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Toward a Consensus for Musculoskeletal Ultrasonography Education in Physical Medicine and Rehabilitation

A National Poll of Residency Directors

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Objectives: The aims of the study were to evaluate integration of musculoskeletal ultrasonography education in physical medicine and rehabilitation training programs in 2014–2015, when the American Academy of Physical Medicine & Rehabilitation and Accreditation Council for Graduate Medical Education Residency Review Committee both recognized it as a fundamental component of physiatric practice, to identify common musculoskeletal ultrasonography components of physical medicine and rehabilitation residency curricula, and to identify common barriers to integration.

Design: Survey of 78 Accreditation Council for Graduate Medical Education–accredited physical medicine and rehabilitation residency programs was conducted.

Results: The 2015 survey response rate was more than 50%, and respondents were representative of programs across the United States. Most programs (80%) reported teaching musculoskeletal ultrasonography, whereas a minority (20%) required mastery of ultrasonography skills for graduation. Ultrasonography curricula varied, although most programs agreed that the scope of resident training in physical medicine and rehabilitation should include diagnostic and interventional musculoskeletal ultrasonography, especially for key joints (shoulder, elbow, knee, wrist, hip, and ankle) and nerves (median, ulnar, fibular, tibial, radial, and sciatic). Barriers to teaching included insufficient expertise of instructors, poor access to equipment, and lack of a structured curriculum.

Conclusions: Musculoskeletal ultrasonography has become a required component of physical medicine and rehabilitation residency training. Based on survey responses and expert recommendations, we propose a structure for musculoskeletal ultrasonography curricular standards and milestones for trainee competency.

Key Words: Ultrasonography, Physical and Rehabilitation Medicine, Education, Medical, Graduate, Musculoskeletal System
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In accordance with the American Medical Association Resolution 802, medical specialties including physical medicine and rehabilitation (PM&R) have begun to define their own scope of practice and training for ultrasonography.¹ International surveys of practicing physiatrists reveal that most respondents perceive that neuro/musculoskeletal ultrasonography (MSKUS) belongs within the scope of physiatric practice.² Within the United States, the American Academy of Physical Medicine and Rehabilitation has echoed this sentiment, calling MSKUS

an essential tool and fundamental component of physiatric practice.³ Subsequently, PM&R residency training requirements were updated in 2015 through the Accreditation Council for Graduate Medical Education (ACGME) Residency Review Committee and American Board of Physical Medicine and Rehabilitation to require exposure to 15 MSKUS procedures.^{4,5}

An evaluation of the state of resident training in 2014 found that 45% of the ACGME-accredited PM&R programs surveyed (or 97% of respondents) provided exposure to MSKUS

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Ryan D. Thompson is in training.

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during training.⁶ However, only 61% responded that MSKUS training was mandatory during residency. Among these programs, 44% had a formal written curriculum and 39% did not formally evaluate learners. A concurrent multispecialty survey of MSKUS education in residency and fellowship programs reported similar findings, although its response rates for PM&R were low (23%).⁷

The previous surveys suggest variability in training and educational practices among PM&R residency programs. However, a model PM&R curriculum for MSKUS was first published in 2010⁸ and physician training guidelines for MSKUS have been articulated by multiple professional organizations.^{9–12} The aim of this study was to expand upon previous research to determine the following: what, if any, aspects of proposed curricula and training guidelines were being consistently implemented across the ACGME-accredited PM&R residency programs in 2015; whether there is consensus among program directors for what MSKUS topics should be taught; and whether common barriers prevented PM&R residency programs from teaching MSKUS.

METHODS

Population

The target population included program directors from all ACGME-accredited PM&R residency programs. The 2015 roster and contact information were obtained and confirmed through the Association of Academic Physiatrists, Association of American Medical Colleges (AAMC), and American Osteopathic Association. Additional program demographics, such as type of affiliated medical school (public vs. private); program size; region of the country (Northeast, Central, South, West); and most recent US News and World Reports (USNWR) PM&R ranking were obtained through online resources of the American Medical Association (FREIDA Online), AAMC (Regional Membership Rosters), and USNWR (<http://health.usnews.com/best-hospitals/rehabilitation>). US News and World Reports rankings were divided into the following three tiers: Tier 1 comprised the top 25% of programs ($n = 20$), all of which had reputation scores of higher than 5; Tier 2 included the programs in the top 26%–50% ($n = 18$), all of which had reputation scores of higher than 1, and all remaining programs ($n = 40$) were in Tier 3. Program size was divided into quartiles based on the number of enrolled residents (<25th percentile, 25th–50th percentile, 50th–75th percentile, >75th percentile).

Survey Development

Survey content was drawn from material developed for evaluation of ultrasonography education for medical students^{13,14} as well as curricular topics proposed for specialties using MSKUS, including PM&R,^{8,15–17} rheumatology,¹⁸ pain medicine,¹⁹ and sports medicine.²⁰ A survey development specialist formatted items into a questionnaire, which was reviewed iteratively until both the survey developer and MSKUS educators on the team were satisfied with the questions and survey format.

The final survey covered 18 topic areas including program and faculty demographics, curriculum content, educational

methods and resources, and barriers to integrating MSKUS into residency training. Program director characteristics included duration of clinical practice, level of ultrasonography training, and clinical experience with MSKUS. Curriculum content covered the following three broad topics: introductory ultrasonography concepts; diagnostic imaging for joints and peripheral nerves; and interventional procedures with ultrasonography. The survey further evaluated whether certain ultrasound-guided procedures were within the scope of PM&R training, taught with ultrasound guidance, or required by programs for graduation from residency. The survey did not ask how programs evaluated MSKUS competency for graduation from residency.

Survey Implementation

The survey was implemented in 2014–2015 using the Dillman Tailored Survey Design Method.²¹ A link to an electronic version of the survey was e-mailed to program directors via SurveyMonkey (<http://www.surveymonkey.com>). The e-mail included a cover letter describing the project, an invitation to participate, and explanation that survey response constituted implied consent to participate. Two follow-up e-mails were sent at 1-wk intervals, the final one informing the respondent that they would also receive paper versions of the survey through the US mail. Delivery of the paper versions of the survey were timed to arrive at approximately 1 and 3 mos after the final electronic version. Survey responses were tracked for follow-up but were deidentified after data collection was completed. All results were reported in an aggregate manner, so that individual survey responses were not identifiable. The study protocol (2014E0275) and consent process were approved by the committee on research ethics at the institution at which the research was conducted in accordance with the Declaration of the World Medical Association.

Data Analysis

Respondents who reported having no formal MSKUS curriculum or who had missing responses for a question were scored as not including individual topics in their curriculum. Descriptive and inferential statistics were computed in IBM SPSS Statistics for Windows (v22). χ^2 tests of proportion and Fisher's exact test were used to evaluate for response bias between survey respondents and nonrespondents. Inferential statistics were used to draw conclusions about programs across Tiers and to compare relative curricular representation of introductory ultrasonography topics versus diagnostic or interventional procedures. An α level of 0.05 was used across tests. Rasch analysis was conducted on rank data for MSKUS barriers, converting ordinal rankings into interval scale logit scores,²² which facilitated comparison and interpretation of severity of barriers to teaching MSKUS.

RESULTS

Respondent Demographics and Bias Analyses

Program directors or their delegates from 42 (54%) of 78 ACGME-accredited psychiatry training programs responded

with completed surveys. Bias analyses reported in Table 1 revealed that the responding programs were representative of all ACGME-accredited PM&R programs with regard to type of affiliated medical school (public vs. private), program size (quartiles I–IV), region of the country (Northeast, Central, South, West), and USNWR Tier in 2014 (1–3).

Characteristics of respondent programs with formal MSKUS training (MSKUS+) were compared with respondents without formal MSKUS (MSKUS–) (Table 1). Significantly more responders incorporated MSKUS in residency curricula than not (35 vs. 7), $\chi^2(1) = 18.7$, $P < 0.001$. US News and World Reports Tier discriminated between MSKUS+ and MSKUS–

programs, $\chi^2(2) = 6.4$, $P < 0.05$, such that Tier 1 and Tier 3 programs were more likely than Tier 2 to have formal MSKUS curricula. However, MSKUS+ programs were not found to be associated with a specific AAMC region, institution type, program size, or program director subspecialty certification (Supplemental Table 1, Supplemental Digital Content 1, <http://links.lww.com/PHM/A777>), years in practice, or training with MSKUS. One program director characteristic differed significantly between groups: MSKUS+ program directors reported performing more diagnostic scans than those from MSKUS– programs (239.7 ± 343.4 vs. 65 ± 49.5 , Welch's $t(15.1) = 2.15$, $P < 0.046$). However, there were only two responders in the

TABLE 1. Respondent demographics and bias analyses for the PM&R MSKUS education survey

Characteristic (n)	Bias Analysis		Respondent Program Characteristics		
	Responder Frequency, %	<i>p</i>	Formal MSKUS Curriculum, %: MSKUS+	No Formal Curriculum, %: MSKUS–	<i>p</i>
All institutions (78)	42 (54%)	.466	35 (83%)	7 (17%)	<.001
Institution type					
Private (n = 29)	19 (66%)	.159	15 (79%)	4 (21%)	.488 ^a
Public (n = 49)	23 (47%)		20 (41%)	3 (13%)	
Program size					
Quartile I (19)	10 (53%)	.561	8 (80%)	2 (20%)	.730 ^a
Quartile II (18)	10 (56%)		8 (80%)	2 (20%)	
Quartile III (21)	9 (43%)		7 (78%)	2 (22%)	
Quartile IV (20)	13 (65%)		12 (92%)	1 (8%)	
AAMC region					
Northeast (26)	14 (54%)	.729 ^a	11 (79%)	3 (21%)	^b
Central (23)	12 (52%)		10 (77%)	2 (23%)	
South (21)	13 (62%)		11 (85%)	2 (15%)	
West (8)	3 (38%)		3 (100%)	0 (0%)	
USNWR program ranking					
Tier 1 (20)	14 (70%)	.240	13 (93%)	1 (7%)	<.048^a
Tier 2 (18)	9 (50%)		5 (56%)	4 (44%)	
Tier 3 (40)	19 (48%)		17 (90%)	2 (10%)	
Program director personally performed MSKUS (n = 42)					
Yes			23 (92%)	2 (8%)	.081 ^a
No			12 (71%)	5 (29%)	
Program director subspecialty certification relevant to MSKUS (neuromuscular, pain, sports) (n = 42)					
Yes			14 (93%)	1 (7%)	.197 ^a
No			21 (78%)	6 (22%)	
Program director characteristics, mean (SD)					
Years in practice (n = 37)			14.7 (8.3)	21.0 (9.9)	.270 ^{c,d}
Total hours of hands-on ultrasonography training (n = 24)			99.1 (143.7)	55.0 (7.1)	.143 ^{c,d}
Total no. diagnostic ultrasound examinations performed (n = 24)			239.7 (343.4)	65.0 (49.5)	.046^{c,d}
Program characteristics, mean (SD)					
No. residents per PGY class (n = 42)			5.6 (2.7)	4.6 (2.6)	.245 ^c
No. faculty who directly supervise residents performing ultrasonography (n = 32)			3.5 (2.1)	0 (0)	^b

There was no evidence of responder bias based on institution type, program size, AAMC Region, or USNWR Tier. However, more Tier 1 and 3 programs reported having formal MSKUS curricula than Tier 2 programs. No other differences in program or program director characteristics reached statistical significance. (Missing survey responses were noted for some demographic questions, the number of respondents for these items are indicated in parentheses.)

^aFisher's exact test was used.

^bA zero value for the no curriculum group makes statistical testing not possible.

^cWelch's *t* test was used to compare groups.

^dOnly two program directors responded in the no MSKUS curriculum group, which makes statistical results unstable.

PGY, postgraduate year.

MSKUS- group, so it is unclear whether this difference would remain significant given a larger sample of PM&R programs.

Educational Resources

The MSKUS+ programs reported an average of 3.5 ± 2.1 faculty (range = 1–8) engaged in supervising residents in MSKUS. All reported that ultrasound machines were available for residents to use. Machines were located with PM&R outpatient services (76% of respondents), at bedside for point-of-care MSKUS (43%), in sports medicine clinics (38%), and with PM&R inpatient services (33%). Only 1 program reported having ultrasound machines available in their simulation center.

Educational Practices

Nearly all MSKUS+ programs reported that MSKUS was taught through didactics (81% of respondents). Other popular teaching methods included point-of-care MSKUS at bedside (67%), facilitated proctor guidance (62%), simulation (including cadaver courses, 50%), and resident-initiated instruction (45%). Independent study or use of online learning modules as teaching resources were less common (24%); however, one program reported offering a 1-mo elective ultrasonography rotation.

Competency Expectations

Few respondents (8 programs or 19% of respondents) required MSKUS competency for graduation from residency (the survey did not ask how competency was measured). US News and World Reports Tier 1 programs were more likely to require MSKUS competency for graduation than either Tier

2 or 3 programs, $\chi^2(2) = 7.9, P < 0.020$. However, most programs (80% of respondents and 44% of programs surveyed) expected residents to perform and log clinical ultrasound scans during residency. On average, programs expected residents to perform 35 ± 52 muscle or joint examinations, 22 ± 30 peripheral nerve studies, and 30 ± 44 ultrasound-guided procedures.

Curriculum Content

Figure 1 (left) and Supplemental Table 2 (Supplemental Digital Content 2, <http://links.lww.com/PHM/A778>) display proportion of PM&R programs reporting instruction in foundational ultrasonography topics (knobology/machine operation, ultrasound physics, imaging protocols) and basic MSKUS-specific topics (tissue characteristics, injection techniques).⁸ Only 50%–75% of programs taught foundational ultrasonography topics. Among MSKUS+ programs, three (8.6%) did not teach any and only ten (28.6%) taught all foundational topics. When proportion of foundational topics taught was compared between USNWR Tiers, no overall relationship was found ($P = 0.630$). However, Tier 1 programs tended to teach more basic ultrasonography topics (80% of topics) than Tier 3 programs (68% of topics). The most commonly covered foundational topics were how to adjust depth (71%), focus (71%) or gain (69%), probe selection (69% of respondents), and how to enter patient information (67%) and save images (67%). Tissue characteristics and injection technique were covered by 79% and 74% of survey respondents, respectively. Those programs that taught basic tissue characteristics, joint injection, and perineural injection skills also included an average of 78%, 79%, and 85% of foundational topics in their curriculum, respectively.

Proportion of PM&R Programs Including US Content by Topic

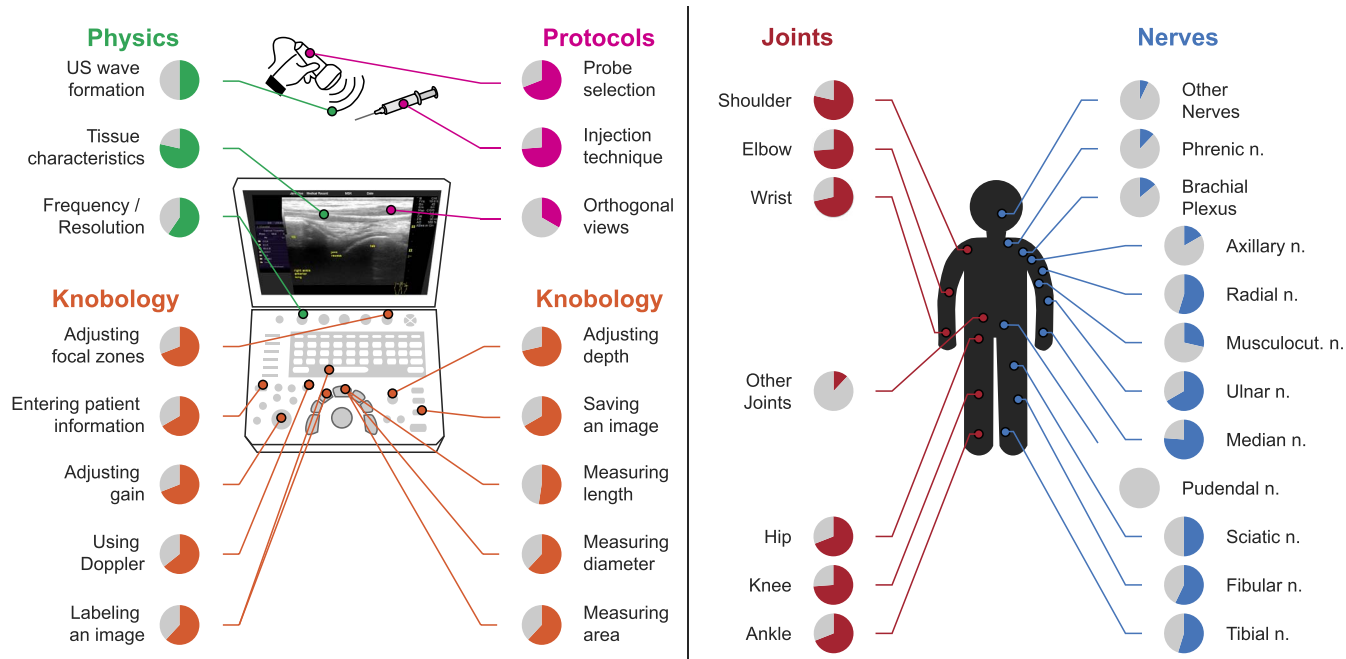


FIGURE 1. Proportion of PM&R survey respondents who endorsed having MSKUS curriculum content for topics in ultrasound physics, imaging protocols, knobology, joints, and peripheral nerves.

Figure 1 (right) summarizes the proportion of responding programs that taught diagnostic imaging for joints and peripheral nerves. Core studies, ie, those most frequently taught by residency programs, included the shoulder (79%), elbow (74%), knee (74%), wrist (71%), hip (69%), and ankle (69%) joints and median (76%), ulnar (67%), fibular (peroneal) (57%), radial (55%), tibial (55%), and sciatic (50%) nerves. Those programs that taught diagnostic evaluation of at least one core joint also taught an average of 78%–81% of foundational topics (see Supplemental Table 3, Supplemental Digital Content 3, <http://links.lww.com/PHM/A779>). Similarly, programs teaching diagnostic evaluation of at least one core nerve covered an average of 79%–89% of foundational topics.

Table 2 shows the diagnostic joint and nerve studies taught by MSKUS+ programs by tier. Technical considerations (multiple cells with expected values <5) prohibited meaningful statistical comparisons, but there is a clear pattern indicating that diagnostic joint evaluations are more commonly taught than diagnostic nerve studies across tiers. In addition, there is a trend for lower tier programs to include a lower percentage of joint or nerve topics than higher tier programs.

Figure 2 shows the disparity between ultrasound-guided interventional procedures that were reported to be within the scope of PM&R residency training (top bar), versus taught most of the time with ultrasonography (middle bar), or required for residency graduation (bottom bar). Most respondents (91%) indicated that ultrasound-guided joint injections were within the scope of residency training, 74% reported that their curriculum included ultrasound-guided joint injections, but only

40% taught these procedures with ultrasonography guidance most of the time, and 26% required competency for graduation. Similarly, most programs reported that ultrasound-guided nerve blocks (67%) or perineural steroid injections (79%) were within the scope of PM&R training, 45% reported that their curriculum included ultrasound-guided nerve injections, but only 31% and 36%, respectively, taught these injections with ultrasound guidance most of the time, and 12% and 14% required competency with these procedures for graduation.

There was less of a consensus that ultrasound-guided botulinum toxin injection (51%), EMG needle placement (32%), baclofen pump refills (30%), paravertebral injections (22%), and other percutaneous procedures (54%) were within the scope of PM&R residency training. Few programs reported that these procedures (other percutaneous procedures [17%], botulinum toxin injection [14%], baclofen pump refills [7%], paravertebral injections [7%], or needle placement for EMG [5%]) were mostly taught with ultrasound guidance. Almost no programs reported that competency with ultrasound guidance for botulinum toxin injection (7%), EMG needle placement (0%), baclofen pump refills (2%), paravertebral joint injections (0%), or other percutaneous procedures (5%) were required for graduation from their PM&R residency program.

Most MSKUS+ programs that taught ultrasound-guided interventional procedures also reported teaching diagnostic evaluation of the same structures. All programs that reported teaching shoulder and elbow injections with ultrasonography also reported covering diagnostic shoulder (31/31) and elbow (29/29) studies in their curriculum. Nearly all programs that reported teaching ultrasound-guided injections of the wrist, hip, knee, and ankle also taught diagnostic evaluation of these joints (29/30, 28/29, 29/30, and 29/30, respectively). Similarly, all 19 programs that taught ultrasound-guided perineural injection of the median nerve also taught diagnostic evaluation of the carpal tunnel. However, not all programs teaching ultrasound-guided perineural injection of the radial, ulnar, fibular (peroneal), tibial, and sciatic nerves also taught diagnostic evaluation of these nerves (14/18, 16/18, 15/18, 16/18, and 14/17, respectively).

Barriers to MSKUS Education

Table 3 lists barriers that survey respondents ranked by importance. “*Inadequate knowledge and experience*” among preceptors was identified as the most significant barrier to MSKUS education by nearly 43% of respondents. “*Lack of availability of ultrasound equipment*” and “*inadequate literature defining what should be taught*” were the next two most important barriers to MSKUS education. Neither “*resident interest*” nor “*inadequate patient numbers*” were considered important barriers; most (77%) respondents ranked “*lack of PM&R resident interest*” as their least significant barrier to MSKUS education.

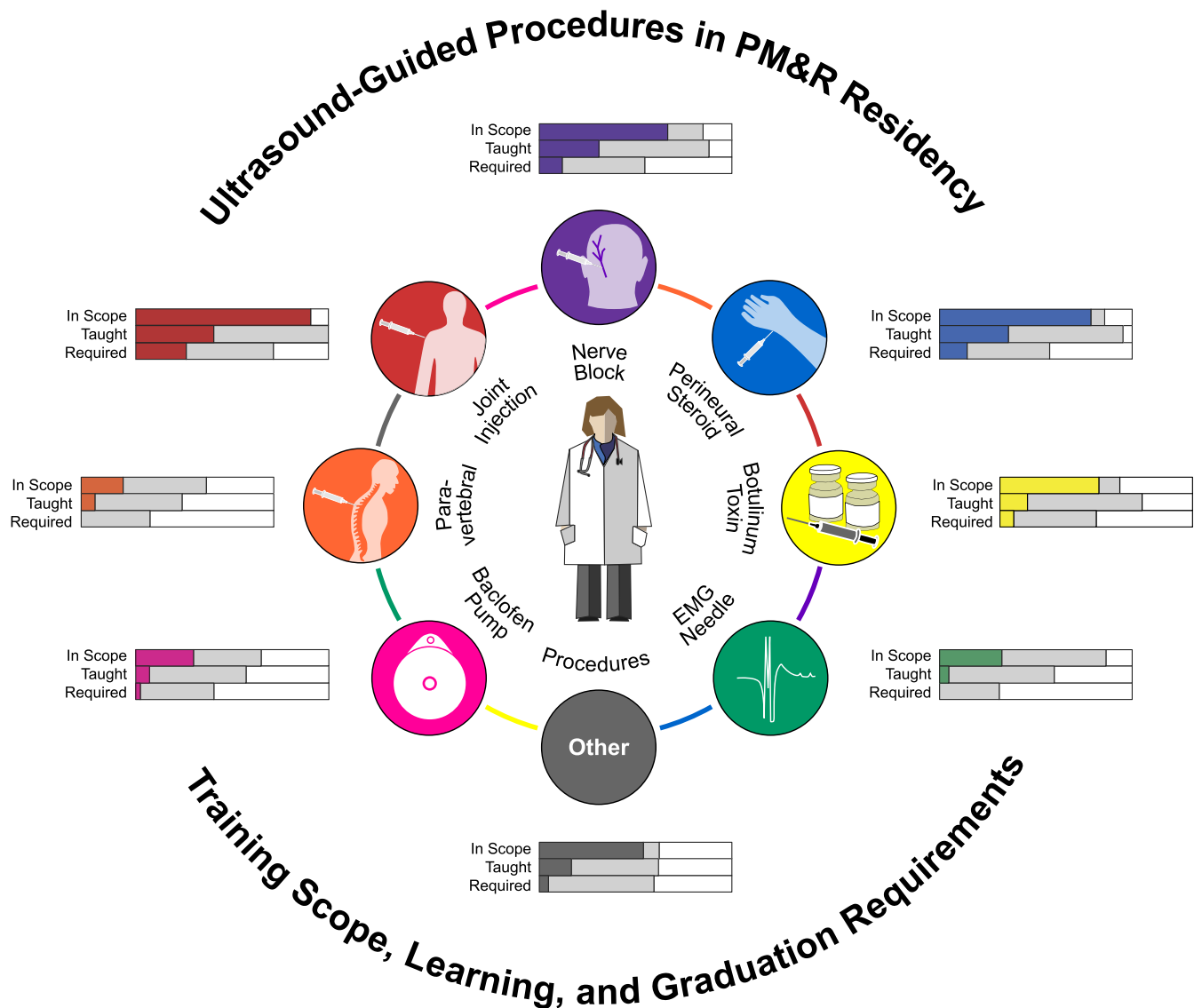
DISCUSSION

The aim of this study was to identify aspects of MSKUS curricula and training that were consistently implemented across ACGME-accredited PM&R residency programs in 2015, identify whether there was a consensus among program directors for what MSKUS topics should be taught, and

TABLE 2. Curriculum content for MSKUS+ PM&R residency programs by USNWR Tier

	Tier 1 (13)		Tier 2 (5)		Tier 3 (17)	
	Yes	No	Yes	No	Yes	No
Diagnostic joint studies						
Shoulder	13	0	4	1	16	1
Elbow	13	0	4	1	14	1
Wrist	13	0	4	1	13	3
Hip	12	0	4	1	13	3
Knee	13	0	4	1	14	2
Ankle	13	0	3	2	13	2
Diagnostic peripheral nerve studies						
Median	13	0	4	1	15	2
Ulnar	12	1	4	1	12	4
Radial	10	3	4	1	9	6
Sciatic	9	4	4	1	8	6
Tibial	11	2	4	1	8	7
Fibular (peroneal)	11	2	3	2	10	6
Other/advanced diagnostic peripheral nerve studies						
Axillary	4	8	1	3	2	10
Brachial plexus	3	9	2	3	1	12
Musculocutaneous	7	6	2	3	3	10
Phrenic	3	9	1	3	1	14
Pudendal	11	0	4	0	15	0

The “yes” and “no” columns under each tier indicate number of programs that do and do not, respectively include procedural instruction for studies in each row.



Legend

This US-guided procedure belongs in the **scope** of PM&R residency training
 This procedure is **taught** with US-guidance $\geq 50\%$ of the time
 All residents are **required** to perform this US-guided procedure independently to graduate

Percent of programs endorsing response: 0% 50% 100%

Yes No Undecided/NA

FIGURE 2. Proportion of PM&R programs reporting that ultrasound-guided procedures are within the training scope of residency (top bar), taught most of the time (middle bar), or required for graduation (bottom bar) by procedure type. Colored portion of bar represents respondents replying “yes,” gray area represents respondents replying “no,” and white portion represents “undecided” respondents. Most responders thought teaching joint injections, perineural steroid injections, and nerve blocks were within the scope of PM&R residency training, although few endorse teaching these procedures with MSKUS most of the time, and even fewer require competency for graduation. There was little consensus whether other named procedures belonged within the PM&R scope of training.

address barriers to learning MSKUS during PM&R residency. At the time of this survey, the ACGME made exposure to ultrasonography a formal requirement for graduation from PM&R residency. However, the PM&R Milestones for assessing trainee competency refer to ultrasonography only in the context of procedural skills for image guidance (PC6). This is reflected in procedural logs of residents graduating in 2015, who averaged 21 ± 45 ultrasound studies for image guidance and 11 ± 28 studies for limb evaluation.²³

Comparison with contemporaneous surveys of MSKUS integration in PM&R programs revealed a similar bias toward respondents reporting exposure to MSKUS (83% of 42 responders in the present study, 97% of 36 programs responding in Siddiqui et al.,⁶ and 100% of 18 programs responding in Berko et al.⁷). However, the present study had the highest response rate (54% compared with 46% and 23%, respectively), and more programs reported having a formal MSKUS curriculum in our 2015 survey (83% or $n = 35$ of 42) compared with

TABLE 3. Barriers to teaching MSKUS identified by PM&R residency program directors

Barriers	Logits	Most 1	2	3	4	5	6	7	Least 8
Inadequate knowledge and experience of preceptors (<i>most significant</i>)	-.38	15	6	1	1	3	3	4	2
Lack of availability of ultrasound equipment	-.15	6	6	4	3	6	5	2	3
Inadequate literature defining what should be taught to PM&R residents	-.11	2	8	5	7	2	5	4	2
Inadequate institutional support for ultrasound scans	-.07	4	2	8	5	6	2	5	3
Inadequate credentialing tools for PM&R physicians to perform ultrasound scans	0.0	3	1	8	6	6	4	6	1
Inadequate reimbursement for scans performed by PM&R physicians	-.03	3	3	6	6	5	8	0	4
Inadequate numbers of patients requiring ultrasound scans	.25	3	4	3	1	0	6	10	8
Lack of PM&R resident interest (<i>least significant</i>)	1.09	0	2	1	0	1	3	1	27

Items are ordered by Rasch Analysis Logits from most to least significant barriers to MSKUS education. Logits were calculated from the frequency of ranks (at right) for each barrier.

the 2014 Siddiqui survey⁶ (44% or $n = 16$ of 36) and the 2015 Berko survey⁷ (100% or $n = 18$ of 18). Based on the present survey, at least 45% of ACGME-accredited PM&R programs included formal MSKUS curricula by 2015 (35/78, including nonresponders), whereas estimates from the Siddiqui survey⁶ (16/78 or 21%) and Berko survey⁷ (18/80 or 23%) are lower, potentially because of lower response rates. Other similarities include the average number of faculty per program teaching MSKUS (3.5 in the present survey, 3 in the Siddiqui survey⁶), inclusion of didactics and hands-on scanning by programs as teaching methods (81% and 50% in the present study, 89% and 89% in the Siddiqui study,⁶ and 100% and 80% in the study by Berko et al.⁷), and the importance of dedicated teaching faculty with adequate MSKUS knowledge and experience.

All three surveys supported the increasing acceptance of MSKUS within the scope of PM&R residency (91% of responders in the present survey) and high resident interest in MSKUS (100%). Responders to the present survey reported that residents were expected to perform an average total of 35 ± 52 muscle or joint examinations, 22 ± 30 peripheral nerve studies, and 30 ± 44 ultrasound-guided procedures by graduation. Survey by Berko et al.⁷ found that most PM&R programs expected residents to interpret an average of 11–25 diagnostic MSKUS scans, perform an average of 26–50 diagnostic MSKUS scans, and perform an average of 26–50 ultrasound-guided procedures by graduation.

The present survey (see Supplemental Table 4, Supplemental Digital Content 4, <http://links.lww.com/PHM/A780>) differed from previous surveys by exploring curricular content, relative barriers to curricular implementation, and program director attitudes toward what should be included in a formal MSKUS curriculum. Survey results indicate that the presence and breadth of MSKUS instruction varies across PM&R residency programs and may differentiate programs, such that late or incomplete adopters of a formal curriculum are less likely to be rated in the top USNWR Tier. Indeed, a 2010 survey noted that presence of a strong MSKUS curriculum influenced applicants' rank of PM&R residency programs.⁸

The variability in MSKUS curricular depth and breadth is consistent with program directors' consensus (63%) belief that there is "inadequate literature defining what should be taught." For example, programs teaching diagnostic joint or nerve imaging tended to include foundational topics in ultrasound physics, machine instrumentation, and imaging protocols; however,

25% taught only half of the foundational topics in Figure 1. Similarly, most programs teaching interventional ultrasonography procedures for common joints and nerves also taught diagnostic imaging of these structures. However, no single joint or nerve study was taught by all 35 MSKUS+ programs. The studies most commonly taught (>85% of MSKUS+ programs) were diagnostic shoulder, elbow, knee, and wrist examinations; diagnostic median nerve imaging; and ultrasound-guided shoulder injections.

Another component of MSKUS education that deserves study and debate is how to best evaluate the combination of procedural skills, knowledge, and medical decision-making that reflects sufficient MSKUS competency for graduation from residency. At the time of this survey, only eight of the existing PM&R residency programs considered MSKUS competency a graduation requirement and these programs' evaluation methods were not reported. However, the survey results of Siddiqui et al.⁶ suggest that a range of tools are used for MSKUS competency assessment, including procedure logs and portfolios, patient encounters and checklists, written and oral examinations, objective structured clinical examinations and standardized patient examinations, global performance ratings, record review, and patient surveys. Because additional programs adopt MSKUS curricula, an important future direction will be to establish agreement across training sites regarding both evaluation methods and minimum standards for competency.

Resources exist to guide PM&R decisions regarding resident MSKUS training, curricula, and competency assessments. Stepwise undergraduate medical education curricula establish common ground for learners in the fundamentals (physics, image optimization, and tissue characteristics) and progress to specialty-specific focused ultrasonography.²⁴ Guidelines for focused ultrasonography instruction delineate the clinical knowledge and skills needed for minimum competency (I-AIM: Indication, Acquisition, Interpretation, and Medical decision-making),²⁵ whereas image evaluation tools (B-QUIET: Brightness mode Quality Ultrasound Imaging Evaluation Technique) aid in standardized assessment and feedback of technical ultrasonography skills.²⁶ Using these concepts, specialties such as PM&R can create a framework for diagnostic and interventional MSKUS Milestones (Fig. 3) populated with specialty-specific content across levels (pre-residency through graduation and aspirational targets). Physical medicine and rehabilitation-specific

content can be borrowed from ultrasonography curricula of medical schools^{14,24,27}; PM&R residency programs⁸; sports medicine,¹¹ rheumatology,²⁸ and pain medicine¹⁹ fellowships;

clinical practice guidelines²⁹; educational demonstrations^{30–32}; and program director responses to this survey. Figure 3 depicts exemplar MSKUS Milestones developed for a PM&R residency

A. Procedural Skills: Diagnostic Ultrasonography						
Core MSK: shoulder, knee, elbow, wrist. Core Nerve: median nerve at wrist and forearm, ulnar nerve at wrist and elbow						
Advanced MSK: hip, ankle, hand, foot, other joints. Advanced Nerve: tibial nerve at ankle, fibular nerve at fibular head to knee, radial nerve at elbow to arm, sciatic nerve branching to fibular and tibial nerve at posterior knee, brachial plexus, sural nerve, digital branches of hand and foot, other nerves or sites.						
Undergraduate Medical Education	Med 1&2		Med 3	Med 4		
Graduate Medical Education	PGY 1		PGY 2	PGY 3	PGY 4	
Fellowship/Continuing Medical Education						Fellow / Attending
Has not Achieved Level 1	Level 1	Level 2	Level 3	Level 4 (Graduation Target)	Level 5 (Aspirational)	
Knows foundational US topics, including: Instrumentation Ergonomics Probe Motions US Physics Tissue characteristics Image artifacts Image optimization: I-AIM B-QUIET	Knows indications , rationale for, and risks associated with the US procedure	Acquires and optimizes US images in a simulated setting (phantoms, standardized patients, or cadavers): ● Exhibits knowledge of appropriate probe for anatomic site ● Demonstrates knowledge of appropriate anatomic landmarks ● Saves & labels good quality images of desired structures in short and long axis Correctly performs core US studies by anatomic site on simulation models for ● joints ● nerves	Acquires and optimizes US images in a clinical setting (patients): ● Uses appropriate probe and positioning ● Locates and uses appropriate anatomic landmarks ● Saves & labels good quality images of desired structures in short and long axis Correctly performs and interprets core diagnostic US studies for Able to use US study results in medical decision-making	Has built a portfolio of scans which have passed quality review. Including: ● a total of at least 25 nerve or joint diagnostic studies ● a minimum of 5 from each of 5 anatomic sites or structures ● a maximum of 1 study at each anatomic site may be from a simulation model Able to teach core procedures to peers and medical students	Able to teach core procedures to faculty and residents Generates appropriate documentation and billing for studies Understands credentialing process for local site Correctly performs and interprets advanced diagnostic US studies for ● joints ● nerves	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Comments:						
B. Procedural Skills: Ultrasound-guided and Ultrasound-aided procedures						
Core MSK: joint injections at shoulder (AC joint, GH joint, subacromial bursa), knee, elbow (lateral epicondyle, olecranon bursa)						
Core Nerve: perineural (e.g. steroid) injections of median nerve at wrist, ulnar nerve at elbow, nerve blocks at common sites						
Advanced: needle visualization for intrathecal baclofen pump refills, botox, EMG, PRP injection; other MSK or Nerve structures						
Undergraduate Medical Education	Med 1&2		Med 3	Med 4		
Graduate Medical Education	PGY 1		PGY 2	PGY 3	PGY 4	
Fellowship/Continuing Medical Education						Fellow / Attending
Has not Achieved Level 1	Level 1	Level 2	Level 3	Level 4 (Graduation Target)	Level 5 (Aspirational)	
Knows foundational US topics, including: Instrumentation Ergonomics Probe Motions US Physics Tissue characteristics Image artifacts Image optimization: I-AIM B-QUIET Needle guidance	Knows indications , rationale for, safety protocols, and risks associated with the US-guided or US-aided procedure	Acquires and optimizes US images in a simulated setting (phantoms or cadavers): ● Exhibits knowledge of appropriate probe & equipment for procedure ● Demonstrates knowledge of appropriate anatomic landmarks ● Saves & labels good quality images of desired structures ● Demonstrates ability to image needles in plane, out of plane Correctly performs core interventional procedures on simulation models for ● joints ● nerves	Acquires and optimizes US images in a clinical setting (patients): ● Uses correct probe & equipment; positions & drapes appropriately ● Uses correct anatomic landmarks ● Saves & labels good quality images of desired structures ● Clearly visualizes needle placement, using appropriate technique Correctly performs core interventional procedures on patients for ● joints ● nerves Demonstrates appropriate medical decision-making for procedures	Has built a portfolio of scans which have passed quality review. Including: ● at least 15 US-guided or US-aided procedures ● a minimum of 5 from each of 3 anatomic sites or structures ● a maximum of 1 study at each site may be from a simulation model Able to teach core procedures to peers and medical students	Able to teach core procedures to faculty and residents Generates appropriate documentation and billing for US-guided or US-aided studies Understands credentialing process for local site May perform advanced interventional procedures for ● implantable pumps ● botox ● EMG ● other structures	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Comments:						

FIGURE 3. Sample MSKUS Milestones for (A) diagnostic nerve and joint studies and (B) interventional procedures. Foundational ultrasonography concepts (ultrasound physics, machine operation) and basic MSKUS skills (tissue characteristics, needle guidance technique) are medical student or intern-level competencies. Musculoskeletal ultrasonography knowledge and skills across core topics comprise graduation target competencies for PM&R residents (Level 4), whereas advanced topics are reserved for fellowship or practicing clinicians. Core and advanced topic divisions are a potential subject for debate by the PM&R Residency Review Committee.

program that can serve as a starting point for conversation and debate among medical educators responsible for defining PM&R curricula through the ACGME and American Board of Physical Medicine and Rehabilitation. For example, the Level 4 (Graduation Target) number of MSKUS scans for diagnosis and injection guidance in Figure 3 are 25 and 15, respectively. These numbers corresponded to the exemplar program's local hospital credentialing requirements for MSKUS billing. One might argue that for the purposes of competency assessment, Graduation Target numbers should be higher, eg, a total of 40 good quality scans for diagnosis and 25 for guided injection. These minimum competency benchmarks require further discussion at the ACGME Residency Review Committee and American Board of Physical Medicine and Rehabilitation level.

Other significant barriers to MSKUS education endorsed by respondents, namely, “*inadequate knowledge & experience of preceptors*” (66%) and “*lack of availability of ultrasound equipment*” (54%), may be slowly resolving. Near-peer teaching of learners by senior trainees can supplement preceptor-mediated training.^{33,34} Meanwhile, MSKUS training opportunities are expanding through professional associations' clinician certificate programs and train-the-trainer sessions (eg, American Academy of Physical Medicine and Rehabilitation's STEP: Skills, Training, Evaluation and Performance, American Association of Neuromuscular and Electrodiagnostic Medicine's Neuromuscular Ultrasound Workshops, AAP's Faculty Development course on Teaching MSKUS Education). This is important because our survey data show a possible bias toward programs having a structured curriculum if the program director performs MSKUS himself/herself. Furthermore, portable, hand-held machines (eg, Butterfly IQ by Butterfly, Lumify by Phillips, IViz by Fuji/Sonosite, and Vscan by GE) are becoming increasingly affordable and thus potentially available at PM&R residency training sites.

In summary, although MSKUS is tracked through the ACGME as a procedural skill, most programs with a formal MSKUS curriculum recognize that didactics are required to convey fundamental knowledge (eg, neuromusculoskeletal anatomy, disease conditions, and basics of ultrasonography) before hands-on skill acquisition. Enthusiasm for MSKUS is high among PM&R residents and program directors. Nevertheless, curricula vary in their coverage of foundational concepts, practical skills, anatomic regions, and assessment methods. The next steps in integrating MSKUS education across PM&R training programs should include standardization of a competency-based curriculum with MSKUS-specific milestones, continuing to train MSKUS educators, and allocating residency training resources to buy inexpensive, portable, point-of-care ultrasound machines.

Limitations

Response rate was limited to 42 of 78 PM&R training programs. Although respondents were evenly distributed across ACGME region, program size, USNWR program status, and institution type, response was likely biased toward programs already integrating MSKUS in their curriculum. Furthermore, response rate may have been negatively influenced by other MSKUS surveys collected coincident with this study. Data

reported here represent the state of MSKUS education in PM&R in 2015, before institution of ACGME program requirements for MSKUS; a similar survey will need to be conducted to evaluate how educational practices have changed in the interim and how MSKUS competency is assessed by residency programs. Finally, resident interest in MSKUS was inferred from program directors' ratings about barriers and not from resident responses.

CONCLUSIONS

Cognitive and technical MSKUS skills are becoming an accepted part of PM&R residency training; however, resident experiences vary by program. As a result, standardization of preceptor training, MSKUS curriculum, and competency-based Ultrasonography Milestones for PM&R residency are needed. The suggested MSKUS Milestones for PM&R proposed here may serve as a starting point for further discussion among PM&R educators. As more programs integrate MSKUS exposure, there will be opportunities to codify milestones matched to minimal core and enriched competencies for ultrasonography in physiatry.

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