Musculoskeletal education in US medical schools: lessons from the past and suggestions for the future

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Abstract Despite the prevalence of musculoskeletal disorders in the United States, physicians have received inadequate training during medical school on how to examine, diagnose, and manage these conditions. This article provides an overview of the existing literature on undergraduate medical musculoskeletal education, including learning objectives, researched methodology, and currently utilized assessment tools. A discussion of challenges to and suggested approaches for the implementation of medical school musculoskeletal curricula is presented.

Keywords Musculoskeletal education · Musculoskeletal disorders · Curriculum development · Learning objectives · Educational methods · Assessment · Musculoskeletal examination

Introduction

Musculoskeletal disorders and diseases are a leading cause of pain, physical disability, and doctor visits throughout the world [1, 2]. Despite this phenomenon, a large body of evidence demonstrates that graduating students and practicing physicians receive inadequate education in musculoskeletal medicine throughout their training, starting with medical school. This problem has long been recognized but has received increased attention over the past decade, and many countries have adopted different approaches to addressing this inadequacy within the medical school curriculum. In the United States, one of the first unified attempts at undergraduate musculoskeletal curriculum reform started with the establishment of the National Bone and Joint Decade (USBJD) 2002–2011 [3]. One area of focus was to ensure dedicated instruction in musculoskeletal medicine in 100% of U.S. medical schools (Project 100), a goal that was approached in a number of ways [4, 5]. This included public endorsement of the Decade by the deans of all American medical schools; passage of legislation by the AMA encouraging reevaluation of musculoskeletal curricula by schools and accreditation bodies; and development of general objectives for undergraduate musculoskeletal education as part of the Medical School Objectives Project (MSOP) [6]. Additionally, the National Board of Medical Examiners developed a subject examination in musculoskeletal medicine [7] which several institutions (including our own) have piloted. By 2010,

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83% of U.S. medical schools had some form of required instruction in musculoskeletal medicine [8].

While these ventures represent important first steps towards improving the state of musculoskeletal education in the U.S., there are still a number of deficiencies that need to be addressed. The USBJD deliberately avoided prescriptive promotion of a uniform musculoskeletal curriculum, citing the breadth and diversity of educational cultures and missions across U.S. medical schools as major impediments. However, it is then particularly important to evaluate different methods for achieving learning objectives and assessing student competence.

In this article, we will analyze the existing literature on musculoskeletal education in U.S. medical schools utilizing several frameworks, including Kern's approach to curriculum development, Bloom's taxonomy to evaluate learning objectives, and Miller's framework for clinical assessment (Table 1) [9, 10, 11]. While our discussion of specific curricula is limited to U.S. medical schools, analysis of educational methodology includes international studies. Our review of experimental studies is deliberately limited to those addressing musculoskeletal educational issues, even though there are many other studies of potential relevance to musculoskeletal education. We will finish by discussing challenges to undergraduate musculoskeletal education and offering suggestions to overcome them.

Problem identification and needs assessment

There is ample documentation of the current burden of musculoskeletal disease in the United States [2]. In 2005, the two most common causes of disability were arthritis and back or spine problems [12]. Three of the top eight primary diagnosis groups presenting to ambulatory care visits in 2007 were for musculoskeletal disorders [13], which are estimated to account for approximately 15–30% of primary care visits in North America [14]. According to the 2008 National Health Interview Survey, an estimated 110 million adults (approximately 50% of the adult population) reported having a disabling musculoskeletal condition [15]. The

economic impact of these conditions is staggering. In 2004, the sum of the direct expenditures in health care costs and the indirect expenditure in lost wages for persons with a musculoskeletal disease diagnosis has been estimated to be \$849 billion dollars, or 7.7% of the GDP [2]. Estimates for 2008 are being assessed at \$932 billion—with the potential in 2030 that incurred direct and indirect costs for these same conditions could constitute 11% of the projected US economy. Beyond these statistics, the anticipated diminished quality of life seems inevitable and immeasurable. The situation is intensify given the current demographics, the epidemic of morbid obesity, and the higher activity levels of the elderly population.

Historically, musculoskeletal medicine has occupied an extremely small proportion of the undergraduate medical curriculum. Formalized musculoskeletal education was extremely sparse in most medical schools in the 1960s and 1970s, a situation personally experienced by one of the authors (CC) [16]. The first year courses pertaining to the musculoskeletal system were usually taught by basic scientists and anatomists with little clinical correlation. During the second year, musculoskeletal disorders were taught by rheumatologists, orthopaedic surgeons, and others from a predominantly discipline-based orientation, in large part dictated by what faculty were available at a particular institution. In 1980, a comprehensive survey of rheumatology education found that less than two thirds of medical schools offered courses on musculoskeletal examination, and that little clinical exposure to rheumatology occurred at most medical schools [17]. While over the years many institutions transitioned from discipline- to organ-based coursework, the overall proportion of curricular time devoted to musculoskeletal medicine remained low. As recently as 2003, only 40% of US medical schools had a required preclinical musculoskeletal course and 20% a required clinical clerkship [18].

In addition, the inadequacy of existing curricula has been well documented [19–22]. Surveys of students, residents, and practicing physicians have consistently demonstrated lack of confidence in diagnosing and managing musculoskeletal problems [19, 22, 23]. As a measure of musculoskeletal cognitive knowledge, the tool

Table 1 Educational frameworks referenced in this paper

Kern's approach to curriculum development/analysis	Blooms taxonomy of learning (cognitive domain)	Miller's framework for clinical assessment
1. Problem identification/ general needs assessment	1. Remembering	1. Knows (knowledge)
2. Targeted needs assessment	2. Understanding	2. Knows how (competence)
3. Goals and Objectives	3. Applying	3. Shows how (performance)
4. Educational Strategies	4. Analyzing	4. Does (action)
5. Implementation	5. Evaluating	
6. Evaluation and Feedback	6. Creating	

most consistently utilized in the past decade's literature is a 25 question short-answer test developed by Freedman and Bernstein, designed to address topics felt to be required knowledge for all physicians [20]. Question validity and mean passing score was determined by surveying U.S. orthopaedic residency program directors (81% response rate) and subsequently internal medicine residency program directors (58% response rate) [21]. This exam was administered to 85 entering medical and surgical interns at the University of Pennsylvania, and 82% did not achieve the minimum passing score. This exam has been administered at other institutions to a variety of medical practitioners, including medical students, with similar low passing rates. [22, 24–26]. While this test may not be the perfect measure of musculoskeletal cognitive competency, and to date has not been correlated with clinical or long-term outcomes, its results are consistent and sobering. It will be useful to compare results from the Freedman-Bernstein test with the more comprehensive NBME-developed shelf exam.

Learning objectives

Learning objectives are outcomes expected of learners following an educational intervention, and are created within each of the three domains of learning: knowledge, attitudes, and skills. Within each domain, further subcategories have been developed by Bloom and others to classify lower and higher order objectives that describe successive levels of learning (Table 1) [10, 27]. In order to achieve higher order learning objectives, students must master the lower ones. Curriculum design and student assessment should likewise reflect and promote this progression of learning.

There have been a number of international and national recommendations for undergraduate musculoskeletal educational goals and objectives, which differ in several ways [6, 28–32, 33•]. One difference is in how the objectives were developed; some were the result of expert (musculoskeletal specialist) opinion alone, while others utilized a modified Delphi technique (whereby numerous stakeholders, including practicing physicians, were surveyed to determine the relative importance of suggested objectives.) Another is in the degree of granularity with which objectives are specified. In general, U.S. recommendations tend to be broad and more along the lines of general educational goals rather than specific learning objectives. The AAMC Medical School Objectives Project has suggested musculoskeletal learning objectives for all three learning domains to help guide medical schools develop their curricula, and provides suggestions for how to achieve these objectives [6].

Educational strategies and implementation

Educational strategies are the means by which learning objectives are achieved, and include both the content (material) and the method of presentation. An important principle in the development of educational strategies is ensuring congruence with the intended learning outcome. For example, if the learning objective is for a student to demonstrate competence in examining a patient with a rotator cuff tear, this will not be achieved by a lecture on shoulder examination techniques alone.

The majority of the literature on educational strategies for musculoskeletal medicine is purely descriptive: i.e., describing curriculum implementation and/or reform at individual institutions. These usually involve individual courses (most commonly in the first and second years) as opposed to more longitudinal interventions across multiple years. Although these papers do not provide data on the effectiveness of specific strategies, they do provide concrete examples of different educational methods which have been employed—such as lectures, small group exercises, web-based modules, patient presentations, etc. They correspondingly describe the system-wide processes required to implement these courses, such as obtaining institutional support, identifying necessary resources and personnel, and administering faculty development programs to ensure consistency of teaching. One important theme in recent years is a multidisciplinary approach towards course design and implementation, which we strongly endorse.

One of the earliest U.S. program descriptions comes from the University of North Carolina [34] in 1973, which documented an orthopaedics-designed 2nd year musculoskeletal course. Notable features included the development of competency-based learning objectives classified according to Bloom's taxonomy, daily quizzes with immediate assessment and feedback, a large component of small group sessions, and psychometric analysis of exam questions. Recently they reported on the evolution of this 40-year-old course [35], and identified the substantial use of small group teaching as integral to its success. Several other institutions have reported on their curricular modifications in the past decade [36–38]. As an example, Saleh, et al. described the introduction of a second-year musculoskeletal sequence at the University of Minnesota [39]. In addition to utilizing small group sessions for teaching the basics of regional musculoskeletal examination, they developed stations in which students were presented with a clinical scenario and had to demonstrate a physical examination technique, make a diagnosis, or describe a treatment plan. The latter sessions engage multiple domains of learning (cognitive and psychomotor) and promote higher order learning; they

were well received by trainees and instructors, and students performed better on their end-of-year objective structured clinical exam (OSCE) as compared to historical controls. These sessions were, however, exceedingly labor intensive, requiring commitment from numerous faculty. Additionally, there was no evidence suggesting that these sessions resulted in improved clinical problem-solving skills above and beyond what might have been achieved in less labor-intensive faculty-facilitated small group discussions. Their course also included large group multidisciplinary case presentations designed to demonstrate the multiple factors involved in the assessment and management of common musculoskeletal disorders (for example, hip fracture and associated osteoporosis, osteoarthritis, and hip arthroplasty). Interestingly, these multidisciplinary sessions were poorly received by students, who reportedly felt that the cases were too long and complex, and the sessions were subsequently dropped. It would be interesting to identify whether certain aspects of those presentations were more problematic than others, and if so whether they could be corrected, in order to maintain the multidisciplinary nature of the educational activity.

A few studies have attempted to directly compare different types of musculoskeletal teaching methodologies. One group randomized students to small group tutorials or large group interactive seminars for cognitive instruction, and found no differences in end-of-sequence test scores, but greater satisfaction with the small group format [40]. Other studies have looked at the benefit of computer-based learning modules as primary or supplemental educational material, with varying results. One group compared a large group lecture and physical examination demonstration with a web-based tutorial, and found no differences in exam or OSCE performance [41]. However, a different study found that addition of a computer-based module to an existing curriculum resulted in improved OSCE results [42]. Interestingly, another group demonstrated that students who received a computer based learning package prior to bedside physical exam teaching performed better on their OSCE and were more satisfied than those who received the package after bedside teaching [43•]; both formats resulted in equivalent performance when compared head-to-head. Generalizability of these studies is problematic. One issue is the variability of assessment tools used in different studies to prove or refute educational effectiveness, rendering direct comparison between them challenging. Another is the inherent problem with comparing two disparate methodologies (for example, computer based learning with a small group tutorial) given the numerous confounding factors [44].

Standardized patients (SPs) are frequently employed in the teaching and assessment of physical exam or diagnostic

skills [45]. While SPs are well trained and allow for the replication of real clinical interactions, they lack the actual clinical findings. One variation on the SP is the patient educator, who has actual disease and can demonstrate abnormal pathology on him/herself. Patient educators with rheumatoid arthritis have been well studied in the musculoskeletal literature and are particularly effective in educating students about the psychosocial aspects of arthritis and chronic musculoskeletal pain/limitation [46]. Additionally, patient educators have been shown to be at least as effective as physicians in teaching physical exam skills [47–49]. Key factors to their effectiveness are excellent communication skills and high levels of training, which can be time and labor intensive to maintain.

Assessment

Assessment of individual learners can and should take many forms. Assessment can be formative (providing feedback and directions for improvement) or summative (as a means to assess competency); the tools to make the assessment should be both valid and reliable. Based on Miller's framework (Table 1), assessment of medical students in the preclinical years is usually limited to demonstrating that students have knowledge and competence. In the clinical years, a number of tools have been developed to assess performance and action, such as the mini-Clinical Evaluation Exercise (CEX) [50, 51]; however, it is not known how frequently these are used specifically to assess musculoskeletal performance.

Assessment of knowledge in the preclinical years predominantly takes the form of written tests associated with musculoskeletal sequences, often in computerized multiple choice formats to allow ease of grading given large class sizes. In the clinical years, while musculoskeletal questions are present on many of the clerkship subject exams, typically there is no well-defined longitudinal assessment of musculoskeletal medicine knowledge acquisition over the course of the 4 years. One way to do so involves progress testing, whereby students are assessed periodically throughout their training with tests reflecting content that should be mastered by graduation. This theoretically documents progression of knowledge acquisition and can evaluate the effectiveness of musculoskeletal educational experiences (formal or unscripted) over the course of medical school. Basu, et al., described the cross-sectional administration of this type of knowledge test to students from all 5 years at the Sheffield University School of Medicine as a way of evaluating their longitudinal musculoskeletal curriculum [52].

Multiple choice questions are typically in the one-best-answer format, which reflects national assessment standards

[53], and there are guidelines for developing questions to assess both lower and higher order learning. However, by definition, one-best-answer questions are not designed to probe decision making in situations of clinical ambiguity, which are more reflective of true medical practice. Script concordance testing is a way to assess clinical reasoning in areas of uncertainty, based on the degree of concordance with experts' opinions [54]. This is a particularly intriguing tool for use in musculoskeletal assessment, given that disorders are managed by many different generalists and specialists with different discipline-based approaches. This type of testing has been described in the assessment of musculoskeletal knowledge gaps for practicing family physicians [54] but not (to our knowledge) with medical students.

Assessment of musculoskeletal clinical skills most commonly utilizes OSCEs, occasionally as part of a specific course assessment, but more often as part of a global assessment at various points prior to graduation. One group described the development and validation of 2 OSCE stations for the hand and knee exam at their institution [55], which included careful psychometric analyses. Musculoskeletal OSCEs can be designed to assess both lower order processes, such as the ability to perform a specific exam maneuver, and higher order processes, such as diagnostic reasoning and clinical decision making in assessing musculoskeletal complaints [45, 56•]. Higher order OSCEs require more rigorous development and validation, and can be labor and resource intensive; however, they provide valuable information about students' skills not easily obtained in other ways.

Program evaluation

Groups instituting musculoskeletal curricular reform have evaluated the success of their program in several ways. One of the most commonly used metrics is student and instructor satisfaction with the course; more objective measures include performance on exams, OSCEs, and the Friedman-Bernstein test. Typically, results are compared to historical controls (before institution of the curriculum), often due to ethical concerns regarding the withholding of an educational intervention from part of a class. Bilderback, et al. demonstrated improved scores on the Friedman-Bernstein test [36]. Saleh, et al. found improved student satisfaction and retention of physical examination skills after 3–4 months [39]. Day, et al., on the other hand, evaluated the effectiveness of musculoskeletal curricular modification at Harvard Medical School utilizing a variety of metrics and was not able to document any meaningful improvement [57]. However, these findings cannot be used to compare effectiveness between different types of curricular reform

methods. They likewise illustrate the challenges in creating appropriate and meaningful instruments to measure educational effectiveness.

Challenges and solutions for undergraduate musculoskeletal education

Interviews with students and teachers have identified a number of barriers to musculoskeletal education [58, 59]. While some are ubiquitous to teaching in general (lack of time, space, resources, etc.), a few were more specific to musculoskeletal medicine and warrant further discussion. These included:

1. Student's lack of basic anatomic knowledge.
2. Lack of consistency in what is taught
3. Lack of teacher confidence in musculoskeletal clinical teaching
4. Lack of reinforcement of clinical skills

Musculoskeletal medicine requires more grounding in basic anatomy than many other disciplines. However, the amount of time allotted for musculoskeletal anatomy at our and other institutions [60] is shrinking in response to numerous competing curricular requirements. Evaluation of existing curricula should determine whether adequate instruction in musculoskeletal anatomy is being provided, both foundationally and in conjunction with clinical experiences.

Lack of consistency in teaching is not surprising, as musculoskeletal medicine is taught by faculty in many disciplines (orthopaedic surgery, physical medicine, rheumatology, radiology, internal, family, and emergency medicine) who have different views regarding the necessary knowledge base and essentials of the musculoskeletal examination. This contributes to lack of teacher confidence, particularly for non-specialist teachers, who themselves may have received conflicting or inadequate education in musculoskeletal medicine. Hopefully, the current trend of multidisciplinary collaboration in curricular development and implementation will diminish variability and inconsistency in what students are taught.

For many U.S. medical schools, there is no mandatory instruction or reinforcement of musculoskeletal clinical examination skills after the pre-clinical years. It is possible for a student to rotate through their required clerkships and not see or examine patients with the most common musculoskeletal complaints. Pressure on clinical faculty to be efficient further exacerbates this issue; students are frequently only able to "shadow" clinicians. Even if the clinician is exceptionally skilled, the musculoskeletal exam is extremely "hands on" (not a spectator sport). Unless the student is allowed to examine patients and subsequently

observed and critiqued by faculty, the musculoskeletal examination cannot be mastered.

Two ways of addressing the lack of formal clinical exposure are “The Stealth Approach”, in which musculoskeletal education is woven throughout all 4 years of medical school with each year reinforcing and adding to the depth of musculoskeletal knowledge; and “Reclaiming the Fourth Year”, in which electives are offered to reintroduce musculoskeletal education last taught in the preclinical years [61]. The fourth year of the typical medical school curriculum is often largely elective to allow students to pursue individual interests. A substantial amount of musculoskeletal medicine could be added in the fourth year’s curricular offerings, tapered to student needs without eliminating anything essential and taking advantage of the clinical expertise derived from third-year clerkships. The Association of Academic Physiatrists (AAP) has suggested musculoskeletal topics to be covered during core clerkship rotations, as well as guidelines for the development and assessment of 4th year musculoskeletal electives [62]. In many of the studies cited above, improved confidence and performance on assessment tools was strongly correlated with participation in musculoskeletal electives.

While educators have attempted to clarify *what* exam skills to teach students, there has been little analysis of *how* to teach these skills. Learning theory regarding motor skills suggests that breaking down a complex task into a series of smaller tasks facilitates acquisition of these skills, a process known as task or skill decomposition [63–65]. The method describes breaking a skill set, such as a tennis serve, into a chain of individual tasks, such as ball toss and free swing. Each task is practiced in isolation in order to reduce variability, and later the tasks are linked together. The advantage of this method is the reduction in stochastic variability; tasks are easier to teach and master in isolation. Applied to a physical examination skill, this allows for mastery of a limited skill set, such as individual components of a complete shoulder examination, and can facilitate assessment with a standardized checklist. In the case of the musculoskeletal exam, the “Look, Feel, Move” approach is an example of task decomposition. Utilizing this educational strategy initially, the first two levels of Bloom’s taxonomy (recall and understanding) are easily mastered, and application can begin.

Whether task decomposition learning produces better clinicians is questionable, as patients by nature are full of stochastic variability. Another strategy, known as varied emphasis training, teaches the full skill set, but varies the emphasis—sometimes focusing on the ball toss, other times focusing on the free swing, but always including both in the task. The advantage of this method is that it requires the learner to manage attention to several tasks

at once, which is a skill in itself. Since real world performance requires the entire skill set, the task is more representative to clinical practice, thus (in theory) achieving improved clinical psychomotor and reasoning skills. Varied emphasis training can involve taking a history and generating a differential diagnosis, with subsequent focus on varying aspects of the examination deemed relevant to the differential (the Hypothesis-Driven physical examination) [56•].

We suggest a consistent two-step method for teaching the musculoskeletal exam that utilizes both strategies. The first step involves the task decomposition approach of a simple, “Look, Feel, Move” examination of a normal standardized patient. When a student can perform the entire examination, a varied emphasis approach should incorporate clinical cases and patient demonstrations. Utilizing some cases with systemic diseases and others with focal or traumatic conditions requires the student to shift attention from one area of emphasis to another, teaching perceptual skill as an added benefit. Students can be asked to think about how they would approach the musculoskeletal examination in various circumstances. Offering a range of experiences allows learners to build upon previous knowledge—facilitating the application of the skill being emphasized. Both of these approaches could occur as part of mandatory instruction in the preclinical years, providing students with a more sophisticated baseline skill set with which to evaluate musculoskeletal disorders during their clerkships.

Conclusion

While musculoskeletal education has evolved considerably over the past 50 years, there still are areas needing improvement. Regardless of how musculoskeletal education is delivered at different institutions, it is reasonable to develop a nationally endorsed, uniform musculoskeletal examination and diagnostic skill set that all students should master prior to graduation, similar to that provided in other countries. Additionally, mandatory and validated assessment of student competence and performance is critical. To ensure that we are appropriately preparing future physicians to deal with the existing and evolving burden of musculoskeletal disease in the United States, further high quality research on undergraduate musculoskeletal education is required.

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