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TOPICS IN TRAINING

Design and Implementation of a System-Based Course in Musculoskeletal Medicine for Medical Students

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Background: The amount of time devoted to musculoskeletal medicine in the typical undergraduate curriculum is disproportionately low compared with the frequency of musculoskeletal complaints that occur in a general practice. Consequently, whether because of the quantity or quality of the education, the competence level of graduating physicians regarding musculoskeletal problems is inadequate. Our purposes were to design a self-contained, system-based course in musculoskeletal medicine for medical students in the preclinical years and to measure the level of competence achieved by a class of first-year medical students who took the course.

Methods: The course was formulated by faculty from the departments of orthopaedic surgery, anatomy, and rheumatology and included elements of both objectives-based and problem-centered curricular models. The clinical lectures were preceded by pertinent anatomy lectures and dissections to provide a context for the clinical information. The lectures on basic science were designed to rationalize and explicate clinical practices. Small-group activities were incorporated to permit engagement of the students in critical thinking and problem-solving. A general musculoskeletal physical examination was taught in two two-hour-long small-group sessions with the orthopaedic residents serving as instructors. Cognitive competency was evaluated with use of comprehensive anatomy laboratory and written examinations, the latter of which included a validated basic competency examination in musculoskeletal medicine. Process-based skills were evaluated in the small-group meetings and in a timed, mock patient encounter in which each student's ability to perform the general musculoskeletal physical examination was assessed.

Results: The course lasted six weeks and consisted of forty-four lecture hours, seventeen hours of small-group meetings, and twenty-eight hours of anatomy laboratory. The average student score on the basic competency examination was 77.8%, compared with 59.6% for a historical comparison group (p < 0.05). Each student demonstrated the ability to adequately perform a general musculoskeletal physical examination in twenty minutes. The survey of student opinion after the course indicated a high level of student satisfaction.

Conclusions: The main features of the course were: (1) an emphasis on both cognitive and process-based knowledge; (2) more contact hours and broader content than in previously described courses in musculoskeletal medicine; (3) the use of small groups to focus on problem-solving and physical examination competencies; (4) basic-science content directly related to clinical goals. These features might be used at other institutions that employ a system-based curriculum for the preclinical years to help improve competence in musculoskeletal medicine.

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The amount of time devoted to musculoskeletal medicine in the typical undergraduate curriculum is disproportionately low compared with the frequency of musculoskeletal complaints that occur in a typical general practice^{1,2}. Not surprisingly, the musculoskeletal competency level of primary-care physicians graduating from medical school has been deemed to be inadequate³⁻⁵. The deficits in instruction and clinical competency indicate the need for curricular reform in undergraduate medical education dealing with the musculoskeletal system^{6,7}.

Appropriate objectives for education in musculoskeletal medicine were suggested^{7,8}, and a course to teach the necessary knowledge and skills was described and evaluated in a prospective outcomes study9. The Association of American Medical Colleges (AAMC) developed reports and a curriculum management database^{7,10,11}; however, the AAMC effort was not directed toward designing a course but rather toward educational philosophy, establishing a rationale for expanding the footprint of musculoskeletal medicine in the preclinical curriculum and encouraging medical school officials to dedicate the appropriate resources. A detailed description of a complete course appropriate for medical students in the first preclinical year is presently not available.

Our primary purposes were to design a self-contained, system-based course in musculoskeletal medicine and to measure the level of competence achieved by a class of first-year medical students who took the course. Our secondary purpose was to assess whether there was a correlation between the students' knowledge of musculoskeletal anatomy and that of the other forms of cognitive knowledge taught in the course.

Materials and Methods *Course Setting*

The Curriculum Committee at our institution redesigned the preclinical curriculum to conform to the Guidelines of the Liaison Committee on Medical Education. The basic principles and language of the sciences per-

TABLE I	Curricul	um for the	Preclinical	Years
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	No. of Weeks
First year	
Core courses	
Biochemistry	19*
Physiology-pharmacology	19*
Anatomy	19*
Immunology	19*
Other learning activities	19*
Organ system courses	
Musculoskeletal medicine	6
Medical neuroscience	13
Second year	
Infectious disease	7
Hematology and oncology	4
Cardiovascular system	5
Integrative processes	2
Renal system	4
Integument	1
Respiratory system	4
Gastrointestinal system	5
Endocrine and reproductive systems	7
*The courses run concurrently.	

tinent to the practice of medicine were introduced in four courses in the first half of year one, all of which were built around a unifying clinical case of the week (Table I). The last half of the first year and the entire second year were organized into eleven systembased courses designed to integrate the teaching of molecular, cellular, and organ-system processes in relation to normal physiology and disease; musculoskeletal medicine was designated as the first course in the series.

Course Design

The course was designed by faculty from the departments of orthopaedic surgery, anatomy, and rheumatology, with the general aim of providing an adequate foundation of primary-care knowledge of the musculoskeletal system (Fig. 1). The learning objectives were defined by formulating answers to two questions: (1) What objectives, if achieved, would best implement the decision of the Curriculum Committee to create a course that deemphasized rote learning in lectures and emphasized knowledge integration and active learning? (2) What cognitive-based and process-based knowledge of musculoskeletal medicine should be expected of a medical school graduate? The starting point for implementation was a decision that competency in musculoskeletal medicine required knowledge of specific material and knowledge of processes that cannot be identified with the high level of specificity possible with lecture-based objectives. We therefore included elements of both objectives-based and problemcentered curricular models. In broad terms, the cognitive objectives for the course corresponded to the first three levels of Bloom's taxonomy of cognitive complexity¹². The required texts were Musculoskeletal Medicine¹³, Primer on the Rheumatic Diseases¹⁴, and Essential Clinical Anatomy¹⁵. The student was expected to learn the important information, recognize its relation to particular clinical problems, and begin learning the process of interpreting and applying information in the context of signs and symptoms manifested by patients with musculoskeletal disorders.

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Fig. 1

Design elements for the course in musculoskeletal medicine.

We assumed that the overall effectiveness of the course would depend substantially on the students' activities outside the classroom¹⁶. Specific readings were assigned for most classes, and PowerPoint slides (Microsoft Office; Microsoft, Redmond, Washington) of the material to be presented were made available for downloading from the course web site prior to the class. Each clinical lecture was preceded by pertinent anatomy lectures and dissections to provide a context for the clinical information presented in the lecture.

Because students who are actively involved in the learning process are more efficient learners¹⁷, smallgroup activities were incorporated into the course to facilitate engagement of the students in critical thinking and problem-solving. The small-group setting allowed the students to interact with the instructor and with their peers, both giving and receiving immediate feedback. The basic idea was that the instructor should serve more as a facilitator and less as an oracle¹⁸. The students worked on particular clinical problems as a means of developing both interpersonal skills (an ability to work with other students) and the ability to reflect on and analyze the meaning of particular items of evidence associated with a case (intrapersonal skills).

The orthopaedists and rheumatologists had different understandings of the technique and principles of physical examination; both approaches were taught in small-group sessions. The rheumatologic approach was based on the *Primer on the Rheumatic Diseases* (pages 117 to 124)¹⁴, and student performance was evaluated by the instructor at the end of the session. The orthopaedic approach was based on the general musculoskeletal physical examination as demonstrated on the compact disc accompanying *Musculoskeletal Medicine*¹³.

The general musculoskeletal physical examination was taught in two twohour-long small-group sessions on the upper and lower extremities, respectively; spine and gait were included in the second session. The goal was to develop competency regarding how a patient should be approached, addressed, questioned, and physically examined from the neck to the toes for musculoskeletal problems; the sessions closely followed the students' anatomic studies of the related body areas so that the rationale for the particular steps in the physical examination could be related to the musculoskeletal anatomy. A typical session on the general musculoskeletal physical examination consisted of a mock patient (the examinee) and five students, with an orthopaedic surgery resident serving as the instructor. These residents had been recruited by the orthopaedic program director because teaching undergraduates is an important part of resident education. The residents were trained to ensure uniformity in the manner in which the material on the compact disc was taught. A standardized list that comprised items from specific examinations, anatomic landmarks to be identified, and basic orthopaedic terminology required for properly performing or explaining a musculoskeletal examination was developed; the residents used the list to evaluate and critique each student's performance of the examination.

We emphasized intrapersonal, interpersonal, and sensory motor skills but did not explicitly address attitudes (altruism and sense of duty, for example) because they were addressed in other curriculum activities, some of which took place during the course in musculoskeletal medicine and others that occurred before and/or after the course.

Evaluation

The form of the assessment used in a course typically triggers a strategic approach by the students regarding how to cope with the demands of that assessment. We designed the assessment tools with the aim of reinforcing the course objectives. Mid-course and final multiple-choice examinations were given; they consisted mainly of vignettestyle questions that required the students to know the information presented and how it should be applied. The questions were prepared by the class instructor and were vetted to ensure that they dealt with the most important aspects of what was taught. An average of five questions was included on the written examinations for

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	Hours in Small		
		Group Meetings	
	Lecture	or Anatomy	
	Hours	Laboratory	
Orthopaedics			
History-taking	1	-	
Physical examination	2	4	
Spine	2	2	
Hand	2	-	
Shoulder and elbow	1	-	
Upper extremity	-	2	
Pediatric	1	-	
Trauma	1	2	
Metabolic disease	1	_	
Pelvis and hip	1	_	
Knee	1	_	
Foot and ankle	1	_	
Lower extremity	_	2	
Sports medicine	1	_	
Radiology	3	-	
Total	18	12	
Basic sciences			
Muscle	1		
Bone	1		
Soft tissue	1		
Drugs	3		
Pathology	2		
Total	8		
Anatomy			
Back and spinal column	1	6	
Shoulder and arm	2	6	
Wrist and hand	2	3	
Gluteal region and thigh	1	3	
Leg	1	3	
Foot	1	2	
Hip, knee, and ankle	1	3	
Histology of cartilage and bone	2	2	
Embryology	1	-	
Total	12	28	
Rheumatology			
Arthritis	2	3	
Spondyloarthropathy	1	_	
Scleroderma	1	-	
Myositis	1	-	
Lupus erythematosus	1	-	
Physical examination	-	2	
Total	6	5	

each hour of lecture or small-group meeting. The final examination was comprehensive but contained fewer than five questions for each of the classes in the first half of the course. The basic competency examination in musculoskeletal medicine, developed and validated by Freedman and Bernstein^{3,19}, was included in the final examination, which also contained 125 multiple-choice questions; none of the thirty course faculty (except for the first and last authors) were aware that the basic competency examination would be included. The results from the basic competency examination were compared with those from a historical control group^{3,19}, with use of the Fisher exact test.

Weekly quizzes were given in the anatomy laboratories; the students in a particular laboratory session were required to demonstrate an appropriate level of mastery of the material presented before being permitted to proceed to the next session. Mid-course and final anatomy laboratory examinations were given, and each consisted of a series of timed stations where the students identified structures in tagged cadavers.

In the small groups, the students were expected to synthesize information to reach a diagnosis or estimate a prognosis. The primary technique was the creation of cases in which sketchy information regarding signs and symptoms of a patient was given and then was used as a springboard to question individual students regarding what other information might be needed, why, and what the implications might be, depending on precisely what information was received. The focus of the sessions was less on objective content (compared with the lectures) and more on learning processbased skills, including how meaning is made from signs and symptoms, how information necessary for that process is obtained and evaluated, and how patients are examined.

Each student's ability to perform the general musculoskeletal physical examination was assessed in a simulated doctor-patient encounter in which only the student and the examinee were present in the examination room. The student was required to perform the complete examination within twenty minutes, and the encounter was videotaped with use of multiple cameras to allow an assessment of whether each step in the examination had been performed properly. In addition, fifteenitem checklists (based on the list used in the resident teaching sessions) were prepared to aid in probing the students' knowledge of individual steps in the physical examination, anatomic



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Fig. 2

Performance of the 112 first-year medical students on the orthopaedic cognitive mastery test developed by Freedman and Bernstein compared with their results from a group of eighty-five first-year residents^{3,19}.

landmarks, and key terminology (for example, active compared with passive range of motion, and flexion compared with extension). Six different checklists were developed; the one used to structure the evaluation of any particular student was determined by chance. The performance of the examination was also graded by the examinee who had been trained in the various knowledgebased items pertinent to it. Students who performed inadequately were allowed remediation with a repeat doctor-patient encounter, including the use of a different checklist.

The written and laboratory examinations contributed 75% and 25%, respectively, to the final course grade. The percent ranges for the letter grades were defined before the course began; consequently, the students did not compete against one another. The written examinations were not returned to the students; further, the students were charged under the student honor code to never discuss any question with any other person other than a member of the class. This rule, which permitted the reuse of questions previously shown to be probative and statistically valid, resulted from our decision that the ability to reliably measure the knowledge produced by the faculty's effort was more important than apprising individual students regarding

which questions they had answered incorrectly.

To evaluate the relationship between anatomic knowledge and the other kinds of cognitive knowledge presented in the course, we calculated each student's anatomy score (defined as the percentage of correct answers on the final laboratory examination and to the questions on the final written examination that were propounded by the anatomists) and clinical and basicscience score (defined as the percentage of correct answers to all other questions on the final examination except the basic competency examination questions), and calculated the Pearson correlation coefficient (r) between the two scores.

The students were required to rate each faculty lecturer and smallgroup leader (with a rating of 1 indicating unsatisfactory; 2, satisfactory; and 3, exceptional) and the orthopaedic residents who led the small-group meetings on the general musculoskeletal physical examination (with use of an analog scale of 1 to 5, with a score of 5 indicating exceptional).

Results

The course consisted of forty-four lecture hours, seventeen hours of smallgroup meetings, and twenty-eight hours of anatomy laboratory (Table II). The anatomy lectures and laboratories covered essentially the same





Correlation between the anatomy scores and the clinical and basic-science scores of the 112 students on the final examinations (Pearson r = 0.73, p < 0.05).

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The results of a survey performed after the course to assess the opinions of the 112 students with regard to faculty performance, showing the average scores (and standard error) within the indicated topic areas.

material as in the old curriculum but in six consecutive weeks rather than over two years. The sequence in which the anatomic areas were taught served as the basic organizing principle for the presentation of the clinical topics. On the average, the six-week course consisted of 7.3 hours per week of lecture, 4.7 hours per week of anatomy laboratory, and 2.8 hours per week of smallgroup meetings.

The orthopaedic lectures were organized anatomically and topically to correspond to the common orthopaedic subspecialties; the lectures were given by an orthopaedic surgeon with fellowship training in the topic presented. The orthopaedic small-group meetings were a series of case-based discussions centered on cases dealing with the upper extremity, lower extremity, spine, and trauma. The primary technique was the creation of cases in which sketchy information regarding signs and symptoms of a patient was given and then was used as a springboard to question individual students regarding what other information might be needed, why, and what the implications might be, depending on precisely what information was received.

The rheumatology lectures were given by rheumatologists and were organized on the basis of the major rheumatologic diseases (Table II). The small-group meetings dealt with rheumatoid arthritis, gout, virus-induced arthritis, and principles of the joint examination.

Non-neoplastic and neoplastic bone diseases were presented in separate lectures by a pathologist. Two drug lectures dealing, respectively, with steroidal medications and nonsteroidal medications were given by basic scientists; the third lecture on drugs was given by a rheumatologist and was focused on clinical considerations. The lectures on muscle, bone, and soft tissue were given by basic scientists and covered the material at the scientific depth presented in *Musculoskeletal Medicine*. Following separate lectures on orthopaedic history-taking and on the general considerations involved in approaching and initiating a physical examination of a patient, a third lecture dealt with how the general musculoskeletal physical examination would be taught and evaluated. In subsequent small-group sessions (five students per instructor), the students performed each part of the examination on one another and on an examinee.

Attendance at lectures was not mandatory, but students who missed no more than two lectures were offered a bonus on the final written examination (slightly less than 2% of the final examination grade); 92% of the class accepted the offer. Attendance at all small-group meetings was mandatory because grading and evaluation were dependent on student participation. A student who missed a small-group meeting was allowed remediation, but that process was relatively onerous and was invoked rarely; the remediation rate (the number of cases divided by the number of possible cases) was 2/448 = 0.005.

All students successfully performed the general musculoskeletal physical examination; 6% performed it successfully only after remediation. The average score (and standard error) on the basic competency examination was 77.8% \pm 4.3% (Fig. 2); the historical comparison group, which consisted of eighty-five medical and surgical residents who were in their first postgraduate year, was 59.6% \pm 4.8%¹⁹ (p < 0.05, Fisher exact test).

The anatomy scores and clinical and basic-science scores were strongly correlated (p < 0.05) (Fig. 3). The correlation occurred for both the sixty-four male students (r = 0.78, p < 0.05) and the forty-eight female students (r = 0.66, p < 0.05).

No formal feedback was obtained during the course. After the course, an opinion survey of faculty teaching performance, in which all students participated, indicated that the course was well accepted by the students (Fig. 4). The average ratings assigned by the medical students to the fourteen or-

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thopaedic residents who led the general musculoskeletal physical examination sessions ranged from 4.85 to 5.

Discussion

Musculoskeletal medicine has not received adequate attention in the typical undergraduate curriculum for U.S. medical schools. As a consequence, graduates of these medical schools are likely to be inadequately prepared to evaluate or manage musculoskeletal complaints. Our primary purpose was to design, implement, and evaluate a system-based course to teach cognitive and process-based skills necessary to achieve an adequate level of competency in musculoskeletal medicine; we did not explicitly seek to test any particular hypothesis. The course was designed to provide comprehensive training in the anatomy, biology, and clinical aspects of the musculoskeletal system at an instructional level appropriate for students in the preclinical years. To achieve our cognitive objectives, we used standard texts and a blend of different teaching methods. Our skills-based objectives, which in broad terms were to teach the students how to think like physicians and to conduct an adequate physical examination, were accomplished primarily in the context of small-group meetings structured to promote active learning.

Our system of assessment included the basic competency examination, which is a useful tool for measuring basic cognitive competency in musculoskeletal medicine^{3,5,19,20}, although to our knowledge there is no evidence that performance on it translates into clinical performance later. The class score on the basic competency examination was 77.8%; thus, on the average, the students who took the course exceeded the minimum score deemed necessary by residency program directors in orthopaedics $(73.1\%)^3$ and internal medicine $(70\%)^{19}$. The evidence of skills-based competency was the result that all 112 students demonstrated an ability to successfully perform the general musculoskeletal physical examination in less than twenty minutes. Taken together, these results are good evidence that the course

objectives regarding competency in musculoskeletal medicine were achieved.

Limitations

We used a historical control group (recent graduates of medical school) for statistical comparison of the performance of our students (freshmen) on the basic competency examination. The two cohorts undoubtedly differed in many salient respects; consequently, for methodological reasons, these differences must be considered with regard to the inference that the course was responsible for the observed average improvement.

Although the average class score on the basic competency examination was above the criteria set by the orthopaedic and internal medicine program directors, at the individual level, 45% of the students failed to achieve the 70% criterion. This was an improvement on the results obtained by Freedman and Bernstein¹⁹ (a 78% failure rate), indicating that further improvement in basic musculoskeletal competency was needed. However, the examination was designed for senior students, and consequently the 45% failure rate may not be particularly meaningful because our students were only freshmen.

It could be argued that the achieved levels of cognitive knowledge (as assessed with use of the basic competency examination) and clinical skills (assessed with use of the general musculoskeletal physical examination) might not be maintained throughout medical school and that, even if maintained, they might not translate into adequate clinical performance later. We did not address those issues. Nevertheless, during the remaining years of medical school, the students will take required and optional rotations in orthopaedic surgery and will also encounter musculoskeletal problems in many other courses and clinical rotations. We therefore believe that their knowledge of musculoskeletal medicine will grow and that, whatever their level of competence when they graduate, it will be greater than would have been the case in the absence of this

course, which was an addition to the preclinical curriculum.

The course dealt only obliquely with the prevention of musculoskeletal problems, for example, in the lectures on sports medicine and metabolic disease (in relation to osteoporosis). An explicit focus on problem prevention, for example, by the inclusion of a lecture on exercise physiology, is probably desirable because the students will be asked for advice in this area after they begin practicing. There are also other topics that arguably ought to be included in the course.

The successful implementation of the course depended substantially on the institutional framework. The clinical goals were keyed to the lecture and laboratory schedules of the anatomy department, which made fundamental changes in its traditional curriculum to accommodate all of the system-based courses but especially musculoskeletal medicine. Further, a large commitment of resources was needed to teach and evaluate the general musculoskeletal physical examination.

We designed the course for medical students in the preclinical years with the intent that it would be a required course in a system-based preclinical curriculum. We do not know how useful the course would be in other curricular structures. We taught the course to first-year students, but, with suitable modifications, it would probably work well in the second preclinical year. For example, musculoskeletal anatomy would presumably have been covered, and thus its footprint in our course would be correspondingly reduced.

The institutional Curriculum Committee made the philosophical decision that medical education would be improved if clinical instruction began during what traditionally had been considered to be the preclinical years, and it adopted our present curricular structure (Table I); the Committee had been strongly encouraged by the Liaison Committee on Medical Education to adopt this innovative curriculum. We do not know whether the impact and retention of information would have been

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greater if some or all of the courses were presented later in medical school, when there is a better understanding of clinical medicine and the implications of musculoskeletal disease.

Special Issues

We encountered a basic concern on the part of the students that stemmed from their expectations regarding the knowledge they would be expected to master. In the first-semester basicscience courses (Table I), the students had been held responsible on examinations for all of the assigned material. However, there was no possibility that the students could master all of the material in the clinical texts^{13,14} while simultaneously being introduced to process-based skills. We dealt with this problem by encouraging the students to recognize that the ability to triage information and focus on the most important part was an essential skill for a physician. The students were told to read the assigned material in preparation for the lecture (chapters two through five in Musculoskeletal Medicine for soft tissue and chapters fifteen and sixteen for trauma, as examples) but that the lecturer would focus on only the most important parts of the material. They were also told that the examination questions would involve a still narrower range of material, namely, the most important points presented by the lecturer. Thus, the students knew that they were responsible on the examinations for only the most central material presented in the lecture.

When we designed the course, we wrote on a clean slate because musculoskeletal medicine essentially had no presence in the old preclinical curriculum. No serious questions arose regarding educational priorities. In practical terms, the course consisted of teaching particular cognitive and skills-based knowledge¹³⁻¹⁵ in lectures and small-group meetings, synchronized with the type of anatomic instruction that had traditionally been offered. Given the structure of orthopaedic specialization, we listed lecture topics according to those topics presented in the textbook *Essentials of Musculoskeletal Care* published by the American Academy of Orthopaedic Surgeons²¹.

The recruiting of the course faculty was done by the course directors with the tacit approval of the section chiefs, department heads, and the dean. In the lectures given by physicians, the information presented was that which the lecturer believed to be the knowledge that should be possessed by every medical school graduate (even if the material was not covered in the text). In the case of the basic-science lectures, the course directors identified the material that they judged essential and then recruited basic-science experts in those areas to teach the material. This amounted to a reversal of the traditional role of the basic scientist as the arbiter of the basic-science content of the preclinical curriculum. However, the basic-science departments had not been strongly focused on musculoskeletal issues under the old curriculum, and, consequently, we had no difficulty in exercising control over the basic-science content of the course.

Anatomy

On the basis of the accepted educational principle that students learn and remember better when the information is presented in context¹⁸, we designed the course under the assumption that the students would better grasp the clinical material if anatomy were taught simultaneously. Notwithstanding what may be true generally, appropriate studies might show that anatomy education should precede musculoskeletal education, as in the traditional medical school curriculum.

Proficiency in gross anatomy is a predictor for performance on Step 1 of the United States Medical Licensing Examination²² (Pearson r = 0.58). We considered the possibility that proficiency in anatomy would also be correlated with performance on the nonanatomic portions of the final written examination, because anatomic knowledge is an absolute prerequisite for competence in musculoskeletal medicine. The observed correlation between the two kinds of knowledge (Fig. 3) might be only statistical in nature, with no deeper meaning. For example, the anatomy score may simply be a surrogate for general academic aptitude. Even if this were the case, it would be useful for a musculoskeletal-medicine course director to know that poorly performing students might be identified during the course on the basis of their performance in the anatomy laboratory.

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