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REVIEW

A History of Musculoskeletal Medicine and Its Place and Progress in Undergraduate Medical Education

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Abstract
Musculoskeletal diseases are responsible for some of the most prevalent conditions affecting population health in the world. Despite the prevalence of these conditions, musculoskeletal medicine has a fraught history within the world of undergraduate medical education. We review the origins of musculoskeletal medicine, its evolution in undergraduate medical education, and progress that has been made over the last decade as a result of global initiatives such as the Bone and Joint Decade. Understanding the history of musculoskeletal medicine is essential to contextualizing the problems that exist today and creating comprehensive solutions to fill the gaps that persist in musculoskeletal curricula.

Keywords Musculoskeletal medicine · Undergraduate medical education · Medical students · Musculoskeletal education

Introduction

Musculoskeletal (MSK) diseases are some of the most common causes of long-term pain and disability and are responsible for some of the most prevalent conditions affecting population health in the world [1, 2]. Untreated MSK conditions present a substantial risk to an individual's ability to participate in community and occupational activities and can even be life-threatening if untreated [1]. Despite their prevalence, previous research has identified deficiencies in the instruction surrounding the diagnosis and treatment of MSK conditions, as well as their management within healthcare systems as a whole [3, 4]. This has been demonstrated by poor passing scores on basic MSK competency examinations in medical students, residents, and practicing physicians, as well as curriculum evaluations demonstrating insufficient time and resources allocated to MSK training [4–6].

Understanding the history of MSK medicine is essential to contextualizing present-day issues in medical education around this subject; to look for future curriculum reform opportunities, the past must be evaluated to build on work that has already been completed and understand the challenges that exist. This historical review outlines the progression of using exercise as medicine in ancient civilizations and the shift to curative from preventative medicine. This leads to the eventual attention that MSK medicine and the education of healthcare providers received during the 1900s, after which the Bone and Joint Decade was established. Finally, a review of the progress of MSK education over the last decade is provided, and opportunities for educators to implement meaningful changes in their curricula are presented.

A Brief History of MSK Medicine

Exercise as Medicine in Ancient Civilizations

For thousands of years, the relationship between a healthy MSK system and longevity has been recognized. Ancient

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civilizations and physicians used muscular exercise as a way to prevent and treat disease, the concepts of which can be traced all the way back to 1250 before common era (BCE) [7]. While historical contributions to exercise physiology and are typically attributed to the ancient Greeks, these concepts existed prior to the emergence of Mycenaean cultures. Susruta, an ancient Indian physician and surgeon who lived during 600 BCE, was the first physician recorded to recommend moderate daily exercise to prevent disease [8]. Susruta supposed that moderate exercise improved the growth of limbs; enhanced muscular strength, endurance, and development; increased digestion and resistance against fatigue; and reduced corpulence [8].

The Ancient Greeks undoubtably played a large role in promoting the practice of exercise for disease prevention and treatment [7]. Although exercise was deeply embedded in ancient Greek culture centuries before his existence, Hippocrates, the father of medicine, is credited as being a defining influence in promoting muscular exercise as a medicinal practice during the "Golden Age" of Ancient Greece [8]. Similarly, to Susruta, Hippocrates believed that muscular training had a number of beneficial effects, including increased stature, bone and muscle mass, tone, endurance, and tolerance against fatigue. Hippocrates was the first physician to prescribe exercise to a patient afflicted with consumption, and his ideas informed many of Claudius Galenus' (Galen) beliefs and practice, who was arguably the most important physician of the Roman Empire [7]. Galen's use of exercise to promote good health in the practice of medicine lasted around 1400 years into the Middle Ages within Arabic and European countries [9]. With the emergence of the Renaissance period and individualism between the fourteenth and seventeenth centuries, the ideal of personal responsibility for good health garnered even more traction and maintained its position in medicine for centuries after Galen [10].

Numerous examples of physicians advocating for the use of exercise in promoting health persisted throughout the eighteenth century [10]. Although many of the ideas that had become prevalent amongst Ancient Greek and Roman physicians were eventually replaced by anatomy and physiology and therapeutic interventions, the principle of using exercise as medicine maintained a prominent place in society. Ultimately, the roots of exercise physiology in history provided for a base that contributed to our understanding of the importance of muscular fitness in the prevention of disease and maintenance of good health.

The Overshadowing and Rediscovery of MSK Medicine

The nineteenth and twentieth centuries brought about significant technological advancements to society that fundamentally changed the way that healthcare was provided. The practice of using exercise as a therapeutic tool was overshadowed by inventions and discoveries such as general anaesthetic, insulin, new surgical techniques, antisepsis, and germ theory, and as a result, and the emphasis of medical practice shifted away from prevention to treatment [10, 11]. Advancements in the workplace also contributed to this shift, and many individuals became inactive within their occupations as physically demanding jobs were replaced with technology.

Around the same time, medical education institutions in America were being challenged by a report produced by the Carnegie Foundation in 1910 that would change medical education forever. It had become evident that many physicians were being trained without rigour and that the lack of standards across medical schools was contributing to a general lack of competency amongst medical graduates to provide care to patients [12]. Abraham Flexner, the main investigator and author of the report, identified low admission standards, inadequate exposure to clinical material, and poor laboratory facilities amongst the majority of medical schools [12]. As a result of his recommendations for improving the state of medical education, the number of medical schools dropped, training became longer and more scientific, and there was a greater emphasis placed on curative rather than preventative medicine in training [10]. Moreover, the fewer number of physicians being trained did not see physical exercise as a potential field for use of their expertise and exercise lost its place as a prominent treatment modality [10].

Eventually, the sedentary lifestyle that was produced by the combination technological advancements and the shift away from preventative medicine was associated with an increase in morbidity and mortality from a number of diseases [11]. As the concept of MSK health and exercise as medicine was "rediscovered" in the mid-1900s, physicians and governmental agencies encouraged the general public to engage in physical activity [11]. Epidemiological data continued to establish links between MSK health, exercise, and disease prevention throughout the late 1990s and with the resurgence of physical activity that emerged as a result of this attention came the inevitable increase in MSK injuries related to exercise. Even prior to this resurgence, studies reported that up to 20% of patients in primary care settings complained of MSK-related problems [11].

However, studies conducted throughout the 1970s and 1980s alluded to disparities between the frequency of MSK conditions seen in primary care settings and the preparedness of medical graduates to practice MSK medicine. Several studies conducted in the USA revealed possible deficiencies in MSK physical examination skills and perceptions of inadequate orthopaedics training amongst medical students, residents, and practicing physicians [13–15]. In

1997, nine major physician organizations[1] formed a Steering Committee on Collaboration amongst Physician Providers Involved in Musculoskeletal Care. This committee had the common purpose of ensuring cost-effective and high-quality diagnosis and treatment of MSK conditions through the promotion of MSK knowledge amongst physicians [16]. As part of their activities, this group created and distributed a survey to over 5,000 residents in primary care programs across the USA to assess the preparation of physicians entering postgraduate training to diagnose and treat MSK problems. The results of this survey revealed shocking perceptions of the quality of residents' previous MSK education [16]. Up to 60% of residents felt that their training to conduct an MSK examination to assess problems of various areas of the body was poor or very poor [16]. Furthermore, when residents were asked to describe their training for treating common fractures and interpreting MSK radiographs, 40% indicated that their preparation was poor or very poor. Following the results of this survey, the steering committee members recommended that greater effort be made by medical institutions to assess the preparedness of physicians entering practice to deal with MSK problems in addition to assessing the quality of their existing curricula.

Similarly, in 1998, Freedman and Bernstein developed a basic MSK competency examination to assess medical trainee's understanding of MSK conditions [17]. This examination was validated through a survey distributed to all of the orthopaedic residency program chairs in the USA. Through this survey, it was determined that a score of 73.1% on Freedman and Bernstein's assessment represented basic competency in MSK medicine. This assessment was administered to 85 recent medical school graduates in various specialties to examine their MSK knowledge. Over 80% (70/85) of residents failed to demonstrate basic competency on Freedman and Bernstein's examination based on the criterion set by the orthopaedic chairs, with the mean examination score being 59.6 ± 12% (range, 35 to 86%). Residents who had graduated from medical school without completing a rotation in orthopaedic surgery had the lowest mean score (55.9%) and the highest failure rate (93%) [17].

The Initiation of the Bone and Joint Decade

Taken with the increasing burden of MSK conditions on society, there was compelling evidence in the late 1990s that supported the need to ensure a strong foundation of knowledge in the diagnosis and treatment of MSK conditions. The healthcare professionals responsible for treating and managing these conditions realized the need for a high-profile campaign to remedy the lack of attention provided to the seriousness of MSK conditions by policy makers, the media, and the medical profession as a whole [18–20]. Moreover, with the state of MSK medical education being questioned, there came a need to thoroughly identify the knowledge gaps present in MSK curricula and provide recommendations for further action.

To bring attention to these issues, over 100 experts from national and international organizations, including healthcare professionals and individuals from patient organizations attended a meeting in Lund, Sweden in April of 1998 to consider the global impact of MSK disorders and strategies to increase public and professional awareness of these conditions [21, 22]. At this inaugural meeting, it was agreed that the first decade of the twenty-first century would be designated "The Bone and Joint Decade" to raise awareness of the impact of MSK conditions on society and improve the quality of life for individuals living with MSK disorders across the globe [23–25]. One of the primary goals of this global campaign was to advance the understanding and treatment of these conditions through research, prevention, and education of patients and healthcare providers [20, 26].

The Bone and Joint Decade catalysed widespread efforts to assess the quality of MSK education medical trainees were receiving and the MSK knowledge base of students and practicing physicians. In the early 2000s, Freedman and Bernstein's original findings were replicated in medical students, residents, and practicing physicians in various academic medical institutions around the globe [27–31]. For example, Jones administered the MSK examination to final year medical students at the University of West Indies in Barbados, and over 80% of students failed to achieve basic competency [28]. Similarly, Matzkin and colleagues gave the examination to 334 medical students, residents, and staff physicians, only 21% of whom reached the recommended mean passing score of 73.1% [29]. In 2006, Lynch et al. administered the Freedman and Bernstein examination to family medicine, internal medicine, and paediatric faculty along with a survey to assess self-perceived confidence for managing common MSK problems [32]. Only 59 (64%) of the 92 physicians achieved basic competency. When compared to managing medically related problems, physicians also reported significantly lower confidence in dealing with MSK-related issues [32, 33].

These gaps in medical trainee and physician MSK knowledge and confidence were quickly linked back to deficiencies in MSK instruction within the early years of medical training. Various curriculum evaluations conducted at the undergraduate level of medical education found that the amount of time training medical students for MSK medicine

[1] The American Academy of Family Physicians, the American College of Physicians, the American College of Emergency Physicians, the American Academy of Pediatrics, the American Geriatrics Society, the American Academy of Physical Medicine and Rehabilitation, the American Osteopathic Association, the American Academy of Orthopaedic Surgeons, and the American College of Rheumatology.

as well as the quality of MSK curricula was deficient. In 2001, Pinney and Regan surveyed the directors of the sixteen existing medical schools in Canada to determine the proportion of curricula time dedicated to MSK education as well as the perceived quality of MSK education offered at each institution. It was determined that on average, only 2.26% (range, 0.61 to 4.81%) of curriculum time in Canadian medical schools was devoted to MSK education [5]. Furthermore, 11 of the 16 respondents indicated that the time available in their medical school's MSK curriculum was inadequate, and 7 of the 16 program directors rated their curriculum as inadequate overall to prepare students to deal with MSK problems. As part of their analysis, the authors estimated the prevalence of MSK-related complaints in primary care settings in North America through a literature review and survey administered to local family physicians. This review revealed that up to 27.8% of patients presenting to primary care have an MSK-related complaint [5]. When compared with the amount of time dedicated to MSK education in medical school, there was a clear and notable discrepancy that existed between the prevalence of MSK issues and the time spent teaching about them. In 2003, a similar evaluation was conducted in American medical schools by DiCaprio et al., which revealed that only 51 (41.8%) of the 122 allopathic medical schools in the USA required a MSK preclinical module or instruction and only 25 (20.5%) medical schools required students to rotate through an MSK clerkship during their clinical years. Additionally, close to half of the medical schools had no required MSK medicine instruction [34]. A survey of medical schools within the UK conducted in 2001 demonstrated similar time disparities in MSK teaching and indicated that under 4% of curriculum time was dedicated to MSK medicine within undergraduate medical education [35]. Multiple studies conducted within the UK also displayed consistent poor scores amongst medical students and residents on Freedman and Bernstein's examination in addition to low self-rated confidence in MSK assessment skills [36–39].

Efforts and Initiatives Inspired by the Bone and Joint Decade

As the first decade of the twenty-first century progressed, more countries verified inadequacies in MSK curricula as well as medical trainee and practitioner MSK knowledge. Australia identified the standard of MSK education in their medical schools as insufficient to meet the needs of MSK care in the country [40], and studies conducted in Egypt, India, Ireland, and Nigeria illustrated more gaps in MSK knowledge amongst medical students, residents, and practicing physicians using Freedman and Bernstein's examination [41–44]. Taken together, these curriculum evaluations and trainee knowledge assessments illustrated the dire state of MSK medical education around the world and the obligation of academic medical institutions to improve the quality of instruction provided to students.

A number of curriculum reform initiatives were inspired as a result of the increased attention brought to this issue. The largest effort to revamp MSK curricula was coordinated by the Bone and Joint Decade's Education Task Force, who initiated a consultation process with experts from around the world to produce MSK learning outcomes applicable to all physicians. These individuals formed the Bone and Joint Decade Undergraduate Curriculum Development Group (BJDUCDG) and created global recommendations for a set of core undergraduate curriculum items regarding MSK conditions [45, 46]. These recommendations were determined to be the minimum level of physician competence for MSK-related management regardless of further specialization and were designed with the intent of being able to be applied to any medical school in the world [46].

Other efforts were initiated at the national level in various countries. These included the American Medical Association's Resolution 310, which encouraged medical institutions in the USA to make changes to their curriculum to ensure students have appropriate education and training in musculoskeletal care and are able to demonstrate competence in basic musculoskeletal principles a graduation requirement for medical schools [47]. The Association of American Medical Colleges (AAMC) also created a dedicated MSK panel within its medical school objectives project, and the National Board of Medical Examiners (NBME) developed a subject examination in MSK medicine. In Canada, the BJDUCG core curriculum recommendations for MSK education were reviewed by Canadian physicians and surgeons to evaluate their level of agreement with the recommendations and add items they thought to be important at the postgraduate level of education [45]. Statistical evidence of agreement was demonstrated, and topics that were deemed as being important by Canadian physicians to post-graduate medical practice were also added, producing the Canadian Multidisciplinary Core Curriculum for MSK Health [45].

Outside of North America, the Australian Musculoskeletal Education Collaboration (AMSEC) was formed in 2005 with the goal of improving the delivery of MSK care in Australia by establishing a minimum national baseline in MSK education [40]. This AMSEC project established a minimum national benchmark for MSK education in Australian medical schools using a national consensus process involving interdisciplinary and interprofessional working groups. The evidence-informed, principle-based core competencies that were developed through this initiative were implemented in Australian medical schools in 2010 [48]. Other recommendations developed during this time included involving different specialists in the development of MSK curricula to ensure a multidisciplinary and comprehensive approach to teaching

this subject. In particular, the Association of Academic Physiatrists formed recommendations on how the specialty could contribute to MSK education within UGME and provided overarching guidance on the development of MSK curricula [49]. These widespread and intensive initiatives marked the beginning of a promising era of curriculum reform for MSK medicine and provided a comprehensive framework for medical schools around the world to follow suit.

At the end of the Bone and Joint Decade, Bernstein et al. set out to evaluate whether the aforementioned initiatives resulted in a change in the prevalence of MSK instruction within American medical schools. When compared to the 2003 report, there was a 37% increase in medical schools that required students to complete a preclinical course in MSK medicine, a 4% increase in those that required a clerkship in MSK medicine, and a 30% decrease in schools that had no required MSK instruction at all [50]. Although these results showed MSK medicine's progress in attaining a more prominent place in medical school curricula, the era of MSK curriculum reform in medical education was far from complete. Despite the presence of evidence indicating an increase in the overall instruction and clinical time dedicated to MSK medicine in American Medical Schools over the course of the decade, the methods used to characterize this change failed to capture the exact content taught within the curriculum and the quality of the instruction provided to students. The first objective of curriculum reform, ensuring MSK medicine had a defined place in medical training, seems well underway, but the broader challenge of evaluating the quality of the content necessitated more work.

Progress of MSK Medical Education Over the Last Decade

Ten years after the Bone and Joint Decade, various MSK learning and teaching approaches have been examined in isolation and as part of broader curricula renewal in order to address the remaining deficiencies in MSK curricula and ensure quality instruction within undergraduate medical education. Curriculum reform efforts conducted in this area have included increasing the time dedicated to MSK instruction, adding more clinical opportunities, and developing integrated, multidisciplinary courses on MSK conditions. Other popular approaches to enhancing MSK curricula include interprofessional education opportunities, experiential and active learning, e-learning, and peer- and patient-assisted learning. Evaluation efforts have also continued, both in terms of student knowledge and MSK curriculum assessments. The following sections outline the efforts that have been made towards improving MSK curricula over the last decade (2010–2020) and the state of MSK medicine instruction as we know it today.

Themes that Emerged from the Bone and Joint Decade

In keeping with the trend of curriculum renewal during The Bone and Joint Decade, many medical schools have continued to increase the clinical and classroom-based time dedicated to MSK medicine [51, 52]. For example, Leicester Medical School increased their dedicated clinical MSK coursework by 3 weeks by integrating instruction in rheumatology, trauma and orthopaedic surgery, and other allied specialties into their curriculum [51]; at the Royal College of Surgeons in Ireland, an interactive MSK module was added as a newly designed 2-week compulsory clinical rotation. Features of this module included lectures, case discussions, clinical examinations, interactive tutorials, and patient interactions [52]. After identifying region-specific educational inadequacies, Harvard Medical School produced an integrated MSK curriculum based on the AAMC recommendations and added MSK content across their preclinical curriculum for a longitudinal approach [30, 53, 54]. Other medical schools created completely new modules and courses spanning various MSK specialities and topics during preclinical years, including rheumatology, orthopaedics, clinical anatomy, and rehabilitation medicine [55–57].

Interprofessional Education

Interprofessional education refers to the collaborative learning process through which students from different healthcare fields learn from, with, and about each other in an interactive setting [58, 59]. Within the context of MSK curricula, the fields of physical therapy, massage therapy, and medicine have been combined in MSK curricular components including lectures, laboratories, and small group learning to improve MSK instruction [58, 60–63]. These interprofessional education pairings have yielded largely positive results with students from both fields, particularly physical therapy and medicine, reporting their interprofessional experiences as being beneficial to their learning and demonstrating improved scores on post-program or session testing in specific MSK clinical skills [58, 61, 63, 64].

Integrated and Interdisciplinary MSK Teaching

Many MSK courses and curricula have also introduced integrated, interdisciplinary approaches to their MSK teaching. This has included vertical integration of basic science content, such as anatomy into MSK clinical education [65–70], and the involvement of various MSK specialists, such as anatomists, physiatrists, and orthopaedic surgeons, within curricula development and clinical teaching activities [71–75]. Morgan et al. describe the integration of anatomical education into specialty-specific senior electives, including

MSK medicine. This institution's MSK course had the aim of presenting MSK anatomical concepts within a clinical framework and is co-taught by anatomy and orthopaedic specialists [68]. The course evaluations of these electives have yielded extremely positive results, with students demonstrating significant post-course improvements on applied clinical MSK anatomy assessments and providing positive comments about the usefulness of the course [68]. Interdisciplinary approaches coordinated between MSK radiology and anatomy, as well as having physiatry-based teaching of MSK examinations, have also been documented [71, 76–78].

Experiential and Active Learning

Various experiential and active learning techniques have been incorporated into curricula to enhance MSK education. Active learning involves having students directly engaged in the learning process through strategies such as team-based learning, case-based learning, and problem-based learning. These strategies have been examined within MSK medicine for both pre-clinical and clinical curricula and have played a large role in curriculum renewal activities [79–82]. Experiential learning has also become prevalent in this area and involves students participating in a hands-on learning experience that includes clinical and patient interactions within the context of medical training. For example, ambulatory teaching days and participation in medical student-run clinics in which students receive experience with patients have been implemented within MSK teaching, providing more opportunities for clinical exposure to MSK conditions [83–87]. Through these experiences, students are able to contribute meaningfully to patient care in underserved populations while engaging with MSK complaints in a direct manner. Experiential learning opportunities within the field of MSK medicine have also been offered through student interest groups which provide supplemental educational experiences within the field of MSK medicine, including additional instruction, clinical opportunities, networking, and mentorship [88].

MSK Anatomy, Physical Examinations, and Procedural Skills

Cadaveric dissection has long been used as a method for teaching anatomical concepts and continues to be used to instruct medical students in the basics of MSK anatomy and physiology [89–91]. Newer methods of teaching including synthetic models, simulators, and three-dimensional anatomy software have been explored as a way to assist students in learning MSK anatomy and are also being applied to physical examination and procedural skills instruction [92–95]. MSK ultrasound has been implemented in curricula during lectures and laboratory sessions as a way to improve student physical examination skills and MSK anatomy knowledge [96–98]. This technique has been reported as being highly valued by students and an effective way to increase their understanding of MSK pathology, anatomy, and physical examination skills [99–101]. Companion checklists and standardized approaches to MSK examination have been developed to assist students in learning these concepts [102, 103]. For example, the pediatric Gait, Arms, Legs, Spine (pGALS) technique was developed as an evidence-based approach for non-specialists to assess pediatric MSK abnormalities during physical examinations [104]. This assessment involves a simple screening approach whereby clinicians perform basic manoeuvres used in clinical practice to diagnose MSK conditions, taking an average of 2 min to complete [105]. This approach has been shown to be highly sensitive in detecting abnormalities and easy for medical learners to complete. Similarly, the GALS and the Regional Examination of the MSK System (REMS) function as methods to assess adults. These educational resources have been integrated into a number of medical schools' MSK curricula and have been shown to increase student confidence and physical examination performance [102, 106, 107].

Peer and Patient-Assisted Learning

Patient educators have been introduced in many MSK curricular components, including pre-clinical education, physical examination skills, and history-taking instruction. Assessments have indicated that with appropriate training, patients with MSK conditions have the ability to enhance student learning and provide valid assessments of student performance [108]. Students report that patient-lead teaching enables them to understand the impact of MSK disease on patients and their families and improve their physical examination skills [109–112].

Near-peer teaching is a type of peer-assisted learning that refers to the process of a physician trainee teaching a junior colleague. This technique has become more common over the last decade, and evidence suggests that both students and student teachers academically and professionally benefit from participating in these programs [113]. Peer-assisted learning has been integrated into undergraduate medical MSK curricula for the purpose of delivering clinical skills and content instruction, including MSK anatomy, as well as MSK examinations and ultrasound skills [114–121].

E-Learning and Flipped Classrooms

E-learning modalities developed within the context of MSK medical education have ranged from virtual patients and hospitals [122], modules and e-learning tools [123–128], blogs [129], mobile applications [130, 131], web-based videos [132–134], and evidence-based websites concerning

common MSK issues. Paediatric musculoskeletal matters (PMM) is one such website which aims to raise the awareness and help medical trainees and practicing clinicians gain the knowledge and skills needed to recognize paediatric MSK conditions and facilitate early diagnosis and referral to specialist care [135–137]. Web-based teaching modules have also been constructed to deliver MSK content to medical students and range in focus from specific-topics such as lower back pain and the examination of the hand [138, 139] to broader areas of MSK medicine like rheumatology [140–142]. These modules have frequently incorporated case-based learning through virtual patients or case simulations that present clinical MSK applications to medical students [125, 143–149]. Simulated patients have typically been presented in the form of module applications or virtual hospitals in which students are able to access various outpatient clinics and examination rooms [122, 131, 150]. Many of these e-learning interventions have been piloted as part of flipped classroom settings and blended learning approaches in MSK or rheumatology curricula, as well as adjuncts to MSK clinical rotations [142, 151–157].

Curriculum Recommendations

Recommendations for MSK medical education produced over the last decade have ranged from pediatric MSK conditions and MSK anatomy to broad syllabus and course development [158–161]. Many of these recommendations were formed using stakeholder focus groups and interviews, surveys, and modified Delphi processes [161–163]. For example, Jandial and colleagues (2015) developed learning outcomes specifically for pediatric MSK clinical skills and knowledge important at the medical student level through a modified Delphi process. Stakeholders involved included generalists and specialists involved in treating MSK conditions such as paediatrics, primary care, rheumatology, and orthopaedics, as well as medical students from schools in the UK [164]. The learning outcomes produced by this study related to MSK specific history taking, examination, development, clinical presentation of key conditions, and referral pathways within the scope of child health.

Orthopaedic surgeons have also played a large role in both MSK curriculum development and the procurement of recommendations for MSK instruction over the last decade. Specifically, the American Orthopaedic Association symposium report offered guidance for MSK curricula through the description of strategies used by orthopaedic surgeons to expand MSK curricula [160]. Modified Delphi processes have also been used to identify orthopaedic-related knowledge topics, clinical cases and skills that are relevant to medical students [165], and relevant orthopaedic anatomical components to be taught in UGME [166]. Other specialist-involved recommendations incorporated the opinions of practicing physicians to inform the development of an MSK curriculum, with an emphasis on common conditions seen in general practice [163].

Ongoing Assessment and Evaluation

In addition to the exploration of novel learning interventions and pedagogical approaches for their application to MSK medicine, there have also been continued curriculum evaluation and student assessment efforts. However, when compared to the evaluation work that occurred during the Bone and Joint Decade, many of these initiatives focused on more specialist-driven content and specific areas of MSK medicine. Evaluations of student MSK knowledge, confidence, perceived quality of teaching, and preferred instructional techniques have also been gathered within MSK radiology [167, 168], rheumatology [169–172], paediatric MSK clinical skills [173, 174], MSK physical examinations [175–177], orthopaedics and trauma subspecialties [178–181], and MSK anatomy [182–184]. These evaluations have indicated that the clinical confidence and knowledge of medical students within these various subsections of MSK medicine is severely lacking, and the instructional techniques utilized in these areas need improvement. Freedman and Bernstein's MSK knowledge assessment has also continued to be used around the world, with studies further demonstrating and affirming deficiencies in MSK knowledge amongst medical students in various countries [185–191].

In terms of curriculum evaluations, barriers to implementing effective and comprehensive MSK education have been cited as insufficient time and resources dedicated to this subject area [4, 192]. This includes a lack of exposure to patients in clinical settings, a shortage of faculty instructors able to teach clinical examination skills and effective teaching patients, and time constraints that are imposed on course content delivery [4, 173]. For example, DiGiovanni and colleagues re-evaluated the prevalence of MSK clinical instruction in American medical schools in 2015 and found that a required rotation was found in only 15% of medical schools, making it the least represented subject within specialties [193]. Students have also indicated that there is a lack of clarity of what is expected of them in various portions of their MSK curriculum, and clinical instructors have struggled with a perceived lack of consensus on what topics are important to teach in MSK medicine despite the recommendations that have been produced by various experts [167, 175, 194].

Gaps in the Literature and Progress Needed

Ten years after the Bone and Joint Decade ended, the literature indicates that meaningful efforts have been made to reform MSK curricula. However, there is evidence that

MSK knowledge gaps persist amongst medical students, even in medical schools that have implemented renewed curricula [57, 195]. Some have suggested that this is due to a "repackaging issue", meaning that schools may have compiled pre-existing MSK instruction into newly labelled courses or modules while making little to no change to the actual curriculum content [50]. Moreover, there are few examples of competency-based curricula, as well as a lack of longitudinal integration of MSK content and clinical experience opportunities demonstrated throughout preclinical and clinical years. Most of the interventions implemented and within undergraduate medical curricula have assessed the impact of the learning intervention or curriculum modification immediately after the students have completed it, rather than examining whether these changes yield meaningful improvements over time.

There is an intense competition for time within medical school curricula, which only continues to grow as expectations of physician's knowledge base increase with society's evolving healthcare needs. Unfortunately, MSK medicine is one of many subjects that continues to grapple with this dilemma. With limited funding available for medical education initiatives, resource intensive solutions to this problem are not viable for many medical schools. Moreover, the MSK learning modalities that have been constructed have largely focused on singular interventions with limited scope or specialist-specific content. The vast majority of modifications implemented in MSK curricula have also been evaluated based on student perceptions and satisfaction rather than the assessment of student knowledge or skill. Thus, there is a need for efficient, cost-effective, and evidence-based interventions that span a broad range of MSK topics. While there have undoubtably been advancements in the field of MSK education, continued and sustained effort is needed to fill the gaps that remain in medical training. It is pertinent that medical education institutions around the globe provide medical trainees with a solid foundation of knowledge in the diagnosis and treatment of MSK conditions to support the needs of society.

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