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# A Hybrid Musculoskeletal Ultrasound Curriculum for Physical Medicine and Rehabilitation Residents—a Multi-center Pilot Program

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## Abstract

**Purpose of Review** The increased use of musculoskeletal ultrasound (MSKUS) in clinical practice warrants achieving competency earlier in physiatrists' careers. Physical Medicine and Rehabilitation (PM&R) residency programs have started incorporating formal MSKUS training in their curricula; however, significant heterogeneity remains in MSKUS education.

**Recent Findings** Numerous barriers contribute to the lack of consensus for MSKUS training during residency, but the COVID-19 pandemic severely disrupted in-person learning. As an adjunct or alternative to in-person learning, teleguided technology is being utilized.

**Summary** This curriculum demonstrates the role of a hybrid MSKUS training with interinstitutional collaboration. Twenty PM&R learners, from two institutions, were divided into a fundamental or advanced track. Virtual didactic sessions alternated weekly with hands-on ultrasonographic scanning sessions. Following a 12-month longitudinal curriculum, an end-of-year practical examination was used for competency assessment, in addition to a survey assessing resident perceptions and feedback. To our knowledge, this is the first collaborative and hybrid MSKUS curriculum for PM&R learners that can be easily reproduced at most training institutions and circumvent some of the barriers amplified by the COVID-19 pandemic.

**Keywords** Musculoskeletal ultrasound (MSKUS) · Physical Medicine and Rehabilitation (PM&R) · Residency education · Curriculum · Virtual learning

## Introduction

Musculoskeletal ultrasound (MSKUS) is a point-of-care dynamic imaging modality that supplements the clinician's physical exam and improves diagnostic and interventional accuracy [1–11]. MSKUS utility has increased over the past few decades for various musculoskeletal conditions, and it can even help guide minimally invasive procedures [12–16]. Recent literature demonstrates that current and future residents continue to express a growing interest and weighted importance in learning MSKUS [17–20].

The American College of Graduate Medical Education (ACGME) Review Committee for Physical Medicine and Rehabilitation (PM&R) has recommended progressive responsibility with MSKUS but placed minimum expectations for residents (10 cases of MSKUS use), and the American Academy of Physical Medicine and Rehabilitation concluded that MSKUS plays an integral role in providing care for physiatric patients [21, 22]. Unlike in emergency medicine residencies or sports medicine fellowships, there are no PM&R MSKUS core competencies or a standard curriculum [23, 24]. MSKUS milestones and a potential curriculum have been suggested for PM&R residents, but proficiency or graduation standards have yet to be determined [19, 20, 25••, 26, 27]. Insufficient literature, lack of experienced MSKUS instructors, equipment access, shared available time, and inadequate cases are some of the barriers to obtaining MSKUS education [17, 25••, 28].

MSKUS remains a hands-on skill that is traditionally taught in didactic lectures with or without hands-on training, during workshops at conferences, at the bedside or during outpatient clinical rotations, and/or via self-directed learning [17, 19, 20, 25••, 27]. With the emergence of the

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COVID-19 pandemic, more teleguided technology has been utilized, which can supplement education to increase familiarity and training frequency. To enhance MSKUS residency education, novel approaches are being developed for distance learning with real-time ultrasound (US) visualization and instructor feedback [29, 30•, 31•, 32]. This facilitates opportunities for more contact hours, didactic learning, and collaboration between programs/specialties.

The primary objective of this curriculum was to help improve MSKUS education for PM&R trainees with the imposed limitations during the COVID-19 pandemic. The secondary objective was to assess whether multi-center collaboration can be utilized to augment MSKUS training.

## Methods

### Design and Implementation

At the beginning of the academic year, a short survey was distributed among the Johns Hopkins PM&R trainees to assess learners' level of interest in MSKUS, their current level of US knowledge/skill, and goals for using MSKUS in their future practice. Of the 18 learners surveyed, 13 indicated a desire to achieve mastery with MSKUS. Two PM&R-trained sports medicine fellows from Burke Rehabilitation Hospital were also included as part of an inter-institutional MSKUS training collaboration. The course was divided into two tracks (fundamental and advanced), depending on self-reported familiarity with MSKUS.

The fundamental track explored the basics of sonography, technique, and identification of principal anatomical structures for each topic with an emphasis on general PM&R. Five major joints were prioritized including the shoulder, wrist, elbow, knee, and ankle. Additionally, the curriculum included routine management of upper and lower extremity spasticity as well as basic joint injections (Table 1). The advanced track explored beyond the basics. In addition to the six major joints, this track included training in US-guided interventional spine procedures and peripheral nerve block/hydrodissection procedures (Table 1). Both tracks were provided with a learning checklist to utilize throughout the year in order to achieve competency and for preparation for the end-of-the-year Objective Structured Clinical Exam (OSCE) (Supplemental Digital Content Fig. 1 and Fig. 2).

Three faculty instructors with 5–15 years of MSKUS experience taught the advanced group, whereas another three faculty members with 2–5 years of MSKUS experience taught the fundamental group. The lectures and observation sessions were divided among the faculty allowing for trainees at both institutions to learn from collective musculoskeletal sonographers at the two academic centers. Virtual sessions via Zoom are allowed for remote teaching and supervision. For both tracks, virtual didactic sessions alternated weekly with hands-on ultrasonographic scanning sessions for each structure/topic of interest over a given month. All sessions were led by a faculty member, either virtually or in-person.

### Execution/Technical Aspects

After a 30-min virtual lecture covering anatomy, pathophysiology, and routine diagnostic/interventional approaches, a live, virtual, hands-on demonstration was performed on a learner volunteer who served as a model. For the demonstration, a US machine was connected directly via a High-Definition Multimedia Interface (HDMI) cable to a video capture card which provided an

**Table 1** Fundamental and advanced track schedule

| Month | Fundamental | Advanced |
|---|---|---|
| Month 1 | Foundational topics (knobology/machine operation, ultrasound physics, tissue characteristics, injection techniques, imaging protocols) | Foundational topics (knobology/machine operation, ultrasound physics, tissue characteristics, injection techniques, imaging protocols) |
| Month 2 | Limited knee | Complete knee |
| Month 3 | Distal leg—spasticity | Complete ankle/foot |
| Month 4 | Limited wrist | Complete wrist and hand |
| Month 5 | Review | Review |
| Month 6 | Complete shoulder | Complete shoulder |
| Month 7 | Thigh—spasticity | Complete elbow |
| Month 8 | Complete elbow | Complete hip |
| Month 9 | Review | Review |
| Month 10 | Limited ankle and foot | High yield spine |
| Month 11 | Upper extremity—spasticity | Nerve blocks/hydrodissection |
| Month 12 | Review and assessments (OSCE) | Review and assessments (OSCE) |

input signal to a computer (input 1). Simultaneously, we used a webcam mounted to a compatible flexible long arm stand positioned over the structures of interest. This provided a second input signal into a separate computer (input 2). The images from both devices were integrated using Zoom (Fig. 1). Lastly, the meeting host adjusted the settings to spotlight input 1 for all participants. This allowed for a side-by-side visualization of the US image and transducer positioning on the model with an emphasis on the US screen (Fig. 1). Lectures/demonstrations were recorded to allow for future review.

For the hands-on scanning sessions, a limit of six residents, split into two groups, was imposed to maintain institutional protocols for social distancing. During the scanning sessions, in-person supervision was provided by faculty from the same institution as the learners or virtually by faculty from the outside institution. This was done by creating one virtual room and multiple break-out rooms on Zoom. The supervising faculty member was able to enter and leave the breakout rooms freely to provide real-time feedback.

## Assessments

To assess MSKUS competency for the enrolled PM&R residents, an OSCE was conducted at the end of the academic year. The OSCE was designed to highlight several components of the milestones that evaluate competency of PM&R residents prior to graduation [33, 34]. The milestones incorporated into the OSCE include musculoskeletal medicine, diagnostic skills, procedural skills, and self-directed learning and teaching. Residents were divided according to their respective tracks, which were further divided into subgroups of three residents to rotate through the three different testing stations. In order to ensure conformity and confidentiality, residents in one group (fundamental or advanced) served as models for the other group.

Two of the stations consisted of a series of scanning exercises and structure identification. One station was established for assessment of upper extremity structures, while the other station was designated for lower extremity assessment. The third station evaluated the residents on procedure set-up, including identification of target structure(s),

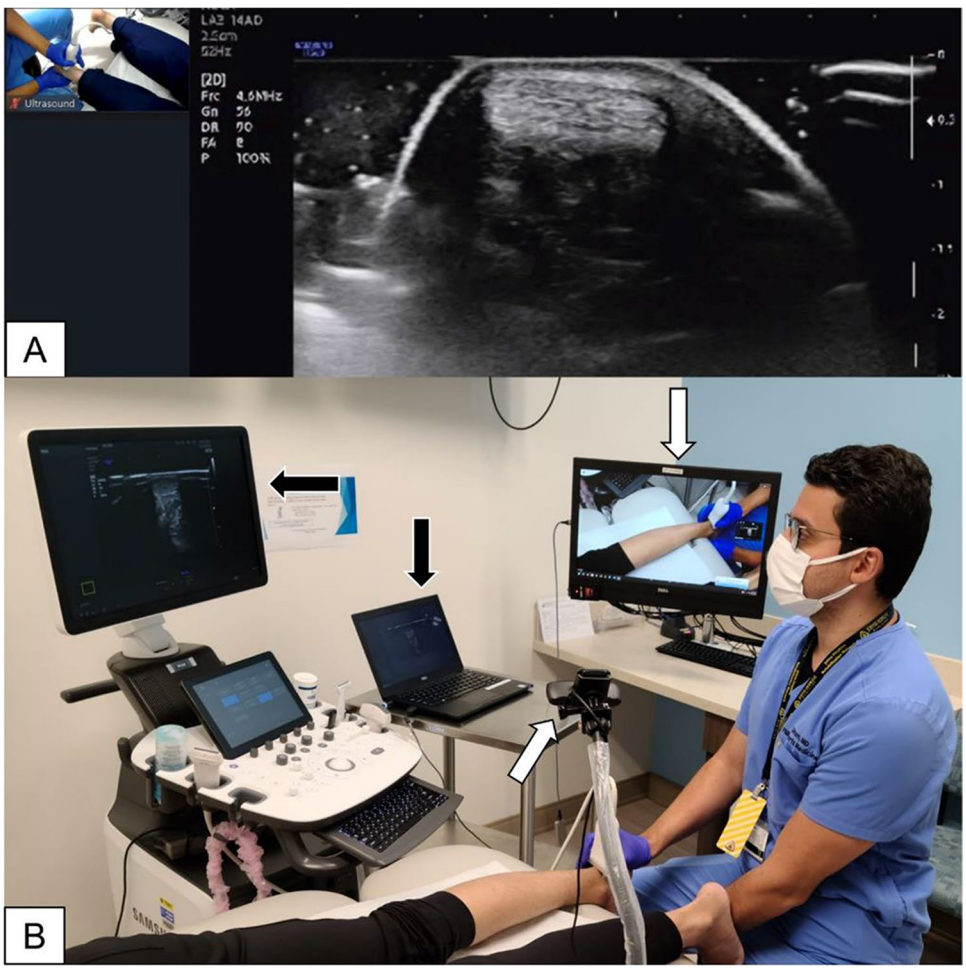


**Fig. 1** **A** Zoom screen showing integrated images with ultrasound image spotlighted. **B** Input 1 = ultrasound connected directly to a laptop computer (black arrows) via video capture card (not shown). Input 2 = webcam mounted on a flexible long arm stand positioned over the model and connected to a second computer (white arrows)

structure(s) to avoid, techniques for performing the intervention, and potential pitfalls. Three board-certified PM&R physicians, with a subspecialty in pain or sports medicine, served as the examiners for each station. Examiners used a standardized group of assessment items for both groups with an allotment of 10 min to complete each station.

The difficulty of these stations varied between both groups (fundamental and advanced) to match the level of training. Test performance was compared to other residents within the same group. The five categories for scoring included positioning and equipment setup, applied knowledge of US equipment, image acquisition and optimization, systematic examination, and interpretation of images. Scores from each individual testing station were combined accumulating to a total of 15 points for each of the five categories. The maximum score achievable was 75 (Table 2). The purpose of the scoring was twofold: to give residents and educators an idea of their current skill level and to allow the residents to compare their performance against a benchmark as they progress through their training.

## Results

### OSCE Results

Fifteen residents completed the OSCE, nine in the advanced group and six in the fundamental group. Participant scores from the individual checklist elements were averaged for each station. A composite OSCE score was derived for each participant by averaging the participant's mean scores across stations (Table 2). The advanced group mean score was 58.56, and the fundamental group mean score was 41.7 (Table 2). In the advanced group, the post-graduate year (PGY) 4 s scored higher than the PGY-3 s. In the fundamental group the PGY-3 s and 4 s scored higher than the PGY-2 s. In addition, residents in the advanced group achieved higher scores than the residents in the fundamental group.

### End-of-Year Survey Results

At the conclusion of the year, a survey was sent to the residents of the Johns Hopkins PM&R program to gauge resident perceptions and obtain feedback on the curriculum (Fig. 2). Residents were asked to self-evaluate their musculoskeletal anatomy knowledge, diagnostic/interventional US skills, and ability to operate an US unit, with respect to their PGY level using a Likert scale. Response options ranged from "1 = Much Lower" to "5 = Much Higher" or "1 = Very Low" to "5 = Very High" or "1 = Very Poor" to "5 = Excellent." Finally, residents were asked about the overall efficacy and what they felt their respective track placement should be for the subsequent year. A comments section for feedback and suggestions was also included (Fig. 2).

The survey was completed by 17 residents. The interest in MSKUS was graded as ≥ 4 by 11/17 residents. Fourteen residents felt they were at least average when operating an US machine. Seven residents felt that they were on par with their PGY level of training, whereas 9/17 residents felt they were above average with respect to their musculoskeletal anatomy knowledge at the conclusion of the curriculum. When grading their own diagnostic and interventional US skills, 12/17 residents believed they were on par or ahead of their PGY level of training (Fig. 3). When asked to grade the structures in order of difficulty, the knee was selected as the easiest, followed by the shoulder, elbow, wrist/hand, hip, and ankle/foot. The spine was graded as the most difficult structure to learn. The hybrid curriculum was regarded as efficacious for MSKUS learning by 12/17 residents, and 11/17 residents felt the overall curriculum design, implementation, and execution were "good" or "very good." Lastly, 12 residents believed they should be placed in the advanced track during the following academic year.

## Discussion

MSKUS is an operator-dependent skill that requires extensive training to develop competence in image acquisition, optimization, and interpretation [35–38]. Various studies have provided practical and feasible methods for designing a MSKUS curriculum in residency to meet the demand for this skill [19, 25••, 26, 27]. This pilot hybrid curriculum adds to the previously designed models for MSKUS education in PM&R residency training while overcoming the barriers imposed by the COVID-19 pandemic. However, to our knowledge, this is the first MSKUS curriculum utilizing collaboration between institutions to enhance the MSKUS education for PM&R trainees.

The emergence of the COVID-19 pandemic has required significant reformatting of education delivery for trainees worldwide [39, 40]. Due to social distancing precautions, typical barriers for MSKUS training were amplified [25••, 30•, 31•, 32, 41, 42]. The lack of expert faculty and travel restrictions hindered MSKUS training and development of competency for PM&R residents in the USA. Although prerecorded videos, webinars, textbooks, and guidelines can aid self-directed learning, hands-on, in-person training has been demonstrated to be superior for skill acquisition [24, 43]. Furthermore, real-time feedback from an expert sonographer can facilitate the process of achieving competency in MSKUS [44–47].

Various online meeting platforms have been utilized for virtual education over the past few years. We elected to use

1. **How would you rate your level of interest in MSKUS?**

☐ 1= Very Low ☐ 2 = Below Average ☐ 3 = Average ☐ 4 = Above Average ☐ 5 = Very High

2. **How would you rate your ability to operate an US machine?**

☐ 1= Very Low ☐ 2 = Below Average ☐ 3 = Average ☐ 4 = Above Average ☐ 5 = Very High

3. **Based on your PGY level, how would you grade your competency with DIAGNOSTIC MSKUS?**

☐ 1= Much Lower ☐ 2 = Lower ☐ 3 = About the Same ☐ 4 = Higher ☐ 5 = Much Higher

4. **Based on your PGY level, how would you grade your competency with INTERVENTIONAL MSKUS?**

☐ 1= Much Lower ☐ 2 = Lower ☐ 3 = About the Same ☐ 4 = Higher ☐ 5 = Much Higher

5. **Based on your PGY level, how would you grade your competency with MSK ANATOMY?**

☐ 1= Much Lower ☐ 2 = Lower ☐ 3 = About the Same ☐ 4 = Higher ☐ 5 = Much Higher

6. **Please rank the following structures in order of difficulty, from easiest to most difficult (1=Easiest, 7=Hardest).**

1. Shoulder 2. Elbow 3. Wrist/hand 4. Hip 5. Knee 6. Ankle/foot 7. Spine

7. **If you were a medical student, how likely would you be to place Johns Hopkins at the top of your rank list considering the presence of a MSKUS curriculum?**

☐ Very likely ☐ Likely ☐ Neither likely nor unlikely ☐ Unlikely ☐ Very Unlikely

8. **How likely would you be to recommend the Johns Hopkins PM&R residency to prospective PM&R applicants because of this MSKUS curriculum?**

☐ Very likely ☐ Likely ☐ Neither likely nor unlikely ☐ Unlikely ☐ Very Unlikely

9. **The virtual sessions/hybrid curriculum was beneficial for MSKUS learning.**

☐ Strongly Agree ☐ Agree ☐ Neither Agree nor Disagree ☐ Disagree ☐ Strongly Disagree

10. **Which track do you believe is more appropriate for you during the next academic year?**

☐ Fundamental ☐ Advanced

11. **How would you rate the MSKUS Curriculum?**

☐ 1= Very Poor ☐ 2 = Poor ☐ 3 = Acceptable ☐ 4 = Good ☐ 5 = Very Good

12. **Please provide any comments or suggestions that you feel may help improve the curriculum.**

**Fig. 2** Survey questions

**Table 2** OSCE criteria and scores

| Resident | Operator/patient positioning and equipment setup | Applied knowledge of ultrasound equipment | Image optimization | Systematic examination | Interpretation of images | Total score |
|---|---|---|---|---|---|---|
| Fundamental | | | | | | |
| PGY-4 | 9.5 | 10.5 | 10.5 | 10.5 | 9 | 50 |
| PGY-3 | 9 | 9 | 9 | 11 | 11.5 | 49.5 |
| PGY-2 | 10 | 8.5 | 8 | 10.5 | 10 | 47 |
| PGY-2 | 10 | 7 | 8 | 9 | 9 | 43 |
| PGY-2 | 6 | 7 | 6.5 | 6.5 | 6 | 32 |
| PGY-2 | 5 | 6 | 6 | 6 | 6 | 29 |
| | | | | | **Mean** | **41.75** |
| Advanced | | | | | | |
| PGY-4 | 14 | 14 | 13 | 13.5 | 14 | 68.5 |
| PGY-4 | 13 | 14 | 14 | 13 | 14 | 68 |
| PGY-4 | 13 | 13 | 13 | 14 | 13 | 66 |
| PGY-4 | 14 | 13 | 12 | 13 | 13 | 65 |
| PGY-4 | 12 | 12 | 11 | 11.5 | 12.5 | 59 |
| PGY-3 | 11.5 | 12.5 | 9.5 | 11.5 | 12 | 57 |
| PGY-3 | 11 | 9 | 9 | 10 | 11.5 | 50.5 |
| PGY-3 | 10 | 9 | 10 | 9 | 10 | 48 |
| PGY-3 | 10 | 9 | 8 | 9 | 9 | 45 |
| | | | | | **Mean** | **58.56** |

Values in bold indicate mean group OSCE score out of maximum score of 75 points

Zoom due to its widespread familiarity; however, any virtual platform would be sufficient. Previous studies have described two main methods in which a virtual US scanning session can be taught: (A) picture-in-picture (PIP) method and (B) two-camera method [30•, 31•, 48]. The former method requires a video capture device and special software with the appropriate input/output cables. The primary advantage of this method is superior image quality but comes at a greater cost with technological barriers (video software and hardware). The latter, two-camera method, uses a smartphone, tablet, or computer device to video stream the US screen while another device is used to simultaneously display the position of the transducer on the model. This method creates a side-by-side image of the US screen and transducer positioning. Considering most trainees have smart devices readily available, this method is relatively low cost but may sacrifice image quality [30•].

The COVID-19 pandemic continues to financially burden many institutions; therefore, developing an adequate educational experience with minimal equipment and set-up was a key determinant for this curriculum's technical requirements. Our experience of combining the previously described methods for virtual US education proved to be effective for allowing real-time display of high-quality US images and transducer positioning [30•, 31•, 48]. By electing to only purchase the video capture card and deferring the video capture software, we were able to keep the cost relatively low while optimizing image quality for learners during demonstrations. Alternatively, if a webcam is unavailable or cost-prohibitive, a tablet or smartphone (logged into the virtual meeting platform) can be used as the second input source. The Zoom platform was easily operable by faculty and learners, allowing for successful audiovisual interaction and US training. This supports previous evidence that virtual US education is a feasible and effective strategy for providing US education [30•, 32].

Survey studies demonstrate that formal MSKUS curricula is present in at least 45% of PM&R residency programs, when accounting for survey non-responders [17, 19, 25••]. This suggests that many trainees graduate from residency without competence in the use of MSKUS. Consequently, much of the knowledge and skills are acquired by attending academy courses which pose a significant financial and temporal burden. Travel restrictions and cancelation of various local, regional, and national academic meetings during the pandemic has potentially increased the knowledge gap as instructors and learners have been unable to participate in routine US workshops. Virtual US training can help close that gap and may be a viable alternative for hands-on US training as we slowly return to in-person education. The curriculum in this study utilized multi-center collaboration to increase the number of expert faculty available for instruction since access to expert faculty appears to be a primary limitation for a robust MSKUS curriculum [25••]. Faculty from

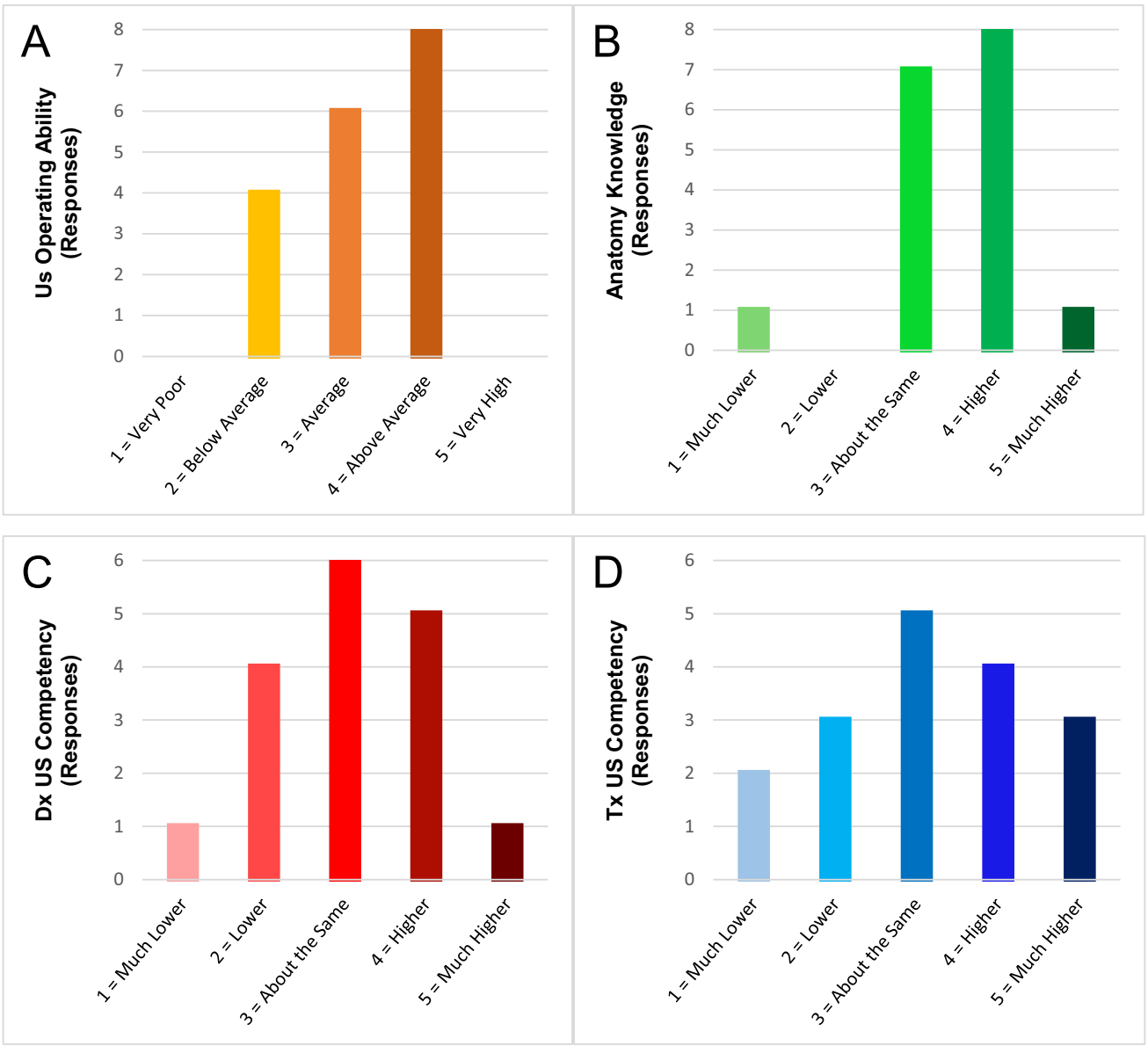


**Fig. 3** Likert scale responses for four survey questions demonstrating residents' self-perceived competency with respect to PGY level. **A** Ability to operate an ultrasound machine, **B** musculoskeletal anatomy knowledge, **C** diagnostic musculoskeletal ultrasound, **D** interventional musculoskeletal ultrasound

the collaborating institutions alternated monthly to teach and supervise scanning sessions, which reduced academic burden, while facilitating learner exposure to various techniques and readily available mentorship. As the landscape of MSKUS in PM&R residencies continues to develop, interinstitutional collaboration may be an important consideration for augmenting MSKUS education.

Although 18 residents enrolled in the curriculum, one resident did not complete the course due to medical reasons. Additionally, two residents were on out-of-state clinical rotations and were unable to participate in the OSCE. Interestingly, 53%, 71%, 71%, and 82% of survey responders felt they were at or above average compared to their peers for the same PGY level of training for musculoskeletal anatomy knowledge, diagnostic US, interventional US, and US machine operation, respectively. It is worth noting that unlike the PM&R Self Assessments Examinations (SAEs), currently there is no national benchmark for residents to gauge competency in MSKUS relative to their peers [49]. Approaching a consensus for a standardized curriculum with milestones can help overcome this limitation while allowing residents to improve upon their MSKUS training, much like the annual SAE administered by PM&R residencies nationwide [25••, 49].

### Assessments and Gauging Competency

The PM&R ACGME Milestones were used to provide a standard framework for evaluating resident competency in core areas required to become a licensed physiatrist [33, 34]. The assessments of residents via OSCE covered several components of the milestones that can be utilized by residency program directors and faculty members.

This examination allowed residents to be evaluated based on their ability to use ultrasound as a diagnostic tool and interpret their findings. Residents were also instructed to discuss what pathology could be expected and to describe how the US findings would appear. Residents did not perform interventional procedures during their OSCE; however, they were evaluated for readiness to proceed with procedures including proper setup, identification of target structures, injection approaches, and demonstration of precautions in order to avoid injury to neighboring anatomical structures. In addition, the US curriculum and opportunity to excel at this training requires self-directed learning, which is another milestone. Observing the residents as they expand on their own knowledge through group and individual practice as well as peer teaching can help gauge this milestone.

Although previous studies have proposed assessment processes, uniformity and baseline standards for MSKUS training in PM&R programs are still lacking [25••, 26]. Fortunately, we are closer to a consensus regarding MSKUS education in residency programs [25••]. However, with the COVID-19 outbreak, institutions likely face unique challenges that may preclude utilizing previously proposed models. Our curriculum also sought to employ periodic review months for further skill development and facilitating opportunities for residents to make up previously missed sessions. Considering residents have other educational requirements and clinical duties which may have been amplified during the COVID-19 pandemic, providing additional opportunities for learning is advantageous. Lastly, intermittent or continuous repetition is crucial for skill acquisition, which has been demonstrated across various domains [50–56].

## Limitations

This curriculum has a few notable limitations. Lack of access to essential equipment (US, virtual meeting platforms, and laptop/tablet/smartphones) would prevent replication of the curriculum. However, most institutions have likely shifted to some form of online education and meetings via virtual meeting platform(s). Similarly, most organizational members have a smartphone device in today's environment making the input barrier insignificant [57]. Alternatives to a webcam and video capture card use have been described using the two-camera method but would result in reduced image quality [30•].

Another major limitation is that during virtual supervision, faculty exclusively provided verbal feedback and did not utilize screen-sharing to further demonstrate techniques/transducer positioning for image acquisition or optimization. Although Winn et al. demonstrated that two-way, synchronous, remote learning is a reasonable method for US learning, it comes at a cost of significant technical limitations [47]. With the proposed virtual platform in the present study, learners were forced to incorporate verbal and somatosensory feedback, which may be more effective in psychomotor skill development [58, 59].

Though the curriculum was geared toward physiatry residents, two sports medicine fellows also participated in this program. Rather than piloting the program with the second institution's PM&R residents, we elected to enroll fellows with primary training in PM&R, to demonstrate the feasibility of multi-center collaboration. Moreover, as previously mentioned, the main benefit of multi-center collaboration is access to various faculty members which would improve the MSKUS education for trainees by circumventing the most significant barrier to quality MSKUS training [25••]. Finally, we did not have trainees complete a written pre-test or post-test which may reinforce MSKUS knowledge and augment the evaluation process by providing a baseline that can better gauge competency and/or mastery throughout the academic years [19, 20, 25••].

## Conclusions

The COVID-19 pandemic has emphasized the utility of virtual education for residency training. Virtual MSKUS training can serve as an alternative to in-person scanning since many faculty and learners are unable to attend local, regional, and national meetings due to financial, temporal, and travel restrictions. The efficacy of virtual MSKUS education compared to live, in-person training will need to be weighed against the financial and temporal burden of attending workshops to ascertain if one approach is more favorable. However, considering the notable advantages of virtual US learning, it should be considered as an adjunct for PM&R residencies to improve and standardize their respective curriculums as we approach a consensus.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s40141-023-00380-z.

**Data Availability** All data available has been provided as supporting documents to this manuscript.

### Declarations

**Conflict of Interest** The authors declare no competing interests.

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Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance


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