

# Deconstructing the Joint Examination: A Novel Approach to Teaching Introductory Musculoskeletal Physical Examination Skills for Medical Students

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## Abstract

**Introduction:** Musculoskeletal (MSK) disorders are very common, but suboptimal teaching of MSK medicine occurs and expert clinicians agree that MSK physical examination (PE) skills can be confusing and complicated for medical students. An innovative approach in introductory teaching of MSK PE skills was developed using constructivist theory for second-year medical students. **Methods:** We implemented the MSK PE curriculum innovation in the second year of a four-year MD program, utilizing a standard framework with spaced practice and clinician coaching. We evaluated this curriculum by comparing the innovation group ( $n = 123$ ) to a historical control group ( $n = 134$ ) using an anonymous survey and OSCE station scores. Data analysis included repeated measures analysis of variance comparing students' self-confidence in MSK PE to students' self-confidence in other systems-based PEs, as well as independent  $t$ -test comparisons of self-confidence scores and MSK-specific OSCE station scores between the historical and innovation groups. **Results:** The mean self-assessed confidence of the historical group was significantly lower for the MSK PE than all other PEs ( $p < 0.001$ ), except for the neurological PE. Significant improvement in MSK PE self-confidence was noted with the innovation group ( $t(259) = -4.05, p < 0.001$ ). OSCE scores significantly improved in MSK-specific stations, with medium to large effect size across the different stations. **Discussion:** We successfully used a framework of deconstruction, repetition, and spaced practice to develop fundamental MSK PE skills in preclerkship medical students. This curriculum structure provides an effective example for teaching introductory MSK PE skills to early medical learners.

## Keywords

Preclerkship, Examination, Physical, Physical Examination, Musculoskeletal, Physiology, Musculoskeletal, Confidence, Physical Medicine & Rehabilitation, Rheumatology, Sports Medicine, Orthopedic Surgery, Clinical Skills Assessment, OSCEs, Clinical/Procedural Skills, Program Evaluation, Quantitative Research

## Educational Objectives

Following completion of all four sessions of the Musculoskeletal (MSK) Physical Examination (PE) series, students will be able to:

1. Apply a consistent approach and framework to each regional joint examination, including peripheral joints and the neck and back.
2. Identify and appropriately palpate bony and soft tissue structures using surface anatomical landmarks as a component of the regional joint exam.
3. Describe and demonstrate regional special tests for common disorders of the hip, knee, foot, ankle, shoulder, elbow, wrist, hand, and spine.
4. Describe and demonstrate a screening neurological examination of the cervical and lumbosacral regions, including dermatomes, myotomes, and deep tendon reflexes.
5. Describe positive findings on PE associated with common MSK disorders.

## Introduction

Musculoskeletal (MSK) disorders are common, comprising a significant number of health care visits to generalist and specialist physicians, and have a major impact on health care costs and utilization.<sup>1-3</sup> Despite the prevalence of MSK conditions and the potential to encounter such issues across different

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specialties, medical education authors have highlighted the suboptimal teaching of MSK medicine at all levels of medical education and across many geographical locations.<sup>4-6</sup> The inadequate foundational competence in MSK medicine at an early level of training may increase the potential for diagnostic and management errors for future physicians.<sup>7</sup> Improving the curriculum and teaching methods around MSK medicine was thus a significant focus from 2000-2010, a part of a global “Bone and Joint Decade” initiative.<sup>8</sup> The overarching goal was to improve the quality of life of individuals with MSK disorders.<sup>8</sup> However, nearly a decade after this global initiative, confidence and competence of medical learners in assessing and managing MSK disorders remains suboptimal.<sup>9-13</sup>

The clinical area of MSK medicine encompasses many different specialties, including rheumatology, sports medicine, orthopedic surgery, physical medicine and rehabilitation, emergency care and trauma, and primary care. One significant component of the MSK medicine curriculum is the teaching and learning of physical examination (PE) skills specific to MSK conditions. Many MSK conditions lack specific gold standard investigations to confirm a diagnosis, and accurate diagnosis is reliant on sound clinical reasoning involved in obtaining an appropriate history and a detailed and specific clinical examination. Expert clinicians in MSK medicine agree that MSK PE skills can be confusing and complicated for medical students,<sup>14,15</sup> and many attempts have been made to simplify or standardize the MSK PE curriculum.<sup>16-19</sup> Previously developed curricular approaches to teaching MSK PE skills have included the establishment of a core set of MSK clinical skills for medical students,<sup>16,17</sup> various checklist or objective structured clinical examination (OSCE) style approaches,<sup>20-28</sup> computer-assisted educational tools,<sup>29,30</sup> and utilization of many different types of teachers (e.g., MSK specialists vs. generalist clinician teachers,<sup>31,32</sup> trained patient volunteers,<sup>33-44</sup> or peer/near-peer facilitators<sup>45-51</sup>). Despite the abundant literature outlining a plethora of methods and approaches for the delivery and teaching of MSK PE skills, low student confidence and competence in MSK PE skills persist.<sup>9-11,13,23,26,52,53</sup> No prior work has taken the approach of deconstructing the MSK PE content, as described below, in order to focus on enhanced student understanding of the relevant anatomy and associated clinical correlations.

#### Theoretical Basis of Curriculum

Our novel curriculum was developed using constructivist theory, as described by Jerome Bruner, by creating a framework for learners to build new knowledge on top of their prior knowledge and experiences, and by utilizing a spiral curriculum with basic

ideas repeated to build mastery of the concepts and skills.<sup>54</sup> A standard framework for the MSK PE has existed for many years, with historical and modern texts describing a similar sequence for the MSK PE of inspection, palpation, range of motion, and special tests (e.g., “look, feel, move, special tests”).<sup>55,56</sup> Despite the existence of this framework and various tools such as the checklists described above, students have continued to struggle with learning the components of the MSK PE. One major barrier for medical students has been identified as a deficiency in the basic relevant anatomical knowledge.<sup>14</sup> Our curricular innovation thus restructured the historical framework and deconstructed each of the regional joint examinations into an introductory session covering the relevant MSK anatomy, joint range of motion, and palpation of the basic structures in a region, followed by a second session covering the MSK special tests for each region. The goal of this deconstructed approach was to allow novice learners to develop comfort and experience with the applicable functional anatomy, have an opportunity for repeated exposure to each joint over two sessions, and add the more complex special tests in the second session. Each session also included stations on multiple joints presented in a similar format to emphasize the standard framework of a regional joint examination regardless of the specific joint.

In our effort to provide repeated exposure to a spiral curriculum and to enhance motor learning of the PE skills,<sup>57-59</sup> we also incorporated spaced timing of the introductory and special tests sessions with a minimum of one week between each session for the lower and upper limbs. Furthermore, we recruited MSK specialty clinicians as session tutors in order to provide opportunities for formal feedback and supervised deliberate practice of the students’ examination skills during each session.

#### Local Context and Impetus for Change

At our institution, MSK PE is introduced in the second year of a four-year medical school program, as part of a longitudinal clinical skills curriculum that runs parallel to the systems-based course on MSK medicine. Prior to this, students are exposed to and have opportunities to practice the PEs of other systems, including the cardiovascular, pulmonary, and abdominal systems. Opportunistic exposure to the MSK PE may occur for some students during clinical shadowing or preceptorship experiences, but there is no formal teaching of MSK PE or exposure to MSK anatomy, pathophysiology, and common disorders until this course. The MSK PE curriculum at our institution historically included two introductory sessions (one lower limb session and one upper limb session) taught by trained patient volunteers from the local Arthritis Society (based on prior educational evidence),<sup>33-44</sup> and

two more specialized sessions (one lower limb session and one upper limb session) taught by MSK clinicians. In 2016-2017, a needs assessment was performed using a survey of student self-confidence in MSK PE skills for evaluation of our current status. These results confirmed low student confidence in MSK PE skills compared to other systems-based PE skills (Table 1). Curricular change was thus initiated, with implementation of the current resource in the 2017-2018 academic year. In addition to the new curriculum, another major change included the use of MSK clinicians exclusively as session tutors, as the patient volunteer tutor program was discontinued due to lack of volunteer availability. The primary goals of our curricular approach were to provide a structured framework and spaced practice for the introduction of MSK PE skills to the novice learner, in order to improve learner confidence and competence. We introduced a new approach of deconstructing the regional joint examination into component parts taught over several sessions, which, to our knowledge, has not been previously described in any prior publication in an academic journal such as *MedEdPORTAL*.

**Methods**

**Implementation**

*Scheduling* The MSK PE curriculum was delivered on four separate days, with each day spaced at least one week apart. Each day consisted a 2-hour session that included four or five PE stations, with each station having one clinician tutor and lasting 20 to 25 minutes. Students were divided into small groups of four to six students per group, and groups then rotated through the stations. The duration for one full rotation through all PE stations was 110 minutes. Several sets of PE station rotations were run concurrently, and each full rotation of PE stations ran twice in a half-day for us to be able to accommodate 160 students each year. The total number of tutors and rotations can be modified depending on the number of students and the available time in the curriculum for each session. Appendix A contains the example scheduling format used for all sessions.

**Table 1.** Repeated Measures of Analysis of Variance Comparing Student Mean Self-Confidence Scores Between Various System PEs and MSK PE

System PE	M Difference Between Each System PE and MSK PE	
	Traditional Group <sup>a</sup>	Innovation Group <sup>b</sup>
Abdominal	.66 <sup>c</sup>	.37 <sup>c</sup>
Cardiovascular	.53 <sup>c</sup>	.14 <sup>c</sup>
Neurological	.10	-.08
Respiratory	.70 <sup>c</sup>	.33 <sup>c</sup>

Abbreviations: PE, physical examination; MSK, musculoskeletal.  
<sup>a</sup>n = 134  
<sup>b</sup>n = 123  
<sup>c</sup>p ≤ .05

*Personnel and teaching materials:* Clinician tutors were recruited several months in advance and provided with the session Student Guide (Appendix B) and Tutor Guide (Appendix C) for review approximately 1 to 2 weeks prior to the session. Tutors were asked to review these documents in advance so that they were aware of the expectations of the content that was to be covered at each station during each session. A brief 5-minute orientation emphasizing the structured framework and goal for deliberate practice was provided by the module coordinator (Jaime C. Yu) at the beginning of each session. All tutors were assigned to only one individual station during each session so that preparation time was manageable. All tutors had regular clinical experience in MSK medicine, with broad specialty representation including rheumatology, physical medicine and rehabilitation, orthopedic surgery, and sports medicine (a family medicine subspecialty). Participating resident physicians were in their second postgraduate year or higher and included trainees from the disciplines listed above.

The module coordinator (Jaime C. Yu), an MSK-expert clinician, provided the introductory lecture and orientation to the four-session curriculum. This introductory lecture was given at the beginning of Session 1 as a large-group session with all students in the auditorium, who then moved to the clinical skills rooms to continue the rotational format of the session. Lecture slides and details are provided in Appendix D and could be used as either prereading for students or delivered in a lecture-style session by a clinical teacher. Following standard institutional policy, students were asked to practice examination techniques on each other during these sessions; standardized or volunteer patients were not used. All students and tutors were informed that any student could ask to be exempt from being examined at their discretion, and that this would be respected (Appendix E). Our curriculum could be implemented with standardized or volunteer patients if such resources were available. A focused history station with real volunteer patients was included in the first session for objectives outside the scope of our curriculum and was not a formal component of the MSK PE curriculum; these patients were not examined by students.

*Resource materials for students:* Students were provided with the Student Guide (Appendix B) for each session at least one week prior to the scheduled session. A brief 10-minute introductory lecture (Appendix D) was provided at the beginning of Session 1 for all students, outlining the overall curriculum and emphasizing the standard framework and approach to the MSK PE. Setting the stage with this introduction was a crucial component of our approach, as “novice learners lack proper schemas to integrate the new information with their prior knowledge.”<sup>60</sup>

Organization and use of teaching and resource materials: All required teaching materials are provided in the Appendices.

Table 2 summarizes the objectives and timing for the use of each Appendix.

Evaluation Strategy

**Needs assessment:** Student self-confidence in various systems-based PE skills was tested in our local medical student population using an anonymous survey administered at the beginning of third year for both groups, approximately 6 months after the completion of the MSK PE curriculum. Students were given a web address to complete the survey, and no identifying information was requested. The Musculoskeletal Self-Assessment Tool (MSAT) developed by Vivekanandanda-Schmidt and colleagues was reviewed as a basis for the evaluation survey,<sup>13</sup> but ultimately survey questions were created de novo by the research team as the MSAT questions were too broad and not primarily focused on MSK PE. Our survey was piloted with an unrelated group of summer research students to refine question syntax and time for completion of the survey prior to being implemented. Students were asked whether they agreed with the statement, “I feel confident performing the [insert system] physical exam,” using a 4-point Likert scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *agree*, and 4 = *strongly agree*), with higher scores indicating higher self-confidence (Appendix F). Systems included cardiovascular, respiratory, abdominal, MSK, and neurological. Survey data was collected and managed using REDCap<sup>61</sup> electronic data capture tools. The PE curriculum for all systems, except for MSK, was taught using a similar approach within a longitudinal clinical skills curriculum. Our first evaluation

question was: “Is student self-confidence in MSK PE skills lower than self-confidence in the other systems-based PEs?” We examined this question using a repeated measures analysis of variance to compare reported self-confidence in MSK PE to other systems-based PEs in each cohort. For the post hoc comparisons, we used the least squares difference method, and the a priori significance level was set as  $p < 0.05$ . Statistical analysis was completed using SPSS (version 25).

**Curriculum evaluation:** We evaluated the new MSK PE curriculum by comparing the 2016-2017 historical control cohort, taught with the traditional curriculum described above, to the 2017-2018 innovation cohort, taught with the new curriculum. Our second evaluation question was: “Is there a difference between reported self-confidence in MSK PE in the traditional versus innovation cohorts?” Mean self-confidence scores were compared using an independent *t*-test using SPSS (version 25). Our third evaluation question was: “Does the new curriculum improve student MSK PE competence, as measured by mean scores on MSK-specific stations within the comprehensive end-of-second-year OSCE examination covering all systems-based PEs?” Each student was examined on a combination of three out of four possible MSK-specific stations (hand, shoulder, knee, or back) as part of this regular year-end examination, occurring four months after completion of the MSK PE curriculum. Stations were scored using a standardized checklist of required PE maneuvers. Mean scores were compared for each MSK-specific station between the traditional and innovation cohorts using an independent *t*-test, and Cohen’s *d* effect sizes were also calculated.

Table 2. MSK PE Teaching and Educational Resources

Resource	Intended User	Objective of Resource and Timing of Use
Appendix A: Session & Station Schedule	Module coordinator	The schedule is used to organize rotational stations for each session and assign clinical tutors to each small group. The schedule should be completed by the module coordinator at least two weeks in advance of first session.
Appendix B: Student Guide	Students	The student guide contains documents for all four sessions. Resource documents can be provided to students as a complete package, but students must be reminded to read and review the appropriate session documents at least one week prior to each specific session.
	Clinician tutors	The student guide is also provided to all tutors so that they are aware of what preparation materials students are given prior to the sessions, as well as to ensure tutors are aware of expectations regarding content being covered at each station. These should be provided to tutors at least one week in advance of the session they are teaching.
Appendix C: Tutor Guide	Clinical tutors	The tutor guide lists specific instructions to tutors for each station and highlights any physical examination skills that are essential to learn at a station. The tutor guide references the student guide for specific station content. These should be provided to tutors at least one week in advance of the session they are teaching.
Appendix D: Introductory Lecture Slides	Module coordinator or introductory lecturer	The lecture slides are used by the module coordinator to introduce students to the “Look, Move, Feel” framework of the MSK physical examination. This lecture is delivered at the beginning of Session 1 as a brief introduction for the students, with the duration of the lecture being 10-15 minutes.
	Students	Lecture slides are provided to the students following the introductory lecture. Recommended resources are listed within the slides.
Appendix E: Student Notice	Students and clinical tutors	The policy on peer examination is provided to students and tutors one week prior to Session 1 so that they are aware the sessions involve peer examination, as well as so that any student wishing to opt out of being examined may do so by notifying the module coordinator. All students reserve the right to decline being examined during the sessions as well, and the clinical tutors are made aware of this.

Abbreviations: MSK, musculoskeletal; PE, physical examination.

**Ethics:** This project was approved by the University of Alberta Research Ethics Board.

**Results**

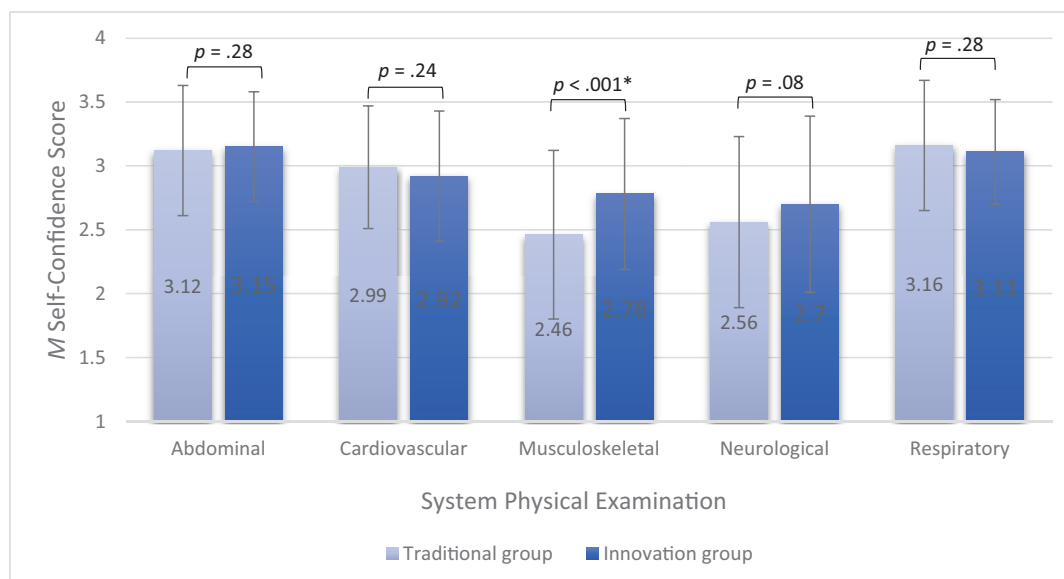
The response rate for the online survey was 83% (134/162) of students in the traditional cohort and 75% (123/164) of students in the innovation cohort. Survey responses regarding student self-confidence in PE skills showed a significantly lower mean self-confidence rating for MSK PE compared to all other systems-based PE, except for the neurological PE, for students in both the traditional and innovation cohorts (Table 1).

Regarding the efficacy of the new MSK PE curriculum, a significant increase in reported self-confidence scores for MSK PE was noted in the innovation group ( $M = 2.78$ ,  $SD = 0.59$ ) compared to the traditional group ( $M = 2.46$ ,  $SD = 0.66$ );  $t(259) = -4.05$ ,  $p < 0.001$ . A trend of improvement in self-confidence scores for the neurological PE was noted, but this did not statistically significant. No other system-based PE showed improvement in student self-confidence (Figure). Student performance in the MSK-specific stations for the OSCE examination at the end of the second year also improved, with significant increases noted in the mean OSCE station scores for all stations except the hand station, with medium to large Cohen’s  $d$  effect size (Table 3).

**Discussion**

Despite an extensive array of available curricular approaches and educational tools targeting the teaching and learning of MSK PE, medical learners continue to struggle with the acquisition of these important clinical skills. Our curricular innovation represents an innovative and efficacious approach for those educators involved in the design and delivery of curriculum for introductory MSK PE teaching. The use of a standard framework—the “look, move, feel, special tests” approach—in itself is not unique, as many different resources have previously been developed with this in mind.<sup>55,56,62,63</sup> However, our use of this standard approach with the intentional repetition across all regional joint examinations emphasized the sameness of the MSK PE regardless of the specific joint and assisted students in learning categories and an approach, rather than simple memorization of a list. The particularly unique feature of our curricular innovation was deconstructing the components of each detailed examination and repeating this across several joints in the same day. Students were provided experiences with multiple joints during a single session through the rotating station format, and this repetitive framework emphasized the foundational functional anatomy.

Our curriculum was designed using a constructivist or spiral curriculum style of learning. Students focused on fundamental knowledge and simple hands-on skills in the first session,



**Figure.** Mean self-confidence scores comparing traditional and innovation groups for each system physical examination, as rated on a 4-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). Error bars demonstrate SD of reported M scores. Significant change between groups is denoted by an asterisk, indicating  $p < 0.05$ .

**Table 3.** Comparison of MSK-Specific OSCE Station *M* Scores Between Traditional and Innovation Student Groups

Station	Traditional Group <sup>a</sup>		Innovation Group <sup>b</sup>		<i>M</i> Difference Between Traditional and Innovation Groups (%)	<i>t</i> -value	<i>p</i>	Cohen's <i>d</i>
	<i>M</i> Station Score (%)	<i>SD</i> (%)	<i>M</i> Station Score (%)	<i>SD</i> (%)				
Hand	90	6	88	9	-2	-2.33	.020 <sup>c</sup>	-0.37
Shoulder	86	9	94	6	+8	8.12	< .001 <sup>c</sup>	1.56
Knee	85	8	88	8	+3	3.22	.001 <sup>c</sup>	0.62
Back	87	9	91	7	+4	3.23	.001 <sup>c</sup>	0.62

Abbreviation: MSK, musculoskeletal.

<sup>a</sup>*n* = 134

<sup>b</sup>*n* = 123

<sup>c</sup>*p* ≤ .05

including recognizing surface anatomy, palpation of appropriate structures, and recognizing range of motion of the joints. They returned to the same joint one to two weeks later, building on these basic skills by next learning and practicing the special tests for each joint. The time between sessions allowed for spaced practice, during which students had the opportunity to practice their skills with each other and further consolidate their learning. The repeated exposure to each joint over two sessions, compared to the more traditional massed practice approach of teaching each regional joint exam in detail in a single session, provided further opportunities for students to build on their prior experiences from the first session and any other MSK content knowledge acquired between sessions. With regards to medical education, Reg Dennick described that, “The constructivist theory of learning... is based on the premise that the act of learning is based on a process which connects new knowledge to preexisting knowledge,” and “if sense or meaning can be attached to [an] experience then the experience fits with existing cognitive structures.”<sup>64</sup> By applying such theories at the preclerkship training level, we hoped that a strong foundation was established for these students as they progressed into their clinical training years and continue to gain further episodic exposures and opportunities to practice their MSK clinical skills.

Our evaluation measures for this curriculum included a baseline assessment of student self-confidence, which confirmed significantly lower MSK PE self-confidence compared to other systems-based PEs. This finding supported established literature showing low confidence in MSK PE and provided a good indication for the need for curricular change. Our curriculum innovation successfully increased student reported self-confidence and competence (as measured by improvements on the MSK-specific OSCE stations) in the performance of these important MSK clinical skills. The noted improvements represented a meaningful change, as shown by the medium to large effect sizes across the shoulder, knee, and back examination OSCE stations. There was a decrease in the mean scores of the hand examination station, with small effect size,

which was likely related to the shift from having the trained patient volunteers teaching the introductory sessions in the traditional group, as their session was more specifically focused on the hand examination. Although students had less detail regarding the hand examination, which resulted in lower scores for that particular MSK PE skill, students overall demonstrated meaningful improvements in confidence and competence across a broader range of MSK PE skills.

There were some limitations to the implementation and evaluation of this educational resource. The most significant issue was that all sessions required facilitation by clinicians, including both resident physicians and faculty clinicians. Such high levels of clinician human resources may not be available at all medical schools, and recruitment for teaching these sessions remains a concern at our institution. Several recent studies have shown success for near-peer teachers, using either senior medical students or early resident physicians as the primary teachers for MSK PE,<sup>45-51,65</sup> and thus alternatives for session tutors could be considered in order to increase the pool of potential teachers. In terms of our evaluation, comparisons were made between only one preimplementation and one postimplementation group. There remains the potential that the significant difference noted between groups in MSK PE self-confidence scores represented a single cohort effect; however, the corresponding medium to large effect size of the significant improvements in MSK-specific OSCE station mean scores provided further confirmation of the positive impact of this curricular change. Lastly, this curriculum has been implemented in only one medical school, and thus it would be interesting and beneficial to note if similar improvements occurred at another institution.

Future directions for this curriculum include ongoing evaluation for continuous quality improvement, including monitoring student outcomes as measured by success on assessments during training, and review of student evaluations and narrative comments regarding acceptability of this curriculum from the learner perspective. Other potential tools to augment the

curriculum include the use of joint models or skeletons to assist in learning bony landmarks and surface anatomy within the sessions and incorporation of point-of-care ultrasound technology to allow real-time dynamic visualization of the MSK structures being examined. Further studies to compare MSK PE student self-confidence levels to other systems-based PE student self-confidence levels, to determine which factors contribute to increased MSK PE self-confidence, and to understand the learner perspective with regards to the teaching and learning of the MSK PE are underway. Analyzing future results may be useful to further refine this curriculum. Ongoing updates to the curriculum resource documents (e.g., the Student Guide and the Tutor Guide) are also planned, to ensure the information remains appropriately current and clinically relevant.

## Appendices

- A. Session & Station Schedule.docx
- B. Student Guide.docx
- C. Tutor Guide.docx
- D. Introductory Lecture Slides.pptx
- E. Student Notice.docx
- F. Student Confidence Survey.docx

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

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## Prior Presentations

Yu JC, Satkunam J, Davila-Cervantes A, Rashid M, Hodgson CS. A mixed methods study of University of Alberta medical students' confidence and perceptions on their musculoskeletal (MSK) physical examination curriculum. Poster presented at: Canadian Association of Physical Medicine and Rehabilitation 66th Annual Scientific Meeting; June 1, 2018; Whitehorse, YK.

Yu JC, Guo Q, Hodgson CS. The musculoskeletal (MSK) physical exam: improving learner confidence in an essential clinical skill. Podium presentation at: University of Southern California Keck School of Medicine 2019 Innovations in Medical Education Conference; February 22, 2019; Los Angeles, CA.

## Ethical Approval

The University of Alberta Research Ethics Board approved this study.

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