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Changes in Breast Warning Sign Recognition and Simulated Breast Self-Examination Skills Following Physical Simulator–Based Training Among Women of Reproductive Age: A Quasi-Experimental Study

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Abstract

Background*:* Recognition of breast changes and timely clinical assessment are important components of breast health education. Physical breast simulators provide opportunities for hands-on practice and assessment of visual recognition and palpation skills. This study evaluated changes in breast warning-sign recognition, simulated mass detection, and intended help-seeking responses following physical simulator-based training among female university employees of reproductive age.

Materials and Methods: This quasi-experimental study used a one-group pretest–posttest design involving 40 female employees aged 15–49 years, recruited through convenience sampling from the central administrative building of Kerman University of Medical Sciences, Iran. Participants received individual simulator-based training using a researcher-developed breast simulator featuring six visible warning signs and eight concealed, three-dimensionally printed masses. The assessment instruments demonstrated acceptable content validity (CVR = 0.85; CVI = 0.92) and inter-rater reliability (Cohen's κ = 0.88; ICC = 0.91). Warning-sign recognition, simulated mass detection, and intended help-seeking responses were assessed before and immediately after training. Data were analyzed using McNemar's test and paired-samples *t*-tests in IBM SPSS Statistics, version 26.

Results*:* Recognition of selected visible warning signs, including peau d'orange, dilated superficial veins, and abnormal nipple discharge, improved significantly after training (all $p < 0.05$). The proportion of participants selecting immediate specialist consultation increased from 82.5% before training to 100% after training ($p = 0.008$). The mean number of correctly detected concealed simulated masses increased from 3.38 to 4.83 out of eight masses ($p < 0.001$).

Conclusion*:* Simulator-based training was associated with improved breast warning-sign recognition, simulated mass detection, and intended help-seeking. Controlled studies with longer follow-up are needed to assess skill retention, real-world applicability, and cost-effectiveness.

Key Words*:* Breast cancer, Breast self-examination, Breast simulator, Reproductive age, Simulation-based training.

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1- INTRODUCTION

Breast cancer is the most commonly diagnosed cancer and a leading cause of cancer-related mortality among women worldwide. According to the Global Cancer Observatory (GLOBOCAN) 2022 estimates, female breast cancer accounted for approximately 2.3 million new cases and 666,000 deaths globally, representing 23.8% of all new cancer cases and 15.4% of cancer deaths among women (1, 2). The World Health Organization (WHO) also identifies breast cancer as the most common cancer among women and emphasizes that awareness of breast changes, timely clinical evaluation, and appropriate referral are essential components of early diagnosis (3).

Although breast cancer is more commonly diagnosed in middle-aged and older women, delayed presentation and late-stage diagnosis remain major challenges, particularly in low- and middle-income countries. Women in these settings may be diagnosed at younger ages and experience poorer outcomes because of limited awareness, restricted access to diagnostic services, and delays in seeking medical care (2). Therefore, strengthening breast health awareness, recognition of warning signs, and appropriate help-seeking behavior among women is an important component of early detection programs (3–5).

Breast self-examination (BSE) and breast self-awareness are simple, low-cost, and accessible approaches that may help women become familiar with the normal appearance and texture of their breasts and recognize changes that require clinical evaluation. These changes may include a new lump or thickening, skin changes such as peau d'orange, nipple retraction or discharge, and changes in breast size, shape, or appearance (3, 5). BSE is not a substitute for organized mammography screening or clinical breast examination; rather, it should be considered a complementary strategy that promotes breast awareness and timely presentation to health services when an abnormal change is noticed (4, 5).

The effectiveness of BSE education depends largely on women's knowledge, confidence, and practical ability to perform the examination correctly. Traditional lecture-based education may improve theoretical knowledge, but it often provides limited opportunity for hands-on practice, tactile feedback, and objective assessment of examination skills (6–8). A recent systematic review and meta-analysis of 24 interventional studies involving 5,095 women found that educational interventions consistently improved BSE-related knowledge, beliefs, and practices; meta-analysis of 10 experimental studies showed a significantly higher likelihood of BSE practice among intervention participants (odds ratio = 8.30; 95% confidence interval: 4.42–15.57) (8).

Physical simulators have increasingly been used in health education because they allow learners to practice palpation skills in a controlled, repeatable, and realistic environment. A simulator containing visible warning signs and embedded masses can support both visual recognition of external breast changes and tactile identification of abnormal masses. Simulation-based education has been shown to improve breast cancer awareness, confidence, and BSE skills, while also providing a standardized framework for assessing learning outcomes (6, 7, 9). Nevertheless, objective evaluation of both visual awareness and palpation skills using a dedicated physical simulator remains limited among women of reproductive age.

Therefore, this quasi-experimental study was conducted to evaluate the effectiveness of a researcher-made physical simulator on breast warning-sign awareness and breast self-examination skills among female employees of Kerman University of Medical Sciences. The

physical simulator included six external warning signs and eight concealed breast masses fabricated using three-dimensional (3D) printing. The study assessed changes in visual identification of warning signs, tactile palpation accuracy, willingness to take appropriate clinical action, and overall BSE performance before and after simulator-based training.

2- MATERIALS AND METHODS

2-1. Study Design and Setting

This quasi-experimental study used a single-group, pretest–posttest design and was conducted at an interactive health exhibition booth located in the central building of Kerman University of Medical Sciences, Kerman, Iran. The study evaluated the immediate effect of a researcher-made, physical simulator-based educational intervention on breast warning-sign awareness, breast self-examination (BSE) palpation skills, and clinical decision-making among female university employees. The reporting of this non-randomized interventional study was guided by the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statement (10).

2-2. Participants and Eligibility Criteria

The study population consisted of female administrative and support staff employed at Kerman University of Medical Sciences. Female employees aged 15–49 years were eligible for participation if they provided written informed consent, had no previously diagnosed breast malignancy, and were able to complete both the theoretical and practical assessments.

Participants were excluded if they declined to continue participation at any stage of the study or did not complete the questionnaires and practical assessments.

2-3. Sample Size

The sample size was calculated using G*Power software (version 3.1.9.7) for a paired-samples comparison. The calculation was based on the effect size reported in a comparable simulation-based BSE training study (7). Assuming a two-sided significance level of 0.05, a statistical power of 0.80, and a moderate-to-large effect size, the minimum required sample size was 36 participants. To allow for an anticipated attrition rate of approximately 10%, the final sample size was set at 40 eligible female employees, recruited through convenience sampling.

2-4. Data Collection Instruments

The data collection tools consisted of three components: a demographic and background information questionnaire, a researcher-made physical simulator with an evaluation checklist, and clinical decision-making scenarios.

2-4-1. Demographic and Background Questionnaire

A six-item questionnaire was used to collect information on age, educational level, marital status, history of pregnancy or lactation, family history of breast disease among first- or second-degree relatives, and previous participation in education on BSE or breast cancer warning signs.

2-4-2. Researcher-Made Physical Simulator and Evaluation Checklist

The researcher-made physical simulator included two assessment components:

- **Visual awareness assessment board:** This board included three-dimensional simulated models of six breast cancer warning signs: abnormal or bloody nipple discharge, nipple retraction, superficial vascular dilatation, persistent erythema or inflammation suggestive of inflammatory breast cancer, marked breast asymmetry, and peau d’orange skin changes.
- **Tactile palpation phantom:** The breast phantom was fabricated from silicone

elastomer with softness and elasticity properties approximating those of natural breast tissue. Eight three-dimensionally printed simulated masses, made of photopolymer resin with irregular and spiculated margins, were embedded at different sizes (5–20 mm) and depths (1–3 cm).

2-4-3. Clinical Decision-Making and Help-Seeking Scenarios

Clinical decision-making was assessed using standardized scenarios describing suspicious breast findings. Participants were asked to identify the most appropriate action, including immediate referral for specialized clinical evaluation or appropriate follow-up.

2-5. Validity and Reliability

Face validity was assessed through pilot testing with 10 women similar to the target population. Based on their feedback, necessary modifications were made to the clarity, appearance, and wording of the instruments.

Content validity was evaluated by a panel of 10 experts in reproductive health, midwifery, and women's oncology. The Content Validity Ratio (CVR) and Content Validity Index (CVI) were calculated. An overall CVR of 0.85 and an overall CVI of 0.92 were obtained, indicating acceptable content validity.

Inter-rater reliability of the practical palpation assessment was evaluated by two independent raters using 10 pilot participants. Cohen's kappa and the intraclass correlation coefficient (ICC) were calculated to assess agreement between raters. A kappa of 0.88 and an ICC of 0.91 indicated strong agreement between raters.

2-6. Intervention and Procedure

After obtaining approval from the Ethics Committee of Kerman University of Medical Sciences (Ethics Code: IR.KMU.REC.1405.329) and coordinating with the relevant administrative departments, the study was conducted in a private and quiet space. Participant privacy, confidentiality, and voluntary participation were maintained throughout the study.

2-6-1. Pre-Test

After providing written informed consent, participants completed the demographic questionnaire. Visual awareness was then assessed by asking participants to identify six warning signs displayed on the simulation board. Subsequently, tactile palpation skills were assessed using the silicone phantom within a standardized time limit of 120 seconds.

To minimize observer bias, the timing and counting of correctly palpated masses were performed by a second rater who was blinded to the participants' visual awareness scores.

2-6-2. Educational Intervention

Immediately after the pretest, participants received a face-to-face, four-stage guided-discovery training program with sequential visual and tactile feedback. The intervention lasted approximately [insert duration] minutes per participant and included:

- Explanation of the clinical guide cards displayed beside the simulator models.
- Description of the pathophysiology of breast warning signs, including vascular dilatation related to angiogenesis and inflammatory breast cancer findings.
- Instruction on standard palpation techniques, including use of the pads of the middle three fingers, application of light, medium, and deep pressure, and continuous circular movements.
- Supervised practice using the physical simulator, with immediate feedback on palpation technique and identification of embedded masses.

This intervention was designed according to the principles of simulation-based health education, in which theoretical instruction is followed by supervised hands-on practice using breast models or simulators (6, 7). The intervention content and delivery procedure were described in detail to support transparency and reproducibility, as recommended for non-randomized interventional studies (10).

2-6-3. Post-Test

Immediately after the intervention, visual awareness and tactile palpation skills were reassessed under conditions identical to those of the pretest. The same warning signs, phantom masses, time limit, and evaluation criteria were used to ensure comparability between the pretest and posttest measurements.

2-7. Statistical Analysis

Data were analyzed using IBM SPSS Statistics software (version 26). Categorical variables were summarized as frequencies and percentages, and continuous variables as mean ± standard deviation.

The normality of continuous variables was assessed using the Kolmogorov–Smirnov test and Q–Q plots. Within-subject changes in the mean number of correctly palpated embedded masses were compared using a paired-samples *t*-test, and the mean difference was reported with a 95% confidence interval. If the normality assumption had not been met, the Wilcoxon signed-rank test would have been used.

Changes in paired binary visual-awareness outcomes were analyzed using McNemar's test. The exact binomial version of McNemar's test was applied when required by the distribution of discordant pairs. Absolute changes were calculated as the post-intervention proportion minus the pre-intervention proportion.

The association between pre- and post-intervention tactile palpation scores was assessed using Pearson's correlation coefficient. Missing responses were not imputed and were excluded from the analysis of the corresponding item. All tests were two-sided, and $P < 0.05$ was considered statistically significant.

2-8. Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and the ethical principles governing research involving human participants. The study protocol was reviewed and approved by the Ethics Committee of Kerman University of Medical Sciences, Kerman, Iran (Ethics Code: IR.KMU.REC.1405.329).

Before participation, all eligible participants received a clear explanation of the study objectives, procedures, potential benefits, possible risks, confidentiality measures, and their right to withdraw from the study at any time without any consequence. Written informed consent was obtained from all participants prior to enrollment. Participation was entirely voluntary, and refusal to participate or withdrawal did not affect participants' employment status, workplace benefits, or access to healthcare services.

No personally identifiable information was collected or reported. All questionnaires and assessment forms were coded, and the data were stored securely and used only for research purposes. The physical breast simulator was used exclusively for educational and skill-assessment purposes; no invasive procedure or clinical breast examination of the participants was performed. Participants were informed that the simulator-based assessment was not a substitute for clinical evaluation and were advised to seek medical assessment if they noticed any breast changes.

3- RESULTS

3-1. Demographic and Background Characteristics

As summarized in **Table 1**, a total of 40 women employed at Kerman University of Medical Sciences were evaluated. The mean age of the participants was 35.25 ± 7.80 years, ranging from 23 to 53 years. Most participants had a postgraduate or higher educational level (23; 57.5%), followed by a bachelor's degree (14; 35.0%) and a diploma (3; 7.5%).

The majority of participants were married (31; 77.5%), and 26 participants (65.0%) reported a history of breastfeeding. A family history of breast cancer was reported by 3 participants (7.5%), whereas 34 participants (85.0%) reported no family history and 3 participants (7.5%) did not provide this information. In addition, 26 participants (65.0%) had previously received education on breast self-examination (BSE), while 14 participants (35.0%) reported no prior BSE training.

Table-1: Demographic and background characteristics of the study participants (n = 40).

Variable / characteristic	Category / subgroup	Frequency / statistic	Percentage / value
Age, years	Mean ± SD	35.25 ± 7.80	—
	Range (minimum–maximum)	23–53	—
Education level	Diploma	3	7.5
	Bachelor's degree	14	35.0
	Postgraduate or higher	23	57.5
Marital status	Single	9	22.5
	Married	31	77.5
History of breastfeeding	Yes	26	65.0
	No	14	35.0
Family history of breast cancer	Yes	3	7.5
	No	34	85.0
	No information / unknown	3	7.5
Prior BSE training	Yes	26	65.0
	No	14	35.0
Total sample size		40	100.0

Note: SD: standard deviation.

3-2. Visual Awareness and Clinical Decision-Making

As presented in **Table 2**, simulator-based education improved participants' recognition of several breast cancer warning signs and their selection of appropriate clinical action.

The proportion of participants who correctly identified abnormal or bloody nipple discharge increased from 26 (65.0%) at pre-test to 33 (82.5%) at post-test, representing an absolute improvement of 17.5% (McNemar test, $P = 0.039$). Correct identification of superficial engorged and dilated collateral veins increased from 17 (42.5%) to 25 (62.5%), an absolute improvement of 20.0% ($P = 0.021$). Recognition of cutaneous dimpling and peau d'orange appearance increased from 20 (50.0%) to 30 (75.0%), representing an absolute improvement of 25.0% ($P = 0.006$).

The proportion of participants who selected immediate specialist consultation after identifying a suspicious finding increased from 33 (82.5%) at pre-test to 40 (100.0%) at post-test, an absolute improvement of 17.5% (McNemar exact test, $P = 0.008$).

Although improvements were also observed in the recognition of nipple retraction, localized inflammatory changes, sudden asymmetrical enlargement, and the conceptual identification of a suspicious breast mass, these changes did not reach statistical significance ($P > 0.05$).

Table-2: Comparison of participants' visual recognition of breast cancer warning signs and clinical decision-making before and after simulator-based education (n = 40).

Item	Warning sign / knowledge domain	Pre-intervention, *n*(%)	Post-intervention, *n*(%)	Absolute change (%)	Statistical test	*P*-value
1	Abnormal or bloody nipple discharge	26 (65.0)	33 (82.5)	+17.5	McNemar test	0.039
2	Nipple retraction, indentation, or inversion	22 (55.0)	26 (65.0)	+10.0	McNemar test	0.344
3	Superficial engorged and dilated collateral veins	17 (42.5)	25 (62.5)	+20.0	McNemar test	0.021
4	Localized erythema, eczema, or thermal sensation	16 (40.0)	21 (52.5)	+12.5	McNemar test	0.125
5	Sudden asymmetrical enlargement or distortion	15 (37.5)	20 (50.0)	+12.5	McNemar test	0.125
6	Cutaneous dimpling and peau d'orange appearance	20 (50.0)	30 (75.0)	+25.0	McNemar test	0.006
7	Conceptual identification of malignant mass consistency	31 (77.5)	35 (87.5)	+10.0	McNemar test	0.125
8	Appropriate clinical action upon detection	33 (82.5)	40 (100.0)	+17.5	McNemar exact test	0.008

Note: *P*values were calculated using the two-tailed McNemar test for paired binary categorical variables. The exact binomial version of McNemar's test was applied when required by the distribution of discordant pairs. Bold values indicate statistical significance at $P < 0.05$.

3-3. Tactile Palpation Skills

As shown in **Table 3**, the mean number of correctly palpated embedded masses increased significantly from 3.38 ± 2.56 at pre-test to 4.83 ± 1.06 at post-test, out of a total of eight embedded masses. The mean improvement was 1.45 masses (95% confidence interval: 0.68–2.22; paired-samples t-test, $t(39) = -3.827$, $P < 0.001$).

The reduction in the standard deviation from 2.56 at pre-test to 1.06 at post-test indicates that participants' palpation performance became less variable after the intervention. A positive correlation was observed between pre-test and post-test individual performance scores ($r = 0.356$, $P = 0.024$).

Table-3: Comparison of participants' tactile breast self-examination palpation scores before and after simulator-based education (n = 40).

Variable / assessment stage	Mean	SD	SE	Paired correlation, $r(P)$	Mean difference	95% CI of difference	Test statistic	P-value
Pre-test tactile tumor detection score	3.38	2.56	0.40	—	—	—	—	—
Post-test tactile tumor detection score	4.83	1.06	0.17	0.356 (0.024)	—	—	—	—
Paired difference	—	—	—	—	-1.45	-2.22 to -0.68	$t(39) = -3.827$	< 0.001

Note: The paired difference was calculated as the pre-test score minus the post-test score. Therefore, the negative mean difference reflects an increase of 1.45 correctly detected masses after the intervention. The paired-samples t-test was used to compare pre- and post-intervention scores. SD: standard deviation; SE: standard error; CI: confidence interval; r: Pearson correlation coefficient; t: paired-samples t-test statistic; P: p-value.

4- DISCUSSION

This study aimed to assess breast warning-sign awareness and breast self-examination (BSE) skills among female employees at Kerman University of Medical Sciences, using a cost-effective, researcher-made physical simulator. Following simulator-based education, participants showed significant improvements in the recognition of several breast cancer warning signs and in the selection of appropriate clinical action. Significant improvements were observed in the recognition of abnormal or bloody nipple discharge, superficial engorged and dilated collateral veins, and cutaneous dimpling with peau d'orange appearance. In addition, the mean number of correctly palpated embedded masses increased from 3.38 to 4.83 out of eight, and the proportion of participants selecting immediate specialist consultation increased from 82.5% to 100%.

These findings are consistent with evidence that educational interventions can improve breast awareness, BSE knowledge, skills, and practice. A recent systematic review and meta-analysis of 10 experimental studies involving 2,424 women found that educational interventions substantially increased the likelihood of BSE practice (OR = 8.30;

95% CI: 4.42–15.57), although substantial heterogeneity was reported among studies (8). Similarly, simulation-based breast-health education in a randomized controlled trial significantly improved confidence, skills, and behavior awareness among Afghan refugee women compared with controls (6). The present findings extend this evidence by showing that a low-cost physical simulator can improve not only general awareness but also task-specific visual recognition and palpation performance.

The improvement in mass-detection performance is particularly relevant because practical palpation is difficult to teach through lectures or pamphlets alone. An integrated intervention combining face-to-face education, simulator-supported hands-on practice, printed and electronic materials, and reminders improved breast cancer knowledge, perceived benefits, confidence, and health motivation in a randomized controlled trial (11). Likewise, a virtual self-efficacy-based intervention among working women significantly improved BSE skills in the intervention group compared with controls (9). In addition, hybrid simulation-based training among nursing students improved knowledge, practical skills, and the ability to correctly evaluate pathological findings (7). These results support the view that experiential learning, repeated practice, immediate feedback, and self-efficacy enhancement are important components of effective BSE education.

A key feature of this study was the development and use of a physical simulator containing visual warning signs and eight concealed masses of varying size and depth, fabricated using 3D printing and hard resin. This approach is consistent with recent work on low-cost, anatomically realistic breast models for self-diagnosis training. Gabryszewski et al. developed a rapid, low-cost method for producing glandular breast models using 3D printing and silicone molding, capable of representing adipose tissue and cancerous lesions (16). Similarly, Idrees et al. validated a cost-effective breast model for BSE training and reported that it could improve women's ability to detect breast lumps (17). Furthermore, Katori et al. developed and evaluated 3D-printed palpation models for breast tumor detection and found them feasible and usable for training purposes (12). Our simulator therefore provides a practical, standardized, and reproducible platform for both training and objective skill assessment, particularly in settings where commercial manikins may be unaffordable or unavailable.

The complete post-intervention selection of immediate specialist consultation is an important behavioral outcome. Awareness alone does not necessarily translate into timely help-seeking; fear, embarrassment, stigma, limited knowledge, and access barriers can delay presentation. A systematic review of barriers to early breast cancer diagnosis identified limited knowledge, poor healthcare access, fear of diagnosis or treatment, and stigma as important barriers, particularly among rural and less-educated women (13). Another systematic review and meta-analysis similarly identified fear, embarrassment, and lack of awareness as major barriers to breast cancer screening (14). The improvement observed in this study suggests that hands-on simulation may reduce uncertainty and increase confidence by allowing participants to recognize abnormal findings in a controlled, non-threatening environment. However, because the clinical-action outcome was measured immediately after training, its durability and translation into actual help-seeking behavior require longitudinal evaluation.

The findings have practical implications for workplace health promotion and primary healthcare. The World Health

Organization's Global Breast Cancer Initiative emphasizes health promotion for early detection, timely diagnosis, and comprehensive management, and recommends strengthening early-detection services according to country-specific needs (4). The WHO also emphasizes that awareness of breast changes and timely clinical evaluation are essential components of early diagnosis (3). The WHO Regional Office for the Eastern Mediterranean similarly highlights the importance of familiarizing women with the normal appearance and feel of their breasts and encouraging prompt medical assessment when changes are noticed (5). Furthermore, a systematic review of public-health interventions in low- and middle-income countries found that educational interventions can improve screening uptake and contribute to earlier diagnosis (15). Integrating low-cost simulator-based BSE education into occupational health programs, university health services, and primary-care settings may therefore provide a scalable strategy for improving early recognition of breast changes.

Nevertheless, the findings should be interpreted with caution. First, convenience sampling and recruitment from a single university in Kerman limit external validity. Second, the pretest–posttest design without a concurrent control group cannot isolate the intervention effect from practice effects, maturation, testing effects, or other co-interventions. Third, self-reported outcomes may be influenced by social-desirability bias. Fourth, although the simulator demonstrated acceptable validity and reliability, it cannot fully reproduce the anatomical, tactile, and pathological variability of human breast tissue. Finally, BSE should be positioned as breast awareness and prompt help-seeking rather than as a replacement for organized screening or clinical breast examination.

Future studies should use randomized controlled designs comparing simulator-based training with standard education, video-based instruction, or no training. Longitudinal follow-up at 3 and 6 months is needed to determine retention of visual and palpation skills and whether improved referral intention translates into timely clinical consultation. Future research should also assess the simulator in diverse occupational, cultural, and socioeconomic settings and evaluate blended approaches combining physical simulation with digital or mobile-based educational materials and reminders (6–9, 11, 12, 15–17).

5- CONCLUSION

This study demonstrated that a cost-effective physical breast simulator improved visual recognition of breast cancer warning signs and palpation skills among female employees. Simulator-based training significantly improved identification of clinical warning signs, detection of hidden breast masses, and selection of immediate specialist consultation.

These findings suggest that low-cost, hands-on simulation can translate breast-health knowledge into practical skills and appropriate clinical action. Such simulators may be useful educational tools in universities, workplaces, primary healthcare centers, and community-based programs. Further randomized controlled and longitudinal studies are needed to confirm long-term effectiveness and real-world impact.

6- CONFLICT OF INTEREST: None.

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