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AOA Critical Issues

Musculoskeletal Educational Resources for the Aspiring Orthopaedic Surgeon

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Abstract

Musculoskeletal (MSK) education is underemphasized in medical school curricula, which can lead to decreased confidence in treating MSK conditions and suboptimal performance on orthopaedic surgery elective rotations or subinternships. Given the low amount of formalized education in MSK medicine, students aiming to learn about orthopaedic surgery must gain much of their foundational knowledge from other resources. However, there are currently no centralized introductory educational resources to fill this need. We provide a framework for navigating the different types of resources available for trainees and highlight the unaddressed needs in this area.

Patients present to a diverse group of healthcare providers with musculoskeletal (MSK) complaints, comprising 130 million physician visits annually in the United States alone¹. Despite this high prevalence, undergraduate medical education in MSK medicine is lacking because only 83% of medical schools have required preclinical MSK education and only 15% have a required MSK clerkship²⁻⁵. Given that classroom education does not increase MSK knowledge proficiency without clinical context⁶, this approach leads to inadequate training, even among fourth-year students¹. The underrepresentation of MSK medicine in curricula results in medical students reporting less confidence in treating MSK conditions compared with internal medicine conditions and physicians from multiple specialties performing poorly on an MSK competency examination^{4,7,8}. Lack of foun-

dational knowledge in MSK medicine can also adversely affect student performance on orthopaedic rotations, where a strong performance helps maximize chances of matching successfully in such a competitive specialty^{9,10}. Certain institutions have attempted to address this gap in education for all medical students, using techniques such as near-peer learning and spaced practice¹¹⁻¹³. Although near-peer learning strategies have the benefit of offering students a more comfortable learning environment and easier availability than faculty members, residents may not have the skills or experience necessary to lead these sessions¹⁴. Preclinical anatomy education is increasingly shifting toward alternative teaching methods not involving cadaveric dissection¹⁵, although the impact of this change on MSK anatomy knowledge is unclear^{15,16}. Although efforts to improve MSK education for

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TABLE 1 Written Resources Available for Medical Student Education*

Name	Pros	Cons	Cost	URL
Anatomy				
Netter's <i>Atlas of Human Anatomy</i>	<ul style="list-style-type: none"> • Thorough introduction to anatomy • Visual learning through illustrations 	<ul style="list-style-type: none"> • Not orthopaedic-specific • Only contains anatomy information 	\$35-75	https://evolve.elsevier.com/cs/product/9780323393225?role=student
Hoppenfeld's <i>Physical Examination of the Spine and Extremities</i>	<ul style="list-style-type: none"> • Connects anatomy to physical examination 	<ul style="list-style-type: none"> • Does not cover advanced maneuvers • No information on management 	\$60-300	https://www.pearson.com/uk/educators/higher-education-educators/program/Hoppenfeld-Physical-Examination-of-the-Spine-and-Extremities-Pearson-New-International-Edition/PGM1053391.html
Netter's <i>Concise Atlas of Orthopaedic Anatomy</i>	<ul style="list-style-type: none"> • Focused anatomy review • Highlights common pathology 	<ul style="list-style-type: none"> • Not useful for comprehensive review • No management guidelines 	\$50-63	https://www.us.elsevierhealth.com/netters-concise-orthopaedic-anatomy-updated-edition-9780323429702.html
AAOS <i>Essentials of Musculoskeletal Care</i>	<ul style="list-style-type: none"> • Evaluation of musculoskeletal complaints • Ideal for students and other healthcare practitioners 	<ul style="list-style-type: none"> • Requires basic anatomy and pathology knowledge 	\$118	https://www5.aaos.org/store/product/?productId=18,847,403&ssopc=1
Surgical Preparation				
Hoppenfeld's <i>Surgical Exposures</i>	<ul style="list-style-type: none"> • Teaches important anatomic landmarks and structures • Reviews techniques step-by-step 	<ul style="list-style-type: none"> • Newer or specific techniques not included 	\$100-250	https://www.wolterskluwer.com/en/solutions/ovid/surgical-exposures-in-orthopaedics-the-anatomic-approach-2672
Campbell's <i>Operative Orthopaedics</i>	<ul style="list-style-type: none"> • Descriptions of many orthopaedic procedures • Visual aids and digital format with video available 	<ul style="list-style-type: none"> • Requires some background knowledge 	\$92-500	http://www.campbell-foundation.org/publications/Campbells-Operative-Orthopaedics/
Operative Techniques in Orthopaedic Surgery	<ul style="list-style-type: none"> • Comprehensive review from anatomy to management and complications • Pictures and illustrations included 	<ul style="list-style-type: none"> • No videos available • Cannot be quickly referenced 	\$65-600	https://shop.lww.com/Operative-Techniques-in-Orthopaedic-Surgery/p/9781496314758
Quick Reference				
<i>Pocket Pimped</i>	<ul style="list-style-type: none"> • Reviews common didactic 'pimp' questions • Classified by subspecialty 	<ul style="list-style-type: none"> • Not useful for primary learning • Explanations not included 	\$50	https://pocketpimped.com/products/pocket-pimped-orthopedic-surgery
<i>The Handbook of Fractures</i>	<ul style="list-style-type: none"> • Covers fracture evaluation and management 	<ul style="list-style-type: none"> • Many classifications may not be clinically relevant • Pictures and explanations infrequent 	\$31-80	https://shop.lww.com/Handbook-of-Fractures/p/9781496384850
Review Texts				
<i>The Journal of the AAOS</i>	<ul style="list-style-type: none"> • Comprehensive reviews of various topics • Updated with recent primary literature 	<ul style="list-style-type: none"> • Some content too dense for medical students 	Free with institutional access; open access articles	https://journals.lww.com/jaaos/pages/default.aspx

continued

TABLE I (continued)

Name	Pros	Cons	Cost	URL
<i>Orthopaedic Knowledge Update</i>	<ul style="list-style-type: none"> • Updates from primary literature 	<ul style="list-style-type: none"> • Generally beyond medical student scope 	\$160-370	https://shop.lww.com/Orthopaedic-Knowledge-Update-13-Print-Ebook/p/9781975129521
<i>Miller's Review of Orthopaedics</i>	<ul style="list-style-type: none"> • Broad content review 	<ul style="list-style-type: none"> • Generally beyond medical student scope 	\$35-124	https://www.us.elsevierhealth.com/millers-review-of-orthopaedics-9780323609784.html

*AAOS = American Academy of Orthopaedic Surgeons.

medical students are ongoing, there are currently no centralized introductory educational resources that provide foundational MSK knowledge. In this review, we consolidate the best available resources and their associated costs for aspiring orthopaedic surgeons and practitioners pursuing MSK medicine education by highlighting the resources currently available. We additionally identify the unaddressed needs in this area. The materials listed in this review are recommended for Surgical Exposures trainees pursuing orthopaedic surgery as part of their general education in MSK issues.

Written Resources

Anatomy

The importance of anatomical knowledge in understanding and treating MSK conditions cannot be overstated. This is the core foundation of the specialty because it underlies every type of pathology the physician may encounter. Although there is a large amount of information and material to master, there are fortunately a number of high-quality resources to assist students in this pursuit. Classic texts include Netter's *Atlas of Human Anatomy* and Hoppenfeld's *Physical Examination of the Spine and Extremities*^{17,18}. Netter's *Atlas of Human Anatomy* provides a thorough introduction to human anatomy, with illustrations representing various dissections and an appendix of muscle origins, insertions, innervations, and blood supply, which provide a foundation for further MSK-specific knowledge. Hoppenfeld's *Physical Examination of the Spine and Extremities*¹⁸ integrates this anatomy knowledge with the physical examination. This approach encourages students to understand the anatomical rationale for physical examination and assist in long-term recall. After understanding the basics of MSK anatomy and patient assessment, medical students often supplement their knowledge with Netter's *Concise Atlas of Orthopaedic Anatomy*. This is useful for focused anatomy review and bullet points about common pathology but is not as helpful for management guidelines or comprehensive learning¹⁹. Before entering the operating room, many students also study Hoppenfeld's *Surgical Exposures*, a textbook that details various surgical approaches in orthopaedics²⁰. Hoppenfeld's *Surgical Exposures* covers various landmarks and crucial structures that must be protected and/or avoided, enabling medical students to follow along during the procedure,

although newer techniques may not be included. These anatomy texts (Table I) provide students with a thorough foundation of MSK knowledge which can be built on from other resources.

Orthopaedic Management

In addition to anatomy, there are written resources available to help students learn about the various MSK pathologies likely to be encountered in clinical practice. The *Orthopaedic Knowledge Update* books from the American Academy of Orthopaedic Surgeons (AAOS) offer an easily digestible update of evidence-based practices for different orthopaedic conditions, but not ideal for primary or basic learning. Another broad overview text is Miller's *Review of Orthopaedics*, designed for residents preparing for in-training and board examinations²¹. Miller's *Review of Orthopaedics* bulleted lists allow rapid review, but pre-existing foundational knowledge is required because it is not intended for in-depth learning. *AAOS Essentials of Musculoskeletal Care* is a text that connects focused examination to common MSK complaints based on the anatomic region, which is easily digestible by medical students. However, it requires some basic anatomy and pathology knowledge. Other textbooks designed for residents that are sometimes used by medical students include Campbell's *Operative Orthopaedics and Wiesel's Operative Techniques in Orthopaedic Surgery*^{19,20}. These are more comprehensive but also quite dense and may be difficult to digest for those who are new to the field. To prepare for rounds, *Pocket Pimped* provides common questions asked during the orthopaedic surgery rotation, categorized by subspecialty²². However, given its concise nature, it is not as useful for building a knowledge base. For quick information about fracture evaluation and management, many students consult *The Handbook of Fractures*, often referenced before seeing a patient in the emergency department²³. More in-depth information on management of MSK trauma can be obtained from textbooks such as *Skeletal Trauma and Rockwood and Green's Fractures in Adults*^{24,25}. Finally, the *Journal of the American Academy of Orthopaedic Surgeons (AAOS)*, nicknamed the "Yellow Journal", publishes thorough reviews that medical students can use as a comprehensive overview of a topic of interest, although some are better suited for the early resident level. In summary,

multiple written resources are available, all with strengths and weaknesses. Students should choose their source material based on their foundational knowledge and the clinical setting for which they are preparing. Although textbooks and written resources are a high-quality source of information, their content can be outdated, particularly if not revised through new editions.

Websites

Outside of traditional textbooks, websites represent an additional valuable resource to medical students at all training levels. For medical students learning or reviewing anatomy, several are helpful. Published by anatomy professors at George Washington University, NetAnatomy.com teaches gross anatomy by region and system through cadaveric specimens. It additionally supplies quizzes and integrates radiology to consolidate information. The Visible Body Human Anatomy Atlas presents realistic three-dimensional renderings of anatomical structures. However, unlike NetAnatomy, these renderings are not similar to the cadaveric appearance.

Certain online resources also provide information on the MSK clinical assessment. *Wheeless' Textbook of Orthopaedics* is an online textbook published by Duke University and Data Trace that offers information on focused orthopaedic anatomy, common pathology, and management, presented in an outline format with links to primary literature³⁶. Although it can serve as a reference, it is not ideal for in-depth learning, as can be obtained from the comprehensive written texts. The San Diego (SD) MSK Project is a series of online videos created by sports medicine physicians who reviews MSK physical examination maneuvers for the medical student or primary care provider. It additionally offers comprehensive integrated exams, such as the "Primary Care 3 Minute Shoulder Exam" or "Primary Care 2 Minute Knee Exam". Although *Wheeless' Textbook of Orthopaedics* is most appropriate for students considering a career in orthopaedic surgery, the SD MSK Project library can be useful for all physicians and particularly primary care and emergency medicine physicians who are looking to efficiently incorporate additional physical examination maneuvers into their armamentarium. Unfortunately, there are only a limited number of videos. Beyond the clinical examination, the University of Virginia Skeletal Trauma Radiology course is a self-guided tutorial of orthopaedic trauma radiograph assessment developed for medical students. By integrating the material from these written resources and websites, new learners can gather a strong MSK knowledge base of anatomy, pathology, clinical, and radiographic evaluation, and management to further build on in later years.

Medical students preparing for their subinternship can leverage the University of Chicago Ortho Acting-Intern Coordinated Clinical Education and Surgical Skills curriculum, designed specifically to teach the basics of orthopaedic surgery to fourth-year medical students. This curriculum includes webinars, relevant literature, and didactic videos for practical skills (e.g., splinting and suturing). To reference or review information, Orthobullets presents concise outlines

of many orthopaedic topics. However, this should not serve as a primary resource, particularly for new learners, because it does not provide enough information to develop a holistic understanding of the topic.

Subspecialty websites can offer additional information about orthopaedic subspecialties. For example, the AO Trauma website contains various e-learning modules on the basics of fracture healing biology and principles of fracture fixation, and a surgery reference that covers surgical techniques for the medical student interested in orthopaedics. The Pediatric Orthopaedic Society of North America also offers webinars on specific pediatric pathologies, although the content is largely targeted to residents and fellows. Similar content is available through the AAOS and Orthopaedic Trauma Association (OTA). In summary, websites provide information about numerous MSK topics for all stages of learners in an easily accessible format.

Mobile Applications

Smartphones have facilitated rapid access to a large amount of information outside of typical study environments. Medical students frequently use mobile "apps" between classes and on the wards to review and search for information. Such apps include anatomy tools such as Essential Anatomy 5 from 3D4Medical/Elsevier. This platform serves as a comprehensive, three-dimensional atlas of human anatomy that can be used to learn regional or systemic anatomy, highlight and/or fade structures to understand spatial relationships, and even correlate anatomy with radiology. Although subscriptions can be expensive, many institutions purchase group access for their students. Complete Anatomy is a similar app that can be used to learn anatomy through prebuilt regional "models". The platform also integrates expert videos, radiology, and cadaveric images. Gross Anatomy of the Human Skeleton presents the NetAnatomy.com content in an app format. A more specific anatomy tool is Nerve Whiz. Not only this app covers the anatomy of the peripheral nervous system but also localizes lesions based on regions of sensory and/or motor loss. This proves useful for building thorough foundational anatomy knowledge as a preclinical student and interpreting pertinent examination findings as a clinical student.

Beyond anatomical knowledge, apps can offer information on clinical examinations and patient management. The AO Foundation has created the AO Surgery Reference app, which can be used as a review of the decision-making tree. Unfortunately, this app does not teach the basics for early medical students and is currently limited to trauma and spine pathology. Another app useful for review is Ortho Traumapedia, an orthopaedic trauma-specific resource formatted as outlines of certain topics. Finally, the information from the Orthobullets website is also available as an app for easy access on one's phone. Web links to these mobile applications are listed in Table II. Ultimately, these apps, although useful for review of previously studied topics, are typically not comprehensive enough to teach information, particularly for

TABLE II Other Resources Available for Medical Student Education*

Name	Pros	Cons	Cost	URL
Websites				
NetAnatomy.com	<ul style="list-style-type: none"> • Anatomy information by region and system • Cadaveric images and radiology integration 	<ul style="list-style-type: none"> • Requires institutional access • Not orthopaedic-specific 	Institutional subscription only; cost not available	https://www.netanatomy.com/
Visible Body Human Anatomy Atlas	<ul style="list-style-type: none"> • Three-dimensional anatomy resource 	<ul style="list-style-type: none"> • No cadaveric images • Not orthopaedic-specific 	Institutional access; \$50 for 2-year subscription	https://www.visiblebody.com/
Wheeless' <i>Textbook of Orthopaedics</i>	<ul style="list-style-type: none"> • Outline of anatomy, pathology, and management • Easily digestible for medical students 	<ul style="list-style-type: none"> • Bulleted; not useful for primary learning 	Free	https://www.wheelsonline.com/
The San Diego MSK Project	<ul style="list-style-type: none"> • MSK physical examination at the medical student level • Comprehensive integrated exams useful for clinic 	<ul style="list-style-type: none"> • Advanced maneuvers may be missing • Poorly organized 	Free	https://www.youtube.com/channel/UCkXg4f8pFtWjHj_84QAJy-w
University of Virginia Skeletal Trauma Radiology	<ul style="list-style-type: none"> • Tutorial on radiograph assessment • Easily digestible for medical students 	<ul style="list-style-type: none"> • Specific to trauma 	Free	https://www.med-ed.virginia.edu/courses/rad/ext/index.html
University of Chicago OrthoACCESS	<ul style="list-style-type: none"> • Webinars, presentations, and literature (multimodal) • Integration with practical skills 	<ul style="list-style-type: none"> • Curriculum not comprehensive • Requires some basic knowledge 	Free	https://voices.uchicago.edu/orthoaccess/
Orthobullets	<ul style="list-style-type: none"> • Useful for test preparation or rapid review 	<ul style="list-style-type: none"> • Not a primary resource • Requires background knowledge • Not all pathology is included 	Free	https://www.orthobullets.com/
AO Trauma	<ul style="list-style-type: none"> • Introductory modules on basic fracture principles • Easily digestible for medical students 	<ul style="list-style-type: none"> • Trauma-specific 	Free	https://aotrauma.aofoundation.org/clinical-library-and-tools/e-learning/e-learning-modules
POSNA	<ul style="list-style-type: none"> • Informative webinars and lectures 	<ul style="list-style-type: none"> • Beyond medical student scope • Pediatrics-specific 	Free	https://www.posnacademy.org/
AAOS	<ul style="list-style-type: none"> • Informative webinars and lectures 	<ul style="list-style-type: none"> • Beyond medical student scope 	Free	https://www.aaos.org/education/courses/

continued

TABLE II (continued)

Name	Pros	Cons	Cost	URL
OTA	<ul style="list-style-type: none"> ● Informative webinars and lectures 	<ul style="list-style-type: none"> ● Beyond medical student scope 	Free	https://ota.org/education/online-education
Mobile applications				
Essential Anatomy 5	<ul style="list-style-type: none"> ● Three-dimensional comprehensive anatomy atlas ● Can correlate anatomy to radiology 	<ul style="list-style-type: none"> ● Not orthopaedic-specific ● Not easily integrated with cadaver images 	Free trial; Institutional access; \$40 for personal access	https://3d4medical.com/apps/essential-anatomy-5
Complete Anatomy	<ul style="list-style-type: none"> ● Regional three-dimensional anatomy models 	<ul style="list-style-type: none"> ● Custom models not easily created ● Limited in scope 	Institutional access; \$40 for personal access	https://3d4medical.com/
Gross Anatomy of the Human Skeleton	<ul style="list-style-type: none"> ● Cadaveric skeletal anatomy review 	<ul style="list-style-type: none"> ● Limited to osteology 	\$4	https://www.netanatomy.com/
Nerve Whiz	<ul style="list-style-type: none"> ● Reviews peripheral nerve anatomy ● Connects examination findings to nerve lesions 	<ul style="list-style-type: none"> ● Limited to nerve anatomy 	Free	https://oneteam.us/project/nerve-whiz/
AO Surgery Reference	<ul style="list-style-type: none"> ● Classified by anatomic region and fracture/pathology type ● Integrated video resources 	<ul style="list-style-type: none"> ● Limited to trauma and spine ● Newer or specific techniques not included 	Free	https://surgeryreference.aofoundation.org/
Ortho Traumapedia	<ul style="list-style-type: none"> ● Easily digestible by medical students ● Information on anatomy, pathology, and management 	<ul style="list-style-type: none"> ● Trauma-specific ● Not ideal for primary learning ● Not up-to-date with primary literature 	\$10	https://download.cnet.com/Ortho-Traumapedia/3000-2129_4-75912747.html
Orthobullets	<ul style="list-style-type: none"> ● Useful for test preparation or rapid review 	<ul style="list-style-type: none"> ● Not a primary resource ● Requires background knowledge ● Not all pathology is included 	Free	https://www.orthobullets.com/anatomy/12281/iphone-and-android-app
Podcasts				
Ortho Eval Pal	<ul style="list-style-type: none"> ● Covers MSK evaluation and management ● Includes information on advanced techniques 	<ul style="list-style-type: none"> ● Requires some basic knowledge 	Free	https://orthoevalpal.com/
Orthobullets	<ul style="list-style-type: none"> ● Review of various topics in all subspecialties ● Ideal for auditory learners 	<ul style="list-style-type: none"> ● Content not comprehensive 	Free	https://www.orthobullets.com/Site/Podcasts/PodcastsList?p=2

continued

TABLE II (continued)

Name	Pros	Cons	Cost	URL
Nailed It	<ul style="list-style-type: none"> • Informational interviews with faculty • Reviews common pathology in many subspecialties 	<ul style="list-style-type: none"> • Requires background knowledge • Beyond medical student scope 	Free	https://naileditortho.com/
OTA	<ul style="list-style-type: none"> • Informational interviews with faculty • Reviews common pathology in trauma 	<ul style="list-style-type: none"> • Requires background knowledge • Beyond medical student scope 	Free	https://ota.org/education/ota-podcast
AOFAS	<ul style="list-style-type: none"> • Reviews common foot & ankle conditions • Efficiently organized sessions 	<ul style="list-style-type: none"> • Requires background knowledge • Beyond medical student scope 	Free	https://podcasts.apple.com/us/podcast/aofas-resident-lecture-podcast-series/id1457081400
Didactics				
Grand rounds	<ul style="list-style-type: none"> • Easily accessible • Educational lectures 	<ul style="list-style-type: none"> • Requires background knowledge • Beyond medical student scope 	Free	Varies
Conferences	<ul style="list-style-type: none"> • Educational lectures • Networking/mentorship opportunity 	<ul style="list-style-type: none"> • Not all contain medical student sections 	Varies	Varies
Specialty interest groups	<ul style="list-style-type: none"> • Networking/mentorship opportunity • Practical and didactic learning 	<ul style="list-style-type: none"> • Lack of standardization • Programs may vary 	Free	Varies
Early exposure				
Ruth Jackson Orthopaedic Society	<ul style="list-style-type: none"> • Networking and mentorship opportunities for female students • Annual meeting 		Free	http://www.rjos.org/
Perry Initiative	<ul style="list-style-type: none"> • Hands-on bioskills and mentorship for female students 		Free	https://perryinitiative.org/
BONES Initiative	<ul style="list-style-type: none"> • Pipeline program for female students 	<ul style="list-style-type: none"> • Regional program 	Free	https://www.brighamandwomensfaulkner.org/about-bwfh/news/bones-initiative-seeks-to-inspire-young-women-to-pursue-careers-in-orthopaedic-surgery
Nth Dimensions	<ul style="list-style-type: none"> • Mentorship and pipeline programs for female/URM students 	<ul style="list-style-type: none"> • Funding not guaranteed 	Varies	http://www.nthdimensions.org/landing

continued

TABLE II (continued)				
Name	Pros	Cons	Cost	URL
J. Robert Gladden Orthopaedic Society	<ul style="list-style-type: none"> • Mentorship and research funding for URM students 		Free	https://www.gladdensociety.org/
AAOS Medical Student Roadmap	<ul style="list-style-type: none"> • Provides roadmap to residency application with relevant resource links 	<ul style="list-style-type: none"> • Not comprehensive in its information 	Free	https://www.aaos.org/membership/become-an-aaos-member/information-for-medical-students/roadmap-to-orthopaedic-residency/
Summer research internships	<ul style="list-style-type: none"> • Formal or informal didactics • Research experience and mentorship 	<ul style="list-style-type: none"> • Not always available 	Unpaid or paid	Varies
Free clinics	<ul style="list-style-type: none"> • Practical experience with MSK evaluation 	<ul style="list-style-type: none"> • Not always available 	Free	Varies

*AOFAS = American Orthopaedic Foot & Ankle Society; AAOS = American Academy of Orthopaedic Surgeons, MSK, Musculoskeletal, OTA = Orthopaedic Trauma Association, OrthoACCESS = Ortho Acting-Intern Coordinated Clinical Education and Surgical Skills, and POSNA = Pediatric Orthopaedic Society of North America.

medical students. Integration of mobile applications with the resources described elsewhere in this text is necessary for early learners.

Podcasts

Podcasts are another nontraditional source of information for students. There are multiple MSK podcasts, some of which offer didactic knowledge at the medical student level. Medical students developing their physical examination skills can reference the Ortho Eval Pal podcast, which teaches MSK assessment to a general audience. The Orthobullets podcast series highlights common pathology and presents an overview of pathophysiology, evaluation, and management of various conditions. Because this requires some baseline knowledge of orthopaedics, the podcast is ideal for advanced medical students or residents. Similarly, the Nailed It podcast consists of resident-led informational interviews with faculty about common pathology. Specialty-specific podcasts, such as those produced by the American Orthopaedic Foot & Ankle Society and OTA, provide segments on conditions relevant to their subfields. Overall, these podcasts serve as an invaluable resource for auditory learners who do not absorb as well from written texts.

Didactic Learning

In certain venues, medical students can obtain direct teaching from expert faculty members or residents. Most institutions open their grand rounds of lectures to medical students, and some additionally publish them online^{27,28}. Because these sessions are targeted toward residents and faculty, they may require more baseline knowledge and can be challenging for

medical students to follow along. Other venues for medical student education include conferences, particularly those with medical student sections. Beyond lectures, conferences can offer opportunities for networking and mentorship, which can yield indirect educational value. Finally, orthopaedic surgery interest groups can serve as valuable sources of learning by organizing lectures, journal clubs, and/or workshops with residents or faculty members^{29,30}. Unfortunately, there is a significant lack of standardization across schools³¹. Although opportunities for didactic learning can be infrequent, these experiences are advantageous for medical students interested in orthopaedics. When combined with fundamental learning through other resources, didactics can be even more rewarding for students. It is important to note that the written and online resources mentioned previously cannot serve as adequate education in isolation; students must have some exposure to practical education and formal didactics.

Early Exposure/Diversity and Inclusion Programs

Many early medical students gain MSK knowledge indirectly through mentorship, shadowing, research, and diversity and inclusion programs. The Ruth Jackson Orthopaedic Society (RJOS) offers networking and mentorship opportunities for prospective female orthopaedic surgeons through programs such as their annual meeting. Similarly, the Perry Initiative organizes early hands-on exposure programs and mentorship opportunities for female students interested in orthopaedic surgery³². The BONES Initiative (Bringing Orthopaedics to New England Students of medicine) is a regional pipeline program that also offers networking and early exposure to increase female representation in the field³³. Nth Dimensions

and the J. Robert Gladden Society are other groups which aim to encourage female and underrepresented minority representation in orthopaedic surgery. They host similar pipeline initiatives as well as research programs and funding^{34,35}. Recently, RJOS and the Perry Initiative jointly published the “*Medical Student Guide for Orthopaedic Surgery*,” which advises medical students on how to enter and succeed in orthopaedic surgery from a professional development point of view. The Medical Student Roadmap published by the AAOS seeks to accomplish a similar goal, with web links to relevant resources embedded in its platform.

Summer research internship programs for medical students between their first and second year also serve as a source of learning; these can be formally organized with integrated didactics or informal. Many students additionally gain early exposure paired with didactics through their orthopaedic surgery interest groups. Medical student-run free clinics allow students to gain practical experience with the MSK patient evaluation³⁶. These early exposure programs serve as informal, unexpected sources of learning and mentorship that often lead to further involvement and investigation into the field.

Unaddressed Needs

Although there are a large number of MSK resources for medical students, all focus on different areas of knowledge, which must be integrated to build a foundation for further MSK education. With such diverse yet distinct information sources, it is difficult for early medical students to parse through and identify the appropriate resources. Many of these resources are expensive, thus adding another barrier for students. Furthermore, several are targeted toward senior medical students or residents, and thus, the information is inaccessible or confusing for newer students.

There remains a need for a centralized MSK educational resource for medical students initially learning about orthopaedics. The ideal curriculum will provide a mix of learning MSK anatomy, pathology, physical examination, and practical

skills (suturing and splinting). Given the prevalence of online preclinical education, this platform should be easily accessible in website and app format. Ideally, the resource would be open access to reduce disparities in access to MSK education. In addition, integration of multimedia is needed to accommodate the diverse preferred learning styles. Case-based learning and practice questions are invaluable in consolidating information and encouraging long-term retention.

Although this review highlights many important resources, one limitation is that it cannot include every resource currently available. In addition, it is not service-specific or institution-specific. Required reading lists for specific rotations can serve to fill this gap for students.

Conclusion

There are a variety of MSK resources available to medical students in diverse learning formats, but this information is not consolidated in a centralized location or presented in a deliberate manner designed to optimize learning. We have provided an overview of the best available resources at this time and their associated costs, but there exists an unmet need for a comprehensive MSK educational resource for medical students and early-stage trainees. ■

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