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The impact of obesity on follow-up after an abnormal screening mammogram

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Abstract

Background—Effective breast cancer screening and early detection are crucial for obese women, who experience a higher incidence of the disease and present at later stages.

Methods—We examined the association between body mass index (BMI) and timeliness of follow-up after 241,222 abnormal screening mammograms performed on 201,470 women in the Breast Cancer Surveillance Consortium. Each mammogram had one of three recommendations for follow-up: short-interval follow-up; immediate additional diagnostic imaging; and biopsy/surgical consultation. We used logistic regression to estimate the adjusted effect of BMI on any recorded follow-up within 270 days of the recommendation; linear regression was used to model the mean follow-up time among those with recorded follow-up.

Results—As compared to normal-weight women, higher BMI was associated with slightly increased odds of follow-up among women who received a recommendation for short-interval follow-up (odds ratios (ORs) 1.03–1.10; $p=0.04$) or immediate additional imaging (ORs 1.03–1.09; $p=0.01$). No association was found for biopsy/surgical consultation recommendations ($p=0.90$). Among those with recorded follow-up, higher BMI was associated with longer mean time to follow-up for both short-interval (3–10 days; $p<0.001$) and additional imaging recommendations (2–3 days; $p<0.001$), but not biopsy/surgical consultation ($p=0.06$). Regardless of statistical significance, actual differences in days to follow-up across BMI groups were small and unlikely to be clinically significant.

Conclusions—Once obese women access screening mammography, their follow-up after abnormal results is similar to that of normal-weight women.

Impact—Efforts to improve early detection of breast cancer in obese women should focus elsewhere, such as improving participation in screening mammography.

Keywords

mammography; obesity; prevention; breast cancer; screening

INTRODUCTION

Effective post-menopausal breast cancer screening is especially important for obese women, as they are at higher risk for breast cancer(1) and present at later stages with more aggressive forms of the disease.(2–7) Some studies,(4, 8, 9) but not all,(5, 10) have demonstrated higher breast cancer mortality among obese women. Their risk may be exacerbated by the lower rates of screening mammography observed in this population,(6, 11, 12) especially among obese White women.(13–15) In addition, once obese women access screening mammography, they are 20% more likely than normal-weight women to have a positive mammogram.(16) Given the extent of the disease burden in this population, it is particularly important for obese women to obtain timely follow-up after abnormal mammography.

Few studies have evaluated whether obese women receive timely follow-up care in such a situation, and these few have provided inconclusive results. Studies that included body mass index (BMI) as a potential risk factor for delayed follow-up after an abnormal mammogram found no associations.(17, 18) Wernli et al. determined that obese women (BMI > 30 kg/m²) undergoing diagnostic mammography were more likely to receive follow-up care within seven days than were normal-weight women.(19) However, previous studies have been limited by relatively small sample sizes, samples that were not nationally representative,(17, 19) use of self-reported mammogram data,(18) or not accounting for potentially confounding factors such as age, education, or breast density in analyses.(17)

To address these gaps in the literature, we sought to evaluate the impact of BMI on the timeliness of follow-up after an abnormal screening mammogram. Based on studies showing longer intervals between screening mammograms in obese women,(7, 12) we hypothesized that women with higher BMI might be at risk for not obtaining follow-up after an abnormal exam or for a delay in follow-up examinations. Using a large, nationally representative sample of women in the Breast Cancer Surveillance Consortium (BCSC), we investigated: 1) whether BMI was associated with receipt of follow-up studies after an abnormal screening mammogram and 2), among women who did receive follow-up studies, whether the timeliness of follow-up was associated with BMI.

METHODS

Data sources

Funded by the National Cancer Institute, the BCSC is a collaborative network of population-based mammography registries with linkages to pathology and tumor registries.(20,21) Analyses in the present study are based on pooled data from five BCSC registries (Western Washington State, New Hampshire, New Mexico, San Francisco, and Vermont). Along with the Statistical Coordinating Center, each registry has received institutional review board approval for active or passive consenting processes, as well as a Federal Certificate of Confidentiality and other protections for participating women, physicians, and facilities. All BCSC procedures comply with the Health Insurance Portability and Accountability Act.

Data collection

At the time of her mammography visit, each woman completed a self-administered questionnaire with information on age, race or ethnicity, education, self-reported presence of

breast problems, personal history of mammography (time since last screening mammogram and history of prior abnormal mammogram), and personal and first-degree family histories of breast cancer.(20) BMI (kg/m^2) was calculated on the basis of self-reported height and weight information obtained from the questionnaire.

Study sample

The primary units of analysis for this work were abnormal screening mammography examinations with associated recommendations for follow-up. We assessed the timeliness of follow-up care on the basis of the date of the recommendation. The study sample included women aged 40–84 years who received recommendations for follow-up associated with screening mammograms performed between January 1996 and December 2007. Women with a prior history of breast cancer were excluded. We defined a screening mammogram by using standard BCSC criteria:(22) a bilateral examination that the interpreting radiologist reported as a screening mammogram, performed on a woman for whom there was no evidence of breast imaging in the prior nine months.

For each screening mammogram, we identified two recommendations: 1) the highest *initial* recommendation, given on the day of the screening examination, and 2) the highest *final* recommendation, associated with the final BI-RADS assessment at the end of workup. The latter was defined as follows: If the initial assessment (i.e., at the time of the screening examination) was 4 (suspicious abnormality) or 5 (highly suggestive of malignancy), the highest final recommendation was taken to be the same as the highest initial recommendation. If the initial assessment was BI-RADS category 0 (incomplete) without a recommendation for biopsy or surgical consultation, or a BI-RADS category 1 (negative), 2 (benign finding), or 3 (probably benign) with a recommendation for immediate follow-up (other than biopsy), we looked forward 90 days for a final record. If no final record was found within 90 days, the final recommendation was taken to be the same as the initial recommendation.

For both the initial and final recommendations, we evaluated the “highest” such recommendation according to the following ranking: 1) immediate follow-up with core biopsy, fine needle aspiration (FNA), or surgical consultation; 2) immediate follow-up with a clinical exam; 3) immediate follow-up with additional imaging (additional views, ultrasound, MRI, nuclear medicine); 4) immediate follow-up with some other, unspecified work-up procedure; 5) short-interval follow-up; and 6) normal interval follow-up.

We categorized recommendations into three types, as follows: 1) a recommendation for short-interval follow-up mammography (e.g., six months); 2) a recommendation for immediate additional diagnostic imaging, including diagnostic mammography, ultrasound, or magnetic resonance imaging; and 3) a recommendation for biopsy or surgical consultation, including FNA and core biopsy. Recommendations for short-interval follow-up and additional imaging were identified solely by using the highest initial recommendation from the screening mammography examination. Recommendations for biopsy or surgical consultation were identified by using both the highest initial and final recommendations. Thus, based on our criteria, a single screening mammogram might contribute two different recommendations to our analyses. For example, a woman whose initial abnormal screening mammogram assessment was BI-RADS category 0 with a recommendation for ultrasound, but whose final assessment from the ultrasound recommended a biopsy, would be included in both the additional imaging category and the biopsy/surgical consultation category. In such instances the follow-up period after each recommendation was considered to be distinct.

Finally, to examine BMI-related differences in the length of time to follow-up, the sample included only those women for whom follow-up was recorded.

Outcome definitions

Our primary outcome was recorded receipt of any follow-up within 270 days of the recommendation. From the date of an abnormal screening mammogram, we looked forward in time for evidence of any subsequent breast imaging or procedure. Evidence of follow-up examinations or procedures was based on linkage with mammography, radiology, and pathology databases and included: immediate or short-interval diagnostic mammogram views; ultrasound; MRI; FNA; and core biopsy. For women who received recommendations for short-interval follow-up or additional imaging, we searched for evidence of follow-up from the date of the initial screening mammogram. For women in the biopsy/surgical consultation category, we searched from the date of the study for which a biopsy or surgical consultation was recommended.

Our secondary outcome was recorded receipt of the exact procedure that was recommended within 270 days of the recommendation. For example, for biopsy recommendations, this definition ignores subsequent additional imaging procedures until the first evidence of a biopsy or surgical consultation. Finally, to test for delays in follow-up beyond a clinically relevant timeframe, we also examined a “timely follow-up” outcome, defined as recorded receipt of any follow-up procedure within 60 days after a recommendation for additional imaging or biopsy or surgical consultation.

To calculate the length of time to follow-up for all outcomes, we examined only those women with a record of obtaining follow-up. Time to reported follow-up was calculated as the number of days between the exam that resulted in the recommendation and the subsequent follow-up event. Time to follow-up was censored at 270 days to ensure that the follow-up procedure could reasonably be linked to the initial recommendation.

Statistical analysis

Descriptive statistics were calculated for each characteristic as reported by subjects or documented at the time of initial screening mammograms. Data were stratified by BMI at the time of the screening mammogram according to the following groupings: <18.5 (underweight), 18.5–24.9 (normal weight), 25.0–29.9 (overweight), 30.0–34.9 (Class I obesity), 35.0–39.9 (Class II obesity), 40.0 (Class III obesity).⁽²³⁾ We also summarized the distribution of follow-up times among abnormal screening mammograms with a recorded follow-up procedure by calculating the median, interquartile, mean, and standard deviation, by BMI category.

Multivariable logistic regression was used to model the probability of observed follow-up within 270 days of the recommendation, as a function of BMI. In all models, BMI was modeled as a six-level categorical covariate using five dummy variables with normal weight (BMI 18.5–24.9) taken as the referent group. We fit two models for each category of recommendation (short-interval follow-up, additional imaging, and biopsy or surgical consultation) and each outcome. The first model adjusts for study registry, age, education, and race/ethnicity; the second model additionally adjusts for breast density, family history of breast cancer, hormone replacement therapy (HRT) use, and screening interval. The first model was chosen as our primary model *a priori*; the second was fit to explore the impact of potential confounding by additional individual characteristics. As an alternative to the six-level categorical measure, we explored modeling BMI as a continuous measure of exposure for select models (but not for our primary analyses). For these alternative models, we avoided making overly restrictive assumptions about the shape of the association (such as

linearity) by using natural cubic splines with a single knot at the midpoint of the BMI distribution.(24)

Among women with abnormal screening mammograms for whom there was a recorded follow-up, we used multivariable linear regression to explore the association between BMI and mean time to follow-up. In these models, we used the same strategy for confounding adjustment as described above.

A number of covariates had missing values. We used multiple imputation by chained equations to construct 10 “complete” datasets.(25) This approach works by sequentially iterating through each variable with missing data and imputing values by using a model that conditions on other variables in the dataset. All analyses were conducted for each of the 10 imputed datasets, with the results combined to appropriately account for the uncertainty in the missing data.(26)

Generalized estimating equations (GEE) were used throughout to estimate model parameters.(27) To account for possible within-woman correlations, we adopted a working independence correlation structure and based inference (standard errors, confidence intervals, and two-sided p-values) on the robust sandwich standard error estimator. The statistical significance of the association between BMI and receipt of follow-up was based on a hypothesis test that simultaneously evaluated coefficients for all five BMI dummy variables (a Wald test with five degrees of freedom). In both logistic models for follow-up within 270 days and linear models for mean time to follow-up, we explored potential effect modification of BMI by race/ethnicity by using GEE and robust standard errors. Because of sample size considerations, the two lowest BMI categories (underweight and normal weight) were combined; hence, statistical significance was based on a Wald test with $16 = (5-1) \times (5-1)$ degrees of freedom. All analyses were performed by using R v.2.12.0.(28)

RESULTS

Participant characteristics

A total of 241,222 screening mammography exams, performed on 201,470 unique women, were interpreted as abnormal with recommendations for additional evaluation. Of these, 3,624 (1.5%) mammograms were of women who were underweight at the time of the mammogram; 109,738 (45.5%) were of normal-weight women; 73,477 (30.5%) were of overweight women; and 54,383 (22.5%) were of obese women (14.2% Class I, 5.3% Class II, and 3.0% Class III). The mean age of the entire sample was 55 years, with an interquartile range of 46–62 years. Approximately 77% were White, 12%, Hispanic, 4% Asian, and 2% Black.

Table 1 reports woman-level characteristics, reported at the time of screening mammography, by BMI category. Underweight women tended to be older (age >70 years) and Asian. Obese women tended to be middle-aged (50–59 years), Black, have less than a college education, and have almost entirely fatty breasts. Obese women tended to report no prior mammograms or a longer time elapsed since their last mammogram.

A total of 262,867 distinct recommendations for follow-up resulted from the 241,222 abnormal screening mammograms (Table 2). Of the recommendations, 27,057 (10.3%) were for short-interval follow-up; 201,204 (76.5%) for additional imaging; and 34,606 (13.2%) for biopsy or surgical consultation. Of the 241,222 mammograms, 21,645 (9.0%) had an initial recommendation for short-interval follow-up or additional imaging as well as a final recommendation for biopsy or surgical consultation after the workup was completed. Overweight and obese women received more recommendations for short-interval follow-up

(14.3% and 16.0% for Class II and Class III obese women, respectively; Table 2) than underweight or normal-weight women (8.9% and 8.7%, respectively), whereas underweight and normal-weight women received more recommendations for additional imaging (76.0% and 78.7%, compared to 70.8% and 69.1% for Class II and Class III obese women, respectively).

Relationships between BMI and obtaining follow-up for an abnormal mammogram

Overall, 198,456 of the 262,867 recommendations (75.5%) had a recorded follow-up in the BCSC system. Among short-interval follow-up recommendations, the overall percentage with a recorded follow-up was 56.2%; among the additional imaging and biopsy/surgical consultation recommendations, the percentage was higher, at 78.0% and 76.0%, respectively (Table 2). Within each of the recommendations, the percentage with observed follow-up did not vary substantially by BMI category, providing little evidence of an unadjusted association. For additional imaging, the percentage increased from 76.4% for underweight women to 81.1% for Class II obese women. Similarly, there was little variability across the BMI groups for either the median or mean follow-up times.

In logistic regression analyses, BMI had a statistically significant effect on recorded follow-up among women with a recommendation for short-interval follow-up ($p=0.04$; Table 3). Compared to normal-weight women, women in the overweight and obese groups had equal or slightly better adjusted odds of recorded follow-up within 270 days; the estimated odds ratio (OR) varied between 1.02 and 1.10, although no consistent pattern was observed. Compared to normal-weight women, underweight women were estimated to have slightly lower odds of recorded follow-up (OR 0.81; 95% CI 0.65, 1.01). Figure 1 further explores the reduced odds among lower-weight women by presenting results based on a model in which BMI was treated as a continuous exposure. We found that the odds of recorded follow-up increase fairly linearly until a BMI of approximately 30 and plateau thereafter. The association persisted in the fully adjusted model ($p=0.025$; Table 3). Findings were similar when we used our secondary outcome of recorded receipt of the exact procedure recommended, with women in the overweight and obese groups having slightly higher odds of a recorded follow-up after a short-interval follow-up recommendation ($p<0.01$ for both adjustment models; data not shown).

For women with a recommendation for additional imaging, higher BMI was statistically significantly associated with increased odds of recorded follow-up within 270 days based on our primary model ($p=0.01$; Table 3); estimated OR varied between 1.03 and 1.09 for overweight and obese women compared to normal-weight women. However, this association did not persist in a fully adjusted model ($p=0.44$; Table 3), nor when we used our secondary outcome of recorded receipt of the exact procedure recommended (data not shown). For women who received a recommendation for biopsy or surgical consultation, there was no evidence of an association between BMI and any recorded follow-up (Table 3) or receipt of biopsy (data not shown).

BMI and time to recorded follow-up

Among short-interval follow-up recommendations, the mean number of days to follow-up for women in the normal weight range was 170 days (standard deviation (SD) 60 days); for overweight and obese women, the mean time was longer by 4–12 days (Table 2). Median times to recorded follow-up were 183–185 days among all groups. While linear regression analyses indicate a statistically significant adjusted association between BMI and time to recorded follow-up ($p<0.001$ for both adjustment models; Table 4), differences across the BMI groups were small relative to the overall mean of 173 days. For example, compared to normal-weight women, the mean time to follow-up was estimated to be 6 days longer for the

Class I obesity group (95% confidence interval (CI) 4–6) and 10 days longer for the Class III obesity group (95% CI 6–14). Results did not change based on the secondary outcome of recorded receipt of the exact procedure recommended (data not shown).

Among additional imaging recommendations, the mean number of days varied only slightly across BMI categories (range 23–25 days); the median was 13 days for each category (Table 2). Based on adjusted analyses, obese women (Classes I–III) were estimated to have a mean time to follow-up that was 2–3 days longer than women in the normal weight range ($p < 0.001$ for both adjustment models; Table 4). Again, results did not change when the outcome was restricted to receipt of recommended examination.

Finally, among recommendations for biopsy or surgical consultation, the mean time to obtaining any follow-up ranged from 33 to 35 days (Table 2). Based on adjusted analyses, we found no evidence of an effect of BMI on time for any recorded follow-up after a recommendation for biopsy or surgical consultation (Table 3). Results did not change based on the secondary outcome, which was restricted to receipt of biopsy (data not shown).

BMI and timely follow-up

To further assess timeliness of follow-up, we performed an additional analysis to examine the effect of BMI on the likelihood of obtaining a recorded follow-up within 60 days of recommendations for additional imaging or biopsy/surgical consultation. Results were non-significant for our primary model when we examined outcomes of receipt of either any follow-up examination ($p = 0.53$) or the specified procedure after a request for additional imaging ($p = 0.12$). However, the fully adjusted model that, in addition to study site, age, education, and race, adjusted for breast density, family history of breast cancer, hormone use, and screening interval, showed consistent evidence of an effect of BMI across all BMI groups (any follow-up outcome $p < 0.01$; specified examination only $p < 0.001$). Among the obese groups, the actual reduction in odds of recorded follow-up within 60 days was small; no OR for any BMI group was < 0.93 . Thus, only in our fully adjusted models, higher-weight women were 3–8% less likely to obtain follow-up examinations within 60 days after a recommendation for additional imaging. There were no significant differences by BMI in the odds of follow-up within 60 days after a recommendation for biopsy or surgical consultation for any follow-up procedure ($p = 0.53$, fully adjusted $p = 0.62$) or for biopsy specifically ($p = 0.67$, fully adjusted $p = 0.71$).

Interactions between BMI and race/ethnicity

Effect modification by race/ethnicity was explored by using the categories presented in Table 1, with “White, non-Hispanic” taken to be the referent group. Neither of our logistic regression analyses of receipt of follow-up within 270 days provided evidence of a significant interaction between race/ethnicity and BMI for any of the three recommendation types (data not shown). For linear regression analyses of time to follow-up, a statistically significant interaction was found between race and BMI among additional imaging recommendations ($p = 0.03$ for both adjustment models; data not shown). However, as with the results from the main analyses, race-specific differences across BMI groups were slight. The only BMI category with a consistent difference in mean time to follow-up across race/ethnicity was the Class III obese group: three days (95% CI 2–4) for Whites, eight days (95% CI 0–15) for Blacks, and five days (95% CI 1–10) for Hispanics.

CONCLUSIONS

Obesity raises a woman’s risk of post-menopausal breast cancer,⁽¹⁾ so that effective cancer screening is essential for obese women. Among women in a large national community-based

registry of mammography screening, we found no evidence to support the hypothesis that women with high BMI delayed further evaluation after a breast abnormality was noted on their screening mammograms. In fact, the proportion of obese women who obtained follow-up after recommendations for a short-interval follow-up study was similar to or higher than the proportion of normal-weight women who did so. We noted a relationship between BMI and the timeliness of follow-up, insofar as overweight and obese women had slightly longer follow-up times (on the order of days) after recommendations for short-interval studies or immediate additional diagnostic imaging. Nevertheless, these delays were not of a clinically significant duration, nor did we see differences in the rates or timeliness of follow-up when biopsies or surgical consultations were recommended.

Our results concur with prior studies that found no evidence that BMI was a risk factor for delayed follow-up after abnormal imaging studies.(17–19) Further, the present work represents the largest study to date that addresses this question. We add to prior literature by presenting data obtained from a community-based, geographically dispersed U.S. sample in which diverse models of health care delivery are in use. We also were able to appropriately account for potentially confounding factors such as age, education, and race/ethnicity.

These reassuring findings should be considered in the context of the literature on screening mammography, in which lower rates of screening are observed among obese women,(11, 29) especially obese White women.(13–15) The obese women in the current study were also more likely to report either never receiving a mammogram or experiencing long intervals between mammograms. Thus, although obese women demonstrate less adherence to physician recommendations for screening mammography,(30) and may delay medical care,(31) once they engage in screening mammography, they obtain timely follow-up after abnormal results. Given limited resources for increasing the efficacy of breast cancer prevention efforts in this high-risk group, existing literature suggests that, for obese women, emphasis should be placed on improving access to or compliance with screening mammography.(6, 11)

In our analysis of time to follow-up, BMI was associated with an increase in the number of days elapsed before women obtained follow-up imaging. However, this finding must be interpreted cautiously for several reasons. Given our large sample size, small differences in mean time to follow-up (3–10 days) were statistically significant, but their clinical relevance is limited. Delays were as long as one week only among women with a BMI in excess of 40 kg/m² who received recommendations for short-interval follow-up. However, the average time to a documented follow-up mammogram for these women was almost exactly six months, whereas normal-weight (referent group) and overweight women obtained follow-up, on average, earlier than six months. Of note, underweight and even low normal-weight women were slightly more likely to forgo follow-up. However, given the high percentage of women in this group with ages of 70–80 years, such a course may be clinically appropriate.

Nonetheless, it is worth noting that weight limits for MRI scanners or other equipment may apply to women whose weight exceeds 300 pounds. Therefore, particular imaging modalities may be less available to extremely obese women, requiring clinical flexibility and extra attention to ensure prompt follow-up. In addition, obese and overweight women report negative experiences within the health care system related to their weight.(32) Accommodations aimed at improving the experience of overweight and obese women during breast imaging and interventions are described elsewhere.(33)

Several limitations of our data merit discussion. First, BMI values rely on self-reported heights and weights. Prior research shows that higher-weight participants are more likely to underestimate their weight than normal-weight participants, resulting in misclassification of

BMI.(34) However, our findings were consistent across all weight categories, limiting the impact of any possible misclassification. Second, we have no data on clinical care received outside the BCSC system. Although we do not expect women seeking care outside the system to differ by weight category, we have no way to verify that hypothesis. Third, while we used multiple imputation to mitigate missingness in several adjustment variables, the validity of the results rely on the missing-at-random assumption, which cannot be guaranteed to hold. Fourth, while we used education as a proxy of socioeconomic status, we were unable to evaluate other possible confounders, such as insurance status. Finally, sample size was limited in some racial categories, particularly Black women. Therefore, despite the overall large sample size, our analysis of the modification of the effect of BMI by race or ethnicity may have been underpowered.

Summary

Although overweight and obese women are less likely to participate in screening mammography, once these women access screening they obtain follow-up for abnormal mammograms at rates similar to or higher than those of normal-weight women.

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Figure 1.

Estimated adjusted odds ratio (OR) association between body mass index (BMI) and recorded receipt of follow-up within 270 days of an abnormal screening mammogram with a recommendation for short-interval follow-up. Estimates are from a logistic regression model using a natural cubic smoothing spline for the BMI effect, adjusting for Breast Cancer Surveillance Consortium (BCSC) study site, age, education, and race/ethnicity. Dotted black lines are pointwise 95% confidence intervals; the solid grey line is the estimated OR based on the fully adjusted model. The lower panel provides a histogram of the observed BMI values.

Table 1

Woman-level characteristics at the time of the index screening mammogram. * Values are column percentages of non-missing observations, within body mass index (BMI) categories

	BMI category, kg/m ²					
	Underweight < 18.5 (n=3,624)	Normal weight 18.5 – 24.9 (n=109,738)	Overweight 25.0 – 29.9 (n=73,477)	Class I obesity 30.0 – 34.9 (n=34,288)	Class II obesity 35.0 – 39.9 (n=12,760)	Class III obesity 40 (n=7,335)
Age, yrs						
< 50	40.3	41.8	33.7	33.3	35.2	40.1
50 – 59	25.3	30.8	32.6	33.7	36.2	37.1
60 – 69	16.4	15.8	20.0	20.3	19.1	17.2
70 – 79	13.8	9.4	11.5	10.9	8.5	5.1
80	4.2	2.2	2.2	1.8	0.9	0.5
Race/Ethnicity						
White, non-Hispanic	81.0	80.7	77.4	78.3	80.1	80.7
Black, non-Hispanic	1.1	0.8	1.6	2.7	3.8	5.1
Asian	8.7	5.3	3.3	1.6	1.1	0.6
Hispanic	7.3	11.1	14.6	13.7	11.3	9.5
Other	1.9	2.1	3.0	3.6	3.7	4.1
Missing	3.6	2.8	2.7	2.7	2.8	2.4
Education						
< High school	8.7	5.2	8.0	8.9	9.3	9.5
High school	22.7	21.1	26.9	28.7	28.0	27.2
Some college	22.9	24.4	28.4	30.4	33.0	34.6
College	45.6	49.4	36.7	31.9	29.8	28.7
Missing	31.2	31.0	25.6	19.5	12.9	9.4
Family history						
No	83.3	84.2	84.0	83.8	83.3	83.1
Yes	16.7	15.8	16.0	16.2	16.7	16.9
Missing	11.0	11.4	11.6	10.6	9.3	9.0
HRT use						
No	72.6	72.8	71.9	74.7	77.4	80.7
Yes	27.4	27.2	28.1	25.3	22.6	19.3

	BMI category, kg/m ²					
	Underweight < 18.5 (n=3,624)	Normal weight 18.5 – 24.9 (n=109,738)	Overweight 25.0 – 29.9 (n=73,477)	Class I obesity 30.0 – 34.9 (n=34,288)	Class II obesity 35.0 – 39.9 (n=12,760)	Class III obesity 40 (n=7,335)
Missing	13.2	12.4	12.5	11.3	10.0	9.5
Breast density						
Almost entirely fat	1.8	2.1	4.7	8.2	11.5	16.5
Scattered fibroglandular tissue	23.7	31.7	45.0	53.4	56.5	58.7
Heterogeneously dense	46.1	52.2	44.5	35.1	30.0	23.3
Extremely dense	28.5	14.0	5.9	3.3	1.9	1.5
Missing	42.3	41.2	35.6	29.8	24.5	22.0
Time since last mammogram, months						
No previous mammogram	8.0	7.7	8.1	9.5	10.9	13.5
< 12	2.4	2.2	1.9	1.8	1.5	1.7
12 – 35	73.0	75.9	74.5	71.3	68.3	62.7
36 – 59	9.6	8.3	8.9	9.5	10.1	11.2
60+	7.1	5.9	6.6	7.8	9.2	10.9
Missing	8.5	7.0	6.7	6.3	5.8	5.7

* 241,222 exams of 201,470 unique women.

Table 2

Follow-up after abnormal screening mammograms by follow-up recommendation and self-reported body mass index (BMI)

	BMI category, kg/m^2					
	Underweight < 18.5	Normal weight 18.5 – 24.9	Overweight 25.0 – 29.9	Class I obesity 30.0 – 34.9	Class II obesity 35.0 – 39.9	Class III obesity 40
Short-interval follow-up, N (% of total recommendations)						
	351 (8.9)	10,337 (8.7)	8,303 (10.4)	4,748 (12.6)	2,017 (14.3)	1,301 (16.0)
Observed follow-up for any procedure, N (%) [*]	177 (50.4)	5,755 (55.7)	4,672 (56.3)	2,747 (57.9)	1,144 (56.7)	721 (55.4)
Observed follow-up for the recommended procedure, N (%) [*]	171 (48.7)	5,621 (54.4)	4,601 (55.4)	2,715 (57.2)	1,128 (55.9)	711 (54.7)
Time to observed follow-up [†]						
Median, days (IQR)	183 (163, 201)	183 (168, 198)	184 (169, 198)	184 (172, 200)	183 (170, 195)	185 (175, 203)
Mean, days (SD)	171 (57)	170 (60)	174 (55)	177 (51)	175 (51)	182 (47)
Immediate Additional Diagnostic Imaging, N (% of total recommendations)						
	3,037 (76.9)	93,724 (78.7)	61,311 (76.6)	27,558 (73.3)	9,966 (70.8)	5,608 (69.1)
Observed follow-up for any procedure, N (%) [*]	2,320 (76.4)	72,110 (76.9)	48,010 (78.3)	21,886 (79.4)	8,070 (81.0)	4,547 (81.1)
Observed follow-up for the recommended procedure, N (%) [*]	2,239 (73.7)	70,391 (75.1)	46,830 (76.4)	21,314 (77.3)	7,861 (78.9)	4,458 (79.5)
Time to observed follow-up [†]						
Median, days (IQR)	13 (7, 21)	13 (7, 21)	13 (7, 21)	13 (7, 22)	13 (7, 22)	13 (8, 22)
Mean, days (SD)	24 (40)	23 (39)	24 (41)	25 (41)	25 (42)	25 (42)
Biopsy/FNA/surgical consultation, N (% of total recommendations) [‡]						
	562 (14.2)	14,981 (12.6)	10,478 (13.1)	5,284 (14.1)	2,091 (14.9)	1,210 (14.9)
Observed follow-up for any procedure, N (%) [*]	412 (73.3)	11,337 (75.7)	7,957 (75.9)	4,038 (76.4)	1,603 (76.7)	950 (78.5)
Observed follow-up for the recommended procedure, N (%) [*]	367 (65.3)	10,038 (67.0)	7,099 (67.8)	3,592 (68.0)	1,423 (68.1)	853 (70.5)
Time to observed follow-up [†]						
Median, days (IQR)	17 (8, 30)	16 (8, 31)	16 (8, 30)	17 (9, 32)	17 (9, 31)	16 (9, 30)
Mean, days (SD)	33 (47)	34 (52)	33 (49)	35 (52)	34 (52)	33 (49)

^{*} Within 270 days of the date of recommendation.

[†] For those who were observed to experience follow-up based on any procedure.

[‡] Abnormal screening mammograms in the category for biopsy/surgical consultation recommendation overlap with the categories for short-interval follow-up and immediate additional diagnostic studies if subsequent exams recommended at the time of the index abnormal screening mammogram resulted in a final recommendation for biopsy or surgical consultation.

Notes: IQR=interquartile range; SD=standard deviation.

Table 3

The relationship of women's body mass index (BMI) to recorded receipt of follow-up within 270 days after abnormal screening mammogram recommendations

	<u>Model 1</u>		<u>Model 2</u>	
	Adjusted for age, education, race/ethnicity, and BCSC site*		Adjusted for all patient characteristics†	
<u>BMI category‡</u>	OR (95% CI)	p-value§	OR (95% CI)	p-value§
Short-interval Follow-up				
Underweight	0.81 (0.65, 1.01)	0.044	0.86 (0.68, 1.07)	0.025
Normal weight	1.00		1.00	
Overweight	1.03 (0.97, 1.09)		1.03 (0.96, 1.09)	
Class I obesity	1.10 (1.02, 1.18)		1.12 (1.04, 1.21)	
Class II obesity	1.08 (0.97, 1.19)		1.11 (1.00, 1.23)	
Class III obesity	1.02 (0.90, 1.15)		1.08 (0.95, 1.23)	
Immediate Additional Diagnostic Imaging				
Underweight	1.03 (0.95, 1.13)	0.013	1.06 (0.97, 1.16)	0.436
Normal weight	1.00		1.00	
Overweight	1.03 (1.00, 1.05)		1.01 (0.98, 1.04)	
Class I obesity	1.04 (1.01, 1.08)		1.01 (0.98, 1.05)	
Class II obesity	1.09 (1.03, 1.15)		1.05 (0.99, 1.11)	
Class III obesity	1.05 (0.98, 1.13)		1.01 (0.93, 1.08)	
Biopsy/Surgical Consultation				
Underweight	0.94 (0.76, 1.16)	0.904	0.95 (0.77, 1.18)	0.898
Normal weight	1.00		1.00	
Overweight	0.97 (0.91, 1.04)		0.99 (0.93, 1.06)	
Class I obesity	0.96 (0.88, 1.05)		1.00 (0.92, 1.09)	
Class II obesity	0.96 (0.85, 1.09)		1.02 (0.90, 1.16)	
Class III obesity	1.01 (0.86, 1.19)		1.09 (0.93, 1.29)	

^{*} Estimated odds ratio (OR) from logistic regression analyses of 10 imputed datasets, adjusted for Breast Cancer Surveillance Consortium (BCSC) study site, age, education, and race/ethnicity.

[‡] Estimated OR from logistic regression analyses of 10 imputed datasets, adjusted for BCSC study site, age, education, race, breast density, family history of breast cancer, HRT use, and screening interval.

[‡] BMI is classified by WHO(23) criteria as follows: underweight <18.5 kg/m², normal weight = 18.5–24.9 kg/m², overweight = 25.0–29.9 kg/m², Class I obesity = 30.0–34.9 kg/m², Class II obesity = 35.0–39.9 kg/m², Class III obesity = 40.0 kg/m².

[§] Based on a Wald test with 5 degrees of freedom.

Table 4

The relationship of body mass index (BMI) to the timing of observed follow-up for abnormal screening mammogram recommendations

BMI category [*]	Model 1 Adjusted for age, education, race/ethnicity, and BCSC site [†]		Model 2 Adjusted for all patient characteristics [‡]	
	β (95% CI)	p-value[§]	β (95% CI)	p-value[§]
Short-interval Follow-up				
Underweight	0 (−8, 8)		0 (−8, 8)	
Normal weight	0.0	< 0.001	0.0	< 0.001
Overweight	3 (1, 6)		3 (1, 5)	
Class I obesity	6 (4, 8)		5 (2, 7)	
Class II obesity	3 (−1, 6)		1 (−2, 5)	
Class III obesity	10 (6, 14)		8 (4, 12)	
Immediate Additional Diagnostic Imaging				
Underweight	0 (−2, 1)		−1 (−2, 1)	
Normal weight	0	< 0.001	0	< 0.001
Overweight	2 (1, 2)		2 (1, 2)	
Class I obesity	3 (2, 3)		3 (2, 4)	
Class II obesity	3 (2, 4)		3 (2, 4)	
Class III obesity	3 (2, 5)		4 (2, 5)	
Biopsy/Surgical Consultation				
Underweight	−2 (−7, 2)		−2 (−7, 2)	
Normal weight	0	0.056	0	0.062
Overweight	−2 (−3, 0)		−2 (−3, 0)	
Class I obesity	1 (−1, 3)		1 (−1, 3)	
Class II obesity	1 (−2, 3)		0 (−2, 3)	
Class III obesity	0 (−4, 3)		0 (−4, 3)	

^{*} BMI is classified by WHO(23) criteria as follows: underweight <18.5 kg/m², normal weight = 18.5–24.9 kg/m², overweight = 25.0–29.9 kg/m², Class I obesity = 30.0–34.9 kg/m², Class II obesity = 35.0–39.9 kg/m², Class III obesity = 40.0 kg/m².

[†]β values generated from linear regression are adjusted for Breast Cancer Surveillance Consortium (BCSC) study site, age, education, and race/ethnicity.

[‡]β values generated from linear regression are adjusted for BCSC study site, age, education, race/ethnicity, breast density, family history of breast cancer, HRT use, and screening interval.

[§]Based on a Wald test with 5 degrees of freedom.