Journal of Acupuncture Research

Journal homepage: http://www.e-jar.org

Review Article

Trends in Acupuncture Training Research: Focus on Practical Phantom Models

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Article history:
Submitted: January 25, 2022
Accepted: March 11, 2022

Keywords:
acupoint, acupuncture, education, training

https://doi.org/10.13045/jar.2022.00024
pISSN 2586-288X eISSN 2586-2898

ABSTRACT

The purpose of this review was to identify research trends in acupuncture training systems and models and to analyze acupuncture training using phantom models. Articles on acupuncture training were retrieved from domestic and foreign electronic databases (PubMed, CNKI, CiNii, NDSL, KISS, RISS and KMBase). The search included studies conducted from January 1, 2010 to October 1, 2021. Acupuncture training was analyzed by categorization into acupoint location training and needling training. Acupuncture training was most frequently studied in China, acupoint location training was the most studied in 2012, and needling training was the most studied in 2013 and 2020. Among them, a silicone model with a sensor was used for training in acupoint location, and silicone and agarose gel were frequently used for needling training. Classifications of the phantom models for needling training by topic included phantom development, phantom-based education and evaluation system, phantom-based quantitative measurement, comparison of kinematic characteristics of hand motion between experts and beginners, and phantom models for acupoint location and needling training. Further research on the development of acupuncture practice training systems to improve practical skills is needed.

Introduction

Acupuncture is a unique treatment in oriental medicine with a therapeutic effect that mainly depends on the doctor's understanding and skill of acupuncture [1]. Acupuncture training is essential to ensure the correct needling (speed, frequency, amplitude, and strength) for the patients' physique and pattern identification [2]. The angle and depth of needling varies for each acupoint, even if the needle is inserted at the same point. In addition, to increase the effectiveness of acupuncture training, it is necessary to train practitioners in the appropriate amount of stimulation required to access qi [3].

To apply academic knowledge, students work in clinical practice to train in standard procedures [4]. In 2009, the Clinical Skills Examination was introduced in Korea as a national examination for practitioners to not only examine medical knowledge, but also examine basic skills in clinical performance [5]. Through practice in the clinical setting, students majoring in health and medical science had reduced anxiety regarding implementation of skills and improved these skills and their knowledge [6]. Furthermore,

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students' confidence improved as their clinical performance improved with practice [7], which in turn contributed to the safety of patients and practitioners and prevented medical accidents [8].

Traditionally, clinical skills have been taught academically which were then followed by an apprenticeship system. However, more recently programs have been developed to teach medical skills during the students' education. In addition to traditional teaching methods such as lectures, practical education methods using animals and practice models have been established [9], as have online education such as web-based training as an alternative to traditional practical education [10]. University students majoring in health and medical science undertake practice of skills using videos and this gives immediate feedback to the students' [11]. Content that combines virtual reality and augmented reality technology for acupuncture skills education is increasing, along with further technological developments considered to be the 4th Industrial Revolution [12,13].

There are various methods for improving clinical practice skills, however, the optimal way is to practice the techniques on a human body. However, in the case of invasive techniques, for ethical reasons, this is impossible [14]. Thus, a realistic practice model is required as a substitute for the human body. Through an objective structured clinical examination (OSCE), which was 1st presented by Harden in 1975, repetitive skill practice through simulation education is performed using models of the human body. As the OSCE evaluation method becomes more common, phantom models have been used in practical education to mimic the patient and these include simulation methods used in nursing colleges [15,16], medical schools [17-19], and veterinary colleges [20].

The College of Oriental Medicine recognizes the need for clinical practice education and conducts evaluations using the OSCE and clinical performance examination for clinical practice. However, it has been reported that in most departments, traditional passive practices are mainly conducted such as ward rounds, observations, and lectures [21,22]. There remains a lack of models and systems for acupuncture training and evaluation, thus, classmates practice on, and evaluate each other to gain practical skills in the practice of acupuncture [23]. Even when a model is used to replace the human body, the model is insufficient, and there has previously been little development of suitable models. Accordingly, satisfaction of clinical skill education is low in oriental medical students [24,25]. However, in the last decade in the field of oriental medicine, various acupuncture training methods are being studied by combining advanced digital systems such as virtual reality and mixed reality, and models necessary for practicing techniques are being developed [26-28].

Therefore, the purpose of this study was to investigate Eastern and Western research trends in acupuncture training systems and models reported between January 1, 2010 [when the standards for reporting interventions in clinical trials of acupuncture (STRICTA) was revised] and October 1, 2021, to provide a foundation for the development of an acupuncture practice education system that can be applied to practical learning by focusing on training using phantom models.

Materials and Methods

The article search was conducted on October 1, 2021, and articles published after 2010 (when STRICTA was revised) were targeted. Articles were retrieved from domestic databases (NDSL, KISS, RISS, and KMBase) by using combinations of the search terms "acupuncture," "practice," "training," "education," and "model." Articles were retrieved from international databases (PubMed, CiNii, and CNKI) using combinations of search terms "acupuncture," "skill," "training," "model," "phantom," "education," "learning," "teaching," "manipulation," and "OSCE." Based on the references of the searched articles, a further search was conducted to ensure that no relevant articles were omitted from this review (Fig. 1).

Acupuncture training was divided into training before, and after needling, and included training to accurately locate acupoints, and needling training.

Selection criteria

- Articles on the acupuncture training system and model (acupuncture is based on the use of a filiform needle, but it also includes warm needling and virtual acupuncture used as a simulator).
- Articles written in Korean, English, Chinese, and Japanese.
- Articles published in journals.

Exclusion criteria

- Articles not related to acupuncture training.
- Articles on acupuncture related systems and models not used for acupuncture training.
- Articles related to anatomy training, rather than acupoints and meridians.
- Articles without full text.
- Review articles and duplicate articles.

There were 2 researchers who independently retrieved and screened (according to the selection and exclusion criteria) the articles, if there was a disagreement between selected articles a 3rd researcher made the decision.

Results

Among the selected 140 articles for review; (1) acupoint location training; and (2) needling training were used to classify the type of research.

Training of acupoint locations

There were a total of 94 articles on training to locate acupoints, 19 of which were also categorized as articles that corresponded with needling training. According to the training mode, they were classified into 6 topics; (1) training modes using multimedia, such as videos for training on acupoint location (n = 30); (2) training using an acupoint detection device to locate acupoints such as a laser or a deep convolutional neural network-based device (n = 2); (3)

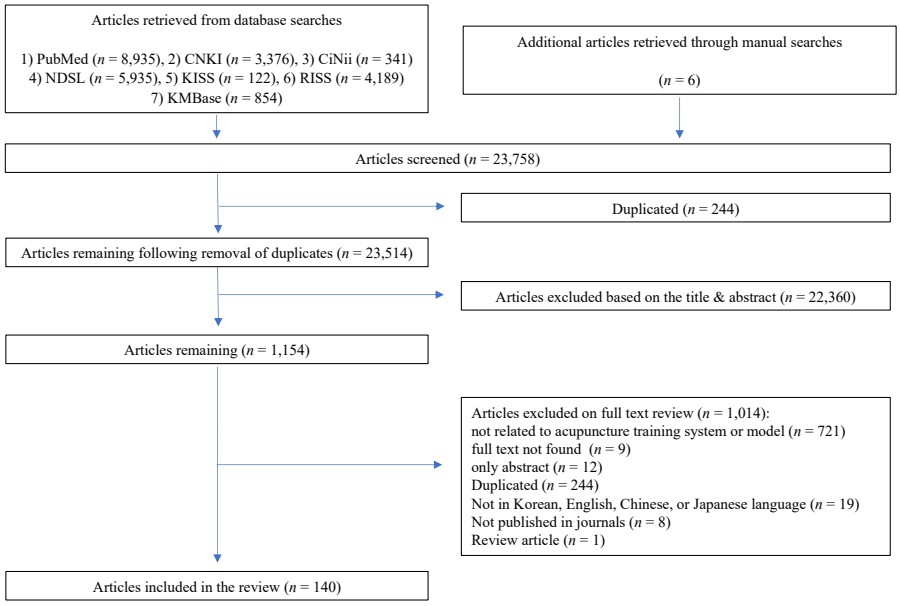

Fig. 1. Flow chart of the screening process.

training using a 3D human model using software such as OpenGL and Unity3D where the external appearance of the human body can be visualized without realizing anatomical structures (n = 33); (4) training using a 3D human model with anatomical structures (n = 10); (5) training using a digital human acupoint system based on image data of the human body such as X-ray and magnetic resonance imaging (n = 5); and (6) training using phantom models which mimic the response of the human body (n = 14).

Comparison by country

The country in which the research was conducted was the standard for categorization by country. If the location was not specified, the affiliation of the 1st author was used. Most studies were conducted in China (n = 74), followed by Korea (n = 15), Japan (n = 3), and Hong Kong and the United Kingdom (UK; 1 each; Fig. 2). According to the national distribution by topic, 30 articles related to training using multimedia, such as videos, were conducted in relatively diverse countries. Among them, most (n = 26) articles were from China, followed by 2 from Korea, 1 from Hong Kong, and 1 from the UK. There were 2 articles related to training using an acupoint detection device, 1 each in China and Korea. There were 33 articles related to training using a 3D human model that visualizes the external appearance of the human body without anatomical structures, of which 30 were conducted in China, 2 in Korea, and 1 in Japan. Of the 10 articles on training using a 3D human model with anatomical structures, 5 were from China, 3 from Korea, and 2 from Japan. Of the 5 articles on training using a digital human acupoint system based on human body image data, 3 were from China, and 2 were from Korea. Of the 14 articles on training using phantom models, 9 were from China and 5 were from Korea. Among Korean articles, training using the phantom model was the most frequent.

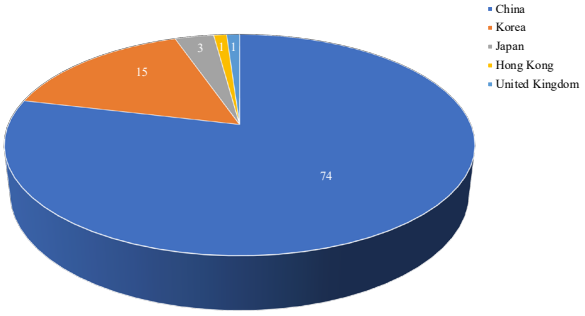

Fig. 2. Number of articles by country/territory related to acupoint location training.

Comparison by year

For research on training to locate acupoints, the year of publication was the classification criterion. Of the 94 articles, most articles were published in 2012 (n = 15), followed by 2019 (n = 13), 2020 (n = 13), and 2013 (n = 12; Fig. 3). According to the year distribution by topic, most articles in early 2010 were on training using multimedia, such as video. In the latter half of 2010, research on training using a 3D human model that visualized the external appearance of the human body and training using a phantom model were conducted relatively actively. In 2020 and 2021, the number of articles on training using a 3D human model with anatomical structures gradually increased (Fig. 4).

Phantom models for acupoint location training

Among articles regarding phantom models for acupuncture training, 14 articles were related to acupoint location training, of which 8 involved the model marked with acupoints, and 6 involved the model without acupoints. Among them, 2 articles on a model

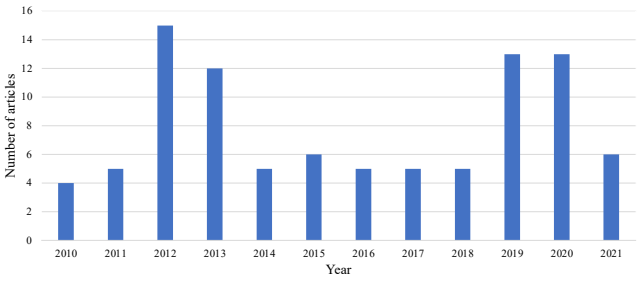

Fig. 3. Number of articles by year related to acupoint location training.

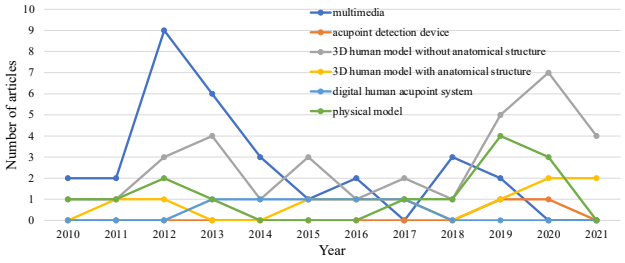

Fig. 4. Number of articles through annual progress related to acupoint location training by topic.

that can train acupoint locations and needling were counted in duplicate. When 8 articles related to the model marked with acupoints were classified by model material, 7 used bronze and 1 did not mention the material. The 6 articles related to the model without acupoints were classified by model material; silicone was the most common (n = 4; Table 1) [26,29–33]. Cheung et al [30] used 3 layers of material, with an outer surface of silicone. However, the silicone model involved only 1 portion of the human body. All models allowed for the training or evaluation of the location of acupoints through internal or external attached sensors. Of these, 2 articles mentioned the evaluation of using a phantom model application in acupoint location training. Yeo et al [31] mentioned, but did not evaluate the applicability of the model, while the remaining articles [26,32,33] mentioned only the technical evaluation of the model.

Needling training after needle insertion

A total of 65 articles involved needling training after the insertion of acupuncture needles. There were 19 articles also categorized as acupoint location training. Articles were classified according to the acupuncture training target: a phantom model, directly on the human body, virtual model (i.e., 3D human model), and acupuncture training systems for which the presence or absence of a model was not mentioned. In this study, the acupuncture training system refers to a training system that quantifies force, position, and motion with sensors and cameras during needling. There were 22 articles which entailed training using a phantom model, 2 of which were also categorized with articles of acupoint location training. There were 7 articles which entailed acupuncture training for needling on the human body; 5 of them mentioned the acupuncture training site, which included PC6, the upper 18 cm area of the patella, LI11, LI10, and ST36. Among them, 3 articles selected LI11 as the acupuncture training site. Of the 25 articles on training using a virtual model, articles on training only with a virtual model without force feedback were the most abundant (n = 20), and 5 articles included a haptic device combined with force feedback. There were 11 articles which only mentioned the acupuncture training system without mentioning the presence or absence of a model; 2 of them entailed the warm needling training system.

Comparison by country

Most studies were conducted in China (46/65: 70%; Fig. 5). The national distribution by training target was as follows: among 22 articles on training using phantom models, 10 each were from China and Korea, and 2 were from Canada. Of the 7 articles on acupuncture training for needling on the human body, 5 were from China, and 1 each from Switzerland and Singapore. Among the 25 articles on training using a virtual model, most were from China (n = 21), followed by Japan (n = 3) and Brazil (n = 1). Among them, 5 articles

Table 1. Summary of Phantom Models for Acupoint Location Training.

First author [ref] (y)	Material of the model	Body part of the model	Sensor for detecting the needle	Evaluation of the model application in acupoint location training
Cai et al [29] (2013)	Silicone	Eyes, back, head	2 conductive layers	Improve the ability to determining acupoint location.
Cheung et al [30] (2019)	VMQ, PMMA, PVC	Arm	REP 601 pressure sensor	After 3 training sessions, the name and location of the acupoints were better understood.
Yeo et al [31] (2019)	Silicone	Foot	Light sensor	n.r.
Ryu et al [26] (2020)	n.r.	Whole body	Tracking sensor	n.r.
Ryu et al [32] (2020)	FRP	Whole body	Tracking sensor	n.r.
Liu et al [33] (2020)	Silicone	Arm	High precision pressure sensor	n.r.

FRP, fiber reinforced plastics; MR, mixed reality; n.r., not reported; PMMA, methyl methacrylate; PVC, polyvinyl chloride; VMQ, methyl vinyl silicone rubber.

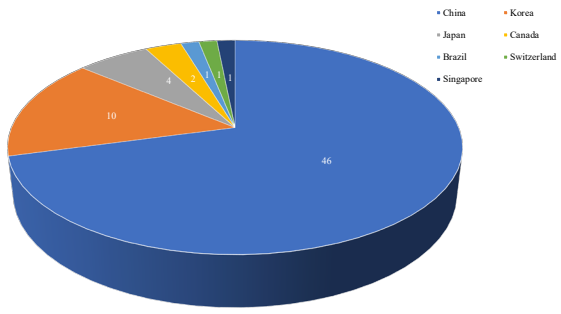

Fig. 5. Number of articles by country/territory related to needling training.

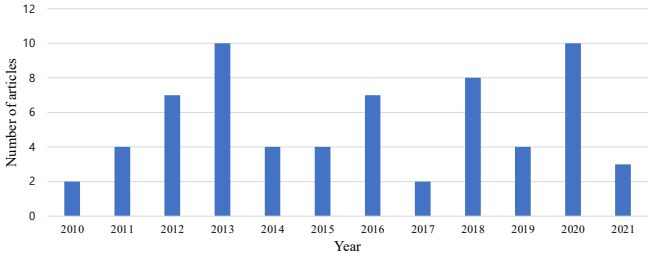

Fig. 6. Number of articles by year related to needling training.

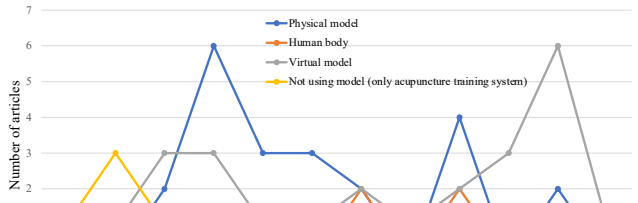

Fig. 7. Number of articles by training target through annual progress related to needling training.

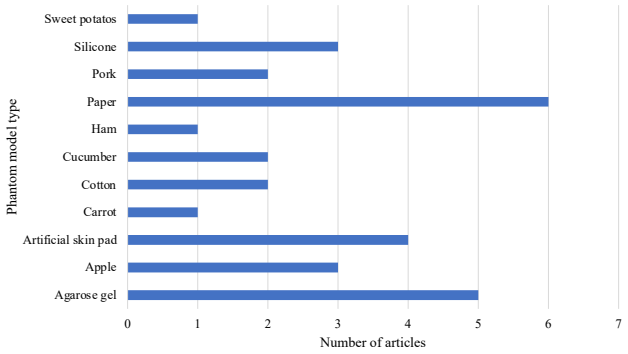

Fig. 8. Number of articles used for needling training by phantom model type*.
* If multiple models were mentioned in one article, they were counted repeatedly.

were on haptic devices: 3 from China and 2 from Japan. Of the 11 articles that mentioned an acupuncture training system without mentioning the presence or absence of a model, 10 were from China. The 2 articles on the warm needling training system were also from China.

Comparison by year

Classification by year of publication indicated that 10/65 articles were published in 2013 and 2020, followed by 8 in 2018 (Fig. 6). According to year, the number of articles mentioning only the acupuncture training system, without mentioning the presence or absence of a model, was the highest in 2011; many articles entailed training using a phantom model in 2013, and many articles involved training using the virtual model in 2020 (Fig. 7).

Phantom models for needling training

Among the phantom models for acupuncture training, the 22 articles on needling training after the insertion of acupuncture needles included 2 articles on acupoint location training that were counted in duplicate. Classification by phantom model type revealed that paper was the most common material used (n = 6), followed by agarose gel (n = 5), artificial skin pads (n = 4), apples and silicone (n = 3 each), pork, cotton and cucumbers (n = 2 each), and sweet potatoes, carrots, ham, and konjac (n = 1 each; Fig. 8). There were 22 articles which were divided by topic: 6 entailed stacked paper and solid cotton (used to increase finger strength during needle insertion and needling); 3 were on the development of a phantom to replace the human body; 7 entailed the phantom-based acupuncture education program; 4 were on phantom-based quantitative evaluation for the standardization and objectification of acupuncture training; and 2 compared the kinematic characteristics of hand motions of experts and beginners during needling into the phantom.

While some studies conducted acupuncture training with objects common in daily life such as paper and cotton to develop finger strength, there were also cases of developing a phantom model with a needle sensation similar to that of the human body (n = 3; Table 2) [34-36]. All 3 studies were conducted in Korea; needle sensation using the numeral rating scale or visual analog scale to measure pain, and needle force using a 6-axis force sensor were compared. There were 2 articles which used a human body as the control and included ST36. All needle manipulations involved twirling; only the manipulations of the experimental group differed. Only 1 article used pork, and (forelimb meat from domestic pigs 7 to 10 days deceased) was used as a control.

There were 7 articles related to phantom-based acupuncture education programs (Table 3) [29,33,37-41]. The phantoms used in the acupuncture education program included agarose gels (n = 4) and silicone (n = 3), of which 2 articles were counted in duplicate. In 6 of the 7 articles, visual feedback on the motion pattern of acupuncture was used through motion, stress, and pressure sensors; 5 of these studies evaluated the learner's skill improvement, and 1 (without visual feedback) included training wherein an alarm signal was activated by recognizing the depth of input through the

Table 2. Summary of Phantom Development.

First author [ref] (y)	*N*	Needle size (mm)	Control group	Experimental group	Needling manipulation	Evaluation index of phantom	Result of the study
Han et al [34] (2013)	3	0.40×40	Human (ST36)	Cucumber, apple, sweet potato, carrot, ham, konjac	Twisting rotating	1) Toque Z force 2) Needle sensation	Cucumber and apple are slightly similar to ST36.
Lee et al [35] (2014)	1	0.25×40	Human (LI4, LI11, LR3, ST36, ST25, BL25)	1–7% agarose gel	Twisting	1) Rotation force 2) Needle sensation	5% agarose gel and LI4 are similar.
Lee et al [36] (2018)	7	0.35×40	Pork (forelimb)	Tissue paper, cotton, cucumber, apple, IM injection pad	Lifting thrusting	1) Friction force 2) Needle sensation	There is no similar model.

IM, intra muscular.

Table 3. Summary of Phantom-Based Acupuncture Education Programs.

First author [ref] (y)	*N*	Phantom	Training feedback method	Devices for feedback	Needling manipulation	Training time	Training period	Evaluation index of training	Result of the study
Cai et al [29] (2013)	118 undergraduate students	Silicone	n.r.	n.r.	n.r.	n.r.	n.r.	1) Needle depth 2) Needle angle	Improving the depth of insertion and the angle of the needle.
Lim et al [37] (2014)	10 students in the 2nd y or less of the Department of Oriental Medicine	5% agarose gel	Visual	Motion sensor (Acusensor2)	Complex lifting thrusting	1 min	8 times	Motion pattern error	50% improve
Lee et al [38] (2015)	12 4th grade students	5% agarose gel	Visual	Motion sensor (Acusensor2)	Rotation, reinforcing and reducing lifting thrusting	10–20 s	10 d	1) Needle depth 2) Depth error 3) Time 4) Time error 5) Time ratio	Ddepth error, thumb forward and backward time error, lifting time error are decreased
Jung et al [39] (2015)	21 Kyunghee University students with less than 4 y of medical education	5% agarose gel	Visual	Motion sensor (Acusensor2)	Simple and complicated lifting thrusting	n.r.	Trial 8	Motion pattern Error magnitudes	Concurrent visual feedback was further improved.
Lee et al [40] (2016)	Students	5% agarose gel	Visual	Motion sensor	Lifting thrusting, rotating	1 min	n.r.	MSE	Complex Lifting thrusting session are improved
Zhang et al [41] (2016)	Learner	Silicone	Visual	1) Optical motion capture camera 2) Baroreceptor (stress sensor)	n.r.	n.r.	n.r.	Needle manipulation data	n.r.
Liu et al [33] (2020)	Students	Silicone	Visual	High precision pressure sensor	Lifting-thrusting, twirling, needle insertion	n.r.	n.r.	Acupuncture force data	Through the BP neural network, the identification accuracy of needle manipulation is 93–98%, which increases the efficiency of acupuncture training.

BP, back-propagation; MSE, mean squared error; n.r., not reported.

2 conductive layers embedded in the model. Liu et al [33] used a training method of identifying needle manipulation through a back-propagation neural network with acupuncture force data output from a high-precision pressure sensor.

There were 4 articles which entailed phantom-based quantitative measurements, and the phantoms used varied (Table 4) [42-45]. In 3 Korean articles [42-44], needle force with respect to amplitude and frequency was measured with a 6-axis force sensor using the lifting-thrusting technique, while needle force with respect to rotation angle and frequency was measured using the twirling technique. The variables affecting needle force were needle diameter, amplitude, and frequency for the lifting-thrusting technique, and angle for the twirling technique. Unlike the Korean articles, 1 Chinese article [45] employed a voltage signal using a coil for quantitative measurement. The voltage signals for the manipulation times of the lifting-thrusting and twirling techniques were compared between experts and beginners.

There were 2 articles regarding the difference in kinematic characteristics of hand motion between experts and beginners (Table 5) [46,47]. All artificial skin pads were phantom models, and

Table 4. Summary of Phantom-Based Quantitative Measurements.

First author [ref] (y)	Phantom	Needle size(mm)	Needling manipulation	No. of needling (cycles)	Detailed conditions of needling	Sensor for detecting needle	Quantitative evaluation index	Result of the study
Lee et al [42] (2014)	Apple	0.40×40	Lifting-thrusting	10	Range (mm): 2, 4, 6, 8, 10 Frequency (Hz): 0.25, 0.50, 0.75, 1	6-Axis F sensor	Acupuncture needle force	Needle force is proportional to range and frequency.
Han et al [43] (2015)	Cucumber	0.40×40	Twisting-rotating	10	1) Angle (°): 60, 90, 120, 180 2) Frequency (Hz): 0.05, 0.10, 0.15, 0.20	6-Axis F/T sensor	Torque Z force amplitude	The difference in force change in angle rather than frequency is greater.
Lee et al [44] (2018)	Pork	0.20×40, 0.25×40, 0.25×40, 0.30×40, 0.35×40, 0.40×40	Lifting-thrusting, twisting-rotating	10	1) Lifting-thrusting: amplitude 5 mm, frequency 1 Hz 2) Twisting-rotating: amplitude 180°, frequency 0.2 Hz	6-Axis F/T sensor	Needle force magnitude	There was a significant positive correlation between needle diameter and force magnitude during lifting-thrusting movements.
Zhang et al [45] (2018)	Simulated tissue	n.r.	Lifting-thrusting, entwisting	n.r.	1) Lifting-thrusting: needle length in coil 10 mm, 20 mm, 30 mm 2) Entwisting: 60 rpm, 120 rpm, 180 rpm	1) Exciting coil 2) Induction coil	1) Rise time 2) Fall time 3) Ratio of rise time to fall time 4) Magnitude of the voltage 5) Frequency of entwisting 6) Time of manipulation	Coefficients of dispersion, the time of voltage rise, voltage fall and total manipulation time of experts are lesser than those of novices.

F/T, force/torque; n.r., not reported.

Table 5. Summary of Kinematic Characteristic Comparisons of Hand Motion Through Quantitative Measurement of Force.

First author [ref] (y)	Phantom	Needle size (mm)	Needling manipulation	Expert acupuncturists (*n*)	Beginner (*n*)	Devices for detecting needle	Devices for detecting hand motion	Comparative indexes	Expert skills
Li et al [46] (2013)	4 cm thick artificial skin pad	0.25×40	Reinforcing and reducing technique of twirling	12	12	6 axis F/T force transducer	1) LED marker diodes 2) 3D motor Analysis system	1) Needling amplitude 2) Needling frequency 3) Needling force 4) Operation time	Movement frequency consistency and temporal efficiency
Li et al [47] (2013)	Artificial skin pad	0.25×40	Reinforcing and reducing technique of lifting-thrusting	12	12	6 axis force transducer	1) Infrared LED 2) An optoelectrical camera	1) Needling amplitude 2) Needling velocity 3) Needling time	Movement amplitude and velocity consistency and temporal efficiency

F/T, Force/Torque; LED, light emitting diode; n.r., not reported.

Table 6. Summary of Phantom Models that can Acupoint Location Training and Needling Training at the Same Time.

First author [ref] (y)	Sensor for detecting needle	Material of model	Training acupoint	Training contents	Training method	Advantage of model	Disadvantage of model
Cai et al [29] (2013)	2 conductive layers	1) Skin: silicone rubber 2) Subcutaneous tissue: silicone latex	BL1, ST1, GV16, GV15, GB20, CV22, GV14, GV9, BL11, BL13, BL15, BL17	1) Acupoint location 2) Safe inserting depth 3) Needling method	When the needle touches the conductive layer, an alarm signal such as music or lights flashing is activated	Durable	Long term repeated training affects needle sensation
Liu et al [33] (2020)	High precision pressure sensor	Silicone	PC6, PC7, LU6, LU5, HT3	1) Acupoint position 2) Needle insertion 3) Twirling 4) Lifting	Judge acupuncture manipulation using BP Neural Network algorithm	Closer to the actual clinical scenes of acupuncture	n.r.

BP, back-propagation; n.r., not reported.

the needles used were 0.25 × 40 mm. Experts included 12 oriental doctors with ≥ 2 years of clinical experience [46], or ≥ 350 hours of clinical acupuncture practice [47]; the 12 beginners had no experience in acupuncture. Needle manipulation differed between the twirling and lifting-thrusting techniques. In both techniques, the amplitude and velocity of movement were constant for experts, and the temporal efficiency was higher.

There were 19 articles on acupoint location training and needling training which were conducted simultaneously; among them, 2 articles involved training using a phantom model (Table 6) [29,33]. Both models were silicone models that did not mark acupoints and were equipped with sensors for needling training. The silicone model has the advantage of allowing continuous training with a similar clinical experience, but it has the disadvantage of altering the needle sensation with repeated use.

Discussion

Acupuncture is the process of locating the acupoint and inserting the needle, and it can be divided into determining the exact acupoint location before insertion, and needling after insertion. Accordingly, acupuncture training in this study was classified and organized into acupoint location and needling training.

In the Song Dynasty, a bronze figure was used as a practical tool for learning and evaluating acupoints. Since mercury was contained in the acupoints of the figure, when the acupoints were accurately punctured with a needle, the mercury flowed out. This, relatively objectively, evaluated the extent to which acupoints were located. However, whilst the bronze figure currently used in acupuncture training is suitable for learning acupoint positions, it is not suitable for evaluation because information regarding meridians and acupoints are already displayed on the model [31].

Previously, needling training was performed on paper or cotton balls which were used as practical tools to develop the finger strength required for needle insertion [48,49]. A limitation of this method is that it is difficult for the operator assess the depth of the needle insertion or the needle sensation according to needle manipulations [29]. However, with the development of current smelting technology, the material, thickness, and processing of needles has improved compared with earlier types of needles [50]. Additionally, the use of a guide tube reduces pain during skin penetration and makes insertion easier [51]. So, rather than training by piercing the skin alone, training for needle depth, angle, and manipulation can be more focused.

Since acupuncture consists of complex and intricate hand motions, it is not easy for beginners to immediately and precisely imitate expert hand motions. To increase needling skills, an educational simulation system, such as a method of providing visual and tactile feedback of hand motion information, is required [52]. In addition, to mimic qi, a model capable of simulating needle sensations, similar to human tissue, during needling is necessary. Therefore, in this study, the overall research trend of acupuncture training was examined, and analysis of articles dealing with practical phantom models was the focus.

This study reviewed articles related to acupuncture training since 2010, when STRICTA was revised, using 7 domestic and foreign search engines (NDSL, KISS, RISS, KMBase, PubMed, CiNii, CNKI). Among the retrieved articles, a Chinese study on acupuncture training systems and models from 2020 [53] was arranged in the order of development of training systems and models; while it was easy to understand the flow of development, the article was limited to a simple list of Chinese studies. By contrast, this current review included articles related to acupuncture training from several countries, was not limited to a specific country, and identified the status of articles by country, year, and topic. In particular, by systematically classifying articles by phantom model, it was easy to identify research trends such as the development and clinical application of phantom models used in acupuncture training.

Among articles on acupoint location training, most (34%) used a 3D human model that allowed the visualization of the human body. This training included an acupoint database, thus, it was possible to learn about the acupoint position, as well as the acupoint itself. Training, using multimedia such as video, accounted for 31% of training which was a development from lectures alone. Training using phantom models accounted for only 17% of articles, implying

that acupoint location training was being conducted on virtual models, rather than phantom models. The number of articles on acupoint location training was highest in China, the origin of acupuncture and with the largest population in this review (77%), followed by Korea (15%) and Japan (3%); in Western countries, this number was very small, with only 1 study conducted in the UK. In Korea and China, there are universities separate from medical schools that specialize in oriental medicine. Conversely, in Japan, there is a single license system for doctors, without a separate oriental medicine licensing system and training institutions [54]. As a result, compared with the West, acupuncture research is actively being conducted in Eastern countries (centered on China), whilst the number of studies in Japan is relatively small.

When summarized by year, the largest number of articles was published in 2012 (15%), with almost as many articles in 2019 and 2020 (approximately 13%) when technological developments were taking place. According to the year distribution by topic, acupoint location training changed from using simple multimedia to using a training model similar to the human body, whether visually or tactilely. Since only 1 article each was published on training using a digital human acupoint system based on image data of the human body, and training using an acupoint detection device, detection of a trend was not possible.

In acupuncture training, the use a phantom model to replace the human body is necessary so that training is realistic. In this review, 60% of the phantom models used for acupoint location training used a bronze figure. Since all acupoints are marked on the bronze figure, it is easy to learn from but difficult to evaluate knowledge of their location. The model developed afterwards was not marked with acupuncture points, thus, evaluation was possible via sensors. The silicone model was the most commonly used phantom model probably because silicone is similar to the feel of human skin and as such is used as a material for cosmetic prostheses [55]. However, among the silicone models, only specific parts of the human body exist. Therefore, development of a full-body model made of silicone is necessary in the future.

Articles on needle training following needle insertion can be classified into 4 types according to the training target. Among them, in cases of direct acupuncture training for the human body, all extremities, excluding the trunk such as LI11 and ST36, were selected as training sites. It is thought that this is because needle training practice on the extremities eliminates the risk of piercing important organs, and it is easier to assume the correct posture during needling. However, a limitation to this training technique is that it does not permit training in vulnerable areas of the body. Potential solutions include the use of virtual [25,52], and phantom models [26,30].

Similar to acupoint location training, articles related to needling training were the most common in China (70%). This was followed by Korea, Japan, and other Eastern countries. Regarding training with a target, almost all articles were published in China; in particular, articles on training using a virtual model or articles that mentioned an acupuncture training system without mentioning the presence or absence of a model, and this scenario accounted for more than 80% of articles. The articles related to training using a phantom model were similar, with 10 articles each in China and Korea. Considering that all of Korea's needling training studies were conducted using phantom models, this is a field that is being heavily researched in Korea. In Japan, many studies have used virtual, rather than phantom training models, and research on haptic devices combined with force feedback has been relatively active.

By year, the number of publications was highest in 2013 and 2020, which reflected when acupoint location training research was actively conducted. In 2013 there were many studies related to training using phantom models, most of which were cotton, paper, vegetables, and meat, or practical models used in other medical fields, such as artificial skin pads. New models, such as agarose gel and silicone, were subsequently developed. Seven articles which involved needling directly on the human body were evenly distributed by year.

The phantom models for needling training included objects without acupoints or newly developed phantoms. Among them, paper which has long been used was the most common, indicating that paper remains a useful model for needling training. Among the newly developed phantoms, training with agarose gel is being actively conducted. Articles related to phantom-based acupuncture education programs accounted for most articles (31%). Since the ultimate goal in acupuncture training is to improve acupuncture skills, it is considered that research on phantom models should also focus on educational programs for improvement of skill.

There were 3 articles related to phantom model development, including articles that laid the foundation for phantom development. In these articles, the clinical experience of oriental doctors ranged from those that did not mention clinical experience [32], had an average of 5 years [33], and more than 10 years [31]; the needles used were 0.40 × 40 mm, 0.25 × 40 mm, and 0.35 × 40 mm in diameter, all with the same length. When pork was used as a control, (although there was a limitation in that 1 site cannot replace various tissues of the human body), it was meaningful in that the needle sensation in the lifting-thrusting technique was compared differently to the previous studies. In addition, in the 3 articles, only simple needle manipulations such as the lifting-thrusting and twirling techniques were used, however, in clinical practice, complex needle manipulations with 2 or more needle manipulations are commonly used [56]. Therefore, additional research on complex needle manipulation is necessary.

In the articles related to phantom-based acupuncture education programs, the phantom models used were agarose gel, and silicone. Agarose gel is widely used because it is biocompatible with the human body (it is used to make artificial tissue), with advantages such as low price, optical transparency, mechanical strength, and biocompatibility [57]. Silicone is also a material with excellent biocompatibility [55] and durability, and its physical properties can be maintained without being greatly affected by temperature [58], therefore, it is considered suitable as a model. Additionally, most of the needle manipulations used in the phantom-based education program were the lifting-thrusting and twisting techniques; among them, there were many articles on the lifting-thrusting technique. As in phantom model development, an acupuncture education program that can allow training on various needle manipulations is needed. In chronological order, the pattern of acupuncture training changed from comparing motion patterns regarding the position

of the needle, to comparing force. Force refers to the sensation of the needle in the tissue during needling [59], as well as the pressing force of the assisting hand during needle manipulation.

In the articles related to phantom-based quantitative measurement, the force applied to the needle and the voltage applied through the needle were quantitatively measured. While various studies have been conducted on measurement of force using a 6-axis sensor of force, using voltage is a unique method. The movement and trajectory of the needle can be quantified using the induced voltage generated when the needle moves in a uniform magnetic field [42]. Quantitative measurement lays the foundation for setting objective indicators in acupuncture training. Thus, more diverse research on force and voltage should be conducted, and manipulation should be more diversified.

Articles on differences in kinematic characteristics of hand motion between experts and beginners focused on the operator's consistent hand movements through quantitative measurement of force. Therefore, a 6-axis sensor of force and a light-emitting diode marker or optoelectrical camera were attached to the hand and used together. This has the advantage of being easy for learners to practice with respect to needle sensation, as well as the voltage amplitude and speed of manipulation during needling, based on differences in the kinematic characteristics of hand motion between experts and beginners.

In the articles regarding a phantom model for training in acupoint location and needling, acupoint locations used varied in terms of risk to the patient, i.e., when needling the eyes, neck, and back, so, the training areas were narrow. In particular, the model using a high-precision pressure sensor was limited to the arm, thus, it was too local. Further research should focus on expanding the training area.

In this review, the importance of acupuncture training has been emphasized, and acupuncture training systems and acupuncture training education programs continue to develop. In addition, research on phantom models for the development of educational programs and quantitative measurement are ongoing. However, this review indicated that there were few articles related to acupuncture training relative to their importance, and they were mostly published in Asian countries. In addition, although models and training systems for acupuncture have been developed, there are few articles related to the application of acupuncture in clinical practice. The phantom models used for acupuncture training mainly consisted of silicone and agarose gels. Silicone has different sensations when needling is repeated in the same place [29], and agarose gel has size limitation [60] making it difficult to manufacture a shape similar to the human body.

Given the national differences in acupuncture styles [61], multinational research is necessary, and with a model of the human body which retains its structural integrity with repeated use. Furthermore, trends in acupuncture training indicate that training methods using virtual models are increasing. If this virtual model is combined with a phantom model, it may be possible to simulate needling of a real person. In this study, the period of the analyzed articles was limited to after 2010; thus, some articles may have been omitted. However, this study has identified recent research trends of practical phantom models used in acupuncture training, and provides a basis for the development of an improved acupuncture practice training system in the future.

Conclusion

This review of articles on acupuncture training between January 2010 and October 1, 2021 yielded the following conclusions:

1. Research on acupoint location training and needling training was primarily conducted in China. Acupoint location training was studied most frequently in 2012, and needling training was the most prevalent in 2013 and 2020.
2. Among the materials used for acupoint location training using phantom models, silicone was the most common, while among the sensor phantom models, the pressure sensor and tracking sensor were used the most.
3. Among the materials of the phantom model used for needling training, silicone and agarose gel were the most studied, while among the topics, the phantom-based education and evaluation system was studied the most.

Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT). (no.: 2019R1A2C1086643)

Conflicts of Interest

The authors have no conflicts of interest to declare.

Funding

None.

Ethical Statement

This research did not involve any human or animal experiments.

Data Availability

All relevant data are included in this manuscript.

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