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Clinical breast exam training using tactually accurate computer simulation among healthcare providers in ghana☆

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ABSTRACT

Background: The incidence and prevalence of breast cancer continue to grow each year in sub-Saharan Africa. With limited access to diagnostic testing in this resource-limited area, clinical breast exams are a priority. Diversity in clinical breast exam skills contributes to misdiagnosis and delayed diagnosis of breast cancer. Computer-based simulation improves clinical breast exam skills and has the potential to improve patient outcomes.
Objectives: This study aimed to evaluate the effectiveness of tactually accurate computer simulation on participants' clinical breast exam competence, confidence, and intent to perform clinical breast exams in their practice.
Methods: This was a retrospective study design analyzing MammaCare® training data and web-based survey data from 34 healthcare providers, including midwives, nurses, physician assistants, and medical officers, employed at five clinics in Ghana.
Results: Participants demonstrated clinical breast exam skill competence. With each successive training module, the participants increased palpation coverage of breast tissue and decreased the number of false positive lumps identified as well as accurately identified true positive lumps. Participants reported increased confidence and intent to perform clinical breast exams and inquire about risk factors and symptoms patients may be experiencing.
Conclusions: Clinical breast exam skills training using tactually accurate computer simulation was effective and appropriate for practicing healthcare providers. The training may promote enhanced screening practices and early detection of breast cancer.

1. Introduction and Background

Breast cancer is the most common cause of malignancy and cancer-related death in Ghanaian women (Thomas et al., 2017). Projections estimate that breast cancer diagnoses in sub-Saharan Africa will double by 2040 (International Agency for Research on Cancer, 2021). Compared to high-income countries, women with breast cancer in low- and middle-income countries including Ghana are younger, mostly premenopausal women diagnosed at a remarkably late stage and with significantly increased risk of death (Black & Richmond, 2019; Thomas et al., 2019). A study of 223 individuals with breast cancer in a region in Ghana found that 49 % of patients were diagnosed at a late stage, and the 5-year survival rate was 39 % (Thomas et al., 2017), thus emphasizing the importance of screening, early detection, and prompt treatment. Delays between the time women first seek help for breast symptoms and cancer diagnosis contribute to diagnosis at late stages (International Agency for Research on Cancer, 2021). In high-income countries, screening via mammography has been effective in diagnosing breast cancer and reducing mortality (Black & Richmond, 2019). In low-resource settings including Ghana, where access to screening by mammography or ultrasound scans is woefully limited, clinical breast exam (CBE) is crucial in the detection of abnormal breast findings characteristic of breast cancer (Veitch et al., 2019). Building competency in CBE among healthcare providers is important in achieving better outcomes for breast cancer (Mittra et al., 2021).

Clinical breast exams contributed to advanced breast cancer

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diagnosis by primary healthcare workers, a 15 % reduction in breast cancer mortality among all the participants, and a significant reduction in mortality of almost 30 % in women 50 years of age and older (Mittra et al., 2021). Diversity in training and clinical experience contributes to variation in CBE knowledge and skill competency among healthcare providers. Efforts aimed at improving healthcare provider knowledge, skill, and confidence with CBEs by training with tactually appropriate breast computer simulation can impact the trajectory of the current public health concern.

Currently, several methods exist for teaching CBE – textbook readings, lectures, videos demonstrating the exam, plastic or silicone models, computer simulations and models, and standardized patients (Dilaveri et al., 2013). MammaCare® is a tactually accurate computer CBE training simulation for healthcare providers and is one of the most standardized approaches to examination (Brennan, 2016). The simulation software measures and verifies the user's CBE skills in real-time (The MammaCare Foundation, 2022). Throughout the simulation, the user receives instruction, corrections, and competency evaluation. Each of the four breast models has a unique configuration with variations in the density of tissue, size, firmness, mobility, and number, size, and placement of lumps. In the pre-training module, the trainee must discriminate between normal breast nodularity and suspicious lesions. The level of skill and criteria for a successful performance is more stringent with each subsequent module. By module four, all lumps in the breast model must be detected and at least 90 % of the breast tissue must be palpated with no more than one false positive finding reported in order to pass (The MammaCare Foundation, 2022).

A systematic review and *meta*-analysis aimed at synthesizing evidence on technology-based simulation training for breast and pelvic exams found CBE simulation training significantly improved skills compared to no intervention with $p < 0.001$ (Dilaveri et al., 2013). Additionally, breast models that provided tactile feedback resulted in better examination outcomes (Dilaveri et al., 2013). Specifically, when the MammaCare® system was used in training internal medicine interns, skills in performing a thorough exam improved from 63 % of the breast tissue examined to 91 % as measured within the software (Corbelli et al., 2014). Nine months after completing the curriculum, the interns examined 63 % of breast tissue compared to 52 % in a historical comparison group ($p < 0.001$). However, a limited number of publications have included an evaluation of CBE simulation training among actively practicing healthcare providers, especially those in low- to middle-income countries.

2. Aims

A global healthcare system with five clinics in Ghana teamed up with university faculty to evaluate the first of three intervals in a breast cancer early detection program. The initial interval focused on CBE exam training for enhanced screening and early detection of breast cancer among women living in a low-resource area. The purpose of this retrospective study was to evaluate the effectiveness of Ghanaian healthcare providers' MammaCare® training with specific aims to: (a) determine participants' previous CBE training; (b) describe development of competency in CBE skills; (c) describe and compare participants' level of confidence in performing CBEs before and after completing simulation training; and (d) describe participants' intent to use their new CBE skills.

3. Methods

3.1. Design

A retrospective study was conducted analyzing data from the early detection program implemented from September to November 2021 at five clinics in Ghana. Healthcare providers employed at each of the clinics completed MammaCare® training, which included registration, a pre-training module, three palpation training modules (2, 3, and 4) separated by one break and hand stretches, and a course evaluation. During registration, the MammaCare® training collected responses to the following: (a) degrees and/or certifications, (b) clinic name and location, (c) have you performed a CBE on another person? Yes or No, (d) how did you first learn to perform CBE?, and (e) on a scale of 1 to 5, with 5 being the most confident, how would you rate your confidence in your CBE skills? The training required successful completion of a module before continuing to the next. Participants could repeat the modules as many times (termed attempts) as needed for successful module completion. MammaCare® collected the following data for each participant: (a) attempts to pass the module, (b) exam duration in minutes for each attempt, (c) true positive and false positive lump identification for each attempt, and (d) tissue coverage including search pattern and depth of palpation. Each module has two or three lumps to identify, and the lumps are a variety of sizes: 3 mm, 5 mm, 7 mm, and 10 mm. After each attempt, the practitioner received immediate feedback on their performance through MammaCare®. This feedback identified what the practitioner did correctly, as well as areas for improvement, allowing them to improve on the following attempt. Fig. 1 shows example attempt results that are provided to the healthcare provider at the end of an attempt.

At the end of the training, responses to the following questions were collected on the course evaluation: (a) on a scale of 1 to 5, with 5 being the most confident, how would you rate your confidence in your CBE skills?; (b) were the teaching strategies effective for the subject matter covered?; (c) was the time allotted for the subject matter appropriate?; (d) did the program meet your professional needs?; (e) do you have any recommendations for improving the course?; and (f) additional comments.

The healthcare providers completed an additional web-based survey following MammaCare® training. The survey explored previous CBE training and intent to: (a) ask patients about their risk factors for breast cancer; (b) ask patients about symptoms of breast cancer; (c) perform CBEs routinely on women to screen for breast cancer; and (d) refer patients with abnormal CBE findings for specialized care. Intent was rated on a 5-point Likert scale from "most likely" to "very unlikely."

3.2. Setting & sample

Existing data from 34 healthcare providers employed at the five clinics who completed the training in its entirety were included in the analysis. Of the 34 healthcare providers who completed the training, 31 of them completed the additional web-based survey following the training.

3.3. Data analysis

A statistician was consulted for data analysis. Results were analyzed using the IBM SPSS 29.0 [Statistical Package for Social Sciences IBM Corp., Armonk, NYC, USA] package program. The signed rank and Friedman tests were used to compare the distributions for dependent samples. The Mann-Whitney and Kruskal-Wallis tests were conducted to test statistical significance between groups for the independent samples. Statistical significance was declared for p-value < 0.05.

3.4. Ethical Considerations

Participation in the MammaCare® training was mandated, and the web-based survey was voluntary. Both the training data and survey data were anonymous. A Ghana University Ethical and Protocol Review Committee approved the research protocol, and a United States University Institute Review Board deemed this study exempt category 4.

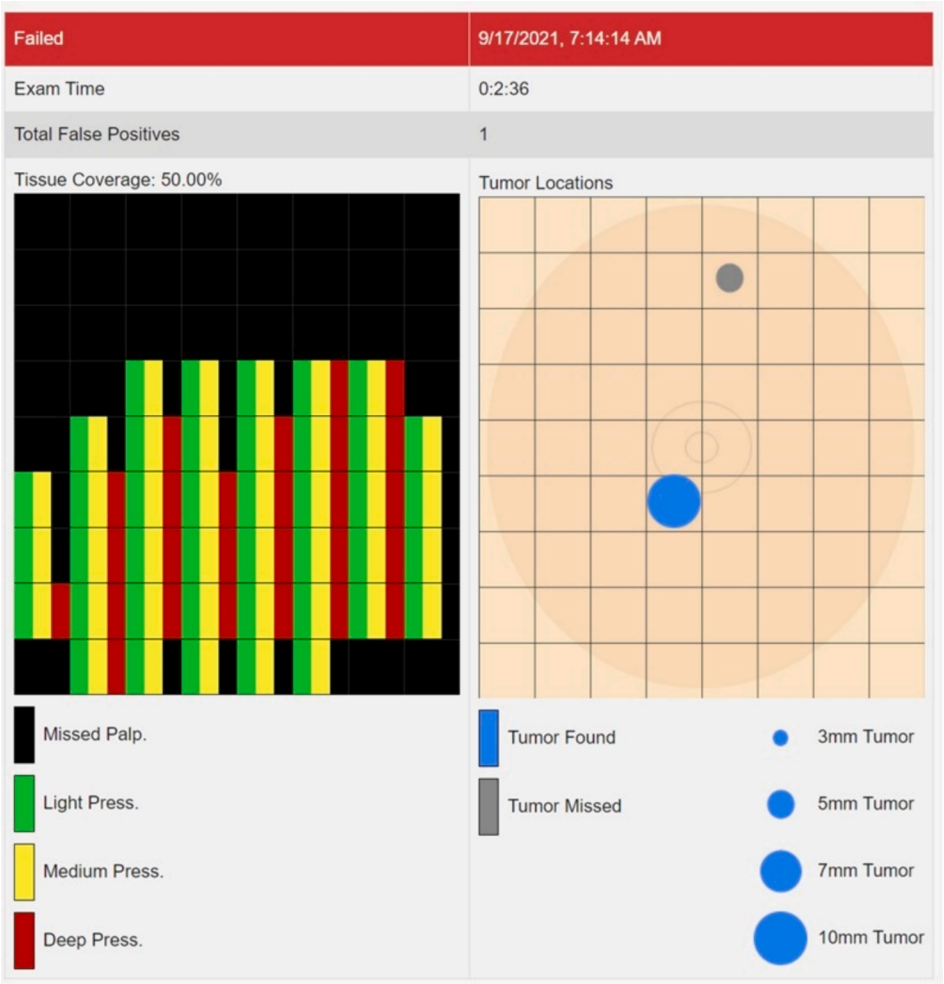

Fig. 1. MammaCare® Feedback.

4. Results

4.1. Demographics

Of the 34 participants, 79.4 % were midwives, 11.8 % were nurses, and 8.8 % were physician assistants or medical officers. The majority were female between 20–39 years of age, had a diploma degree, and had 0 – 3 years of experience as a healthcare provider. Seven participants worked at clinic 1, six at clinic 2, five at clinic 3, 10 at clinic 4, and six at clinic 5. Most participants (42 %) completed the entire training course at one time. Others completed the training in multiple sessions in one day (32 %) or multiple sessions over multiple days (26 %). The majority reported they had previously learned to perform CBE, and most learned at school (47 %); however, there were a variety of other responses. The majority had performed CBEs in their clinical practice before MammaCare® training, but eight participants reported they had never performed CBE. Slightly less than half had experienced CBE as a patient. The majority had no previous personal benign breast disease and no personal, family, or friend history of breast cancer.

4.2. Clinical exam competence

How participants initially learned CBE made a difference in how they performed on the modules. Five categories were compared: (a) no identified training, (b) books and videos, (c) manual, (d) school, and (e) training. Participants who learned via training required more attempts to pass than no previous training ($p = 0.002$) and school ($p = 0.035$). Participants who learned CBE from books and videos required significantly less time to complete the modules when compared to participants who did not identify their training ($p = 0.008$). Participants with no identified training performed a more thorough exam on the breast model than participants who learned via training ($p = 0.001$) and those who learned manually ($p = 0.004$).

Table 1 includes the number of attempts completed to pass each module for the first time, exam duration in minutes, the number of false positive lumps identified, true lumps found, and percent of the breast model palpated. The data was analyzed for all 34 participants as well as subgroups of participants who had previously completed CBE training ($n = 26$) and those who had no previous CBE training ($n = 8$). The eight participants who had no previous CBE training had also never performed a CBE on a patient.

All 34 participants completed the MammaCare® training thus demonstrating CBE competency. An average of 2.0 attempts were required to pass each module for the first time (IQR 1.0). No significant difference was noted in exam duration on attempts passed among the modules. However, the number of false positives decreased, and the percentage of breast tissue palpated increased throughout the training. After the Bonferroni adjustment, false positives decreased significantly between modules 2 and 3 ($p = 0.011$) and modules 2 and 4 ($p = 0.008$) on all attempts (passed and failed). The percent of breast tissue palpated increased significantly between modules 2 and 3 ($p = 0.001$) and modules 2 and 4 ($p = 0.002$) on all attempts.

Interestingly, participants with previous CBE training required more attempts and more time to pass the modules than those who learned by

Table 1
MammaCare® Training Attempt Data.

	Module 2		Module 3		Module 4			
Variable	*Mdn*	*IQR*	*Mdn*	*IQR*	*Mdn*	*IQR*	Statistical test	*p*
Total number of attempts to first pass								
All participants	3.5	3.25	2	3	3	3.25	Friedman	0.055
Previous CBE training	4	3	2	5	3	5	Friedman	0.071
No previous CBE training	2	2.75	3	2.5	3.5	4	Friedman	0.800
Duration per attempt in minutes								
All participants	5.68	5.33	5.19	5.55	5.42	4.63	Kruskal Wallis	0.526
Previous CBE training	5.33	5.84	4.93	4.65	5.00	3.98	Kruskal Wallis	0.353
No previous CBE training	6.42	4.75	9.51	7.38	9.34	7.64	Kruskal Wallis	0.706
Number of false positive lumps found								
All participants	1	2	0	1	0	1	Kruskal Wallis	**0.003**
Previous CBE training	1	3	0	1	0	1	Kruskal Wallis	**0.002**
No previous CBE training	1	2	0	1	1	1	Kruskal Wallis	0.315
Number/percent of true positive lumps found								
All participants	2	0	3	0	3	1	Kruskal Wallis	**<0.001**
Previous CBE training	2	0	3	0	3	1	Kruskal Wallis	**<0.001**
No previous CBE training	2	0	3	0	3	1	Kruskal Wallis	**<0.001**
Percentage of model breast tissue palpated								
All participants	0.99	0.09	0.99	0.02	1.00	0.03	Kruskal Wallis	**<0.001**
Previous CBE training	0.97	0.12	0.99	0.02	1.00	0.03	Kruskal Wallis	**<0.001**
No previous CBE training	1.00	0.01	1.00	0.02	1.00	0.01	Kruskal Wallis	0.879

Note: $N = 34$ ($n = 26$ previous CBE training; $n = 8$ no previous CBE training). *Mdn* = median. *IQR* = interquartile range.

another method (such as reading books, watching videos, and attending school courses) indicating previous training did not impact efficiency in completing the modules. Participants who never had previous training required fewer attempts to pass the modules ($p = 0.017$) and covered more of the breast tissue during palpation ($p < 0.001$), but they took more time on the modules. These findings suggest participants with no previous hands-on training spent more time and were more thorough with each attempt resulting in fewer attempts to pass each module.

4.3. Clinical exam confidence

Most of the participants reported the MammaCare® training teaching strategies were effective for the covered content (93.55 %) and met their professional needs (100 %). They said the training was "helpful," "appreciated," and "should be offered as a refresher course." These positive responses are consistent with the observed increase in confidence. Before the training, the majority of participants rated their confidence from 2 to 4. After the training, nearly 100 % of the participants' confidence was rated 4 or 5 indicating a statistically significant increase in confidence ($p < 0.001$). Furthermore, confidence pre-training had a significant positive association with the number of attempts to pass module 3 ($p = 0.01$) and a higher percentage of palpated breast tissue in module 2 ($p = 0.009$).

4.4. Intent to perform

After training, participants reported they were most likely or likely to ask patients about their risk factors for breast cancer, ask patients about symptoms of breast cancer, and perform CBEs routinely on women to screen for breast cancer. Most participants responded they are most likely or likely to refer a patient with an abnormal CBE finding for specialized care.

5. Discussion

This retrospective study evaluated CBE training data from a tactually accurate breast model computer simulation called MammaCare® and the participants' intent to perform CBEs following training. Overall, the training was well received by the participants. The majority had already received CBE training, and the diversity of their CBE training aligns with the current healthcare environment (Dilaveri et al., 2013). Most participants in this study (76.5 %) had completed CBEs in their clinical practice, which exceeds data from current published literature revealing 53.7 % of health professionals complete CBEs as a screening for their patients (Halmata et al., 2021).

All 34 participants demonstrated CBE competency. Real-time feedback and tracked progress provided by the computer simulation supported skill development. The results of this study are consistent with literature that indicates focused skills training programs are effective in teaching CBE technical skills compared to traditional teaching methods with success attributed to curriculum standardization, opportunity for correction, and improved confidence (Murthy et al., 2020).

A study by Kim et al. (2020) highlighted the relationship between confidence and provider competence, behavior, and motivation in addition to knowledge and skills. Confidence levels varied among providers with similar training, and competency-based training increased confidence to equivalent levels (Kim et al., 2020). Similarly in the present study, MammaCare® training significantly increased the participants' confidence to perform CBEs as well as their intent to perform CBEs and inquire about risk factors and symptoms patients may be experiencing. MammaCare® training, including time spent on training, is appropriate and beneficial for advanced practice providers and nurses despite any previous CBE training. Collectively, these training outcomes may contribute to enhanced screening practices and early detection of breast cancer.

5.1. Strengths & Limitations

To our knowledge, this is the first CBE computer simulation training for currently practicing healthcare providers in Ghana. Related studies published have focused on training outcomes for medical professional students who have not yet graduated or achieved licensure. The retrospective study analyzing a quality improvement initiative within one healthcare organization limits the generalizability of these findings to other settings and providers. The web-based survey was not subjected to formal validity testing.

5.2. Recommendations for Further Research

Areas of interest for further research in this specific Ghanaian healthcare provider group include whether a didactic curriculum might complement the simulation training and how frequently the training should be repeated to maintain competence. Continued evaluation of MammaCare® training with additional populations in diverse settings in

a longitudinal design would provide additional evidence on the effectiveness of CBE computer simulation training. Training simulations with diverse breast characteristics, such as skin color and breast size, representative of the patient population are also prudent. Studies analyzing the frequency of CBEs performed, including CBEs performed on younger women to account for lower ages of breast cancers diagnosed in Ghana, and studies analyzing true positive lumps found from CBE should be considered.

6. Conclusions

This retrospective study aimed to explore Ghanaian providers' CBE competence, confidence, and intent to perform CBE following MammaCare® training. CBEs are a priority for breast cancer screening in countries with limited resources. Our findings highlight CBE training with tactually accurate breast simulation improved skills among the participating providers. Confidence and intent to perform were also positively influenced. CBE training with computer simulation among currently practicing providers may promote enhanced screening practices and early detection of breast cancer in low-resource settings.

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CRediT authorship contribution statement

Dannica Callies: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Danielle Schievelbein:** Writing – review & editing, Methodology, Conceptualization. **Cynthia Elverson:** Writing – review & editing, Methodology, Conceptualization. **Judith Osae-Larbi:** Writing – review & editing, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability.

Data available on request from the authors. This research didn't receive any grant from any funding agency in the public, commercial or not-for-profit sectors.

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