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Musculoskeletal Clinical Online Cases With a Focus on Anatomy for Preclinical Learners

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Abstract

Introduction: While musculoskeletal disorders are leading causes of medical visits, musculoskeletal education is underrepresented in US medical curricula. Previous studies have demonstrated that undergraduate medical students often fail to demonstrate competency surrounding musculoskeletal disorders. More educational content is needed to support musculoskeletal knowledge in learners. **Methods:** We developed an online, case-based musculoskeletal module for second-year medical students alongside their standard course material and presented clinical cases with multiple-choice question quizzes regarding the presentation, diagnosis, and anatomic correlation of musculoskeletal conditions. Cases, under 10 minutes each, targeted common, medically important areas of musculoskeletal health. **Results:** Grades in the required musculoskeletal course were significantly and positively correlated with online module quiz performance. 258 (73%) of 354 students completed at least one quiz, and students completed an average of 14 out of 15 quizzes. Learners who completed more than 50% of the quizzes performed significantly better in the course than those who completed fewer quizzes; this was true for a formative internal course exam ($p = .035$), an NBME customized assessment ($p = .008$), and the course overall ($p = .021$). Additional analyses of students' perceptions revealed that students valued the self-directed online learning environment. The high completion rate (73%) for the online module also signaled student value in the content and format. **Discussion:** This module represents educational material that has been demonstrated to improve medical student musculoskeletal learning. Additionally, the module could be expanded to address inadequacies in orthopedic education among other students, such as allied health learners.

Keywords

Musculoskeletal Health, Case-Based Learning, Preclinical Education, Orthopedics, Online/Distance Learning, Problem-Based Learning

Educational Objectives

By the end of this activity, learners will be able to:

1. Identify common musculoskeletal syndromes and their clinical presentations.
2. Interpret patient history and physical examination findings focused on the musculoskeletal system.
3. Define the anatomic structures involved in the musculoskeletal syndromes, and the dysfunction of those structures leading to signs and symptoms.

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Introduction

Musculoskeletal (MSK) disorders are second only to upper respiratory illness as a primary cause for emergency department visits, and the leading cause of disability in the United States.[1] Further, MSK disorders are encountered outside of the emergency department in a variety of practice settings including orthopedic surgeons, internal medicine, family practice, and pediatrics.[2,3] Thus, it is necessary, in general, for health care providers to be well versed in MSK anatomy and illness. The primary, and often the only, source of MSK system content is provided in undergraduate medical education (UME). Nevertheless, research has found that 82% of medical school graduates failed to meet MSK content competency.[3] Furthermore, there is an apparent disconnect between the perceived importance of MSK content and time spent in the curriculum. A 2007 study found third- and fourth-year medical students ranked MSK medicine as third most important topic (out of eight topics surveyed) for their future career but stated the amount of time spent on MSK was poor.[4] The only

topics that ranked higher were pulmonary and cardiovascular medicine.[4]

As a response to the incongruity between the incidence of MSK conditions and medical student content knowledge, the AAMC addressed the inadequacy of both clinical exposure and MSK content in medical school curricula. As such, the AAMC convened a panel of MSK experts tasked with developing learning objectives on MSK content and best practices for integration into existing curricula. The learning objectives from this report addressed attitudes (e.g., "the physical, psychological, financial and other quality-of-life consequences of living with a chronic musculoskeletal condition"), knowledge (e.g., "the impact of normal aging on musculoskeletal health), and skills (e.g., "the ability to perform a thorough musculoskeletal history and physical on adults and children").[5] As far as educational strategies, suggestions from this report are to insert MSK content throughout all 4 years to address the fragmentation; implement online-based training if clinical training is not an option (e.g., modules, vignettes, and cases); and provide assessment tools to assess MSK attitudes, knowledge, and skills.[5]

Case-based learning (CBL) has been demonstrated to be an effective teaching method within professional health curricula by providing an opportunity to foster critical thinking, improve content knowledge, and develop medical expertise by reasoning through a case as one may during a clinical encounter.[6,7] Additionally, students enjoy CBL and feel that it enhances their learning.[7] Therefore, the presentation of MSK content through CBL may be an effective way to include this content in the UME curriculum. Two systematic reviews examining MSK content delivery in both outcomes and modalities found a range of learners from UME students to residents and a variety of different curricular designs to include: virtual reality, blended learning, technology assisted learning, and a virtual orthopedic clinic.[8,9] However, within those systematic reviews no CBL modules were identified as an educational modality. Overall, with heterogeneity of studies it was challenging to state with confidence the usage of technology assisted learning.[9] Therefore, this curriculum adds a unique combination of CBL, through an elearning platform, targeting UME students, with a focus on MSK content.

In response to the perceived deficit in MSK content, an interdisciplinary team of instructors created an online, asynchronous module using CBL to strengthen MSK content over multiple years of medical school. These CBL modules and associated no-stakes self-assessments should provide students with a dynamic learning experience while building a better MSK foundation, resulting in improved performance on standard curricular assessments.

Methods

A group of medical educators who develop and administer MSK education within the formal curriculum designed this asynchronous curriculum to address perceived gaps in content present due to time constraints. The online module had two purposes: (1) to review content in a clinically-oriented manner that students already learned in the required curriculum, and (2) to provide more in-depth material than is covered in the required curriculum due to time constraints. All content included in the module was covered to a lesser extent throughout the students' preclinical curriculum.

The selection of 10 clinical cases was driven by the AAMC report[5] and the United States Medical Licensing Exam Step 1 content outline[10] with a focus on common musculoskeletal conditions. The foundational material included in the module, clinical case narratives, and embedded multiple-choice self-quiz questions were written by an orthopedic trauma surgeon, an orthopedic surgeon, an internal medicine/pediatrics physician, and two anatomy educators, all experienced in medical education and question writing.

Course Context

We deployed the MSK module in a second-year, preclinical UME integrated basic science course that included content related to the endocrine, reproductive, musculoskeletal, and dermatologic systems. The MSK section of the course covered musculoskeletal physiology, pathology, pharmacology, pathophysiology, and clinical presentation of common musculoskeletal disorders and their treatments over 17 contact hours (8 hours of lecture, 9 hours of small-group case work, coupled with faculty facilitation). Before completing the self-directed online module, students listened to recorded didactic lectures on bone physiology, tendon physiology, calcium and phosphorus metabolism, disorders related to musculoskeletal trauma, and joint and tendon disorders as part of the required MSK curriculum. They also had the opportunity to access self-quiz questions on these topics as part of overall course content.

Implementation

The online module started with four quizzes that allowed students to refresh their memory from previous coursework in foundational areas. The quizzes included: (1) a review of bone physiology, development, and healing (Appendix A); (2) basics of MSK radiography interpretation (Appendix B); (3) basics of

bone fractures (Appendix C); and (4) fracture complications (Appendix D). Students completed these quizzes before progressing into the clinical cases.

Ten clinical cases with embedded self-quiz questions then illustrated common orthopedic conditions and the underlying anatomic principles, including:

1. Shoulder Case (Appedices E & F)
2. Hand Case (Appendices G & H)
3. Hip Case 1 (Appendices I & J)
4. Hip Case 2 (Appendices K & L)
5. Hip Case 3 (Appendices M & N)
6. Knee Case 1 (Appendices O & P)
7. Knee Case 2 (Appendices Q & R)
8. Knee Case 3 (Appendices S & T)
9. Ankle Case (Appendices U & V)
10. Foot Case (Appendices W & X)

Each single-correct-answer quiz question included a rationale, if applicable, to further student learning. The content was built into quizzes in the Canvas learning management system (Instructure) and offered students one quiz attempt, with correct answers and rationales (if applicable) revealed after that attempt. After completing each quiz, students could then review a short, no more than 15 minutes (range: 3 minutes,12 seconds to 14 minutes,15 seconds), prerecorded mini-lecture reviewing the musculoskeletal condition and the underlying anatomical correlation. We recorded mini-lectures covering content using the PowerPoint file (Appendices F, H, J, L, N, P, R, T, V, and X) and embedded these recordings into Canvas.

The final stage of the module contained a comprehensive final quiz (Appendix Y) consisting of 16 multiple-choice questions based on the foundational and clinical material presented in the clinical cases. The comprehensive final quiz offered two attempts for learners to select the correct answer.

Evaluation of Objective Student Performance

We incorporated the online module into the MSK preclinical medical school course in February 2022. Students were told these modules were required by course leadership, however, no points were added nor detracted from their overall course grade based on their completion of these modules. Knowledge gained through course materials and completing the module was assessed on an online asynchronous formative exam taken by students near the end of the course, as well as a National Board of Medical Examiners (NBME) customized subject examination, which served as the final exam for the course. It should be noted that this NBME subject examination also included content related to endocrine, reproductive, and dermatology content that was presented alongside the MSK content in the preclinical medical school course.

All quantitative data were exported from their original platforms and imported into SPSS analysis software (Version27, IBM Inc.). We used Kendall's tau correlation analyses to identify correlations between student performance on the individual case quizzes, final overall module quiz, and performance in the MSK preclinical medical course (specifically the required formative MSK exam and NBME exams). Additionally, we compared performance between scores on the required formative MSK exam and NBME exam using independent-samples Mann–Whitney *U* tests. We compared scores on these assessments between (1) those students who completed any of the case quizzes compared to those who did not complete any of the case quizzes and (2) students who completed any of the quizzes were grouped into those who completed greater than 50% of the case quizzes and those who completed less than 50% of the case quizzes. For all statistical analyses, we utilized the score from the students' first attempt at each quiz to prevent bias as some students completed quizzes more than once.

Evaluation of Subjective Student Perceptions

Additionally, we assessed student perceptions using a 5-point Likert-based questionnaire hosted via an online survey platform (Qualtrics; Appendix Z). The questionnaires were available to learners after each clinical case and asked students to reflect on the effectiveness of each case in teaching them more about a specific MSK topic, whether the content was important to their future work, and whether the case and associated quiz was effective in helping them review the content they had learned in previous coursework (e.g., anatomy, physiology).

All evaluation procedures were deemed exempt by the Indiana University Institutional Review Board (IRB# 13139) and the Purdue University Institutional Review Board (IRB# 2021-1555).

Results

Of the 354 students enrolled in the MSK course, 258 (73%) completed at least one case in the module and associated quiz component of the case. Completion rates for all 15 quizzes ranged from 87% to 100%, with an overall average completion rate of 95%. Students completed an average of 14 out of 15 quizzes (93% of quizzes); the median number of quizzes completed by the students was 15 (100%). Of those who completed the quizzes within the module, the questionnaire response rates for each case averaged 18% (range: 10%-36%).

Objective Student Performance

Average quiz scores (for first attempts) ranged from 75% (fracture complications) to 98% (MSK radiography). The overall average score on all of the quizzes was 95%.

Compared to those who completed no quizzes, those who completed any quizzes received significantly higher grades on the formative MSK exam ($M = 83\%$, $SD = 9\%$, vs. $M = 86\%$, $SD = 8\%$; $p = .010$), the NBME subject exam ($M = 79\%$, $SD = 7\%$, vs. $M = 83\%$, $SD = 7\%$; $p < .001$), and in the multidisciplinary course overall ($M = 80\%$, $SD = 6\%$, vs. $M = 84\%$, $SD = 5\%$; $p < .001$).

Those who completed more than 50% of the quizzes received significantly higher grades compared to those who completed less than 50% of the quizzes on the formative exam ($M = 86\%$, $SD = 8\%$, vs. $M = 81\%$, $SD = 7\%$; $p = .035$), the NBME subject exam ($M = 83\%$, $SD = 7\%$, vs. $M = 79\%$, $SD = 5\%$; $p = .008$), and the multidisciplinary course overall ($M = 84\%$, $SD = 5\%$, vs. $M = 82\%$, $SD = 5\%$; $p = .021$). However, when those who completed the quizzes were split into those who completed all of the quizzes ($n = 15$) compared to those who did not complete all of the quizzes (i.e., completed 14 or fewer), those who completed all of the quizzes only did significantly better on the course final NBME exam ($M = 83\%$, $SD = 7\%$, vs. $M = 80\%$, $SD = 7\%$; $p = .047$) and the course overall ($M = 84\%$, $SD = 5\%$, vs. $M = 82\%$, $SD = 5\%$; $p = .023$). This indicates that the more quizzes the students completed, the better they did on cumulative assessments.

Subjective Student Perceptions

Overall, the individual cases were very well received. Response data from all cases were nearly identical, therefore only aggregate data are reported here. Students felt that the cases overall were effective in teaching them more about specific MSK topics ($M = 4.2$, $SD = 0.9$). They also felt overall that the content presented in the cases will be important to their future professional work ($M = 4.1$, $SD = 0.8$). Lastly, they felt that the modules were effective in helping them review content that they had learned in other courses ($M = 4.2$, $SD = 0.8$).

Discussion

Inadequate coverage of MSK conditions is a chronic problem plaguing medical school curricula.[3,11,12] While overall improvements had been made in MSK education[11], the current trend toward a shortened preclinical phase and omission of required orthopedic and MSK medicine experiences during the clinical phase of UME may potentially result in clinicians who are less competent and confident in their MSK knowledge and skills.[12] In an attempt to address this deficit in competency and knowledge, educational interventions focusing on MSK content among UME students have had variable outcomes.[13,14] However, clinical exposure to MSK conditions has been demonstrated to improve knowledge and confidence at both the undergraduate and graduate level of medical education.[15,16] Therefore, building a knowledge base and skill set in MSK medicine is a developmental process, but involving clinical MSK content in an UME preclinical curriculum could assist in this learning. Indeed, our results demonstrate that students engaged with the material and we demonstrate measurable outcomes using the cases and informal assessments we present in the current work.

Solid foundations in MSK physiology, pathophysiology, clinical anatomy, and clinical presentations of patients with MSK conditions can provide a knowledge base on which growing clinical experience may rest. An online, case-based module, such as the one we developed and tested, can offer a low-stress method for preclinical students to begin to develop the foundational knowledge that will support their ongoing learning over their lifespan as clinicians. The module was based on topics that had been at least touched on in the students' preclinical curriculum but provided more depth and clinical understanding, which allows it to be easily incorporated into other curricula, as the foundational knowledge for each disorder is still included in the materials.

CBL is used widely in medical education throughout the world and can impact learning and even positively impact patient care outcomes;[6] in addition, students simply enjoy learning through CBL.[7] In line with these results, our case-based module increased knowledge in learners, as evidenced by its correlation with higher exam and course grades, and was well received, as evidenced by feedback from the students. The student-driven, online module provided a flexible, low-stress learning environment for students, which was highly accepted by learners as evidenced by high usage rates and case and quiz completion and feedback. However, as previously demonstrated, a student's motivational profile may influence their study hours, use of deeper learning strategies, and result in better academic performance.[17] Therefore, it may stand to reason the results obtained from this current study may have been influenced by the students' motivational profile, however without assessing the students motivational profile it would be only speculation at how that may have influenced results.

Advantages of a comprehensive module that includes rationales for correct answers on quiz questions include the ability to provide symmetrical information across various medical school sites with a high ratio of learners to instructors. Limitations of the format include a restriction on real-time interaction and feedback.

We offered a faculty-moderated online question-and-answer tool within the Canvas learning management system site to provide feedback capability, but learners did not utilize this tool. However, it is important to note that despite this lack of direct interaction between students and faculty, students still improved their MSK knowledge and overall enjoyed and engaged with the content in a robust manner.

With the focus on burnout in academic medicine faculty in part due to excessive expectations, including teaching responsibilities and contact hours,[18] especially following the COVID-19 pandemic,[19] faculty effort is an important consideration when trying to incorporate such content into the curriculum, and our online module requires relatively little faculty effort. On a larger scale, it is difficult to measure the contributions of a single-phase preclinical intervention to building MSK knowledge and skills, and the cumulative effects of foundational modules plus clinical experiences combine to result in the clinician's MSK competence and confidence. While a weakness of this work is that we did not track long-term retention of the content, this module was introduced at the end of students' preclinical education, immediately prior to selection of desired clinical career path and associated clinical experiences. Therefore, tracking knowledge related to a single specialty (i.e., orthopedics) would have been fraught with variation as students who pursued orthopedic-related specialties would have likely retained content knowledge far better than those who did not.

Overall, this online, case-based MSK module provided foundational information in an effective delivery method to build MSK knowledge in preclinical medical students. These cases and concepts may apply to other health professions learners as well, offering content and a structure that could be adapted to various curricula in live settings as well as the online environment.

Appendices

A. Quiz - Bone Physiology Basics.docx

B. Quiz - Basics of Skeletal X-ray.docx

C. Quiz - Basics of Bone Fractures.docx

D. Quiz - Basics of Bone Fracture Complications.docx

E. Quiz - Shoulder Case.docx

F. Mini-Lecture - Shoulder Case.pptx

G. Quiz - Hand Case.docx

H. Mini-Lecture - Hand Case.pptx

I. Quiz - Hip Case 1.docx

J. Mini-Lecture - Hip Case 1.pptx

K. Quiz - Hip Case 2.docx

L. Mini-Lecture - Hip Case 2.pptx

M. Quiz - Hip Case 3.docx

N. Mini-Lecture - Hip Case 3.pptx

O. Quiz - Knee Case 1.docx

P. Mini-Lecture - Knee Case 1.pptx

Q. Quiz - Knee Case 2.docx

R. Mini-Lecture - Knee Case 2.pptx

S. Quiz - Knee Case 3.docx

T. Mini-Lecture - Knee Case 3.pptx

U. Quiz - Ankle Case.docx

V. Mini-Lecture - Ankle Case.pptx

W. Quiz - Foot Case.docx

X. Mini-Lecture - Foot Case.pptx

Y. Final Comprehensive Self-Quiz.docx

Z. Student Perception Assessment.docx

All appendices are peer reviewed as integral parts of the Original Publication.

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Ethical Approval

Indiana University and Purdue University Institutional Review Boards both deemed further review of this project not necessary.

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