Implementing a Sports Ultrasound Curriculum in Undergraduate Medical Education

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Abstract
The utilization of sports ultrasound in the clinical practice of sports medicine physicians is growing rapidly. Simultaneously, ultrasound is being increasingly implemented as a teaching tool in undergraduate medical education. However, a sports ultrasound curriculum for medical students has not been previously described. In this article, we describe methods as well as barriers to implementing a sports ultrasound curriculum at the medical school level. Recommended content for the curriculum also is discussed. While educational goals and resources will vary among institutions, this article may serve as a general roadmap for the creation of a successful curriculum.

Introduction

Sports ultrasound (US) refers to the use of US by a qualified medical professional to diagnose or guide treatment of sport- or exercise-related injuries or conditions (1). US is portable, relatively inexpensive, non-invasive, dynamic, and allows for high resolution visualization of anatomic structures. Sports US is versatile and incorporates the evaluation of structures assessed by many different specialties, including ophthalmology, cardiology, pulmonology, emergency medicine, and radiology (2–5).

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As the utilization of US expands, there has been an impetus to incorporate an US curriculum at the undergraduate medical education level (6–9) in order to improve comprehension of anatomy, as well as accuracy of the physical examination (2,10–13). Previous studies have demonstrated a better understanding of musculoskeletal (MSK) and cardiac anatomy/physiology when US was used as a teaching tool (14–21). Furthermore, it can be used as an adjunct in the teaching of MSK surface anatomy and physical examination skills (11–13,22,23). Specifically, previous studies have demonstrated improvement in performing aspects of the MSK physical examination, such as enhanced accuracy in palpating anatomic landmarks (*e.g.*, acromioclavicular joint), and in detecting pathology such as synovitis (23,24). In addition, the use of US as a teaching tool has been viewed favorably by medical students (15,17,25).

While guidelines exist for teaching sports US to sports medicine fellows (26), guidelines for incorporating sports US into undergraduate medical education have not been previously published. This article seeks to provide guidance for the implementation of a sports US curriculum in undergraduate medical education. These guidelines were developed through consensus recommendations and expert opinions of selected members of the Undergraduate Medical Education Subcommittee and Sports US Education Subcommittee of the American Medical Society for Sports Medicine who have experience in US curricula development and/or implementation. This document discusses recommendations for implementing a sports ultrasound curriculum into an undergraduate medical education curriculum, highlights US basics and normal structures relevant to medical students, and reviews potential barriers to implementation.

Implementation

There are multiple avenues through which a sports US curriculum can be incorporated into undergraduate medical education, and faculty should consider how to best define content

Table 1.
Ultrasound basics.

Ultrasound Basics	
Knobology	Power/on
	Depth Gain Focus Time gain compensation B mode M mode Doppler (color and power) Text/labeling Freeze Image capture Cine loop capture
Physics and image creation	Piezoelectric effect Frequency Wavelength Amplitude Reflection/refraction/scatter/absorption
Echogenicity	Anechoic Hypoechoic Isoechoic Hyperechoic
Transducer selection	Curvilinear Linear Hockey stick (small footprint linear) Phased array
Transducer movements	Slide Heel toe Tilt Compression Rotation Pivot Standoff Oblique standoff Sonopalpation
Imaging planes	Anatomic planes (coronal, sagittal, axial) Body planes (transverse, longitudinal) Scanning planes (long axis, short axis)
Imaging artifacts	Anisotropy Posterior acoustic shadowing Increased through transmission Reverberation Comet tail Mirror image Edge shadowing Ring down
Ultrasound etiquette	Transducer handling/cleaning Patient, operator, and machine positioning Patient comfort

and develop curricula to fit the needs of their institution. Implementation of a sports US curriculum should be a collaborative effort across preclinical courses and clinical specialties. At some institutions, teaching sports US may align best with a certain block (*e.g.*, during preclinical anatomy or during a family medicine rotation), whereas, at other institutions, a longitudinal curriculum would be more optimal (*e.g.*, at an institution where anatomy is integrated throughout the preclinical years). In the preclinical years, general US basics can be introduced, and sports US can be integrated into select courses focusing on augmenting education in anatomy, pathology, physical examination, and diagnostic skills. In the clinical years, sports US can be integrated into relevant core clerkships (*e.g.*, family medicine, radiology, internal medicine/critical care and emergency medicine). Sports US electives may be developed for those who seek a more comprehensive experience.

US should be taught using a multimodal approach, including hands on training (27), simulated scanning, didactic lectures, prerecorded and/or online videos (28), textbooks (29–31) and journal articles. Incorporating peer- or near-peer education (32–36), education through extracurricular interest groups (37,38), case-based discussions (39), and development of US electives (40) can help to facilitate learning. In addition, allowing students to save representative US images with formal faculty review of those images can be integrated into an already established curriculum (41). If in-person educational time is limited, US education also can be provided virtually (42–44).

Curriculum Content

US Basics

A thorough grasp of the basics of US, including knobology, physics of image creation (45,46), echogenicity, transducer selection, transducer movements (1), imaging artifacts (6), and US etiquette, is fundamental for the use of US as a teaching tool and in clinical practice. These principles are a foundational component of any US curriculum (Table 1). In addition, proficiency in agreed-upon sports US terminology and language will enforce useful habits as medical students progress through their medical education (1). It is important to note that not all US conventions are universally agreed upon; some conventions, such as terms to describe transducer manipulation, may differ among abdominal, cardiac, and sports US (1,47,48).

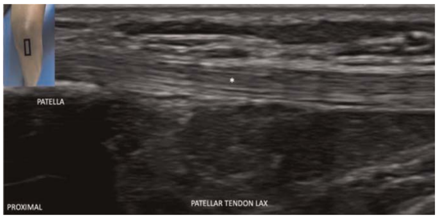
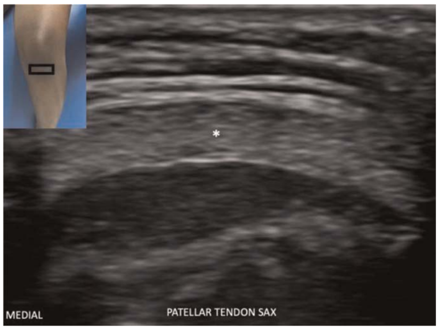
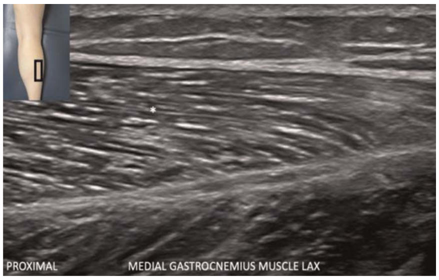
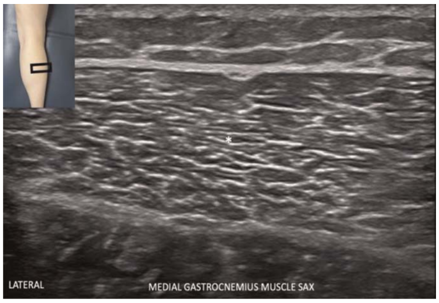
Normal Anatomy

Different anatomic structures have well-described and specific sonographic appearances, which is the result of variable differences in tissue densities. In addition, these structures have different appearances depending on the orientation of the transducer relative to the target structure (30,49). It is critical to recognize the normal sonographic appearances of common MSK structures (Table 2) in order to be able to identify pathologic changes; the focus of an effective undergraduate medical education US curriculum should be on teaching these normal appearances.

Specific Structures

Comprehension of the normal sonographic appearance of different tissue types should be established prior to transitioning to identification of specific anatomic structures. While MSK structures are the primary component of sports US, identification of basic thoracoabdominal structures (such as those included in an extended Focused Assessment of Sonography in

Table 2.
Normal sonographic appearances of common MSK structures.

Structure	Sonographic Appearance	Image	Pearls/Pitfalls
Tendon	LAX: –Hyperechoic, linear, fibrillar. –"Rope-like" appearance. SAX: –Hyperechoic, punctate, "speckled," "broom end" appearance.	 	–Be mindful of tendon anisotropy, which can produce an artificially hypoechoic appearance. Orient the transducer at 90 degrees to the target structure to limit this artifact. –Various tendons have different morphologies (*e.g.,* "circular" forearm flexor tendons, "ovoid" patellar tendon, "beaked/tapered" rotator cuff tendon.
Ligament	LAX: –Hyperechoic, linear, fibrillar appearance. –In a normal state, tension should be maintained across the ligament. SAX: –Hyperechoic, tightly packed, fairly homogenous appearance.		–Ligaments appear similar to tendons in LAX; however, they are less prone to anisotropy. They are typically not imaged in SAX unless to confirm or refute pathology.
Muscle	–In general, muscles have a mixed-echogenic appearance. The hypoechoic regions represent the muscle fibers and fascicles, while the hyperechoic regions represent the fascia and perimysial connective tissue. LAX: –Mixed echogenicity. –"Veins on a leaf" or "feather" appearance. SAX: –Mixed echogenicity. –"Starry night" appearance.	 	–Muscles also are prone to anisotropy, to a lesser degree than tendons. Care should be taken to avoid misinterpreting muscle edema for anisotropy.

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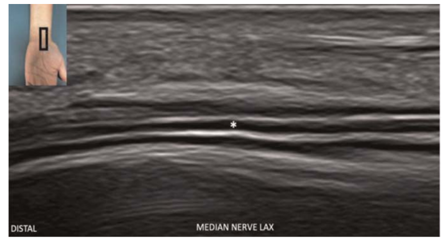
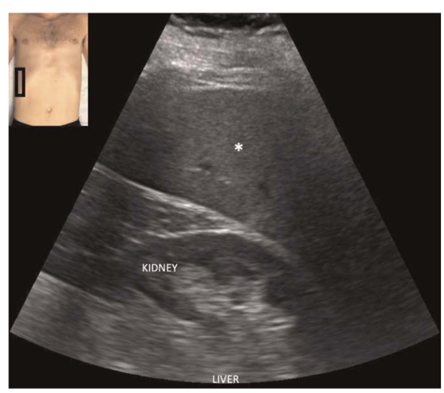
Structure	Sonographic Appearance	Image	Pearls/Pitfalls
Nerve	LAX: –Linear and hyperechoic. –Similar in appearance to tendon; however, the linear fascicles are larger and less tightly packed compared with tendon. –"Railroad track" appearance. SAX: –Large hypoechoic fascicles surrounded by hyperechoic perifascicular tissue produces "honeycomb" appearance.	 	–Sliding the transducer in a quick "sweeping" motion may help with identification of nerves, particularly smaller nerves, as they will change direction and depth on the screen. –Small nerves may appear grossly hypoechoic without the typical "honeycomb" appearance due to their monofascicular or oligofascicular anatomy.
Bone	–Hyperechoic, smooth, linear appearance with complete posterior acoustic shadowing (in LAX or SAX).		–May see small, nonpathologic defects in the cortex which correspond to small "feeder" vessels. These should not be mistaken for a fracture.
Liver	–Uniform, dense, isoechoic, or relatively hypoechoic structure. –The portal triad (hepatic artery, portal vein, and common bile duct) appears as three anechoic structures and is readily identified sonographically.		–Sonographic nearly identical to the spleen. –Anechoic fluid within the hepatorenal recess is concerning for intra-abdominal fluid.
Spleen	–Uniform, dense, isoechoic, or relatively hypoechoic structure. –Various anechoic blood vessels can be seen throughout the spleen.		–Sonographic nearly identical to the liver. –Anechoic fluid within the splenorenal recess is concerning for intra-abdominal fluid.

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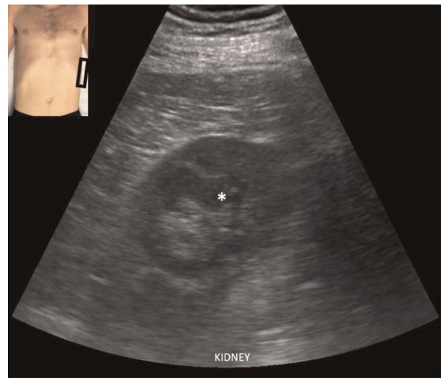
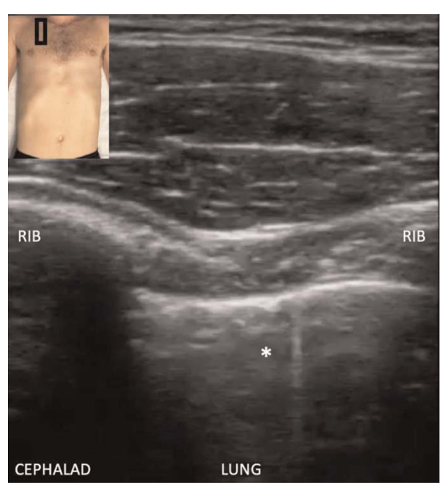
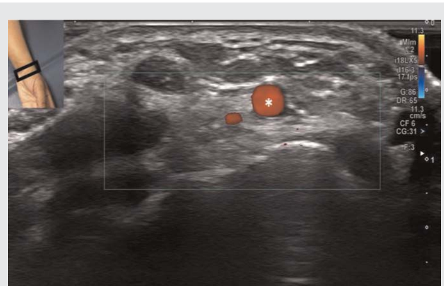
Structure	Sonographic Appearance	Image	Pearls/Pitfalls
Kidney	–“Bean-shaped,” mixed-echogenic structure. –Hypoechoic regions correlate to renal cortex and medullary pyramids. –Hyperechoic regions correlate to renal calyces and pelvis.		–The kidney is best visualized with a far posterolateral transducer placement on the abdomen.
Heart	–Mixed-echogenic appearance. –Hyperechoic regions correlate to the pericardium, myocardium, septae, and valves. –Hypoechoic regions correlate to the fluid-filled atria and ventricles.		–The heart can be visualized with a parasternal or subxiphoid approach. –The subxiphoid approach provides a better image, but is more challenging and may be uncomfortable for the patient.
Lungs	–Linear, hyperechoic pleura is visualized at the superficial aspect of the lung –Hyperechoic, linear, “ring-like” structures deep to the pleura may represent “normal” artifacts. –Regularly spaced, hyperechoic, smooth structures with complete posterior acoustic shadowing represent the ribs.		–Many “normal” artifacts are present during sonographic evaluation of the lung (*e.g.*, A lines, B lines) and a thorough understanding of these “normal” artifacts is important when assessing for pathology. –The sliding of the visceral and parietal pleura produces a “shimmering” or “ants on a log” appearance.
Blood Vessels	–Well-circumscribed, circular, anechoic structures. –May see hyperechoic valves within veins.		–Vascular structures can appear very similar to various cystic structures. The use of Doppler can be helpful in identification. –Veins are highly compressible. It is important to maintain light transducer pressure during visualization.

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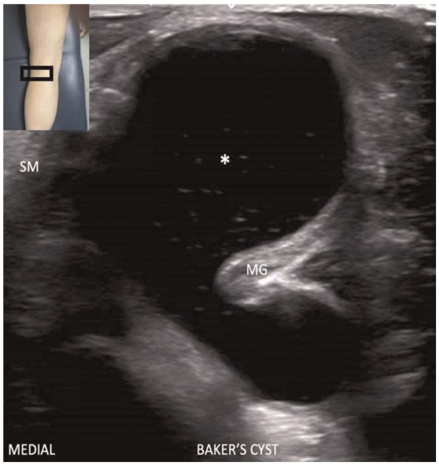
Structure	Sonographic Appearance	Image	Pearls/Pitfalls
Fluid	–Simple fluid is purely anechoic and highly compressible. –Complex fluid may appear heterogenous with mixed echogenicity.		–Enhanced through transmission is typically present, and structures deep to a fluid collection will appear artificially hyperechoic.

Asterisk (*) is in the center of the structure of interest (labeled at the bottom of the image).

LAX, long axis; ME, medial epicondyle; MG, medial gastrocnemius tendon; SAX, short axis; SM, semimembranosus tendon.

Trauma [eFAST]) also is important (2,36,50,51). Structures that may be included in an US curriculum are detailed in Table 3. It is important to keep in mind that these are structures that are recommended, not required, and that this is not a fully comprehensive list.

The following goals should be considered when discussing each specific structure:

- Reinforce basic US principles
- Recall normal anatomy
- Recognize the normal appearance of MSK and non-MSK structures on US
- Correlate sonographic findings with surface anatomy to improve physical examination skills
- Improve US scanning technique (scan in both long and short axis) and image optimization (correct for anisotropy artifact that can mimic pathology)
- Perform dynamic evaluations, as indicated
- Describe how US can be used clinically to guide patient diagnosis and treatment (including injections)

Limitations

There are several challenges to implementing a sports US curriculum in medical school training, including difficulty incorporating additional information to an already compressed undergraduate medical education curriculum, faculty skill level and availability, and the cost of US equipment. With the push to introduce students earlier to the clinical aspects of medicine, many schools are moving toward a compressed preclinical schedule, making it difficult to develop mastery of a skill, such as US, that requires dedicated time and hands on practice (52). In addition, there is concern among education leaders that more material added to existing curricula will lead to poorer knowledge retention rates (53). These concerns must be acknowledged when attempting to develop a robust and well-rounded undergraduate medical education curriculum.

Faculty skill, engagement, and availability present another challenge. Having faculty with adequate skills and knowledge of sports US is crucial for the curriculum to be successful. Use

Table 3.
Structures to consider including in an undergraduate medical education ultrasound curriculum.

Region	Structure
Shoulder	Biceps tendon (long head) Subacromial bursa/supraspinatus tendon ACJ GHJ
Elbow	Elbow joint (humeroulnar and humeroradial) Common extensor tendon UCL Ulnar nerve
Wrist/Hand	Median nerve Carpal tunnel
Hip/Pelvis	Hip joint (femoroacetabular) Femoral neurovasculature
Knee	Quadriceps tendon and muscle Suprapatellar recess Patella and prepatellar bursa Patellar tendon Joint line and medial and lateral menisci MCL Popliteal vessels
Ankle	Achilles tendon Tibiotalar joint ATFL
Foot	Plantar fascia
eFAST	RUQ LUQ Suprapubic Cardiac (subxiphoid and parasternal long axis views) Lung

ACJ, acromioclavicular joint; GHJ, glenohumeral joint; UCL, ulnar collateral ligament; MCL, medial collateral ligament; ATFL, anterior talofibular ligament; eFAST, extended focused assessment with sonography in trauma; RUQ, right upper quadrant; LUQ, left upper quadrant.

of a multidisciplinary effort to teach US and faculty development sessions may be beneficial (54,55). In addition, the time constraints and stressors of being clinically productive on faculty are well documented (56). Developing and implementing sports US programs may support opportunities for promotions if faculty are in an academic center that offers a clinical-educator track (57).

Lastly, access to US machines represents another potential barrier. US machines can be expensive, and initial start-up costs can be prohibitive when planning to integrate an US curriculum (27). Portable US machines can help reduce costs without compromising education, despite reduced image quality (58). Institutions should to be mindful of purchasing enough machines to provide sufficient hands-on experience for every student (59,60).

Conclusion

While curricula may vary across institutions, this article serves as a guide for implementing a sports US curriculum at the undergraduate medical education level. US basics, including normal anatomy, should be a foundational part of any US curriculum. Implementation of US curricula should be tailored to meet the needs of each individual institution.

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References

1. Hall MM, Allen GM, Allison S, *et al.* Recommended musculoskeletal and sports ultrasound terminology: a Delphi-based consensus statement. *Br. J. Sports Med.* 2022; 56:310–9.
2. Hoppmann RA, Mladenovic J, Melniker L, *et al.* International consensus conference recommendations on ultrasound education for undergraduate medical students. *Ultrasound J.* 2022; 14:31.
3. Patel SG, Benninger B, Mirjalili SA. Integrating ultrasound into modern medical curricula. *Clin. Anat.* 2017; 30:452–60.
4. Nelson BP, Narula S, Argulian E, *et al.* Including insonation in undergraduate medical school curriculum. *Ann. Glob. Health.* 2019; 85:135.
5. Hoffmann B, Blaivas M, Abramowicz J, *et al.* Medical student ultrasound education, a WFUMB Position Paper, Part II. A consensus statement of ultrasound societies. *Med. Ultrason.* 2020; 22:220–9.
6. Dinh VA, Lakoff D, Hess J, *et al.* Medical student core clinical ultrasound milestones: a consensus among directors in the United States. *J. Ultrasound Med.* 2016; 35:421–34.
7. Dinh VA, Fu JY, Lu S, *et al.* Integration of ultrasound in medical education at United States medical schools: a National Survey of Directors' experiences. *J. Ultrasound Med.* 2016; 35:413–9.
8. Nicholas E, Ly AA, Prince AM, *et al.* The current status of ultrasound education in United States medical schools. *J. Ultrasound Med.* 2021; 40:2459–65.
9. Smith CJ, Barron K, Shope RJ, *et al.* Motivations, barriers, and professional engagement: a multisite qualitative study of internal medicine faculty's experiences learning and teaching point-of-care ultrasound. *BMC Med. Educ.* 2022; 22:171.
10. So S, Patel RM, Orebaugh SL. Ultrasound imaging in medical student education: impact on learning anatomy and physical diagnosis. *Anat. Sci. Educ.* 2017; 10: 176–89.
11. Shapiro RS, Ko PK, Jacobson S. A pilot project to study the use of ultrasonography for teaching physical examination to medical students. *Comput. Biol. Med.* 2002; 32:403–9.
12. Dinh VA, Frederick J, Bartos R, *et al.* Effects of ultrasound implementation on physical examination learning and teaching during the first year of medical education. *J. Ultrasound Med.* 2015; 34:43–50.
13. Oteri V, Occhipinti F, Gribaudo G, *et al.* Integration of ultrasound in medical school: effects on physical examination skills of undergraduates. *Med. Sci. Educ.* 2020; 30:417–27.
14. Brown CC, Arrington SD, Olson JF, *et al.* Musculoskeletal ultrasound training encourages self-directed learning and increases confidence for clinical and anatomical appreciation of first-year medical students. *Anat. Sci. Educ.* 2022; 15: 508–21.
15. Brown B, Adhikari S, Marx J, *et al.* Introduction of ultrasound into gross anatomy curriculum: perceptions of medical students. *J. Emerg. Med.* 2012; 43: 1098–102.
16. Dreher SM, DePhilip R, Bahner D. Ultrasound exposure during gross anatomy. *J. Emerg. Med.* 2014; 46:231–40.
17. Swamy M, Searle RF. Anatomy teaching with portable ultrasound to medical students. *BMC Med. Educ.* 2012; 12:99.
18. Luetmer MT, Cloud BA, Youdas JW, *et al.* Simulating the multi-disciplinary care team approach: enhancing student understanding of anatomy through an ultrasound-anchored interprofessional session. *Anat. Sci. Educ.* 2018; 11:94–9.
19. Griksaitis MJ, Sawdon MA, Finn GM. Ultrasound and cadaveric prosections as methods for teaching cardiac anatomy: a comparative study. *Anat. Sci. Educ.* 2012; 5:20–6.
20. Kenny EJG, Makwana HN, Thankachan M, *et al.* The use of ultrasound in undergraduate medical anatomy education: a systematic review with narrative synthesis. *Med. Sci. Educ.* 2022; 32:1195–208.
21. Hammoudi N, Arangalage D, Boubrit L, *et al.* Ultrasound-based teaching of cardiac anatomy and physiology to undergraduate medical students. *Arch. Cardiovasc. Dis.* 2013; 106:487–91.
22. Walrod BJ, Boucher LC, Conroy MJ, *et al.* Beyond bones: assessing whether ultrasound-aided instruction and practice improve unassisted soft tissue palpation skills of first-year medical students. *J. Ultrasound Med.* 2019; 38:2047–55.
23. Walrod BJ, Schroeder A, Conroy MJ, *et al.* Does ultrasound-enhanced instruction of musculoskeletal anatomy improve physical examination skills of first-year medical students? *J. Ultrasound Med.* 2018; 37:225–32.
24. Ruiz-Curiel A, Díaz-Barreda MD, González-Rodríguez M, *et al.* Musculoskeletal ultrasound: an effective tool to help medical students improve joint inflammation detection? *Med. Ultrason.* 2016; 18:294–8.
25. Kefala-Karli P, Sassis L, Sassi M, Zervides C. Introduction of ultrasound-based living anatomy into the medical curriculum: a survey on medical students' perceptions. *Ultrasound J.* 2021; 13:47.
26. Hall MM, Bernhardt D, Finnoff JT, *et al.* American Medical Society for Sports Medicine sports ultrasound curriculum for sports medicine fellowships. *Br. J. Sports Med.* 2022; 56:127–37.
27. Bahner DP, Adkins EJ, Hughes D, *et al.* Integrated medical school ultrasound: development of an ultrasound vertical curriculum. *Crit. Ultrasound J.* 2013; 5:6.
28. American Medical Society for Sports Medicine. AMSSM Sports Ultrasound Online Didactics. [cited 2022, November 30]. Available from: https://www.amssm.org/UltrasoundOnlineDidactics.php.
29. Jacobson JA. *Fundamentals of Musculoskeletal Ultrasound E-Book.* Elsevier Health Sciences; 2017.
30. Bianchi S, Martinoli C. *Ultrasound of the Musculoskeletal System.* Springer Science & Business Media; 2007.
31. Iriarte I, Pedret C, Balius R, Cerezal L. *Ultrasound of the Musculoskeletal System: Anatomical Exploration and Pathology.* MSK Books; 2021.
32. Jeppesen KM, Bahner DP. Teaching bedside sonography using peer mentoring: a prospective randomized trial. *J. Ultrasound Med.* 2012; 31:455–9.
33. Smith CJ, Matthias T, Beam E, *et al.* Building a bigger tent in point-of-care ultrasound education: a mixed-methods evaluation of interprofessional, near-peer teaching of internal medicine residents by sonography students. *BMC Med. Educ.* 2018; 18:321.
34. Whitmill A, Edwards T, Charles S. Training medical student facilitators of peer-assisted study sessions using an objective standardized teaching exercise. *MedEdPORTAL.* 2020; 16:10898.
35. Ahn JS, French AJ, Thiessen ME, Kendall JL. Training peer instructors for a combined ultrasound/physical exam curriculum. *Teach. Learn. Med.* 2014; 26:292–5.
36. Knobe M, Münker R, Sellei RM, *et al.* Peer teaching: a randomised controlled trial using student-teachers to teach musculoskeletal ultrasound. *Med. Educ.* 2010; 44:148–55.
37. Linehan V, Ramlackhansingh J, Hartery A, Gullipalli R. The use of a student radiology interest group to promote ultrasound education—a single center experience. *Acad. Radiol.* 2020; 27:724–36.
38. Dubosh NM, Kman N, Bahner D. Ultrasound interest group: a novel method of expanding ultrasound education in medical school. *Crit. Ultrasound J.* 2011; 3:131–4.
39. Russell FM, Herbert A, Peterson D, *et al.* Assessment of medical students' ability to integrate point-of-care cardiac ultrasound into a case-based simulation after a short intervention. *Cureus.* 2022; 14:–e27513.
40. Prats MI, Royall NA, Panchal AR, *et al.* Outcomes of an advanced ultrasound elective: preparing medical students for residency and practice. *J. Ultrasound Med.* 2016; 35:975–82.
41. Boulger C, Prats M, Niku A, *et al.* ITSUS: integrated, tiered, self-directed ultrasound scanning for learning anatomy. *Cureus.* 2021; 13:e16119.

42. DePhilip RM, Quinn MM. Adaptation of an anatomy graduate course in ultrasound imaging from in-person to live, remote instruction during the COVID-19 pandemic. *Anat. Sci. Educ*. 2022; 15:493–507.

43. Schroeder AN, Hall MM, Kruse RC. Sports ultrasound training during a pandemic: developing a "hands-on" skill through distance learning. *Am. J. Phys. Med. Rehabil*. 2020; 99:860–2.

44. Soni NJ, Boyd JS, Mints G, *et al*. Comparison of in-person versus tele-ultrasound point-of-care ultrasound training during the COVID-19 pandemic. *Ultrasound J*. 2021; 13:39.

45. Ma IWY, Steinmetz P, Weerdenburg K, *et al*. The Canadian medical student ultrasound curriculum: a statement from the Canadian ultrasound consensus for undergraduate medical education group. *J. Ultrasound Med*. 2020; 39:1279–87.

46. Dietrich CF, Hoffmann B, Abramowicz J, *et al*. Medical student ultrasound education: a WFUMB position paper, part I. *Ultrasound Med. Biol*. 2019; 45:271–81.

47. End B, Prats MI, Minardi J, *et al*. Language of transducer manipulation 2.0: continuing to codify terms for effective teaching. *Ultrasound J*. 2021; 13:44.

48. Bahner DP, Blickendorf JM, Bockbrader M, *et al*. Language of transducer manipulation: codifying terms for effective teaching. *J. Ultrasound Med*. 2016; 35:183–8.

49. Smith J, Finnoff JT. Diagnostic and interventional musculoskeletal ultrasound: part 1. Fundamentals. *PM R*. 2009; 1:64–75.

50. Hahn M, Ray J, Hall MM, *et al*. Ultrasound in trauma and other acute conditions in sports, part I. *Curr. Sports Med. Rep*. 2020; 19:486–94.

51. Ray JW, Gende AM, Hall MM, *et al*. Ultrasound in trauma and other acute conditions in sports, Part II. *Curr. Sports Med. Rep*. 2020; 19:546–51.

52. Kelley JK, Matusko N, Finks J, *et al*. Shortened pre-clerkship medical school curriculum associated with reduced student performance on surgery clerkship shelf exam. *Am. J. Surg*. 2021; 221:351–5.

53. Bahner DP, Goldman E, Way D, *et al*. The state of ultrasound education in U.S. Medical schools: results of a national survey. *Acad. Med*. 2014; 89:1681–6.

54. Russell FM, Herbert A, Zakeri B, *et al*. Training the trainer: faculty from across multiple specialties show improved confidence, knowledge and skill in point of care ultrasound after a short intervention. *Cureus*. 2020; 12:e11821.

55. Rempell JS, Saldana F, DiSalvo D, *et al*. Pilot point-of-care ultrasound curriculum at Harvard Medical School: early experience. *West. J. Emerg. Med*. 2016; 17:734–40.

56. Mercurio MR. Neonatology's race to the bottom: RVUs, cFTEs, and physician time. *J. Perinatol*. 2021; 41:2561–3.

57. Keating MK, Pasarica M, Stephens MB, *et al*. Promotion preparation tips for academic family medicine educators. *Fam. Med*. 2022; 54:369–75.

58. Slader M, Young H, Barker M, *et al*. A comparison of handheld and standard ultrasound in Swiss medical students. *World J. Emerg. Med*. 2022; 13:85–90.

59. Schieffler DA Jr., Azevedo BM, Culbertson RA, Kahn MJ. Financial implications of increasing medical school class size: does tuition cover cost? *Perm. J*. 2012; 16:10–4.

60. Galusko V, Khanji MY, Bodger O, *et al*. Hand-held ultrasound scanners in medical education: a systematic review. *J. Cardiovasc Ultrasound*. 2017; 25:75–83.