses were conducted using Stata Statistical Software (version 14.2, *Stata Corp*, College Station, Texas, USA)²⁰.

Results

Mean age of the study population was 58.1 years (95% CI: 58.1-58.1) at first screening examination, while mean breast volume, fibroglandular volume and volumetric breast density was 820.3 cm³ (95% CI: 816.5-824.1), 45.5 cm³ (95% CI: 45.3-45.7) and 6.6 % (95% CI: 6.6-6.7), respectively (Table 1). Mean breast volume increased, while fibroglandular volume and volumetric breast density decreased by consecutive screening examinations. Women from Rogaland were slightly younger than women from Hordaland (first consecutive screening examination: 58.0 versus 58.2 years), had higher mean values of breast volume (853.4 versus 772.3 cm³), fibroglandular volume (47.2 versus 42.9 cm³) and volumetric breast density (6.7 versus 6.6) ($p < 0.001$ for all).

Mean observed compression force, compression pressure and compressed breast thickness increased by consecutive screening examinations for CC and MLO view ($p < 0.001$) (Table 2). For CC view, mean observed compression force, compression pressure and compressed breast thickness increased from 106.7 to 121.0 N, from 13.4 to 14.9 kPa and from 52.7 to 55.8 mm respectively, from first to fourth consecutive screening examination. For MLO view, the mean observed compression force, compression pressure and compressed breast thickness increased from 120.2 to 129.8 N, from 9.4 to 10.1 kPa and from 56.5 to 59.0 mm, respectively.

Table 1: Study population characteristics; mean values of age (years), breast volume (cm³), fibroglandular volume (cm³), and volumetric breast density (%) with 95% confidence interval (95% CI), by consecutive screening examinations (first to fourth), in total and by breast centre (Rogaland, Hordaland)

	Consecutive screening examinations							
	Mean	First (95% CI)	Mean	Second (95% CI)	Mean	Third (95% CI)	Mean	Fourth (95% CI)
Total (n= 25,143 women)								
Age, years	58.1	(58.1-58.1)	60.2	(60.1-60.2)	62.3	(62.3-62.3)	64.4	(64.4-64.5)
Breast volume, cm ³	820.3	(816.5-824.1)	835.5	(831.7-839.3)	860.3	(856.6-864.1)	889.4	(885.6-893.1)
Fibroglandular volume, cm ³	45.5	(45.3-45.7)	43.8	(43.6-44.0)	44.6	(44.4-44.8)	43.9	(43.7-44.1)
Volumetric breast density, %	6.6	(6.6-6.7)	6.2	(6.2-6.3)	6.0	(6.0-6.1)	5.7	(5.7-5.7)
Rogaland (n= 14,874 women)								
Age, years	58.0	(58.0-58.0)	60.1	(60.1-60.2)	62.3	(62.2-62.3)	64.5	(64.4-64.5)
Breast volume, cm ³	853.4	(848.2-858.6)	856.7	(851.4-862.0)	865.6	(860.4-870.8)	902.9	(897.7-908.1)
Fibroglandular volume, cm ³	47.2	(47.0-47.5)	44.8	(44.6-45.1)	46.4	(46.1-46.6)	45.4	(45.1-45.7)
Volumetric breast density, %	6.7	(6.7-6.8)	6.3	(6.3-6.3)	6.3	(6.2-6.3)	5.8	(5.8-5.9)
Hordaland (n= 10,269 women)								
Age, years	58.2	(58.2-58.3)	60.2	(60.2-60.3)	62.3	(62.2-62.3)	64.4	(64.4-64.5)
Breast volume, cm ³	772.3	(767.1-777.6)	804.7	(799.5-810.0)	852.7	(847.3-858.0)	869.7	(864.5-875.0)
Fibroglandular volume, cm ³	42.9	(42.6-43.2)	42.1	(42.1-42.6)	41.8	(41.8-42.4)	41.3	(41.3-41.9)
Volumetric breast density, %	6.6	(6.5-6.6)	6.1	(6.1-6.2)	5.7	(5.7-5.8)	5.5	(5.4-5.5)

Table 2: Breast compression parameters: mean observed compression force (Newton, N), compression pressure (kilopascal, kPa), and compressed breast thickness (mm) with 95% confidence interval (95% CI), by consecutive screening examinations (first to fourth) and view (CC, MLO), in total and by breast centre (Rogaland, Hordaland). Percentage change (% change) is from first to fourth screening examination.

	Consecutive screening examinations					% change
	First Mean (95% CI)	Second Mean (95% CI)	Third Mean (95% CI)	Fourth Mean (95% CI)		
Total (n= 25,143 women)	CC view					
Force, Newton	106.7 (106.4-107.0)	114.4 ^b (114.2-114.7)	120.0 ^b (119.7-120.2)	121.0 ^b (120.8-121.2)	13.4 %	
Pressure, kiloPascal	13.4 (13.3-13.5)	14.0 ^b (13.95-14.09)	14.6 ^b (14.5-14.64)	14.9 ^b (14.81-14.96)	11.2 %	
Breast thickness, mm	52.7 (52.5-52.8)	52.2 ^b (52.1-52.4)	53.7 ^b (53.5-53.8)	55.8 ^b (55.6-55.9)	5.9 %	
Rogaland (n= 14,874 women)						
Force, Newton	114.7 (114.3-115.0)	119.5 ^b (119.2-119.8)	124.9 ^b (124.6-125.2)	125.1 (124.9-125.3)	9.1 %	
Pressure, kiloPascal	14.5 (14.4-14.6)	14.5 (14.43-14.62)	14.7 ^a (14.64-14.85)	15.0 ^b (14.94-15.15)	3.4 %	
Breast thickness, mm	53.3 (53.2-53.5)	51.5 ^b (51.3-51.6)	51.5 (51.3-51.6)	54.1 ^b (53.9-54.2)	1.5 %	
Hordaland (n= 10,269 women)						
Force, Newton	95.2 (94.8-95.6)	107.0 ^b (106.8-107.5)	112.9 ^b (112.6-113.2)	115.0 ^b (114.7-115.4)	20.8 %	
Pressure, kiloPascal	11.8 (11.7-11.9)	13.3 ^b (13.19-13.38)	14.3 ^b (14.22-14.42)	14.7 ^b (14.56-14.76)	24.6 %	
Breast thickness, mm	51.7 (51.5-51.9)	53.3 ^b (53.1-53.6)	56.8 ^b (56.6-57.1)	58.3 ^b (58.1-58.5)	12.8 %	
Total (n= 25,143 women)	MLO view					
Force, Newton	120.2 (119.9-120.5)	126.9 ^b (126.6-127.1)	130.4 ^b (130.2-130.7)	129.8 ^a (129.6-130.0)	8.0 %	
Pressure, kiloPascal	9.4 (9.4-9.5)	9.8 ^b (9.7-9.8)	10.0 ^b (10.0-10.1)	10.1 ^a (10.1-10.1)	7.4 %	
Breast thickness, mm	56.5 (56.3-56.6)	56.2 ^a (56.0-56.3)	57.2 ^b (57.0-57.3)	59.0 ^b (58.8-59.1)	4.4 %	
Rogaland (n= 14,874 women)						
Force, Newton	126.3 (125.9-126.6)	129.6 ^b (129.3-129.9)	132.0 ^b (131.7-132.3)	131.6 (131.4-131.9)	4.2 %	
Pressure, kiloPascal	9.8 (9.7-9.8)	9.7 ^a (9.6-9.7)	9.7 (9.7-9.8)	9.8 (9.7-9.8)	0.0%	
Breast thickness, mm	56.9 (56.7-57.1)	55.5 ^b (55.3-55.7)	55.3 (55.1-55.5)	57.5 ^b (57.3-57.7)	1.1 %	
Hordaland (n= 10,269 women)						
Force, Newton	111.4 (110.9-111.9)	123.0 ^b (122.6-123.4)	128.2 ^b (127.9-128.6)	127.2 ^b (126.8-127.5)	14.2 %	
Pressure, kiloPascal	9.0 (8.9-9.0)	9.9 ^b (9.8-9.9)	10.5 ^b (10.5-10.6)	10.6 (10.5-10.6)	17.8 %	
Breast thickness, mm	55.8 (55.5-56.0)	57.1 ^b (56.8-57.3)	60.0 ^b (59.7-60.2)	61.2 ^b (61.0-61.4)	9.7 %	

^aStatistically significantly different to prior screening examination, p <0.05 | ^bStatistically significantly different to prior screening examination, p <0.001

Compression force

Compression force increased by consecutive screening examinations when adjusting for breast volume, fibroglandular volume, the woman's age, breast centre and calendar year (Table 3). For CC view, compression force increased by 5.8, 9.0 and 7.7 N respectively, from first to second, third and fourth consecutive screening examination ($p < 0.001$ for all). For MLO view, it increased by 6.0, 8.9 and 7.5 N respectively, from first to second, third and fourth consecutive screening examination ($p < 0.001$ for all).

Compression force increased relatively by 11.5%, 17.1% and 18.3% in CC view and 9.6%, 12.9% and 12.3% in MLO view, from first to second, third and fourth consecutive screening examination, respectively (Figure 2 and 3, $p < 0.001$ for all).

Compression pressure

Compression pressure increased by consecutive screening examinations when adjusting for fibroglandular volume, the woman's age, breast centre and calendar year (Table 3). For CC view, compression pressure increased by 0.5, 1.1 and 1.4 kPa respectively, from first to second, third and fourth consecutive screening examination ($p < 0.001$ for all). For MLO view, it increased by 0.4, 0.7 and 0.8 kPa respectively, from first to second, third and fourth consecutive screening examination ($p < 0.001$ for all).

Compression pressure increased relatively by 7.7%, 12.1% and 14.4% in CC view and 6.2%, 9.2% and 9.9% in MLO view, from first to second, third and fourth consecutive screening examination, respectively (Figure 2 and 3, $p < 0.001$ for all).

Compressed breast thickness

Compressed breast thickness decreased from first to second screening examination and increased from second to fourth when adjusting for breast volume, fibroglandular volume, the woman's age, breast centre and calendar year (Table 3). For CC view, compressed breast thickness changed by -0.4, 0.6 and 2.3 mm respectively, from first to second, third and fourth consecutive screening examination ($p < 0.001$ for all). For MLO view, it changed by -0.4, 0.7 and 2.2 mm respectively, from first to second, third and fourth consecutive screening examination ($p < 0.001$ for all).

Compressed breast thickness increased relatively by 0.3%, 3.7% and 8.4% in CC view ($p < 0.01$ for all) and 0.5%, 3.1% and 6.9% in MLO view ($p < 0.001$ for all), from first to second, third and fourth consecutive screening examination, respectively (Figure 2 and 3).

Table 3: Results from linear regression of the effect of consecutive screening examination (1-4) on compression force (Newton, N), compression pressure (kilopascal, kPa), and compressed breast thickness (mm), when adjusting for breast volume, fibroglandular volume (FGV), breast centre, the woman's age and calendar year, by view (CC, MLO).

	Compression force		Compression pressure		Compressed breast thickness	
	Coef	95% CI	Coef	95% CI	Coef	95% CI
CC view						
Consecutive screening examination						
1 ^a	1.00		1.00		1.00	
2	5.82 ^b	(5.35 - 6.28)	0.54 ^b	(0.43-0.65)	-0.38 ^b	(-0.55 - -0.21)
3	8.95 ^b	(8.17 - 9.73)	1.11 ^b	(0.90 - 1.32)	0.60 ^b	(0.26 - 0.93)
4	7.68 ^b	(6.56 - 8.81)	1.38 ^b	(1.07 - 1.69)	2.26 ^b	(1.75 - 2.76)
Breast volume	0.01 ^b	(0.01 - 0.01)			0.03 ^b	(0.03 - 0.03)
FGV	0.06 ^b	(0.05 - 0.07)	-0.03 ^b	(-0.03 - -0.03)	-0.04 ^b	(-0.05 - -0.04)
Breast center						
Rogaland ^a	1.00		1.00		1.00	
Hordaland	-13.67 ^b	(-13.93 - -13.41)	-1.51 ^b	(-1.63 - -1.38)	1.92 ^b	(1.72 - 2.12)
Age	0.19 ^b	(0.16 - 0.23)	-0.18 ^b	(-0.20 - 0.24)	-0.30 ^b	(-0.33 - -0.28)
Year	0.69 ^b	(0.52 - 0.86)	0.20 ^b	(0.15 - 0.24)	0.05	(-0.03 - 0.13)
Constant	115.5 ^b	(114.89 - 116.10)	14.07 ^b	(13.89 - 14.26)	52.18 ^b	(51.89 - 52.47)
MLO view						
Consecutive screening examination						
1 ^a	1.00		1.00		1.00	
2	6.04 ^b	(5.55 - 6.53)	0.36 ^b	(0.30 - 0.42)	-0.36 ^b	(-0.52 - -0.20)
3	8.93 ^b	(8.11 - 9.76)	0.71 ^b	(0.60 - 0.82)	0.70 ^b	(0.39 - 1.01)
4	7.50 ^b	(6.32 - 8.69)	0.84 ^b	(0.67 - 1.01)	2.21 ^b	(1.74 - 2.69)
Breast volume	0.01 ^b	(0.01 - 0.01)			0.03 ^b	(0.03 - 0.03)
FGV	0.01 ^b	(0.00 - 0.02)	-0.02 ^b	(-0.02 - -0.02)	-0.04 ^b	(-0.04 - -0.04)
Breast center						
Rogaland ^a	1.00		1.00		1.00	
Hordaland	-6.38 ^b	(-6.66 - -6.09)	0.03 ^b	(-0.03 - 0.08)	4.12 ^b	(3.95 - 4.29)
Age	0.09 ^b	(0.05 - 0.13)	-0.08 ^b	(-0.09 - -0.07)	-0.25 ^b	(-0.28 - -0.23)
Year	0.11	(-0.07 - 0.29)	0.05 ^b	(0.02 - 0.07)	0.00	(-0.07 - 0.08)
Constant	123.82 ^b	(123.18 - 124.46)	9.34 ^b	(9.25 - 9.44)	54.88 ^b	(54.62 - 55.15)

^aReference | ^bStatistically significant, p<0.001

Discussion

Our study identified that compression force, compression pressure and compressed breast thickness increased statistically significantly by consecutive screening examinations when adjusting for breast volume, fibroglandular volume, the woman's age, breast centre and calendar year. From first to fourth consecutive screening examination, compression force, compression pressure and compressed breast thickness increased relatively by 18.3%, 14.4% and 8.4% respectively in CC view and by 12.3%, 9.9% and 6.9% for MLO view.

One explanation for this increase might be related to changes in the breasts; the women's breast volume increased, while fibroglandular volume decreased across consecutive screening examinations, thus the volumetric breast density decreased. Decreasing fibroglandular volume is likely to be a result of involution, the process where dense tissue is replaced by fatty tissue²¹. As the women's age and breasts change over the consecutive screening examinations, one could expect the radiographers to alter the breast compression too, in order to compensate for a different breast composition. However, breast compression parameters also increased when adjusting for breast volume, fibroglandular volume, age, breast centre and calendar year. Thus, other factors related to the practice at the breast centres may be reason for the change in breast compression over time or by consecutive screening examination^{10, 11}.

Nevertheless, radiographers from the two breast centres informed us that no deliberate change in local practice for breast compression or positioning occurred during the study period (email correspondence, November 2017).

Implications for clinical practice

It is unknown what size of changes in breast compression parameters that will cause an effect on image quality. However, we assume that varying breast compression will have

consequences for image quality and experiences of discomfort and pain. With today's guidelines for breast compression, breast compression parameters increase by consecutive screening examinations in BreastScreen XXX, also when adjusting for breast related factors. Thus, the quality between the images from the consecutive screening examinations might be different. This may challenge the screen-reader when comparing with prior mammograms. Further, some women find mammography painful²²⁻²⁴. Increased breast compression over time might have consequences for the experiences of the women. Uncomfortable or painful experiences can influence whether the women re-attend screening^{25, 26}. However, a study by Moshina *et al* observed that women receiving the lowest values of compression force (< 10.0 kg) or compression pressure (< 9.0 kPa) at their prevalent screening examination had the lowest re-attendance for subsequent screening (85 %)²⁷. Further research investigating the effect of varying breast compression on image quality and experiences of discomfort or pain for the women is needed.

Given the assumption that varying breast compression affect image quality and experiences of the women, there should be a goal to reduce this variation in order to have similar experiences and comparable images for the same woman, regardless of location and radiographers performing the examinations.

One way to reduce variation in breast compression is to standardize a compression pressure and implement breast compression paddles displaying the pressure for the radiographers during the examination²⁸⁻³⁰. However, use of such paddles are still highly dependent on positioning, thus the paddle itself does not guarantee similar breast compression. For instance, if pressure is concentrated to the pectoral muscle at one screening examination and at the breast itself at the consecutive^{31, 32}, there might still be different breast compression and image quality.

As a solution to reduce variation in breast compression for women from one screening examination to another, we recommend standardizing positioning technique, thereby increasing focus on and facilitating reproducible imaging. A national step-by-step guide to positioning technique could be developed, as in the Dutch Screening Program³. The radiographers could check prior images and compression force applied at prior screening examination to reduce variation. With only minor changes in breast positioning and compression parameters, the image quality should be comparable. However, if a suboptimal compression force were used at the prior screening examination, this could continue through several consecutive screening examinations, leading to consistent production of images with reduced image quality. However, by performing continuous quality assurance, this issue could be solved.

Limitations

Only two of the sixteen breast centres in BreastScreen XXX were included in the study. The study did not include information about the individual radiographers, which could have provided insight in variation in breast compression between radiographers on the same women, as shown in the longitudinal studies from the UK^{10, 11}. The study population included both women with positive and negative screening examinations. We did not have information about the outcome of the examinations on an individual level; however, most of the examinations were negative screening examinations. Further research investigating variation in breast compression among women with positive versus negative screening examinations is recommended. Further, we did not assess image quality, thus we do not know whether the increased breast compression observed in our study had an effect of image quality. Studies has reported different effects on image quality with changes in breast compression parameters

of this magnitude³³⁻³⁸, from minimal and no impact on image quality³³⁻³⁶, to considerable and significant effects on image quality^{37, 38}.

Conclusions

This is the first study investigating breast compression parameters over consecutive screening examinations in BreastScreen XXX. We identified an increase in compression force, compression pressure and compressed breast thickness over time when adjusting for breast volume, fibroglandular volume, age of the women, breast centre and calendar year. This might impact image quality and experiences of discomfort and pain by the women. Further research investigating the consequences of varying breast compression parameters on image quality and experiences of the women is needed.

Disclosure of Conflicts of Interest

The authors have no relevant conflicts of interest to disclose.

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