DYNAMIC SIMULATOR FOR TRAINING CLINICAL BREAST EXAMINATION

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Clinical breast examinations (CBE) play a role in the detection of breast cancers. However, most physicians receive inadequate training in tactile search of breast tissue to detect small (< 2 cm), hard tumors. The dynamic, variable-lump, silicone breast simulator was designed to improve physicians' CBE performance and increase tumor detection. Water inflates balloons embedded in formed silicone to simulate the presence of tumors and allow independent adjustment of tumor hardness. The advantage, compared to static models with five, non-movable tumors, is that training scenarios can be reconfigured and repeated until each trainee learns the subtle tactile cues associated with tumors. In a study of 48 medical students, training with the dynamic simulator increased the number of tumors found ($F(42)=7.85$, $p=0.0077$), reduced the number of false positives ($F(42)=5.20$, $p=0.0277$), and improved transfer of training. This advancement can allow CBE to become more reliable, consistent, and effective.

INTRODUCTION

Breast cancer kills 40,000 women yearly in the United States, with approximately 200,000 new cases diagnosed in 2001 (American Cancer Society, 2001). Fortunately, with tumors treated before reaching 2.0 cm, the five-year survival rate exceeds 98%. Due to high breast cancer mortality rates worldwide, research has focused on early detection as one possible means of saving lives. Currently, medical organizations recommend breast cancer screening with annual clinical breast examinations (CBE), monthly breast self examinations (BSE), and for women over age 50, annual mammography. Mammography is a valuable detector, but is significantly limited by economic cost and true effectiveness. Its limitations include lower sensitivity in younger patients, high false alarm rate, potential for physical harm, economic exclusion, and a low correlation with a decreased mortality rate (Elmore et al., 1998; Harris, Morrow, & Norton, 1997; Kern, 1992). The literature suggests that CBE has the potential to detect tumors at a rate equal to or greater than mammography (Kuroishi, Hirose, Suzuki, & Tominaga, 2000; Miller, To, Baines, & Wall, 2000).

To perform a CBE, a physician presses the patient's breast towards her rib cage with his fingertips, feeling for tissue irregularities and tumors. Many physicians report a low confidence and skill level, while others never received formal training or ever re-test their skills (Fletcher, O'Malley, & Bunce, 1985; Pilgrim, Lannon, Harris, Cogburn, & Fletcher, 1993; Wiecha & Gann, 1993). Training can substantially improve performance and effective training tools can improve training success (Bennett et al., 1990; Campbell, Fletcher, Pilgrim, Morgan, & Lin, 1991; Hall et al., 1980).

Current, inconsistent tumor detection rates may be related to current training methods, which rely on live patients, artificial breast models, and training videos. The primary educational technique uses breast-shaped silicon models embedded with foreign objects that represent tumors. The trainee practices palpating the silicone to locate the simulated tumors. However, once a trainee has identified all the tumors in these models, little more can be learned. Our research suggests that a training device that allows repeated examination of the same silicone model

with the tumors alternately present and not present may improve training effectiveness.

The dynamic, variable-tumor silicone breast model simulates the presence and absence of tumors in different locations at varying hardness and sizes. Characteristics of the fifteen tumors may be independently adjusted (or "turned off"), which allows trainees to differentiate between the sensations of the presence and absence of a tumor in different tumor configuration. Trainees can repeatedly change and receive immediate feedback about their diagnosis. Because the simulation environment changes, trainees cannot easily memorize all lump positions as they can with traditional models. Our hypothesis is that because training scenarios can be repeated and reconfigured until each trainee learns subtle differences, students trained with the dynamic simulator will have fewer false positives and greater sensitivity than students trained with a static simulator.

METHODS

Experiment Overview

The experiment tests that the hypothesis that will improve students' training with the dynamic, variable-lump breast model. The ability to distinguish between the presence and absence of the tumors (specificity), to discriminate minor differences in texture (sensitivity), and to translate silicone model performance to real breast tissue (transfer) are potential improvement areas. The dynamic simulator will enhance performance because trainees can differentiate between and gain immediate feedback through sensations felt as a result of the presence and absence of tumors in the model. This feature allows trainees to achieve a high tactile discrimination level. The three dependent variables are: correctly found tumors and missed tumors (sensitivity) and false positive reports (specificity).

The 48 participants were in first through third years of medical school. The between-subjects experiment included pre-tests with the both the static and dynamic simulators, a training session with either the static or dynamic simulator, a break, and three post-tests with the static, the dynamic, and a 2nd, softer static simulator. The pre-test and post-test orders were balanced. Each test lasted two minutes, during which time the number of correct, missed, and false positive detection scores were gathered. All tests presented five tumors. The two-minute examination interval is based on the time normally taken in a breast examination (Campbell et al., 1991; Fletcher et al., 1985). The fifteen-minute training session covered training topics of search pattern, finger pressure, part and number of fingers used, finger motion, nodularity effects, breast area coverage, and lump properties on either the static or dynamic breast model. On the dynamic model, tumors could be turned on and off. Since this was not possible with the static model, participants alternately felt areas with and without tumors. After the twenty-minute rest, post-training scores were gathered on each of two models following the pre-test format. This time, however, the same firm static model (Mammacare model HPM-F1) was rotated 90 degrees and the lump positions and properties were changed in the dynamic simulator. To account for a possibility of bias in learning how the dynamic model operates, a third model (Mammacare model HPM-S1) was introduced for the final post-test.

Dynamic Simulator

The dynamic simulator (Figure 1) is a prototype silicone breast model with configurable tumors. It simulates rib and inter-rib muscle structures at the back of a soft, opaque mass of silicone in a breast shape. The silicone matrix has a hard silicone backing to hold the embedded ribs and to provide entry points for thin, polyethylene tubes that lead to inflatable sacs. These sacs are inflated with water to simulate tumors that may appear just underneath the outer silicone surface or deep between the ribs against the back. The device includes 15 sacs that may be individually inflated to different levels of hardness. The simulated tumors vary in size (0.3 to 1.5 cm), hardness (20 to 50 durometers), depth of placement (shallow, medium, and deep), and fixedness (fixed and mobile) and are undetectable when deflated. The silicone matrix is fairly homogeneous with little nodularity.

An external pressure system selectively injects water to inflate the simulated tumors. There is nearly linear relationship between water pressure and simulated tumor hardness. The pressure system delivers between 20 and 45 psi to tumors selected by opening and closing valves. The system also includes a relief valve to protect the balloons from bursting under high pressures.

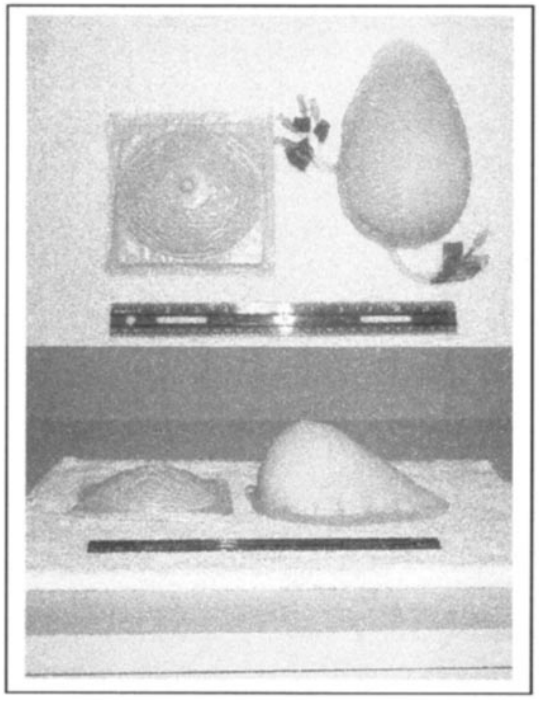

Figure 1: Device comparison, static (left) and dynamic (right) with 12-inch ruler

Static Models

The experimental controls (Figure 1) are round opaque models with square bases. The static models, Mammatech Corporation models HPM-S1 and HPM-F1, have been widely used to assess the lump detection ability, e.g. (Chalabian & Dunnington, 1998; Fletcher et al., 1985). The HPM-F1 model is firmer, otherwise the two models are identical. A thin plastic skin covers an underlying silicone gel matrix, containing five tumors made of fibrous cotton wound tightly into a cylinder. The tumors vary in size (0.3 to 1.0 cm), hardness (20, 40, and 60 durometers), depth of placement (shallow, medium, and deep), and mobility (fixed and mobile). Tumor size, hardness, position, and depth are fixed and equal in both models. The models simulate slight glandular nodularity.

RESULTS

Dynamic simulator training increased the number of tumors found (sensitivity), reduced the number of false positive reports (specificity), and improved performance on the static devices (transfer). Four important experimental results are statistically significant at $p<0.05$.

The sensitivity improvement (Figure 2), measured by the number of tumors found after training minus the number of tumors found on the same device before training, was greater when the training used the dynamic simulator (1.39 tumors) than when the training used the static device (0.60 tumors) ($F(42)=7.85$, $p=0.0077$). Participants also found more tumors on a third model introduced at the end of the experiment (3.04 of 5 versus 2.54 of 5) when trained with the dynamic simulator ($F(42)=2.96$, $p=0.0927$).

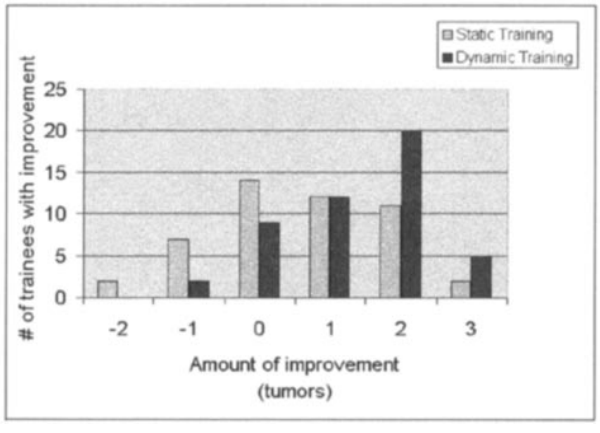

Figure 2: Composite sensitivity increase (static + dynamic) based upon training model

Transfer of skill (Figure 3) is only associated with dynamic simulator training. The dynamic simulator training increases performance in both the static and dynamic simulator post-tests, while the static device only improves performance on the static device. Both types of training increased sensitivity in detecting tumors on the pre-test and post-test assessment with the static model at approximately the same effectiveness; 1.04 and 1.17

more tumors were found on the static models after training for the static model and dynamic simulator, respectively (F(42)=0.11, p=0.7456). However, training with the static model did not lead to sensitivity improvements on the dynamic model. After training on the static model and dynamic simulator, 0.17 versus 1.54 more tumors were found, respectively (F(42)=22.29, p<0.001).

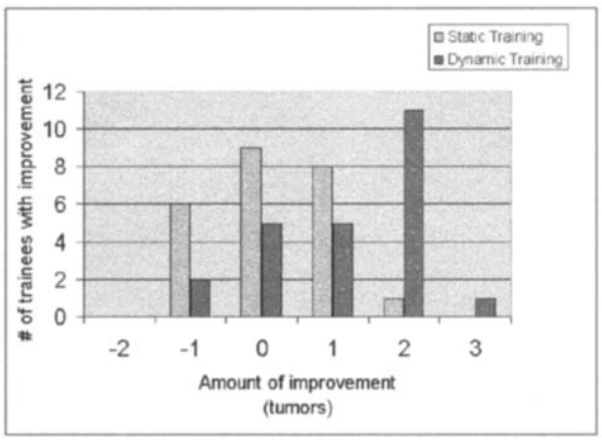

Figure 3: Transfer of training sensitivity improvement based upon training model (ability to locate tumors on the breast model that participants were not trained for)

These results suggest that the static device may develop a subset of skills, specific to itself, rather than general skills for application to other breast models. However, dynamic simulator training improvement transfers to the static simulators. In fact, the slight advantage of 1.17 to 1.04 tumors indicates that the dynamic simulator may even train for the static device better than the static device trains for itself, but this is not statistically significant and would need to be confirmed separately.

In specificity improvement (Figure 4), both overall false positive reporting and the difference in false positive reports on the third model favor dynamic simulator training. Here, false positive reports decreased (-0.70 false tumors) following dynamic simulator training but increased (+0.42 false tumors) following static training, as measured by the number of false positives reported after training minus the number of false positives before training (F(42)=5.20, p=0.0277). Also, in the third model false positives, participants who trained with the static device reported an average of 0.625 false positives versus 0.125 reported after training on the dynamic simulator, also statistically significant (F(42)=6.68, p=0.0133).

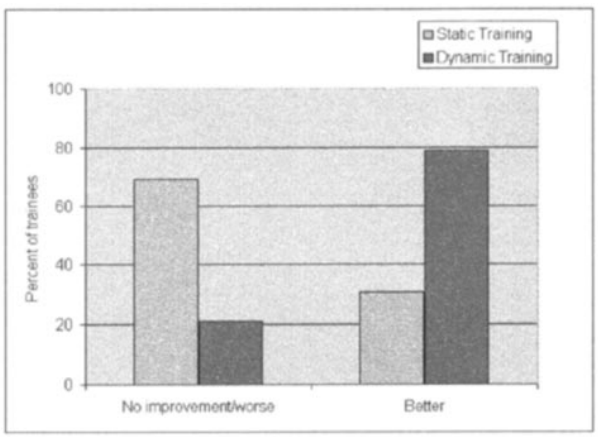

Figure 4: Change in false detections based upon training model (excluding trainees with no false positives on both pre-test and post-test)

DISCUSSION

Without increasing false-positive reports, detection training on a dynamic, variable-lump breast model leads to consistently higher detection sensitivity and greater skill transfer than training with a static breast model. Confirmation of the dynamic simulator's effectiveness verifies its promise, while providing insights into improvements necessary for development of CBE palpation skills. The findings suggest important limitations in current static breast examination training models, which are currently widely used for teaching CBE.

The composite improvement after dynamic simulator training shows nearly a one lump advantage. The advantage of dynamic simulator training on the third model is particularly encouraging because this model was essentially identical to the pre-test, training, and post-test static model. This similarity provided a significant advantage for the static device training group and intriguing results because the post-test static model was essentially identical to the static training model. The tumors were identical and situated in exactly the same locations as the static training model, yet the

dynamic simulator was a better training device for the final post-test. In fact, the static simulator's inability to transfer skills is alarming. Does this suggest that static device training might not transfer to real breast tissue? This suggestive outcome is left for future work.

In training situations, transfer is ultimately the most important instructional outcome (Alessi & Trollip, 1991). Training palpation skills requires adaptation to different tissue types, rather than specializing in a skill subset related to one type of silicone. Dynamic simulator trainees performed with greater tumor detection increases on not only the training device, but also on other breast simulators. Measuring training transfer to real breast tissue is also left for future research.

Traditionally, static Mammacare models increase sensitivity without improving specificity, which causes a high false-positive rate (Bennett et al., 1990; Campbell et al., 1991; Lee, Dunlop, & Dolan, 1998). Here again, static device training led to third model false positive increases of ½ a tumor over dynamic simulator training. False positive detections translate to needless anxiety or painful biopsy. During initial learning stages, specificity should be closely monitored through teaching subtle differences in stages.

CONCLUSION

A breast tumor training model with dynamically configurable, simulated tumors can significantly improve the trainee's sensitivity and specificity in detecting small breast tumors. This advancement can allow CBE to become more reliable, consistent, and effective.

CBE is a good candidate for early detection because it is practical, inexpensive, and highly effective with proper education. The Canadian National Breast Screening Study in 2000 demonstrated that mammography fails to show significant benefit over CBE (Miller et al., 2000). Tactile refinement is very promising, because the sense of touch has resolution rates rivaling those of sight (Heller, 1989). Considering the great potential possibilities of the trained tactile sense, mammography's weaknesses, and the potential for CBE – such tactile training may enable CBE to reach, measure, and retrain foreseen proficiency levels. Improved, consistent training could have a significant impact on high breast cancer occurrence and death rates.

Future work includes refining the simulator, measuring its educational efficacy, exploring training transfer to clinical experience, and the mathematical prediction of performance goals from a human factors context.

REFERENCES

Alessi, S. M., & Trollip, S. R. (1991). *Computer-based instruction: methods and development* (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall, Inc.

American Cancer Society. (2001). *Breast Cancer Facts and Figures 2001-2002*. Atlanta, GA: American Cancer Society.

Bennett, S. E., Lawrence, R. S., Angiolillo, D. F., Bennett, S. D., Budman, S., Schneider, G. M., Assaf, A. R., & Feldstein, M. (1990). Effectiveness of methods used to teach breast self-examination. *American Journal of Preventive Medicine, 6*(4), 208-217.

Campbell, H. S., Fletcher, S. W., Pilgrim, C. A., Morgan, T. M., & Lin, S. (1991). Improving physicians' and nurses' clinical breast examination: a randomized controlled trial. *American Journal of Preventive Medicine, 7*(1), 1-8.

Chalabian, J., & Dunnington, G. (1998). Do our current assessments assure competency in clinical breast evaluation skills? *American Journal of Surgery, 175*(6), 497-502.

Elmore, J. G., Barton, M. B., Moceri, V. M., Polk, S., Arena, P. J., & Fletcher, S. W. (1998). Ten-year risk of false positive screening mammograms and clinical breast examinations. *New England Journal of Medicine, 338*(16), 1089-1096.

Fletcher, S. W., O'Malley, M. S., & Bunce, L. A. (1985). Physicians' abilities to detect lumps in silicone breast models. *Jama, 253*(15), 2224-2228.

Hall, D. C., Adams, C. K., Stein, G. H., Stephenson, H. S., Goldstein, M. K., & Pennypacker, H. S. (1980). Improved detection of human breast lesions following experimental training. *Cancer, 46*(2), 408-414.

Harris, J., Morrow, M., & Norton, L. (1997). Malignant tumors of the breast. In V. Devita & S. Hellman & S. Rosenberg (Eds.), *Cancer Principles & Practice of Oncology* (5th Ed. ed., pp. 1561-1562). Philadelphia: Lippincott-Raven Publishers.

Heller, M. A. (1989). Texture perception in sighted and blind observers. *Perception & Psychophysics, 45*(1), 49-54.

Kern, K. A. (1992). Causes of breast cancer malpractice litigation. A 20-year civil court review. *Archives of Surgery, 127*(5), 542-546; discussion 546-547.

Kuroishi, T., Hirose, K., Suzuki, T., & Tominaga, S. (2000). Effectiveness of mass screening for breast cancer in Japan. *Breast Cancer, 7*(1), 1-8.

Lee, K. C., Dunlop, D., & Dolan, N. C. (1998). Do clinical breast examination skills improve during medical school? *Academic Medicine, 73*(9), 1013-1019.

Miller, A. B., To, T., Baines, C. J., & Wall, C. (2000). Canadian National Breast Screening Study-2: 13-year results of a randomized trial in women aged 50-59 years. *Journal of the National Cancer Institute, 92*(18), 1490-1499.

Pilgrim, C., Lannon, C., Harris, R. P., Cogburn, W., & Fletcher, S. W. (1993). Improving clinical breast examination training in a medical school: a randomized controlled trial. *Journal of General Internal Medicine, 8*(12), 685-688.

Wiecha, J. M., & Gann, P. (1993). Provider confidence in breast examination. *Family Practice Research Journal, 13*(1), 37-41.