

Evaluation of Modified Thiel Soft-embalmed Cadavers as a Novel Teaching Model for Musculoskeletal Ultrasound and Anatomy among Rehabilitation Medicine Residents

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ABSTRACT

Objective. This study aimed to determine the perceptions of rehabilitation medicine resident trainees on using modified Thiel soft-embalmed cadavers as a learning tool in acquiring knowledge on musculoskeletal ultrasound (MSK-UTZ) and anatomy.

Methods. This descriptive cross-sectional study used total enumeration to recruit residents in training under the rehabilitation medicine department of a tertiary referral hospital. An online survey tool was self-administered to determine their perceptions on the use of MSK-UTZ on Thiel-embalmed cadavers. Pre- and post-test scores were compared to determine if their knowledge has improved.

Results. Fifteen participants were recruited, who answered the pre- and post-test, and the online survey. The mean pre-test score of participants was 5.87 (± 1.68), and the mean post-test score was 6.87 (± 2.00). There was no statistically significant difference ($P = 0.20$) using a paired t-test. At an arbitrary passing rate of 70%, only 5/15 participants passed the pre-test while 10/15 passed the post-test. A chi-square test of independence showed that there was no significant association between the number of participants who passed or failed on the pre- and post-test, $X^2(1, N = 15) = 3.3, p = .0068$. Most of the perceptions of the participants were positive in terms of the use of modified Thiel soft-embalmed cadavers as a learning tool, its relevance in the training of a rehabilitation medicine resident, and the overall experience on its use.

Conclusion. Thiel-embalmed cadavers as a learning tool was well-accepted, having generally positive perceptions from the participants mainly in terms of perceived enhancement of the understanding of the anatomical basis of musculoskeletal ultrasound, perceived improvement in skills in performing musculoskeletal ultrasound, and most even recommended that it be part of their training as rehabilitation medicine residents. In terms of acquiring knowledge on musculoskeletal ultrasound (MSK-UTZ) and anatomy, no significant improvement in knowledge was noted. Further studies with larger sample sizes are recommended to yield more statistically significant improvement in knowledge and to observe trends in the perceptions of participants.

Keywords: Thiel soft-embalmed cadavers, musculoskeletal ultrasound, medical education, rehabilitation medicine, musculoskeletal anatomy



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INTRODUCTION

Musculoskeletal ultrasound (MSK-UTZ) is an imaging method that uses high-frequency sound waves to render images of soft tissues and bony structures; and is used by rehabilitation medicine specialists as a diagnostic tool or for guiding real-time interventional procedures.^{1,2}

In order to safely use MSK-UTZ, formal training is essential because it has been documented that users without proper training or practice yield less accurate measurements or subject their patients to complications.³⁻⁵ As such, MSK-UTZ has been a core competency among rehabilitation medicine residents.^{6,7} Several methods to teach MSK-UTZ to trainees have been developed over the years, including internet-based self-guided learning modules,⁸⁻¹³ and performance of MSK-UTZ on phantom¹⁴⁻¹⁷ and cadaver¹⁸ models.

Cadavers have been shown to be crucial in teaching basic and clinical knowledge about the human body due to the opportunity to study actual human anatomy, hence its use for learning and training MSK-UTZ.¹⁸⁻²¹ A popular type of cadaver used is the formalin-embalmed method to preserve the human body post mortem.¹⁹ They have been used in simulation-based teaching of musculoskeletal ultrasound for rehabilitation medicine residents. There are certain limitations using formalin-embalmed cadavers, however, because the tissue stiffness, hardness, and discoloration make the specimens very unlike the live human body; limiting the simulated learning during teaching encounters. These limitations led to an exploration of new methods to preserve cadavers void of these limitations.²² An example of such a novel preservation method is used by the Department of Anatomy of the University of the Philippines College of Medicine (UPCM), which is a modified Thiel preservation technique. The Thiel method, named after Austrian anatomist Dr. Walter Thiel, produces cadavers that have better color, consistency, and plasticity, which confer a more life-like appearance versus formalin-embalmed cadavers.²³ The method uses a mixture of salt compounds with low levels of formaldehyde and formalin, and mixes two solutions for injection into the body adjusted to the weight of the cadaver instead of injecting a formaldehyde-based solution through the arterial system; hence, it does not distort, dehydrate, or discolor the body's tissues the way traditional embalming does. In the Philippines, UPCM is the first and only institution that has the technology to preserve cadavers using a modification of the Thiel method by injecting an arterial pre-injection solution and an arterial injection solution utilizing two separately formulated solutions that are later combined with additional chemicals.²⁴ Using a Thiel soft-embalmed cadaver has the potential to confer advantages in simulated learning of musculoskeletal ultrasound among rehabilitation medicine residents because of the mentioned advantages over formalin-embalmed cadavers. These potential benefits have been documented among several clinical specialties.²⁵⁻³⁰ As an added benefit to learning clinical skills, a simulation-

based learning experience using a human cadaver could allow rehabilitation medicine residents to refresh their knowledge of anatomy as well. Using ultrasound in basic science education has shown increased skills in identifying anatomical structures by correlating cadaveric gross appearance and ultrasound imaging; as well as improved understanding of structure and function relationships of anatomic structures.³¹⁻³⁴

This study aimed to determine the perceptions of rehabilitation medicine resident trainees on using modified Thiel soft-embalmed cadavers as a learning tool in acquiring knowledge on musculoskeletal ultrasound (MSK-UTZ), and basic and clinical anatomy. Furthermore, the following were specific objectives of the study:

1. To determine if there was an objective increase in knowledge on musculoskeletal ultrasound and anatomy.
2. To determine if there is a perceived enhancement of the understanding of the anatomical basis of musculoskeletal ultrasound.
3. To determine if there is a perceived improvement in skills in performing musculoskeletal ultrasound.
4. To determine if there is an overall perceived positive experience.
5. To determine if there is a perceived increase in confidence in performing musculoskeletal ultrasound in a clinical setting.
6. To determine if there is a perceived belief that simulated learning of musculoskeletal ultrasound using Thiel-embalmed cadavers should be part of the learning competencies of rehabilitation medicine residents.
7. To elicit open-ended responses from the participants.

METHODS

This descriptive cross-sectional study used total enumeration to recruit residents in training under the Department of Rehabilitation Medicine, Philippine General Hospital (DRM-PGH) who participated in a musculoskeletal ultrasound workshop using Thiel soft-embalmed cadavers last August 13, 2022 (Figure 1).

Once the study was granted an exemption from the ethics review board, convenience sampling was done based on the following inclusion criteria: 1) part of the active roster of DRM-PGH residents during data collection; 2) attended the aforementioned musculoskeletal workshop; 3) willing to join the study, 4) able to take the pre-test and post-test, and answer the survey instrument. Each participant was asked to accomplish an informed consent form prior to joining the study.

The workshop was conducted by two physiatrists from the DRM-PGH who are subspecialists in musculoskeletal ultrasound. These two physiatrists were not part of this study, nor were they recruited as participants. Before the scheduled musculoskeletal ultrasound workshop commenced, a pre-test was answered by the residents online via Google Forms. After the workshop, a post-test via Google Forms was answered as



Figure 1. Photographs taken during the musculoskeletal ultrasound workshop using Thiel soft-embalmed cadavers. Demonstrations of (A) ultrasound-guided injection on the foot and ankle joint, (B) scanning of the hip joint, and (C) ultrasound-guided injection on the knee joint.

well. Knowledge of musculoskeletal ultrasound and anatomy were assessed using these tests. Both tests were in English and consisted of 10 items each. The choice of including only 10 items was decided by the authors as an arbitrary number based on their experiences in attending workshops in their clinical fields; most pre- and post-tests that the authors answer when they attend workshops are limited to 10 items. Furthermore, they did not want to take up much time away from the participants and the actual workshop. The anatomy questions used in the pre- and post-tests were chosen based on the most common joints that the residents scan, while the musculoskeletal ultrasound questions were chosen based on the most common cases the residents encounter based on their patient census. Permission to use the scores from these tests in this study was granted by DRM-PGH.

A survey questionnaire was designed by the investigators to describe their perceptions on how the workshop on musculoskeletal ultrasound (MSK-UTZ) using Thiel soft-embalmed cadavers affected their performance of MSK-UTZ during their residency training. Cognitive and conventional pre-testing of the questionnaires were done for content validity prior to data collection. The survey questionnaire collected demographic information, such as age and gender, as well as information of prior use of musculoskeletal ultrasound and Thiel soft-embalmed cadavers. Twelve statements designed to compare the participants' perceptions on different aspects of using musculoskeletal ultrasound on Thiel soft-embalmed cadavers were answered using a 4-point Likert scale (4 = strongly agree, 3 = agree, 2 = disagree, 1 = strongly disagree). One statement asked the participants to rank body regions in terms of which they appreciated the most in terms of how scanning it during the workshop helped them during their residency training. These body regions were shoulder, elbow, wrist, hand, hip, knee, ankle, and foot. One last item asked for comments and suggestions, and elicited open-ended responses. No time limit was given to the respondents. The online survey tool was accomplished only once by the participants two months after the workshop. The authors decided to give the residents this time interval

of two months so that they can assess how the workshop has affected the manner they perform MSK-UTZ on their actual clinical training. The authors thought that in a span of two months, they would have seen patients, and they would be able to give their perceptions if the workshop actually helped them in performing the procedure with actual patients.

In summary, the pre- and post-tests were answered by the participants on the same day as the workshop, while the survey questionnaire to describe their perceptions were answered two months after the workshop.

Pre- and post-test scores, and responses of each participant to the twelve items using a 4-point Likert scale were processed with Microsoft Excel using descriptive statistics. Pre- and post-test mean scores were compared using paired t-tests (<https://www.graphpad.com/quickcalcs/ttest1.cfm>) while the number of participants who passed or failed the tests were compared using a chi-square test of independence (<https://www.socscistatistics.com/tests/chisquare2/default2.aspx>). P values ≤ 0.05 were considered statistically significant. The highest and lowest ranked body region were also recorded and the answers to the open-ended questions were collated.

RESULTS

All fifteen (15) residents who participated in the workshop were recruited to the study. None withdrew or dropped out of the study. Most participants were 30 and 31 years old [$n = 8$] and predominantly female [$n = 8$]. All participants had prior experience using musculoskeletal ultrasound and the majority (8) had no previous experience using a Thiel soft-embalmed cadaver.

Knowledge

To assess the use of Thiel soft-embalmed cadavers as a learning tool in acquiring knowledge on MSK-UTZ, all participants ($n=15$) were able to answer the pre- and post-test. Out of 10 items each, there was an increase of 1 from the mean pre-test score of participants from 5.87 (± 1.68),

to the mean post-test score of 6.87 (± 2.00). There was no statistically significant difference ($P = 0.20$) between the pre- and post-test mean scores tested using paired t-tests. At an arbitrary passing rate of 70%, only 5/15 participants passed the pre-test while 10/15 passed the post-test. A chi-square test of independence showed that there was no significant association between the number of participants who passed or failed on the pre- and post-test, $X^2(1, N = 15) = 3.3, p = 0.068$.

Perceptions

The topics covered for perceptions included perceived enhancement of the understanding of the anatomical basis of musculoskeletal ultrasound, perceived improvement in skills in performing musculoskeletal ultrasound, overall perceived positive experience, perceived increase in confidence in performing musculoskeletal ultrasound in a clinical setting, perceived belief that simulated learning of musculoskeletal ultrasound using Thiel-embalmed cadavers should be part of the learning competencies of rehabilitation medicine residents, and open-ended responses from the participants.

Figure 2 shows the summary of responses to the following 12 statements of the questionnaire that were answered with a Likert scale:

1. Using Thiel-embalmed cadavers revealed clear ultrasound images of anatomical points of interest which is at par with the images I see when I perform musculoskeletal ultrasound (MSK-UTZ) on service patients during residency training.
2. Using Thiel-embalmed cadavers has enhanced my understanding of the anatomical basis of musculoskeletal ultrasound (MSK-UTZ) and has helped me perform the procedure better on service patients during residency training.
3. Using Thiel-embalmed cadavers has improved my skills in performing MSK-UTZ and interventional percutaneous procedures associated with it to my service patients during residency training.
4. Performing MSK-UTZ on Thiel-embalmed cadavers feels very similar to performing it on service patients during residency training.
5. Performing percutaneous procedures on Thiel-embalmed cadavers feels very similar to performing it on service patients during residency training.
6. Performing MSK-UTZ on a Thiel-preserved cadaver contributed to an enjoyable and stimulating learning experience.
7. I find the sight/feel/odor of Thiel-embalmed cadavers detestable in the exercise of performing MSK-UTZ and the related percutaneous procedures associated with it.
8. I would prefer learning MSK-UTZ and percutaneous procedures on live patients in a clinical setting without having to learn it first using a Thiel-embalmed cadaver.
9. I believe simulated learning of MSK-UTZ using Thiel-embalmed cadavers should be part of the training of rehabilitation medicine residents.
10. I look forward to having more sessions of MSK-UTZ and percutaneous training using Thiel-embalmed cadavers.
11. I will highly recommend using Thiel-embalmed cadavers to colleagues who wish to learn MSK-UTZ and percutaneous procedures associated with it.
12. I believe patient safety dictates that I practice MSK-UTZ and percutaneous procedures on cadavers before performing it on service patients during residency training.

Responses of “4” and “3” on statements 7 and 8 indicated negative perceptions, hence, the statements were reworded and the inverse of the original responses are presented in this section to avoid confusion. All responses on the Likert scale of “4” and “3” indicate positive perceptions, while responses of “2” and “1” indicate negative perceptions.

Perceived enhancement of the understanding of the anatomical basis of musculoskeletal ultrasound

Statement 2, which stated that using Thiel soft-embalmed cadavers enhanced the participants’ understanding of the anatomical basis of musculoskeletal ultrasound (MSK-UTZ) and has helped them perform the procedure better, received the most positive response, which was given a score of 4 (strongly agree) on the Likert scale by 14 out of 15 participants.

Perceived improvement in skills in performing musculoskeletal ultrasound

Statements from the questionnaire under this topic received scores that were either 4 or 3, which were positive responses.

Overall perceived positive experience

When asked about the sight/feel/odor of Thiel soft-embalmed cadavers, two participants found it very detestable, while three found it detestable.

Perceived increase in confidence in performing musculoskeletal ultrasound in a clinical setting

Two participants did not agree that performing percutaneous procedures on Thiel soft-embalmed cadavers felt very similar to performing it on service patients during residency training. A similar response was noted on the statement that performing MSK-UTZ on Thiel soft-embalmed cadavers felt very similar to performing it on service patients during residency training, wherein one participant did not agree and another strongly disagreed. Two participants strongly preferred and another two preferred learning MSK-UTZ and percutaneous procedures on live patients in a clinical setting without having to learn it first using a Thiel soft-embalmed cadaver. Three participants did not agree that patient safety dictates that they practice MSK-UTZ and percutaneous procedures on cadavers before performing it on service patients during residency training.

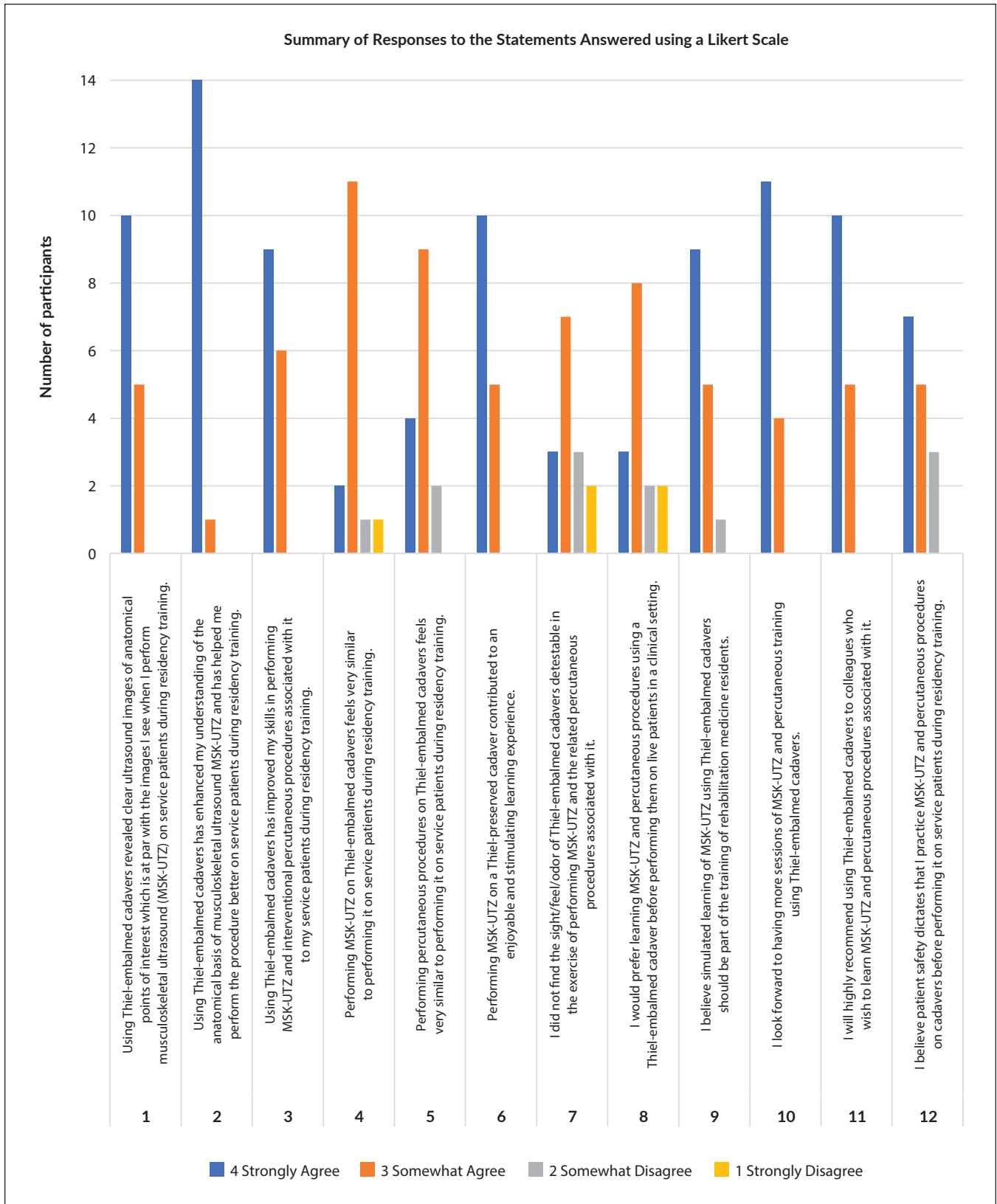


Figure 2. Summary of responses on perceptions.

Perceived belief that simulated learning of musculoskeletal ultrasound using Thiel-embalmed cadavers should be part of the learning competencies of rehabilitation medicine residents

One participant did not agree that simulated learning of MSK-UTZ using Thiel soft-embalmed cadavers should be part of the training of rehabilitation medicine residents.

The body region that the participants appreciated the most in terms of how scanning it during the workshop helped them during their residency training was the shoulder (ranked 1 by eight participants), while the least appreciated was the foot (ranked the lowest by four participants).

Open-ended responses from the participants

The following are responses to the final question, which was open-ended, that asked for comments or suggestions: "Use cadavers with more muscle bulk", "Thank you for the opportunity", "It was a great session", "More joints and procedures, more sessions in the future", "Would be nice to also receive certificates for these MSK-UTZ workshops".

DISCUSSION

The study described the knowledge and perceptions of rehabilitation medicine residents of the Philippine General Hospital Department of Rehabilitation Medicine (PGH-DRM) on their experience in a workshop using musculoskeletal ultrasound (MSK-UTZ) on a Thiel soft-embalmed cadaver.

For the aspect of knowledge, there was a slight improvement in test scores after the workshop, and a large improvement in the passing rate of the participants after the workshop at an arbitrary passing rate of 70%, but these were not statistically significant. It is suggested that similar studies with bigger samples be done to observe if attendance in such workshops would impart greater knowledge of MSK-UTZ and basic human anatomy. Diminishing returns on the mastery of basic anatomy is also a possible factor that can be explored when conducting future studies because participants are medical residents already. The authors discussed that since the participants were medical residents already, they were focused more on clinical knowledge, unlike medical students where they were graded on the knowledge of the mastery of basic anatomy. Because of this premise, the authors realized that a more comprehensive content validity of the questions could be done in the future to make sure that what were asked in the pre- and post-test questions would be most appropriate for the participants.

Results of the online survey tool that described the participants' perceptions on using MSK-UTZ on Thiel soft-embalmed cadavers revealed mostly positive perceptions. This is similar to a study among second year medical students who inserted peripheral and central catheters using a Thiel soft-embalmed cadaver for training. Using a Likert scale, all 13 students agreed that practicing vascular access on a

cadaver improved their understanding of both procedures, majority (12) felt capable of performing both procedures on a cadaver after completing the training, and in performing the procedures in a clinical setting, nine felt capable of performing the peripheral line while 11 felt capable of performing the central line.³⁵ Another study used different types of cadavers (formalin, fresh frozen, Thiel) to conduct simulation training of upper and lower limb blocks among anesthesiologists. Their results showed that only Thiel soft-embalmed cadavers allowed all nerves and plexuses to be visualized consistently by the participants.³⁶ Also, the researchers realized that for question #4, which asked if performing MSK-UTZ on Thiel soft-embalmed cadavers felt similar to performing it on live service patients, it would have been better if there were two separate questions, stated in two different ways, asking MSK-UTZ as a diagnostic, and as an interventional procedure.

There were outlier responses to the statements: those who preferred learning MSK-UTZ and percutaneous procedures on live patients in a clinical setting instead of learning it first on a cadaver, those who did not believe that patient safety dictates that they practice MSK-UTZ and percutaneous procedures on cadavers before performing it on service patients during residency training, and the lone response that did not agree that simulated learning of MSK-UTZ using Thiel soft-embalmed cadavers should be part of the training of rehabilitation medicine residents. The reasons behind these responses are beyond the scope of this study. The reason why the shoulder was ranked the highest body segment and why the foot was ranked the lowest is also beyond the scope of this study. It is recommended that if future studies similar to this would be done, a focused group discussion would be beneficial to gather quantitative data to elucidate the reasons for these unexpected responses and reasons for the rankings.

CONCLUSION

Thiel-embalmed cadavers as a learning tool was well-accepted, having generally positive perceptions from the participants, and most even recommended that it be part of their training as rehabilitation medicine residents. There was no statistically significant improvement in knowledge with the use of Thiel soft-embalmed cadavers.

Further studies with larger sample sizes are recommended to yield more statistically significant comparisons for the knowledge domain and to observe trends in the perceptions of participants. It is also recognized that performing MSK-UTZ and correlating anatomy is a skill, hence a better measure might be to assess the changes in skill pre- and post- workshop, instead of a knowledge measurement tool in future studies.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

All authors declared no conflicts of interest.

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