Original Article

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Effectiveness of a Developed In-House Breast Phantom in Enhancing the Knowledge of Mammographic Positioning in Radiologic Technology Students: A Quasi-Experimental Study in Thailand

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Abstract:

Objective: This study aimed to develop an in-house breast phantom, and assess students' knowledge and satisfaction after using it for mammographic positioning training.

Material and Methods: The breast phantom was designed in a half-body shape, and constructed primarily using gelcoat resin, polyurethane foam, and thermoreversible gel. Additionally, silicone type RA-210, known for its high flexibility, tensile strength, elongation at break (620%), and ability to revert to its original shape, was incorporated. This study evaluated the effectiveness of the breast phantom utility in improving students' knowledge through a nine-item questionnaire; employing a one-group pre-post design. The participants, consisting of 63 Radiologic Technology students, whom rated their satisfaction with the phantom for training purposes using a five-point Likert scale.

Results: The mean knowledge score for the breast phantom positioning significantly improved from 5.35±1.61 points (pretest) to 7.32±1.20 points (post-test), following training (p-value<0.001). The students expressed high overall satisfaction with this training aid (4.49±0.58 points).

Conclusion: Our breast phantom demonstrates its potential as an effective educational tool that enhances Radiologic Technology students' understanding of mammographic positioning. However, further research is warranted to develop more advanced phantoms and to explore alternative experimental designs for effective teaching methods.

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Introduction

Pedagogical strategies as well as learning materials are essential for enhancing student knowledge and skills in health professional programs[1,2]. Mammography is one of the professional knowledge and skill required for radiographers in Thailand. The curriculum of undergraduate radiography educational programs in Thailand as well as some other countries, has included mammographic positioning training[3,4]. Learning and practicing breast positioning methods, used in mammography, are essential for developing knowledge and professional skills of Radiologic Technology students. However, the training opportunities in mammographic positioning are restricted in educational settings, due to the limited number of participants and chances to practice with patients. Hence, training with a breast phantom is a potential alternative.

A study of the material properties required for production of a breast phantom identified that polyurethane foam is suitable for constructing the inner frame of the phantom, because of its strength and light weight.[5] The silicone rubber can be mixed in colors close to a natural skin color, and it has a high elongation to break property.[6] The thermoreversible gel can be inserted into the breast and chest area to reproduce a breast density close to the that of a Thai female breast[7]. With this combination of materials, the breast phantom enables authentic manual positioning and compression with the thermoreversible gel, allowing the flexibility needed for the phantom to revert to its original shape[8].

Various breast phantoms have been used in mammography courses; including an armless half-body phantom made of sponge rubber, a shirt with a breast phantom that must be worn by a subject, and a commercially produced left breast phantom for teaching and learning purposes. These three breast phantoms have been used for training in mammographic positioning; however, they have had limited success. For example, a half-body phantom cannot be used for the MLO view[9], whilst the wearable breast model requires a volunteer[10] and is relatively costly[11]. Therefore, there is a need for a breast phantom that is easy to use for enhancing student learning. Therefore, this study aimed to develop an in-house breast phantom and evaluate students' knowledge and satisfaction when used to train Radiologic Technology students in mammographic positioning.

Material and Methods

Selection of silicone material and development of the breast phantom

The properties of various types of silicone rubber were investigated; including: RA-00AB, RA-22AB, RA-40AB, RA-210, and RA-320 (Rungart Co., Ltd., Bangkok, Thailand) These were tested for:, elongation at break, flexibility, skin texture, durability, and curing time, in terms of their potential for development of a breast phantom ,with a human-like texture that could be compressed during mammography without harm to users.

The designed breast phantom is anatomically close to a human female, with a height of 140 centimeters from the floor to neck level[12], and a bust line of 89 centimeters.[13] The considered materials that would produce a breast phantom suitable for training in mammographic positioning were:, able to withstand positioning and compression as well as being strong, durable, and lightweight. These materials included: gelcoat resin, cobalt, polyurethane foam, thermoreversible gel, silicone rubber, para rubber, and silicone spray. The breast phantom was created using the steps and components as shown in Appendix A. The phantom was convenient to use and move, and mammographic images could be taken from in both the craniocaudal (CC) and mediolateral oblique (MLO) projections (Figure 1).

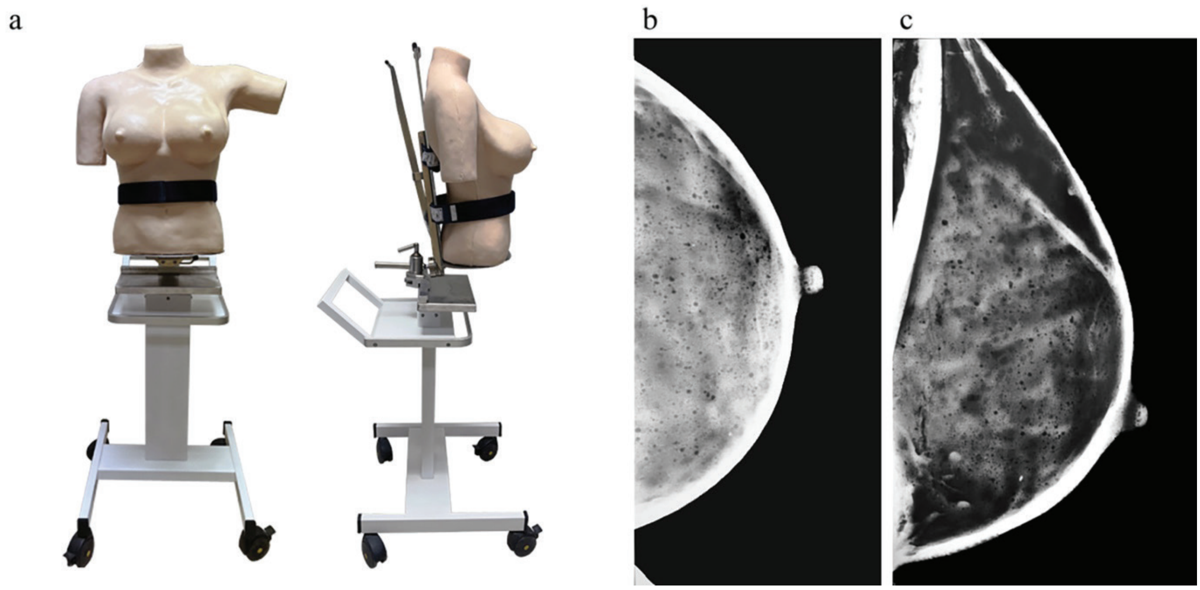

Figure 1 Breast phantom (a) and mammography in the craniocaudal (b) and mediolateral oblique (c) views

Study population

The study participants were 63 undergraduate Radiologic Technology students taking a mammography course that consisted of learning mammographic positioning in both lecture and practice sessions. There were 15 (12.3%) males and 48 (72.7%) females. Participants unwilling to participate in the study, those who provided incomplete information, and those who were absent from lectures and/or training in mammographic positioning were excluded. Participants who wished to withdraw from the study were advised that they were able to do so at any time.

The study was approved by the Human Research Ethics Committee of Chulabhorn Research Institute (Research Project Code 031/2564). All study participants provided written informed consent to be included in the study, after receiving an explanation of the study methodology.

Assessment of students' knowledge

The students' scores on a nine-item questionnaire (five items with four multiple-choice responses and four items presented as true-false questions); as shown in Appendix B. The questionnaire's content was designed to align with lesson learning outcomes of mammographic positioning. The accuracy and validity of the contents of the questionnaire was evaluated according to the teaching objectives by three instructors; each of whom had more than 10 years of working experience in diagnostic radiology, and at least 3 years of teaching experience on this topic (Appendix C). All the students attended a lecture on mammographic positioning in class before the training session. The complete nine-point pre-test and post-test scores were recorded before and after the training session with the breast phantom.

Assessment of satisfaction with the breast phantom

The breast phantom was designed and developed as a teaching support for training on mammographic positioning in the mammography room at two affiliated institutions. The students were asked to evaluate their satisfaction with the breast phantom in terms of teaching and learning using a

12-item questionnaire, with each item evaluated using a 5-point Likert scale (Appendix D).

Statistical analysis

All data are presented as the mean±standard deviation. The pre-test and post-test scores were determined as a normality test by using the Shapiro-Wilk test. The data were analyzed using the Wilcoxon two-sample paired signed-rank test for the data with non-normal distribution. All statistical analyses were performed using Stata/SE 12.1 software (StataCorp, College Station, TX, USA). A p-value<0.05 was considered statistically significant.

Results

Properties of silicone

The results for the properties of hardness (Shore A), viscosity, working time, curing time, tear strength, tensile strength, and elongation at break for the five different types of silicone; namely: RA-00AB, RA-22AB, RA-40AB, RA-210, and RA-320 are shown in Table 1. The silicone was selected based on properties of elongation at break, flexibility, resemblance to the texture of human skin, resistance to pressure, tensile strength, tear strength, reversibility after being pressed by the mammography machine and users, appropriate stabilization time, and ability to do no harm.

It was identified that the various types of silicone materials had different characteristics, both with advantages and disadvantages (Figure 2). For example, for RA-00AB, a very hard or soft touch surface could be maintained; however, it was not possible to mold due to its low viscosity, which meant that other materials could not adhere to the molding surface. RA-22AB (Figure 2a) has a very short curing time, which shortened the preparation process, but had a very hard surface texture. RA-40AB (Figure 2b) had the highest tensile strength with molding stability, but less flexibility. RA-210 (Figure 2c) had a very high elongation at break of 620%. Additionally, it adhered well to the surface while molding, with good stability, a soft touch resemblance to that of human skin, and was also flexible, tensile, and reversible after being pulled. RA-320 (Figure 2d) was an easy-to-use, basic silicone material with high viscosity, good adhesion to the surface while molding, and stability similar to that of RA-210; however, there was no elongation at break. Furthermore, it has a texture only moderately close to that of human skin, with limited flexibility and an inability to withstand high tensile strength, causing a tear during the test. Therefore, the most suitable silicone material for creating a breast phantom was RA-210.

Table 1 Properties of the various types of silicone tested

Property	Type of silicone				
	RA-00AB	RA-22AB	RA-40AB	RA-210	RA-320
Hardness (Shore A)	0	22	40	10	20
Viscosity (centipoise)	7,000-8,000	50,000	40,000-50,000	12,200-14,000	20,000
Working time (minutes)	30–35	4–6	30–35	30–40	30
Curing time	4 hours	15–20 minutes	4 hours	4-6 hours	4 hours
Tear strength (N/mm)	20	14	27	24	28
Tensile strength (mPa)	5	3.8	6	3.6	4.6
Elongation at break (%)	550	550	350	620	N/A

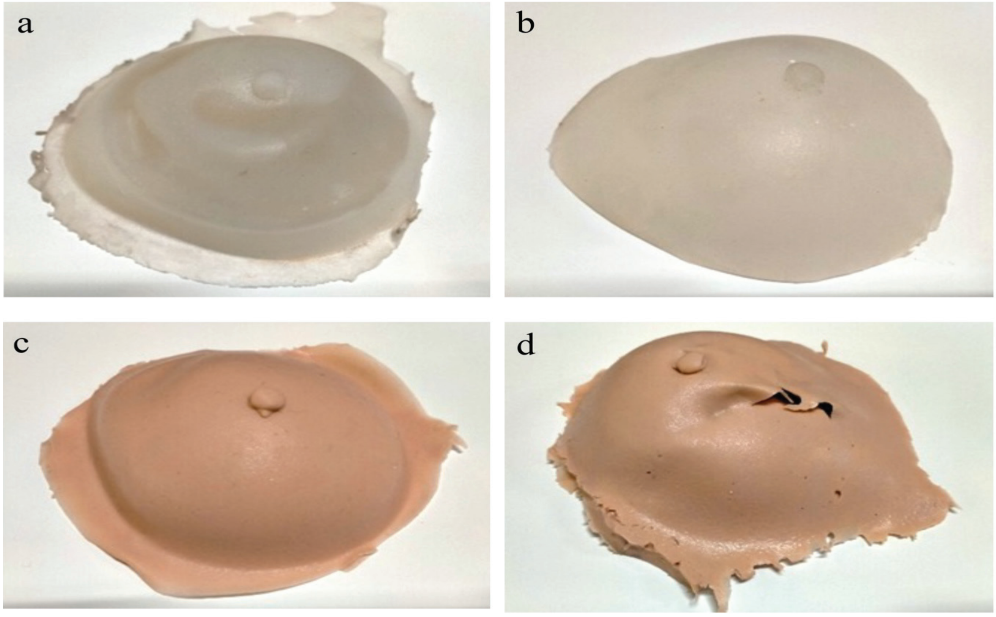

Figure 2 Characteristics of a breast obtained by molding using RA-22AB (a), RA-40AB (b), RA-210 (c), and RA-320 (d) silicone materials (note that RA-00AB could not be molded)

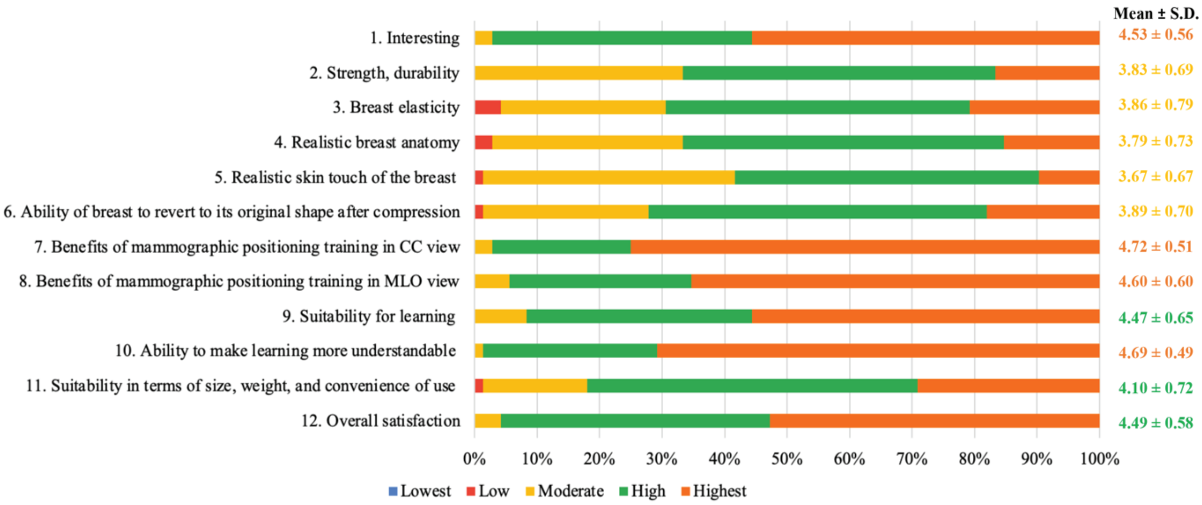

Figure 3 Rating of satisfaction by breast phantom users

Table 2 Pre-test and post-test scores for use of the breast phantom

Test (N=63)	Pre-test score	Post-test score	Post-test – pre-test scores	p-value
Mean score	5.35±1.61	7.32±1.20	1.97±1.76	<0.001*

All data are presented as the mean±standard deviation. *a p-value of<0.05 was considered significant, using the Wilcoxon two-sample paired signed-rank test

Pre-test and post-test scores for use of the breast phantom

The average post-test score for use of the breast phantom was 7.32±1.20 points, which was significantly higher than the mean pre-test score of 5.35±1.61 points (difference, 1.97±1.76 points, p-value<0.001; Table 2).

Satisfaction with use of the breast phantom

The participants rated their satisfaction with the breast phantom for teaching and learning purposes after practical training. The results are shown in Figure 3. Additional comments included the following: "learning by using a phantom made learning enjoyable and more realistic and understandable" and "the locking device should be firm." Furthermore, the phantom should be developed to make the internal components of the breast look realistic after mammographic imaging, have a light weight to facilitate positioning, and be soft.

Discussion

The breast phantom that was developed is mounted on a tripod, with a holder that can adjust the positioning of the phantom in different directions. This makes it easy to move, set positions, compress the breast phantom, and to obtain radiographic images, as it does not require a subject to wear it. Furthermore, the phantom can be used as a teaching aid for students learning both standard CC and MLO projections. The mammographic positioning requires a compression force greater than 100 N (10 daN) depending on individuals with different breast characteristics, and the pain threshold of the patient[14]. Therefore, thermoreversible gel was used to develop the breast phantom. These types of gels have high flexibility, so as that the phantom can revert to its original shape after compression. The RA-210 type of silicone had the highest elongation at break value, which gave the phantom good tensile strength, which meant that there was no tearing during positioning for mammography. The silicone used by the researchers contains elastomers, that is a polymer with elastic properties similar to those of rubber, and was the one most resemblance to human skin with long-term durability. There is no toxicity to users[6,15]. However, the satisfaction scores for strength, durability, flexibility, ability to compress, and realistic breast anatomy as well as texture were only moderate. Therefore, this breast phantom requires further development in terms of improving the formula and thickness of the silicone to make the breast skin thinner, while still providing flexibility and resistance to pulling or compression. There is also a need to identify materials that simulate breast tissue and fat to make this phantom look more realistic.

Positioning of the breast is an important factor when obtaining a good quality mammogram. The improperly positioned breast is the main contributor to poor mammographic imaging quality and difficulty in diagnosis[16], and is a problem at institutions that teach mammography to Radiologic Technology students in Europe. Mammographic positioning is an important skill for Radiologic Technology students, and they should be encouraged to have basic knowledge before being trained in the mammography room. This is to increase their confidence in positioning and their awareness of the future benefits for patients. However, teaching and learning in the curriculum still has some limitations. For example, students are unable to apply theoretical knowledge in practice and some institutions lack a breast phantom for mammography. Furthermore, recent surveys of students' needs have shown that there is a high demand for practical training to develop positioning skills and learn breast compression techniques[17,18]. Moreover, Radiologic Technology students at two universities in Nigeria have suggested that students' academic performance can be increased if they receive more practical training, with appropriate learning supports and materials.[19] Teaching methods for Radiologic Technology students and postgraduates should be varied; especially practical learning to help students gain a deeper professional knowledge[20,21]. The results of this study were in agreement with previous studies, which demonstrated that a significant increase in test scores for understanding mammographic positioning was observed after using the breast phantom as an additional teaching aid; rather than theory-based learning. Therefore, developing educational materials that promote students' knowledge of mammographic positioning is essential. In addition, students' satisfaction with this breast phantom was high. For example, the students indicated that the breast phantom was interesting and useful for training in both CC and MLO projections, provided better learning opportunities, and promoted understanding. The suggestions from students confirmed that use of the breast phantom made their learning more enjoyable, with more realistic training in mammographic positioning.

This study has some limitations. First, the reliability of the questionnaire should be further examined in a pilot group before use in the study participants. Second, this study had no control group. Future studies should compare the teaching methods, where experimental there is the use of the phantom and a control on patients, or non-use of the phantom.

Conclusion

The breast phantom developed in this study can be used by Radiologic Technology students as a training aid for mammographic positioning to contribute to their professional competence. These educational tools can improve the learners' understanding and elicited substantial contentment.

Ethics approval

The study was approved by the Human Research Ethics Committee of Chulabhorn Research Institute (Research Project Code 031/2564). All study participants provided written informed consent to be included in the study after receiving an explanation of the study methodology. Information on all study participants was kept confidential and de-identified.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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References

1. Bwanga O. Teaching professionalism to radiography students in the diagnostic imaging. South Asian Res J Appl Med Sci 2019;1:12-5. doi: 10.36346/sarjams.2019.v01i01.003.

2. Mylopoulos M, Brydges R, Woods NN, Manzone J, Schwartz DL. Preparation for future learning: a missing competency in health professions education?. Medical Education 2016;50:115-23. doi: 10.1111/medu.12893.
3. Strudwick RM, Taylor K. An investigation into breast imaging as part of the undergraduate (UG) education of diagnostic radiography students in the UK. Radiography 2017;23:141-6. doi: 10.1016/j.radi.2016.12.007.
4. Dos Reis CS, Pires-Jorge JA, York H, Flaction L, Johansen S, Maehle S. Curricula, attributes and clinical experiences of radiography programs in four European educational institutions. Radiography 2018;24:e61-8. doi: 10.1016/j.radi.2018.03.002.
5. Gama NV, Ferreira A, Barros-Timmons A. Polyurethane foams: past, present, and future. J Mater 2018;11:1841. doi: 10.3390/ma11101841.
6. Silicone Shin-Etsu. Characteristic properties of silicone rubber compounds. Silicone, Shin-Etsu. 2012. Available from: https://www.shinetsusilicone-global.com/catalog/pdf/rubber_e.pdf
7. Bhothisuwan W. Practicing breast imaging in HRT ladies in Thailand. J Med Assoc Thai 2004;87:S169-73.
8. Borchard W. Properties of thermoreversible gels. Ber Bunsenges Phys Chem. 1998;102:1580–8. doi: 10.1002/bbpc.19981021115.
9. Chusin T, Mahasaranon S, Udee N, Yabsantia S, Thongprong A. The development of breast phantom for clinical practice in mammography. Srinagarind Med J 2016;31:185–91.
10. Chusin T, Sandaeng J, Jirakittikool K, Aukusonsomboon S, Mahasaranon S, Thongprong A. Vest style breast phantom for practicing in mammography positioning. TMJ. 2017;17:325–35.
11. Supertech, Inc. Mammo II Phantom Model RS-750 [homepage on the Internet]. Indiana: Supertech; 2023 [cited 2023 Feb 20]. Available from: https://www.supertechx-ray.com/BreastImagingandMammography/Training/RSDRS-750.php
12. Roser M, Appel C, Ritchie H. Human height. Our world in data. [monograph on the Internet]. Oxford: Our World in Data; 2019 [cited 2023 Feb 20]. Available from: https://ourworldindata.org/human-height
13. Lim LY, Ho PJ, Liu J, Chay WY, Tan MH, Hartman M, et al. Determinants of breast size in Asian women. Sci Rep 2018;8:1201. doi: 10.1038/s41598-018-19437-4.
14. Moshina N, Sagstad S, Sebuødegård S, Waade GG, Gran E, Music J, et al. Breast compression and reported pain during mammographic screening. Radiography 2020;26:133-9. doi: 10.1016/j.radi.2019.10.003.
15. Shit SC, Shah P. A review on silicone rubber. Natl Acad Sci Lett 2013;36:355–65. doi: 10.1007/s40009-013-0150-2.
16. Popli MB, Teotia R, Narang M, Krishna H. Breast positioning during mammography: mistakes to be avoided. breast cancer: Basic Clin Res 2014;8:BCBCR-S17617. doi: 10.4137/BCBCR.S17617.
17. Strøm B, Jorge JP, Meystre NR, Henner A, Kukkes T, Metsälä E, et al. Challenges in mammography education and training today: the perspectives of radiography teachers/mentors and students in five European countries. Radiography 2018;24:41–6. doi: 10.1016/j.radi.2017.08.008.
18. Dos Reis CS, Strøm B, Richli-Meystre N, Jorge JP, Henner A, Kukkes T, et al. Characterization of breast imaging education and insights from students, radiographers and teaching staff about its strengths, difficulties and needs. Radiography 2019;25:e1–10. doi: 10.1016/j.radi.2018.07.001.
19. Uche CH, Chimuanya UD, Chigozie OF. Factors that affect teaching and learning among undergraduate radiography students in two Nigerian universities. J Med Radiat Sci 2019; 33:6–12. doi: 10.48153/jrrs.v33i1.223072.
20. Welch Haynes K, Ashworth Despino J. Teaching professionalism in radiologic technology. RS&E 2021;26:21–9. Available from: https://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=153551260&site=eds-live&authtype=ip,uid
21. Wrenn J, Wrenn B. Enhancing learning by integrating theory and practice. IJTLHE 2009;21:258–65.