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American Medical Society for Sports Medicine recommended sports ultrasound curriculum for sports medicine fellowships

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ABSTRACT

The American Medical Society for Sports Medicine (AMSSM) developed a musculoskeletal ultrasound curriculum for sports medicine fellowships in 2010. As the use of diagnostic and interventional ultrasound in sports medicine has evolved, it became clear that the curriculum needed to be updated. Furthermore, the name 'musculoskeletal ultrasound' was changed to 'sports ultrasound' (SPORTS US) to reflect the broad range of diagnostic and interventional applications of ultrasound in sports medicine.

This document was created to outline the core competencies of SPORTS US and to provide sports medicine fellowship directors and others interested in SPORTS US education with a guide to create a SPORTS US curriculum. By completing this SPORTS US curriculum, sports medicine fellows and physicians can attain proficiency in the core competencies of SPORTS US required for the practice of sports medicine.

INTRODUCTION

The following sports ultrasound (SPORTS US) curriculum is a revision of the curriculum developed by the American Medical Society for Sports Medicine (AMSSM) in 2010.¹ Several changes have been made to the curriculum with the primary aim of providing a pathway by which a sports medicine fellow can obtain sufficient SPORTS US training to become proficient in the core competencies of SPORTS US. The core competencies of SPORTS US are outlined in the learning objectives section of this document.

The term 'SPORTS US' was purposefully chosen rather than 'musculoskeletal ultrasound' (MSK US) since it was recognised by the panel that the evolving field of SPORTS US encompasses non-MSK applications of ultrasound such as the FAST examination (focused assessment with sonography for trauma). While the SPORTS US core competencies in this curriculum are all MSK in nature, they represent the minimum SPORTS US knowledge a sports medicine fellow should acquire during fellowship. However, additional training in more advanced MSK and non-MSK applications of ultrasound can be provided at the fellowship director's discretion.

Completion of this SPORTS US curriculum fulfils the American Institute of Ultrasound in Medicine's (AIUM) requirements to perform a MSK US examination, and the pre-requisites for the American Registry for Diagnostic Medical Sonography's (ARDMS) MSK sonography certification examination.

Overview

The educational process should include four components.

Didactic instructional sessions

Didactic instruction can occur via a dedicated SPORTS US course or scheduled teaching sessions during the fellowship (see Didactic instructional sessions). Didactics should include discussions of ultrasound physics, image acquisition and optimisation, normal and pathological appearance of tissues, ultrasound artifacts, advantages and limitations of SPORTS US relative to other imaging modalities, and diagnostic and interventional techniques pertaining to major body regions encountered in a sports medicine practice.

Didactic practice sessions

Hands-on didactic practice sessions should be completed under the direct supervision of a qualified mentor. A qualified mentor is defined as an individual who has met the qualifications outlined by the AIUM Training Guidelines for Physicians and Chiropractors Who Evaluate and Interpret Diagnostic Musculoskeletal Ultrasound Examinations (<http://www.aium.org>). During these sessions, fellows should apply the knowledge and skills acquired during the didactic instructional sessions in a controlled and supervised environment (see Didactic practice sessions).

Mentored clinical experience

As knowledge and skills are acquired, the fellow should perform diagnostic scanning and interventional procedures on patients in a clinical setting under the direct supervision of a qualified mentor. As the fellow gains proficiency in the clinical application of diagnostic and interventional SPORTS US techniques, the level of supervision may be modified as allowed by institutional policy governing teaching rules.

Supplementary and continuing education

The fellow's education should include supplementary educational experiences to reinforce the knowledge and skills gained during the didactic sessions and mentored clinical experience.

A. Required

1. Independent scanning practice sessions

B. Recommended

1. Reading reference texts and journal article
2. Presenting SPORTS US related articles in journal club



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3. Utilising online educational material and educational DVD's

4. Attending SPORTS US conferences and presentations

The integration of recommended supplementary educational experiences may vary from fellowship to fellowship based on available resources and the overall curriculum structure.

This natural stepwise progression of diagnostic and interventional SPORTS US education will ensure the acquisition of sufficient SPORTS US skills to allow independent practice of the core competencies of diagnostic and interventional SPORTS US on completion of fellowship.

Learning objectives for SPORTS US training during fellowship

- A. Identify and discuss the function of basic controls on an ultrasound machine console, including
 - i. Transducer selection
 - ii. Presets
 - iii. Depth
 - iv. Focal zone/focal region
 - v. Gain
 - vi. Time gain compensation/depth gain compensation
 - vii. Zoom (including read zoom and write zoom)
- B. Discuss the basic physics principles of ultrasound, including
 - i. How an US image is generated
 - ii. Inter-relationship of machine controls (eg, frequency, resolution and depth)
 - iii. Doppler imaging (difference between power Doppler and colour Doppler)
- C. Demonstrate how to optimise an ultrasound image
 - i. Superficial structures
 - ii. Deep structures
- D. Describe the normal ultrasonographic appearance of adipose, muscle, tendon, ligament, bone, fascia, vessels, nerve, and cartilage
- E. Describe the common pathological ultrasonographic appearance of adipose, muscle, tendon, ligament, bone, fascia, vessels, nerve, joint and cartilage
- F. Discuss the benefits and limitations of SPORTS US relative to other imaging modalities
- G. Identify and discuss the source and/or implications of basic ultrasound artefacts, including
 - i. Anisotropy
 - ii. Reverberation
 - iii. Refraction
 - iv. Through transmission
 - v. Acoustic shadowing

Perform image acquisition of vascular structures including neovessels using Color and Power Doppler.

- H. Perform a SPORTS US examination of the following regions as recommended by the AIUM Practice Guidelines for the Performance of the MSK US Examination (see online supplementary appendix 1)
 - i. Shoulder
 - ii. Elbow
 - iii. Wrist-Hand
 - iv. Hip
 - v. Knee
 - vi. Ankle-Foot
- I. Obtain an acceptable set of SPORTS US images of the following regions as recommended by the AIUM Practice Guidelines for the Performance of the MSK US Examination (see online supplementary appendix 1)

- i. Shoulder
- ii. Elbow
- iii. Wrist-Hand
- iv. Hip
- v. Knee
- vi. Ankle-Foot
- J. Demonstrate appropriate labelling of SPORTS US images
 - i. Use of text insertion
 - ii. Use of arrows and measurement calipers
- K. Demonstrate how to capture, store and transfer SPORTS US images
- L. Generate an appropriate diagnostic SPORTS US report
- M. Perform an appropriate SPORTS US evaluation to identify and appropriately document (eg, capture, label, save and transfer images; generate a report) of the following conditions:
 - i. Shoulder
 - 1. Supraspinatus full thickness tear
 - 2. Supraspinatus tendinopathy
 - 3. Bicipital tendinopathy
 - 4. Subacromial-subdeltoid bursopathy
 - 5. Acromioclavicular joint osteoarthritis
 - ii. Elbow
 - 1. Common extensor tendinopathy
 - 2. Dynamic examination of the ulnar nerve at the elbow
 - 3. Common flexor tendinopathy
 - iii. Wrist-Hand
 - 1. DeQuervain's tenosynovitis
 - 2. Carpal tunnel syndrome
 - iv. Hip
 - 1. Gluteus medius/minimus tendinopathy
 - 2. Hamstring tendinopathy
 - v. Knee
 - 1. Patellar tendinopathy
 - 2. Baker's cyst
 - 3. Knee joint effusion
 - vi. Ankle-Foot
 - 1. Peroneal tendinopathy (including dynamic evaluation for instability)
 - 2. Achilles tendinopathy
 - 3. Plantar fasciopathy
- N. Describe the advantages and disadvantages of needle tracking using an in-plane versus out-of-plane approach, and provide clinical examples of when each approach may be beneficial.
- O. Image a needle using an in-plane (longitudinal or long axis) and out-of-plane (short axis or transverse) approach using ultrasound guidance in a phantom, turkey breast, cadaveric specimen or other imaging medium, including demonstration of the following transducer manipulations:
 - i. Translation (sliding/gliding)
 - ii. Rotation
 - 1. Describe 'cross-cut' artefact when imaging/tracking a needle during an interventional procedure
 - iii. Heel-toe
 - iv. Tilting (toggling/wagging)
 - v. Compression
- P. Demonstrate the ability to efficiently relocate a lost needle during an in-plane and out-of-plane needle tracking approach.
- Q. Demonstrate the ability to guide a needle into a target region or structure using an in-plane and out-of-plane approach in a phantom, turkey breast, cadaveric specimen or other imaging medium.

- R. Obtain an acceptable set of preprocedure, intraprocedure and postprocedure images of an ultrasound-guided-procedure.
- S. Demonstrate appropriate labelling of the ultrasound-guided procedure images.
- T. Demonstrate how to store and transfer the ultrasound-guided procedure images.
- U. Generate an appropriate ultrasound-guided procedure report.
- V. Perform and appropriately document (eg, capture, label, save, and transfer images; generate a report) the following ultrasound-guided procedures:
 - i. Shoulder
 - 1. Subacromial-subdeltoid bursa injection
 - 2. Intra-articular glenohumeral joint injection
 - 3. Intra-articular acromioclavicular joint injection
 - 4. Bicipital tendon sheath injection
 - ii. Elbow
 - 1. Intra-articular elbow joint injection
 - 2. Peritendinous or intratendinous injection of the common extensor tendon origin
 - 3. Peritendinous or intratendinous injection of the common flexor tendon origin
 - iii. Wrist-Hand
 - 1. Carpal tunnel injection
 - 2. First dorsal compartment tendon sheath injection
 - 3. Intra-articular wrist injection
 - iv. Hip
 - 1. Intra-articular hip injection
 - 2. Greater trochanteric bursa injection
 - 3. Gluteus medius or minimus peritendinous or intratendinous injection
 - v. Knee
 - 1. Intra-articular knee injection
 - 2. Iliotibial band/bursa (distal) injection
 - vi. Ankle-Foot
 - 1. Intra-articular tibiotalar joint injection
 - 2. Peroneal tendon sheath injection
 - 3. Periplantar or intraplanter fascia injection
 - vii. Miscellaneous
 - 1. Aspiration or injection of a cyst

Resources/references

Books

- Bianchi S, Martinoli C. *Ultrasound of the musculoskeletal system*. New York: Springer, 2007.
- Daniels JM, Dexter WW, eds. *Basics of musculoskeletal ultrasound*. New York: Springer, 2013.
- Jacobson JA. *Fundamentals of musculoskeletal ultrasound*. 2nd edn. Philadelphia: Saunders Elsevier, 2013.
- Malanga G, Mautner K, eds. *Atlas of ultrasound-guided musculoskeletal injections*. New York: McGraw-Hill, 2014.
- O'Neill J, ed. *Musculoskeletal ultrasound: anatomy and technique*. New York: Springer, 2008.
- Sconfienza LM, Serafini G, Silvestri E, eds. *Ultrasound guided musculoskeletal procedures: the upper limb*. New York: Springer, 2012.
- Silvestri E, Muda A, Sconfienza LM, eds. *Normal ultrasound anatomy of the musculoskeletal system: a practical guide*. New York: Springer, 2012.

Additional resources

- American College of Radiology (ACR) Practice Guideline for Communication of Diagnostic Imaging Findings. <http://www.acr.org>

ACR Practice Guidelines for the Performance of the Musculoskeletal Ultrasound Examination. <http://www.acr.org>

American Institute of Ultrasound in Medicine (AIUM) Practice Guidelines for the Performance of the Musculoskeletal Ultrasound Examination, 2012. <http://www.aium.org>, or in the *J Ultrasound Med* 2012;31:1480.

AIUM Practice Guideline for the Performance of the Shoulder Ultrasound Examination. <http://www.aium.org>

AIUM Practice Guideline for Documentation of the Diagnostic Ultrasound Examination. <http://www.aium.org>

AIUM Practice Guideline for Performance of the Diagnostic Ultrasound Examination. <http://www.aium.org>

AIUM Training Guidelines for Physicians and Chiropractors Who Evaluate and Interpret Diagnostic Musculoskeletal Ultrasound Examinations. <http://www.aium.org>

European Society of Skeletal Radiology (ESSR) Musculoskeletal Ultrasound Scanning Technique Demonstrations. <http://www.ESSR.org>

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

Smith J, Finnoff JT. Diagnostic and interventional musculoskeletal ultrasound: part 2. *PMR* 2009;1:162–77.

Didactic instructional sessions

The SPORTS US didactic instructional sessions include six basic units described in this section. Each fellowship should provide appropriate resources for fellows to preview and review the information relevant to each session (see Resource/reference list). Whereas the number of teaching sessions can be modified as desired or necessary, all fellows should receive instruction in all listed topics. It is strongly recommended that teaching sessions for diagnostic scanning (Units 1–5) utilise established scanning protocols to guide learning and ensure compliance with accepted standards (See SPORTS US Scanning Protocol in online supplementary appendix 2). Finally, although the order of Units 2–5 may be modified, fellows should master the diagnostic skills for a specific region before initiating ultrasound-guided procedure training in that region (eg, mastery of the shoulder diagnostic scans should proceed formal training in ultrasound-guided shoulder interventions).

The first unit introduces the fellow to basic SPORTS US physics, image acquisition and optimisation, normal and pathological appearance of tissues, ultrasound artefacts and the advantages and limitations of SPORTS US relative to other imaging modalities. During Units 2–5, a qualified MSK sonographer/sonologist should demonstrate the scanning protocol(s) for one or more body regions, followed by supervised practice. A qualified MSK sonographer is defined as an individual who has met the AIUM Practice Guidelines for the Performance of a MSK US examination. The fellow should only consider these sessions as an introduction to scanning and independent practice between didactic sessions is necessary to facilitate skill acquisition (see Supplementary and continuing education above).

Unit 6 involves at least three individual sessions dedicated to interventional SPORTS US procedures. Initial topics reviewed include pharmacological principles of commonly used medications, patient selection, aseptic technique for ultrasound-guided procedures, procedural risks, and treatment of common adverse events. Thereafter, the fellow should be introduced to methods of ultrasound-guided needle image optimisation, needle relocation and dynamic needle tracking using both in-plane and out-of-plane approaches. Once these skills are mastered, the fellow should be introduced to common upper and lower extremity ultrasound-guided interventional procedures (with a

focus on the core interventional ultrasound competencies) via discussion, demonstration and supervised practice under the guidance of a qualified practitioner. Multiple mediums may be suitable for practising ultrasound-guided interventional procedures. The ideal mediums are unembalmed cadaveric specimens. However, if unembalmed cadaveric specimens are unavailable, the fellow can practice patient positioning and target acquisition on live models followed by practice of needle visualisation and guidance on turkey breasts, pig feet, pig legs, firm tofu, phantoms and/or other non-cadaveric specimens. The fellow should practice needle visualisation and guidance techniques between mentored didactic sessions to enhance his/her skills (see supplementary and continuing education above).¹

Unit 1 Principles of SPORTS US and an Introduction to Scanning Techniques

1. Instruction in 'Knobology' and basic scanning techniques
2. Instruction on basic US physics
3. Demonstration of normal sonographic appearance of adipose, muscle, tendon, ligament, bone, fascia, vessels, nerve, and cartilage
4. Discussion of the common abnormal sonographic appearances of adipose, muscle, tendon, ligament, bone, fascia, vessels, nerve, joint and cartilage
5. Muscle, tendon, ligament and nerve.
6. Demonstration of the use of Color and Power Doppler for imaging vascular and neovascular structures
7. Demonstration of transducer movements to optimise image (translation (sliding), rotation, heel-toe, tilt (toggle) and pressure/compression)
8. Supervised practice

Unit 2 SPORTS US Examination of the Knee-Hip

1. Knee US Scanning Protocol
 - A. Instruction and supervised practice
 - B. Resources
 - i. SPORTS US Scanning Protocol Checklists—Knee
 - ii. AIUM and ACR Guidelines for Performance of the MSK US Examination
2. Hip and Thigh US Scanning Protocol
 - A. Instruction and supervised practice
 - B. Resources
 - i. SPORTS US Scanning Protocol Checklists—Hip-Thigh
 - ii. AIUM and ACR Guidelines for Performance of the MSK US Examination
3. Independent scanning

Unit 3 SPORTS US Examination of the Elbow and Wrist-Hand

1. Elbow US Scanning Protocol
 - A. Instruction and supervised practice
 - B. Resources
 - i. SPORTS US Scanning Protocol Checklists—Elbow
 - ii. AIUM and ACR Guidelines for Performance of the MSK US Examination
2. Wrist-Hand US Scanning Protocol
 - A. Instruction and supervised practice
 - B. Resources

- i. SPORTS US Scanning Protocol Checklists—Wrist-Hand
- ii. AIUM Guidelines for Performance of the MSK US Examination

3. Independent scanning

Unit 4 SPORTS US Examination of the Ankle-Foot

1. Ankle-Foot US Scanning Protocol
 - A. Instruction and supervised practice
 - B. Resources
 - i. SPORTS US Scanning Protocol Checklists—Ankle-Foot
 - ii. AIUM and ACR Guidelines for Performance of the MSK US Examination
2. Independent scanning

Unit 5 SPORTS US Examination of the Shoulder

1. Shoulder US Scanning Protocol
 - A. Instruction and supervised practice
 - B. Resources
 - i. SPORTS US Scanning Protocol Checklists—Shoulder
 - ii. AIUM Guidelines for Performance of the Shoulder Ultrasound Examination
 - iii. AIUM and ACR Guidelines for Performance of the MSK US Examination
2. Independent scanning

Unit 6 US Guided Interventional Procedures

1. Didactic instruction and discussion
 - A. Rationale for US-guided procedures
 - B. Principles of US-guided procedures
 - i. Patient selection
 - ii. Ergonomics
 - iii. Aseptic technique
 - iv. In-plane and out-of-plane needle tracking
 - v. Image optimisation for needle location, relocation and dynamic tracking, including transducer manipulation: translation (sliding), rotation, heel toe, tilting (toggling) and compression
 - vi. Recognising and correcting 'cross-cut' artefact when needle tracking
 - C. Specific applications and techniques
 - i. Joint, tendon sheath, nerve, ligament, bursa/cyst
 - ii. Use of 'stand-off'/oblique stand-off, hydrodissection, lavage and aspiration
2. Demonstration, discussion and practice using unembalmed cadaveric specimens, phantoms, turkey breasts, pig feet, pigs legs, firm tofu or other appropriate medium
 - A. In-plane and out-of-plane needle location and tracking
 - B. Needle relocation
 - C. Cross-cut artefact
 - D. Commonly performed US-guided procedures. It is strongly recommended that these procedures be practiced on an unembalmed cadaveric specimen. However, if this is not feasible, then fellows should practice all aspects of needle visualisation and tracking using other appropriate medium, and the principles of the procedures listed below reviewed in a formal didactic setting.
 - i. Shoulder
 1. Subacromial-subdeltoid bursa injection
 2. Intra-articular glenohumeral joint injection
 3. Intra-articular acromioclavicular joint injection
 4. Bicipital tendon sheath/groove injection
 - ii. Elbow
 1. Intra-articular elbow joint injection

¹Please note that the educational material has been divided into units to facilitate teaching of related concepts and skills. The number of educational sessions required to teach the knowledge and skills contained in a specific unit may vary depending on scheduling and available resources.

2. Peritendinous or intratendinous injection of the common extensor tendon origin
3. Peritendinous or intratendinous injection of the common flexor tendon origin
- iii. Wrist-Hand
 1. Carpal tunnel injection
 2. First dorsal compartment tendon sheath injection
 3. Intra-articular wrist injection
- iv. Hip
 1. Intra-articular hip injection
 2. Greater trochanteric bursa injection
 3. Gluteus medius or minimus peritendinous or intratendinous injection
- v. Knee
 1. Intra-articular knee injection
 2. Iliotibial band/bursa (distal) injection
- vi. Ankle-Foot
 1. Intra-articular tibiotalar joint injection
 2. Peroneal tendon sheath injection
 3. Periplantar or intraplanter fascia injection
- vii. Miscellaneous
 1. Aspiration or injection of a cyst

Didactic practice sessions

Didactic practice sessions should be scheduled with a qualified mentor on regular basis throughout the fellowship. A qualified mentor is one who has met the requirements outlined in the AIUM Training Guidelines for Physicians and Chiropractors Who Evaluate and Interpret Diagnostic Musculoskeletal Ultrasound Examinations (<http://www.aium.org>). During these sessions the fellow should apply the knowledge and skills acquired during the didactic instructional sessions in a controlled and supervised educational environment. The didactic practice sessions should include the following:

1. Practice and demonstration of performing a complete ultrasound evaluation of each major region listed in the scanning protocols including proper image optimisation and acquisition (see online supplementary appendix 1).
2. Practice and demonstration of proper image labelling and storage. Transference of images should follow the guidelines outlined by the Health Insurance Portability and Accountability Act (HIPAA).
3. Review of saved images from the fellow's self-directed practice scanning sessions and provision of constructive feedback regarding study completeness, and proper image optimisation, labeling, storage and transfer. Deficiencies should be reconciled during subsequent scanning sessions.
4. Practice and demonstration of interventional skills, preferably using unembalmed cadaveric specimens. If cadaveric specimens are not available, the fellow should practice appropriate imaging of target structures on live models, and should practice needle imaging and guidance techniques using turkey breasts, pig feet, pig legs, firm tofu, phantoms or other appropriate medium. As the fellow's skills improve, more advanced SPORTS US examination techniques and interventional procedures should be introduced into the didactic practice sessions (eg, hydrodissection, percutaneous treatment of calcific tendinosis, etc).

Mentored clinical experience

The fellow should have regularly scheduled clinical time in which they receive supervised hands-on experience performing diagnostic and interventional SPORTS US on patients. During

this experience, fellows should practice and eventually demonstrate competency in all aspects of SPORTS US outlined in the learning objectives. Special attention should be paid to obtaining proficiency in performing the core competency diagnostic ultrasound examinations of the pathological conditions and ultrasound-guided procedures listed in the learning objectives. Determining competence will be discussed further in Record keeping and competency.

This component of the fellow's SPORTS US training process is required to ensure that the fellow can proficiently perform the core diagnostic and interventional SPORTS US competencies in clinical practice.

Supplementary and continuing SPORTS US education

The fellow's SPORTS US education should not be restricted to the formal educational activities outlined in Didactic instructional sessions through Mentored clinical experience. The fellow should be required to participate in independent practice scanning, during which time they can practice diagnostic scanning techniques, positioning for procedures, and scanning protocols using volunteers. During this time, the fellow should also acquire studies for review with their mentor, as previously discussed. The fellow should also be required to independently practice ultrasound-guided needle tracking using the appropriate medium (eg, cadaver, phantom, etc).

In addition to the above required supplementary and continuing SPORTS US education experiences, as time and resources allow, the fellow should be encouraged to participate in one or more of the following:

1. Reading SPORTS US journals and texts on a regular basis
2. Reviewing SPORTS US-related articles on regular basis. It is recommended that the fellow present a SPORTS US-related journal article during journal club at least on a quarterly basis
3. Participating in online SPORTS US related courses or DVD's
4. Reading online SPORTS US related educational material
5. Attending SPORTS US related conferences

Record keeping and competency

The fellow should maintain detailed records of all SPORTS US educational activities in which they participate throughout the fellowship. The fellow should also maintain a procedure log of all diagnostic and interventional SPORTS US procedures, including their role in the procedure (eg, observation, performance, interpretation or reporting). Detailed recording keeping serves multiple purposes

1. Assists with credentialing
2. Assists in practice accreditation
3. Supports application for certification examinations

Although maintaining records of the type and number of diagnostic and interventional ultrasound procedures is important, performing a specific number of ultrasound procedures does not necessarily determine competence. A milestone system is a more appropriate way of determining competence and is in agreement with graduate medical education competency assessment recommendations by the Accreditation Council for Graduate Medical Education. Milestones use a five-point ordinal scale of escalating skill level, with competence determined when a level three or higher has been achieved. Milestones for each learning objective in the SPORTS US should be developed, and the fellow should achieve competence in all of the milestones on completion of their fellowship. Sample diagnostic and interventional ultrasound milestones are provided in online supplementary appendix 2.

Consensus statement

Finally, it is recommended that an objective written and practical test be developed to assist with assessing the sports medicine fellow's SPORTS US knowledge and skill.

What are the new findings?

This document provides sports medicine fellowship directors and those interested in sports ultrasound education with a guideline for creating a SPORTS US curriculum.

How might it impact on clinical practice in the near future?

Completing this curriculum will prepare sports medicine physicians to proficiently practice the core competencies of SPORTS US.

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Contributors All authors were involved in the initial planning of the curriculum. The structure and content of the entire curriculum was discussed. The initial draft of the document was then created by JTF. The document was subsequently distributed to all of the other authors (DB, FB, JD, MMH, KH, ML, SM, JS, MS) for review. After all of the authors reviewed the document, the authors again collectively discussed further revisions. The suggested revisions were then performed by JTF. The document was reviewed by all of the other authors (DB, FB, JD, MMH, KH, ML, SM, JS, MS) one final time before submission.

Competing interests None.

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Appendix 1. SPORTS US SCANNING PROTOCOLS

The following document provides scanning protocols for each body region and is adopted from the AIUM Guidelines for Performance of the MSK US Examination 2012 (www.aium.org). Please consider this document as a reference when learning and performing SPORTS US examinations. Additional structures or regions should be examined as clinically indicated or based on practice needs.

Shoulder

A complete shoulder examination is performed in most cases, including the structures indicated below. In specific circumstances, a targeted examination of a specific anatomic structure may be performed (e.g., follow-up scan of the supraspinatus tendon to assess for tear progression)

- Biceps tendon and muscle
- Subscapularis muscle and tendon
- Dynamic exam for biceps subluxation & subcoracoid impingement (as indicated)
- Acromioclavicular joint
- Infraspinatus tendon and muscle
- Teres minor tendon and muscle
- Posterior glenohumeral joint (including dynamic imaging as indicated)
- Spinoglenoid notch (as indicated, region of suprascapular nerve)
- Supraspinatus tendon and muscle, with subacromial-subdeltoid bursa

- Dynamic rotator cuff evaluation and impingement testing
- Suprascapular notch (as indicated, region of suprascapular nerve)
- Extended field of view – supraspinatus & infraspinatus muscle bellies (as indicated)

Elbow

Examination may involve a complete assessment of 1 or more quadrants or may be focused on a specific structure.

Anterior:

- Anterior humeroradial joint
- Radial fossa
- Dynamic scan of annular recess of radial neck (supination/pronation, as indicated)
- Anterior humeroulnar joint
- Coronoid fossa
- Biceps tendon and muscle, including dynamic scanning
- Brachialis muscle (as indicated)
- Brachial artery and vein (as indicated)
- Median nerve (as indicated)
- Pronator teres muscle and tendon (as indicated)
- Radial nerve (as indicated)
- Brachioradialis muscle (as indicated)

Lateral:

- Lateral epicondyle, common extensor tendon and muscles
- Lateral collateral ligament complex
- Lateral humeroradial joint (including dynamic imaging as indicated)
- Radial nerve bifurcation and course through supinator muscle
- Proximal attachment of brachioradialis
- Proximal attachment of extensor carpi radialis longus

Medial:

- Medial epicondyle, common flexor-pronator tendon and muscles
- Ulnar collateral ligament
- Dynamic valgus stress of ulnar collateral ligament (as indicated)
- Humeroulnar joint
- Ulnar nerve (also included in posterior region scan)
- Dynamic flexion-extension (as indicated)
 - evaluate for ulnar nerve subluxation
 - evaluate for snapping triceps tendon

Posterior:

- Triceps tendon muscles
- Olecranon fossa and posterior joint space
- Olecranon process

- Olecranon bursa
- Ulnar nerve (also included in medial region scan)
- Dynamic flexion-extension (as indicated) (also included in medial region scan)
 - evaluate for ulnar nerve subluxation
 - evaluate for snapping triceps tendon

Wrist and Hand

Examination may involve a complete assessment of 1 or more of the 3 anatomic regions or may be focused on a specific structure.

Volar:

- Carpal tunnel contents
 - Flexor retinaculum
 - Median nerve
 - Flexor pollicis longus tendon
 - Flexor digitorum profundus and superficialis tendons
 - Dynamic examination with flexion & extension – tendon & nerve motion
- Palmaris longus tendon
- Flexor carpi radialis longus tendon and radial artery
- Ulnar nerve and ulnar artery within Guyon's canal
- Flexor carpi ulnaris tendon
- Joints as clinically indicated (e.g. volar radiocarpal joint)

Ulnar/Medial:

- Extensor carpi ulnaris tendon and muscle
- Dynamic examination for extensor carpi ulnaris subluxation
- Triangular fibrocartilage complex
- Ulnocarpal joint

Dorsal:

- Extensor retinaculum, 6 compartments, 9 tendons and muscles
- Dynamic tendon examination – flexion/extension of the fingers (as indicated)
- Dorsal scapholunate ligament
- Joints (as clinically indicated)
 - Radiocarpal (RC), metacarpophalangeal (MCP), proximal interphalangeal (PIP), distal interphalangeal (DIP)
 - Dorsal and volar
- Superficial radial nerve (as indicated)

Hip

Examination may involve a complete assessment of 1 or more of the 4 anatomic regions or may be focused on a specific anatomic structure.

Anterior Region (patient supine):

Sagittal oblique, parallel to long axis of femoral neck

- Femoral head, neck, capsule, and anterior synovial recess
- Hip joint assessment for effusion

Sagittal plane

- Anterior labrum

Transverse

- Femoral vessels and nerve
- Iliopsoas muscle, tendon and bursa
- Sartorius and tensor fascia lata tendons and muscles
- Lateral femoral cutaneous nerve
- Rectus femoris tendon(s) and muscles
- Dynamic scanning if snapping hip (as indicated).

Lateral Region (side lying with hip flexed 20-30 degrees)

- Gluteus maximus – fascia lata – tensor fascia lata
- Gluteus minimus tendon and muscle
- Gluteus medius tendon and muscle
- Greater trochanteric bursa (subgluteus maximus bursa)
- Dynamic scanning for snapping hip (as indicated)

Medial Region

Supine neutral

- Femoral vessels and nerve (unless already examined with anterior region)

Abducted-Externally rotated (frog leg)

- Adductor muscles (A. longus and gracilis → A. brevis → A. magnus) and tendons
- Distal iliopsoas tendon
- Pubic bone and symphysis (joint)
- Distal rectus abdominis muscle and tendon

Posterior (prone w/wo pillow under hips)

- Gluteus maximus muscle and tendon
- Gluteus medius muscle and tendon
- Deep short external rotators (as indicated)
- Hamstring tendon and muscles
- Ischial tuberosity and bursal region
- Sciatic nerve
- Posterior hip joint (as indicated)

Prosthetic Hip

- Assess for joint effusions and extra-articular fluid collections
- Greater trochanter and integrity of gluteal attachments
- Iliopsoas tendon and bursa
- Impingement on acetabular component

Knee

Examination may involve a complete assessment of 1 or more of the 4 quadrants of may be focused on a specific anatomic structure.

Anterior:

- Quadriceps tendon and muscles
- Suprapatellar recess of knee joint
- Patella and prepatellar bursa
- Patellar tendon and tibial tubercle
- Superficial infrapatellar bursa
- Deep infrapatellar bursa
- Vastus medialis and medial retinaculum (also with medial region scan)
- Vastus lateralis and lateral retinaculum (also with lateral regional scan)
- Distal femoral cartilage (as indicated)

Medial:

- MCL/tibial collateral ligament
- Valgus stress testing (as indicated)
- Medial meniscus and tibiofemoral joint space
- Pes anserine tendons and bursa
- Medial patellar retinaculum and patellofemoral joint (also with anterior region scan)

Lateral:

- Iliotibial band
- Lateral meniscus and tibiofemoral joint space
- LCL/fibular collateral ligament
- Varus stress test (as indicated)
- Biceps femoris tendon and muscles
- Popliteus tendon and muscle
- Lateral patellar retinaculum and patellofemoral joint (also with anterior region scan)
- Proximal tibiofibular joint (as indicated)

Posterior:

- Popliteal fossa
- Popliteal artery and vein
- Semimembranosus tendon and muscle
- Medial & lateral gastrocnemius muscles, tendons, and bursae

- Sciatic, tibial, and common fibular nerves
- Posterior horns of both menisci (as indicated) and tibiofemoral joint
- PCL (as indicated) (may be seen in sagittal oblique plane)

Ankle /Foot

Examination may involve a complete assessment of 1 of the 4 quadrants or may be focused on a specific structure.

Anterior:

- Tibialis anterior (from musculotendinous junction to insertion)
- Extensor hallucis longus tendon and muscle
- Extensor digitorum longus tendon and muscle
- Peroneus tertius (congenitally absent in some patients)
- Deep fibular/peroneal nerve and dorsalis pedis artery
- Anterior joint recess (effusion, loose bodies, and synovial thickening)
- Anterior joint capsule
- Anterior inferior tibiofibular ligament

Medial:

- Posterior tibialis tendon and muscle
- Flexor digitorum longus tendon and muscle
- Posterior tibial nerve

- Medial and lateral plantar nerves (as indicated)
- Tibial artery and veins
- Flexor hallucis longus tendon and muscle
- Deltoid ligament and medial tibiotalar joint

Lateral:

- Fibularis (peroneus) longus & brevis tendons and muscles
- Superior fibular (peroneal) retinaculum
- Dynamic assessment for fibular (peroneal) subluxation (as indicated)
- Anterior talofibular ligament
- Calcaneofibular ligament (incl. lateral tibiotalar joint and posterior subtalar joint)
- Posterior talofibular ligament (as able and indicated)
- Sural nerve (as indicated)

Posterior:

- Achilles tendon and paratenon
- Dynamic scanning in of Achilles (as indicated to assist with tear evaluation)
- Retrocalcaneal bursa
- Retro-Achilles/Superficial Achilles bursa
- Plantaris tendon (may be absent) (as indicated)
- Posterior tibiotalar and subtalar joints
- Plantar fascia
- Plantar fat pad

Digital:

Assess for synovitis, dorsal and/or plantar

Metatarsophalangeal (MTP) joints

Interphalangeal (IP) joints

Interdigital:

Dorsal or plantar approach can be used

Longitudinal and transverse views

Intermetatarsal bursa (on the dorsal aspect of the interdigital nerve)

Dynamic scanning, applying pressure for Morton's neuroma, and/or ultrasonographic

Mulder's click (as indicated)

SPORTS US TRAINING 1

Appendix 2. SPORTS US Milestone Examples.

Diagnostic ultrasound examination of a full thickness supraspinatus tear.				
Level 1	Level 2	Level 3	Level 4	Level 5
Able to verbally describe the indications for a diagnostic ultrasound of the shoulder and list the structures that need to be imaged during a complete sonographic shoulder examination	Able to correctly identify and sonographically image all portions of the supraspinatus tendon in long and short axis in an normal shoulder	Able to correctly identify and sonographically image a full thickness supraspinatus tear, acquire, label, and save an appropriate image; and generate an appropriate report	Able to consistently and independently perform the skills outlined in level 3. Integrates current research and literature with guidelines to recommend management.	Demonstrates expertise in the sonographic evaluation of supraspinatus tendon tears at a level expected of a subspecialist. Performs research related to imaging of the supraspinatus tendon.

Ultrasound guided glenohumeral joint injection.				
Level 1	Level 2	Level 3	Level 4	Level 5
Able to verbally describe the indications, contra-indications, risks and benefits of an ultrasound guided glenohumeral joint injection. Able to verbally describe the procedure.	Able to correctly position a patient, perform a pre-procedure diagnostic scan, identify the target and relevant adjacent structures.	Able to perform an ultrasound guided glenohumeral joint injection, acquire and label appropriate pre-, intra-, and post-procedure images, and generate a procedure note.	Able to consistently and independently perform the skills outlined in level 3. Integrates current research and literature with guidelines relevant to the procedure.	Demonstrates expertise in the performance of ultrasound guided glenohumeral joint injections at a level expected of a subspecialist. Performs research related to this skill.