J. Phys. Ther. Sci. 36: 195–201, 2024

The Journal of Physical Therapy Science

Original Article

Effectiveness of palpation technique training and practice using a muscle-nodule-palpation simulator

Kaoru Isogai, RPT, MS[1)*], Asuka Noda, RPT[2)], Ayumi Matsuzawa, RPT[3)], Shogo Okamoto, PhD[4)]

[1)] *Department of Physical Therapy, Faculty of Health and Medical Sciences, Tokoha University: 1230 Miyakoda-cho, Kita-ku, Hamamatsu-shi, Shizuoka 431-2102, Japan*
[2)] *Department of Rehabilitation, Suzukake Central Hospital, Japan*
[3)] *Independent Researcher, Japan*
[4)] *Department of Computer Science, Graduated School of Systems Design, Tokyo Metropolitan University, Japan*

Abstract. [Purpose] Extant techniques for palpating nodules, a diagnostic criterion of myofascial trigger points, lack high reliability. Therefore, this study aimed to investigate the effects of training and practice using a novel muscle-nodule-palpation simulator. [Participants and Methods] Sixteen university students (age range: 19–22 years) were randomly assigned to the training (*n*=8) and control (*n*=8) groups and used the muscle-nodule-palpation simulator to determine the position and orientation of the muscle nodule embedded in the model. During the experiment, only the participants in the training group were allowed to practice nodule detection while viewing the model through its transparent material. Subsequently, both groups underwent a performance evaluation. [Results] The training group exhibited greater improvement in performance than the control group. The means and standard errors of the improvement in the proportion of successful localization of the muscle nodule were 0.14 ± 0.06 for the control group and 0.42 ± 0.09 for the training group. [Conclusion] Training using the muscle-nodule-palpation simulator improved palpation technique for nodule localization.
Key words: Palpation, Simulator, Muscle nodule

(This article was submitted Nov. 29, 2023, and was accepted Jan. 16, 2024)

INTRODUCTION

Myofascial trigger points (MTrPs) are hyperirritable spots located within taut bands of skeletal muscle that cause myofascial pain and were originally reported to be characterized by local twitch response, referred pain, and jump sign[1)]. Later, nodules in the taut band were included in the criteria for the diagnosis of MTrPs[2)], and these points came to be recognized as palpable nodules existing within skeletal muscle[3–5)]. However, research on the interrater reliability of palpation of taut bands or nodules within a taut band, referred pain, and local twitch response have indicated Kappa scores between −0.08 and 0.75, −0.13 and 0.84, and −0.05 and 0.57, respectively[6)]. Thus, the development of effective training methods to increase the diagnostic skills of inexperienced practitioners is warranted.

Aside from palpable nodules (hereafter referred to as muscle nodules), the diagnostic criteria for MTrPs are derived from biological responses to stimulation of muscle nodules. Therefore, effective improvement of the diagnostic accuracy of MTrPs may be obtained by increasing the precision of identifying muscle nodules, which might result from better understanding of tactile sensation of muscle nodules. This may be achieved by allowing an experienced practitioner to palpate a patient to

*Corresponding author. Kaoru Isogai (E-mail: kisogai@hm.tokoha-u.ac.jp)

locate the muscle nodules, followed by an inexperienced learner pressing those nodules using varying degrees of force and speed; however, it is unlikely that the properties of muscle nodules identified by different experienced clinicians are constant, and therefore this method is not suitable for teaching inexperienced practitioners the properties of typical muscle nodules. Furthermore, because the hardness and shapes of muscle nodules and surrounding tissues are modified when stimulated by palpation, there are limitations to how well these tactile sensations can be conveyed directly to others by experts. Moreover, using actual muscle nodules for training cannot be recommended from an ethical point of view as continued palpation increases the pain of the patient.

Therefore, we developed an artificial muscle-nodule-palpation simulator modeled to reflect gluteus muscle tissues to complement the various problems experienced during palpation technique training[7]. The gluteus medius muscle located in the buttocks is associated with myofascial pain and is a major cause of lower back and leg pain[8, 9]. Similar models used for palpation training have been developed for breast cancer screening, and their educational benefits have been tested[10–15]. However, to the best of our knowledge, no such educational models have been developed for muscle nodule evaluations. The muscle-nodule-palpation simulator we developed is not a simple structure comprising hard material that is embedded in soft material; instead, it exhibits stress-strain characteristics similar to those of the human subcutaneous tissue and muscle. Because this model is transparent, it allows the user to visualize the embedded muscle nodule from the side view; furthermore, the model can be lifted, allowing the user to view the muscle nodule through the bottom of it. Therefore, using this model can help the user to train in the palpation method necessary to understand how muscle nodule models feel when pressed and explored with fingers. Hence, the transparent models are expected to foster the self-learning of palpation techniques.

Using a pre- and post-experimental study design, we have observed improvements in the ability to identify muscle nodules using our muscle-nodule-palpation simulator[16]. However, during a previous study, we did not consider the simple improvement achieved by repeated experience. Therefore, this study is an extension of our previous research that introduces a new between-group comparison of the experiment results and provides clearer conclusions about the effects of training muscle-nodule-palpation using our simulator.

PARTICIPANTS AND METHODS

Participants included 16 university students (8 males, 8 females, and 0 non-responders) aged 19–22 with no upper extremity diseases. None of them had attended the educational program for myofascial pain syndrome nor touched a muscle-nodule-palpation simulator. This study was approved by the Research Ethics Committee of Tokoha University (approval number: 2016-011H).

The muscle-nodule-palpation simulator[7] used in this study was cylindrical with a diameter of 120 mm and a height of 70 mm (Fig. 1a), simulating the subcutaneous tissues and gluteal muscles. The material used for the simulator was liquid rubber (H00-100 J, Exseal Corporation, Gifu, Japan), the hardness of which can be adjusted by changing the amount of hardening agent mixed in before curing. The muscle-nodule-palpation simulator had a four-layer structure, with a modulus of longitudinal elasticity of 20.7 kPa, 250.8 kPa, 20.7 kPa, and 522.1 kPa, respectively, from the top to the bottom layer. Similarly, the thickness of the layer was 6 mm, 6 mm, 34 mm, and 24 mm (Fig. 1b), respectively, from the top to the bottom layer. These specifications were determined in the previous biometrics study by the authors[7]. The top layer of the simulator was covered with knit fabric, and a cotton fabric was then placed between the top layer and the second layer, as well as between the second and third layers. The knit fabric was used to give the muscle-nodule-palpation simulator a tactile sensation similar to live skin and to prevent its upper surface from becoming sticky. Its multilayer structure with the cotton fabric inserts gives the muscle-nodule-palpation simulator stress-strain characteristics similar to those of a live body[7]. The upper two layers simulate subcutaneous tissue, while the lower two layers simulate muscle. The stress-strain characteristics of the subcutaneous tissue layer, muscle layer, and muscle-nodule-palpation simulator do not deviate significantly from those measured on corresponding examples from living subjects (Fig. 2)[17]. A transparent plastic sheet was attached over the bottom of the muscle-nodule-palpation simulator to maintain the transparency of its bottom surface.

A muscle nodule model was also produced with liquid rubber and embedded within the muscle-nodule-palpation simulator. The shape of the muscle nodule model conformed to what we have previously identified as the typical shape of a muscle

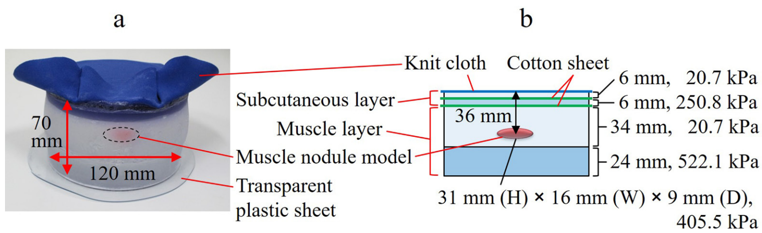

Fig. 1. Photograph (a) and schematic diagram (b) of the muscle-nodule-palpation simulator. In (a), the knit sheet is rolled back to show the structure of the simulator.

nodule: an ellipsoid with a major axis length of 31 mm, a minor axis length of 16 mm, and a thickness of 9 mm[18]. In addition, the stiffness of the muscle nodule model was 405.5 kPa. Although the best nodule hardness for training is unknown, the localization task for investigating the training effect of the simulator should be difficult. Further, since the need to practice identification muscle nodules would be lost when the model itself was too stiff, expert consensus indicated that the stiffness of the nodule should be as soft as the clinically softest nodules.

Five types of muscle-nodule-palpation simulators were fabricated. Simulator type 1 did not include a muscle nodule model, while the other four did. Three types of muscle-nodule-palpation simulators had muscle nodule models embedded radially (Simulator type 2), circumferentially (Simulator type 3), or obliquely (Simulator type 4), each 15 mm from the center when viewed from the top. Simulator type 5 had a muscle nodule model embedded in the center (Fig. 3). All muscle nodule models were implanted at a depth of 36 mm from the top of the muscle-nodule-palpation simulator (Fig. 1). This depth was based on the questionnaire results from the practitioners of manual physical therapy[18]. Since the liquid rubber, the primary material of the muscle-nodule-palpation simulator, is transparent after curing, the muscle nodule model could be seen from the bottom and lateral surfaces of the simulator as it was dyed red (Fig. 1).

This study was configured with two tasks. The first used four types of muscle-nodule-palpation simulators (Simulator types 1–4). Participants were shown the muscle nodule model embedded in the muscle-nodule-palpation simulators but were not allowed to touch it. They were then told that there may or may not be a muscle nodule model embedded in the muscle-nodule-palpation simulators that they would use. If there were one, it would be at a depth of approximately half the height of the simulator and within a radius of 45 mm from the center. Participants were also instructed that when touching the muscle-nodule-palpation simulator, they should not lift it, look into it from the side, or press it hard enough to cause pain, assuming it was human muscle. To determine if a muscle nodule model was present, participants were allowed to touch the muscle-nodule-palpation simulator for up to 1 min. If they determined that a muscle nodule model was present, they were instructed to place a stencil shaped like the muscle nodule model when viewed from the top onto the upper surface of the muscle-nodule-palpation simulator according to what they determined to be the position and orientation of the muscle nodule model. Using a randomized block design, all participants were then presented with four types of muscle-nodule-palpation simulators in a random order and orientation in each block. A total of five blocks (20 trials) were performed, with a 1-min interval after each block.

In task 2, participants were allowed up to 5 min to practice searching for the muscle nodule model in Simulator type 5. Participants were told that during the exercise, they were free to touch the muscle-nodule-palpation simulator as much as they liked and view it from the lateral sides or lift it and view the simulator from the bottom (Fig. 4).

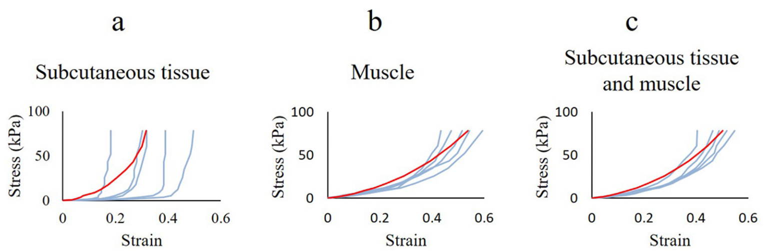

Fig. 2. Stress-strain curves of muscle-nodule-palpation simulator and human buttocks.
a: Subcutaneous tissue, b: Muscle, c: Subcutaneous tissue and muscle; red line: muscle-nodule-palpation simulator, light blue line: human buttocks (showing five cases from the 0th, 25th, 50th, 75th, and 100th percentile of all participants in the experiment described in Isogai et al[17].

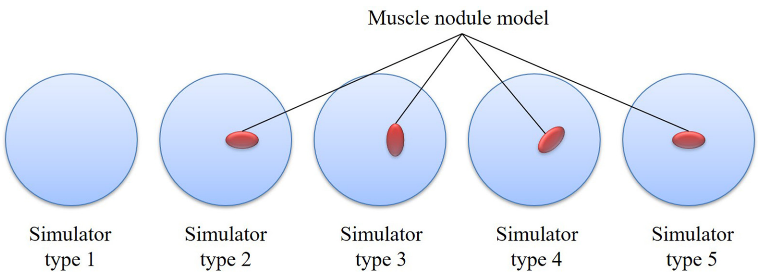

Fig. 3. Schematic diagram of the five types of simulators viewed from above.
Simulator type 1 did not include a muscle nodule model. Simulator types 2–4 had muscle nodule models embedded 15 mm from the center either in the radial direction (Simulator type 2), circumferential direction (Simulator type 3), or oblique direction (Simulator type 4). Simulator type 5 had a muscle nodule model embedded in the center.

The 16 participants were randomly assigned to training and control groups with eight participants each. The training group performed Task 1 in Session 1, Task 2 in Session 2, and Task 1 again in Session 3 (Fig. 5). The control group performed Task 1 in Session 1, rested for 5 mins in Session 2, and performed Task 1 again in Session 3 (Fig. 5). Participants in the training group were allowed to freely comment on what they noticed after practicing in Session 2 and the effect of practicing after Session 3. After completing Session 3, participants in the control group were allowed to express their opinions about the three sessions freely. In addition, we asked participants in both groups whether it was easier to find muscle nodule models in Session 3 than in Session 1.

The participants' responses toward Simulator types 2–4 with the muscle nodule models were analyzed, and those toward Simulator type 1 without the muscle nodule models were not. All muscle-nodule-palpation simulators that the participants judged to contain a muscle nodule model were then covered with a transparent sheet with a contour drawing of the muscle nodule model embedded on its top surface as seen from directly above, and the distance and angle of displacement between the contour drawing and the stencil placed by the participants were measured (Fig. 6). If the distance between the centers of two ellipsoids was less than 16 mm (the minor axis length of the muscle nodule model), this was considered a correct answer (success of localization). In contrast, displacement distances greater than 16 mm were considered incorrect. The misalignment angle was evaluated only if the position answered by the participant was correct. If the misalignment angle was less than 30 degrees, the trial was considered a correct answer (success of localization and direction). We also investigated the accuracy of the direction of muscle nodule, as it may be helpful for diagnosis utilizing the anatomical knowledge of muscle and bone structures. Responses indicating that a muscle nodule model was not present in sessions using Simulator

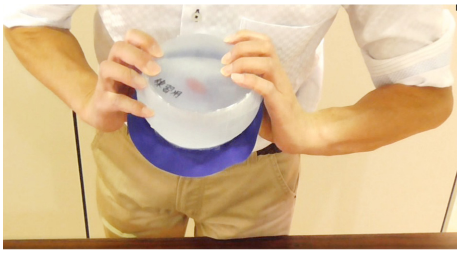

Fig. 4. Training group practices searching for the muscle nodule model in Simulator type 5 during Task 2.

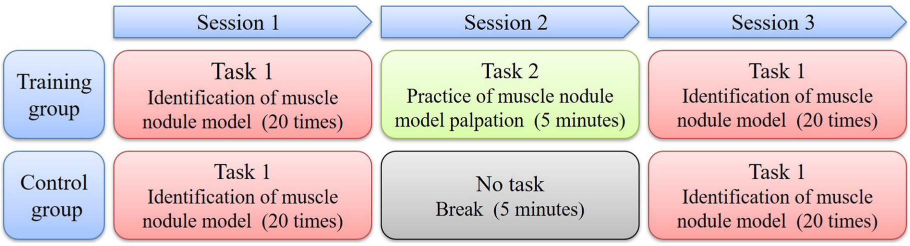

Fig. 5. Tasks for both groups in each session.

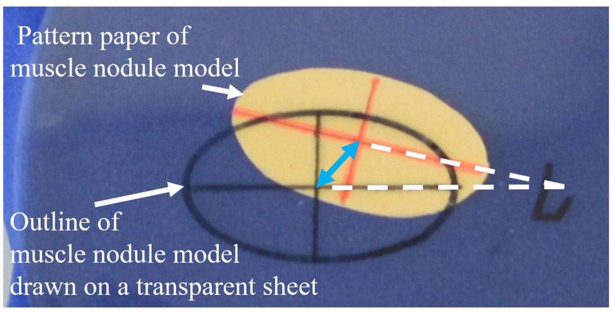

Fig. 6. The stencil of the muscle nodule model placed by participants and the transparent sheet with a contour drawing of the muscle nodule model placed over it. The stencil and contour drawings show lines indicating the major and minor axes of the muscle nodule model. Displacement distance: Length of the blue arrow, Misalignment angle: Angle formed by two white dashed lines.

types 2–4 were also considered incorrect. The proportion of success of localization and that of localization and direction were calculated from the results of the sessions using Simulator types 2–4; hence, a total of 15 trials were analyzed for each participant. For each group, the difference in the proportion of success of localization and proportion of success of localization and direction between Sessions 1 and 3 were calculated. These values are the improvement of success proportions due to training or sensitization. A t-test was then used to compare the improvement values between the two groups. Statistical significance was set at 5%. Microsoft Excel 2019 was used for the t-test.

RESULTS

Of the 16 participants, two were excluded from the analysis: one participant from the training group who lacked the strength to search for the muscle nodule model and one from the control group who could not find the muscle nodule model in any of the sessions.

The mean and standard errors of the improvement in the proportion of success of localization were 0.14 ± 0.06 for the control group and 0.42 ± 0.09 for the training group (Table 1). The mean and standard error of the improvement in the proportion of success of localization and direction were 0.14 ± 0.06 for the control group and 0.34 ± 0.09 for the training group (Table 1). There was a significant difference between the training group and the control group in the improved value of the proportion of success of localization (p=0.029), but there was no significant difference in the improved value of the proportion of success of localization and direction (p=0.091). Regarding Simulator type 1, which lacked the muscle nodule model, the presence of the nodule was incorrectly reported three times in Session 1 and once in Session 3 for both the training and control groups.

Based on the authors' consensus, the freely given opinions of the training and control groups were classified into four categories: understanding of the tactile sensation of the muscle nodule model, understanding of effective search methods, understanding which hand or finger parts to use for an effective search, and improvement due to sensitization. For example, "When I touched the muscle nodule model while looking at it in Session 2, I felt like, 'Oh! This is what it feels like'" and "During practice, I figured out the kind of stiffness and size of the muscle nodule model" were categorized as examples of understanding of the tactile sensation of the muscle nodule model. Items such as, "Before practice, I only pressed the simulator with my fingers in the depth direction, but after practice, I tried finding the muscle nodule model by applying force with my fingers in a horizontal direction as well", and "I had to touch the simulator very hard to find the muscle nodule model", were classified as an understanding of effective search methods. "After practicing, it was easier to find the muscle nodule model by feeling with my thumb" and "It was difficult to find the muscle nodule model with my thumb because the area was too small, so I touched it with my index, middle, and ring fingers together", were categorized as understanding which hand or finger parts to use for an effective search. Finally, responses such as, "I've gotten used to searching for the muscle nodule model because I have done it many times", and "My fingers have become accustomed to the sensation of the muscle nodule model" were categorized as an improvement due to sensitization. Table 2 shows the classified responses from participants, the number of participants in both groups who expressed a given opinion, and the number of participants who reported that Session 3 seemed easier than Session 1.

DISCUSSION

In this study, training using the muscle-nodule-palpation simulator was suggested to improve palpation techniques for nodule localization. Similarly, in a previous study, Gerling et al. developed a breast model that provides visual feedback of

Table 1. Means and standard errors of improved values for success of localization proportion and success of localization and direction proportion

	Control group (*n*=7)	Training group (*n*=7)	p
Localization	0.14 ± 0.06	0.42 ± 0.09	0.029
Localization and direction	0.14 ± 0.06	0.34 ± 0.09	0.091

Table 2. Classified responses from participants and the number of participants for each item

Contents	Training group (*n*=7)		Control group (*n*=7)
	After Session 2	After Session 3	After Session 3
Understanding of the tactile sensation of the muscle nodule model	5	5	1
Understanding of effective search methods	4	3	0
Understanding which hand or finger parts to use for an effective search	0	3	3
Improvement due to sensitization	0	1	2
Session 3 seemed easier than Session 1	–	7	3

pressure changes under palpation for testing the accuracy of breast lump detection. They reported no significant differences in the discrimination abilities of participants who were not trained and participants who were trained with visual feedback[10]. Additionally, they subsequently developed a dynamic breast model equipped with pulsating lumps and compared the accuracy of lump detection after training with this model to that achieved after training with a static breast model. This study found that the improvement in the number of lumps detected for the five lumps embedded in the static model was 1.17 in the group trained with the dynamic model and 1.04 in the group trained with the static model and that there was no significant difference between the two groups[11]. Other studies have also reported training effects using breast models embedded with a model lump. For example, McDermott et al. reported an approximately 10% improvement in sensitivity after training with the lump palpation model[12]. Additionally, Steiner et al. found that 84% of those who trained with a breast model palpated the 3-mm lump, whereas only 46% of those who did not train with a model were able to detect it; this difference was significant[13], and Trapp et al. found that untrained participants found 8 out of 18 lumps in their model, while significantly more lumps (13.7 lumps) were found by trained participants[14]. Multiple studies have shown the various results of training effects using breast models in the field of breast cancer medicine. The effects of training with a muscle nodule model cannot be directly compared to the effects of training with a breast lumps model to detect breast cancer. Nevertheless, it is certainly no coincidence that the improvement in the proportion of success of localization during 15 trials in this study was significantly higher for the training group.

The between-group comparative experimental design showed that the novel muscle-nodule-palpation simulator was effective for training palpation techniques for the purpose of muscle nodule exploration and detection. During the training session, participants in the training group were allowed to touch and move the muscle-nodule-palpation simulator; they were also able to view the muscle nodule model from the bottom. During a free discussion after the experiment, five participants indicated that they achieved a better understanding of the tactile sensation of the muscle nodule model, and four participants mentioned that they achieved a better understanding of effective search methods (Table 2). This suggests that training using the muscle-nodule-palpation simulator allowed the users to inform the tactile sensation of the muscle nodule model and the active manipulation method necessary to produce it, thus contributing to the improved localization success of the training group.

Three participants in the control group thought that the muscle nodule model was detected more easily during the session 3 attempt than during the session 1 attempt. Furthermore, compared to the training group participants, more control group participants mentioned that their understanding improved with repeated practice, which may indicate that sensitization by repeated palpation is a benefit that is more often observed in the control group. After the experiment, three participants in the control group achieved an understanding of the body parts encountered during effective exploration, and one participant achieved an understanding of the tactile sensation of the muscle nodule model. This suggests that sensitization by repeated palpation is caused by participants incidentally noticing the body parts for effective exploration and the tactile sensation of the muscle nodule model.

The average improvements in the proportion of success of localization and direction among the control and training groups were 0.14 and 0.34, respectively; however, this difference was not significant ($p=0.091$). The muscle nodule model embedded in the muscle-nodule-palpation simulator used during this experiment had a long diameter that was almost twice the length of the short diameter and formed an elliptical shape where the thickness tapered toward the end. Moreover, the muscle nodule model was made of soft material so that detection was not too simple. The shape and hardness of the muscle nodule model may have resulted in more difficult detection of the direction. The participants in our study did not provide comments regarding the direction of the muscle nodule model. This suggests that the participants' attention was focused on confirming the existence of the muscle nodule model during training. Therefore, a more emphatic explanation for concentrating on checking the direction of the muscle nodule model before beginning the experiment could improve the direction identification success. Moreover, only 14 participants were analyzed during this study. Thus, the sample size was not large enough to conclude whether the success of direction identification significantly improved.

The majority of earlier studies used breast lump models for training and tested their effect using the same or similar models[10–14]. Some exceptions include the study by Hall et al. in 1980, who tested the benefits of training with a breast model for the detection of lesions in natural breast tissue[15]. Although breast cancer is an active area of research, their study was the last to use an actual lesion to evaluate the palpation technique. To our knowledge, there have been no other similar studies, thus demonstrating the difficulty of using actual biological lesions for the purpose of breast cancer research and education and the importance of models. This indicates that the availability of models for muscle-nodule-palpation training is also important for the field of physical therapy. The findings of this study should lead to the development of commercial models that increase the reliability of palpation of MTrPs and the establishment of educational programs.

Conference presentation

Part of this study was presented at the Conference of Asia Haptics 2016.

Funding

This work was supported by JSPS KAKENHI Grant Numbers 24500520, 17K01536.

Conflict of interest

The authors have no conflicts of interest to declare regarding this study.

REFERENCES

1) Travell JD, Simons DG: Myofascial pain and dysfunction: the trigger point manual. Baltimore: Williams & Wilkins, 1983, pp 59–63.
2) Simons DG, Travell JG, Simons LS: Travell & Simons' myofascial pain and dysfunction: the trigger point manual. Vol. 1. Upper half of body, 2nd ed. Baltimore: Lippincott Williams & Wilkins, 1999, pp 116–122.
3) Sharan D: Myofascial pain syndrome: diagnosis and management. Indian J Rheumatol, 2014, 9: S22–S25. [CrossRef]
4) Holanda L, Fernandes A, Cabral AC, et al.: Pathophysiology of myofascial trigger points: a review of literature. Int J Basic Appl Sci, 2015, 4: 73–77. [CrossRef]
5) Shah JP, Thaker N, Heimur J, et al.: Myofascial trigger points then and now: a historical and scientific perspective. PM R, 2015, 7: 746–761. [Medline] [CrossRef]
6) Lucas N, Macaskill P, Irwig L, et al.: Reliability of physical examination for diagnosis of myofascial trigger points: a systematic review of the literature. Clin J Pain, 2009, 25: 80–89. [Medline] [CrossRef]
7) Isogai K, Okamoto S, Yamada Y, et al.: Skin-fat-muscle urethane model for palpation for muscle disorders. IEEE/SICE International Symposium on System Integration, 2015, 960–964.
8) Kameda M, Tanimae H: Effectiveness of active soft tissue release and trigger point block for the diagnosis and treatment of low back and leg pain of predominantly gluteus medius origin: a report of 115 cases. J Phys Ther Sci, 2019, 31: 141–148. [Medline] [CrossRef]
9) Kameda M, Tanimae H, Kihara A, et al.: Does low back pain or leg pain in gluteus medius syndrome contribute to lumbar degenerative disease and hip osteoarthritis and vice versa? A literature review. J Phys Ther Sci, 2020, 32: 173–191. [Medline] [CrossRef]
10) Gerling GJ, Thomas GW: Effect of augmented visual performance feedback on the effectiveness of clinical breast examination training with a dynamically configurable breast model. SMC'03 Conference proceedings, 2003, 3: 2095–2100.
11) Gerling GJ, Thomas GW: Augmented, pulsating tactile feedback facilitates simulator training of clinical breast examinations. Hum Factors, 2005, 47: 670–681. [Medline] [CrossRef]
12) McDermott MM, Dolan NC, Rademaker A: Effect of breast-tissue characteristics on the outcome of clinical breast examination training. Acad Med, 1996, 71: 505–507. [Medline] [CrossRef]
13) Steiner E, Austin DF, Prouser NC: Detection and description of small breast masses by residents trained using a standardized clinical breast exam curriculum. J Gen Intern Med, 2008, 23: 129–134. [Medline] [CrossRef]
14) Trapp MA, Kottke TE, Vierkant RA, et al.: The ability of trained nurses to detect lumps in a test set of silicone breast models. Cancer, 1999, 86: 1750–1756. [Medline] [CrossRef]
15) Hall DC, Adams CK, Stein GH, et al.: Improved detection of human breast lesions following experimental training. Cancer, 1980, 46: 408–414. [Medline] [CrossRef]
16) Isogai K, Okamoto S, Noda A, et al.: Training on muscle palpation using artificial muscle nodule models. Haptic Interaction, 2016, 432: 335–340.
17) Isogai K, Okamoto S, Asaba T, et al.: Young's moduli of subcutaneous tissues and muscles under different loads at the gluteal region calculated using ultrasonography. J Phys Ther Sci, 2022, 34: 777–783. [Medline] [CrossRef]
18) Isogai K, Okamoto S, Yamada Y: Properties of muscle nodules recognized by manual physical therapy practitioners. J Phys Ther Sci, 2021, 33: 356–361. [Medline] [CrossRef]