BEME Collaboration

Teaching Musculoskeletal Clinical Skills to Medical Trainees and Physicians: A Best Evidence in Medical Education (BEME) Systematic Review of Strategies and their Effectiveness

Alexandra O'Dunn-Orto BA[1]

Lisa Hartling, MSc, PhD[2]

Sandra Campbell BA, MLS, AALIA(CP)[3]

Anna E. Oswald MD, MMEd, FRCPC[4]

1 Medical Student, University of Alberta; 2 Assistant Professor, Department of Pediatrics, University of Alberta; 3 Public Services Librarian and Library Liaison to Medicine, University of Alberta; 4 Assistant Professor, Department of Medicine, University of Alberta, Edmonton, Canada

Corresponding Author:
Anna Oswald
562 Heritage Medical Research Centre
University of Alberta
Edmonton, AB
T6G 2S2
Tel: 780-407-8711
Fax: 780-407-6055
oswald@ualberta.ca

Review team expertise:

Alexandra O'Dunn-Orto BA
Ms. O'Dunn-Orto is a second year medical student and a summer studentship recipient. She has earned a Combined Honours Degree in English and Biology.

Lisa Hartling, MSc, PhD
Assistant Professor, Department of Pediatrics
Ms. Hartling is Co-Director of the Alberta Research Centre for Health Evidence and Associate Director of the University of Alberta Evidence-based Practice Center. In this role she oversees approximately 25 staff in the production of systematic reviews, health technology assessments, and methodological research for evidence synthesis. She is a reviewer with The Cochrane Collaboration (Acute Respiratory Infections, Aneasthesia, Injury, Wounds, Heart, and Infectious Diseases Groups). She has co-authored more than 20 systematic reviews including a systematic review on problem-based learning that has been published as a BEME rapid review.

Sandra Campbell, BA, MLS, AALIA (CP)
Ms. Campbell is a Public Services Librarian and library liaison to the Faculty of Medicine and Dentistry. She is also an expert database searcher and information literacy instructor.

Anna Oswald, MD, MMEd, FRCPC
Dr. Oswald is an Assistant Professor, consultant rheumatologist, and course-coordinator for the undergraduate musculoskeletal medicine course for preclinical medical students at the University of Alberta. She has completed a Masters in Medical Education degree through the University of Dundee. She has co-authored a systematic review on problem-based learning that has been published as a BEME rapid review.

Conflict of interest:
Nil.

Abstract

Background: Musculoskeletal (MSK) complaints make up 12-20% of primary health care visits and are a source of significant health care expenditures and population morbidity in Canada. Despite this, MSK examination is often neglected in clinical practice, and is considered an area of weakness and low confidence among practicing physicians. Several studies have raised concerns regarding the inadequacy of MSK clinical skills teaching including those released by the American Association of Medical Colleges (AAMC) and the Collège des Médecins du Québec. Their reports highlight the need for an increase in MSK physical exam teaching in medical school curricula. However, increased teaching time alone does not guarantee an improvement in MSK clinical skills. This aim can best be achieved once educators have determined the most effective means of achieving competency in the area. Thus, this review aimed to identify which educational interventions have been found to be effective in promoting transfer of MSK clinical skills to medical trainees at varying points in their education.

Methods: A comprehensive search was conducted to identify all potentially relevant studies. Systematic methods were applied to review studies for inclusion, extract data, and assess methodological quality. Comparative studies were included if they evaluated educational interventions for MSK skills among medical professionals or trainees. Data were not pooled statistically due to heterogeneity in interventions, comparators, outcomes, and study designs. A qualitative analysis is presented by intervention and outcome. The review protocol was reviewed and approved by the Best Evidence in Medical Education (BEME) organization.

Results: 5089 titles were screened, from which twenty-four studies were selected for inclusion. All stages of training were represented, although eighteen of twenty-four studies focussed on undergraduate medical education. Studies evaluated patient educators (n=9), interactive small groups (n=6), computer-assisted learning (CAL; n=4), peer-assisted learning (n=2) and one study each examined general practitioners (GPs) vs. physiotherapists (PTs), Standardized Physical Exam Associates (SPEAs) vs. physician-faculty, reminder sheets, and Gait Arms Legs Spine (GALS) teaching. Five of nine patient educator studies favoured patient educators while two found no differences. Five of six studies favoured interactive small groups, two of four studies favoured CAL, and two of two studies favoured peer assisted learning. Individual studies showed no differences between GPs vs. PTs and SPEAs vs. physician-faculty. Individual studies demonstrated effectiveness of reminder sheets and GALS, respectively.

Conclusions:

As curricula evolve, interest in the use of alternate instructional methods is increasing. This study provides support for the use of several different instructional methods that engage learners and provide meaningful learning contexts with the majority of studies supporting patient educators and interactive small group teaching.

Executive Summary

The musculoskeletal (MSK) system is comprised of the bones, joints and muscles that support the human body and facilitate movement. Complaints related to this system are the reason for 12-20% of visits to family physicians' offices, emergency departments and other primary health centers. They are a significant cause of pain, illness and disability among the Canadian population, and are a substantial source of health care expenditures. However, despite the prevalence of MSK conditions, physicians are not confident in their physical examination and history taking skills in this area and report that it is a subject of weakness that is often neglected in their practices.

Recent research from many different countries has raised concerns regarding the teaching of MSK clinical skills throughout medical training, because it has not produced physicians who are comfortable and competent in this field. In response, several organizations that are invested in medical education and the quality of public healthcare released reports emphasizing the need for an increase in MSK physical exam teaching in medical school curricula. However, increased teaching time alone does not guarantee an improvement in MSK clinical skills. This goal can best be achieved by first discovering which teaching methods are most effective for conveying MSK clinical skills to students, and therefore, this is the goal of our review.

A comprehensive search of relevant medical and educational databases, conference proceedings and grey literature was conducted to identify all studies that might be applicable to the research question. 5089 titles were screened, from which twenty-four studies were selected for review. The included studies met the following criteria:

Study population: medical trainees or physicians

Type of teaching intervention: structured teaching tool or session ex. workshop, video, computer program

Study design: controlled (ie. must compare one teaching intervention to another or to standard curriculum)

Outcomes measured: confidence, knowledge, skills, behaviours, patient health

The included studies were organized by teaching intervention. This allowed the authors to draw general conclusions about the success of each strategy. The included studies used a variety of outcomes to measure relative effectiveness or success, including written exams and confidence ratings. However, the majority of studies used practical tests of physical exam and history taking skills on a patient as their measure of efficacy.

Overall, the review findings suggest that the best teaching methods are those which are stimulating, engaging and interactive. The review found evidence that patient educators, small group interactive learning, and computer or web-based programs are a constructive way to teaching MSK clinical skills.

Nine of the included studies examined the use of trained patients with MSK conditions as teachers, and compared them to expert physicians, family practitioners and video. Eight of the nine studies found that the patient educators were better than, or at least no different than the comparable teaching intervention. Five studies investigated small groups, interactive learning strategies compared to large classroom based lecture and four of them favoured the small group method. Four studies examined the use of computer and web-based programs. Two studies were in support of this teaching method, and two found it to be no different than the comparable interventions, which were lecture-based

instruction and small group interactive learning. The remaining studies applied a wide variety of teaching strategies with differing levels of success.

While these findings are significant, it is important to note the limitations of this review. In any case where teaching methods are evaluated it is not possible to control for variables such as teaching skill or external teaching exposures. In addition, the assessment of each included study's quality and credibility found many of them to be at risk of reporting biased results.

In spite of these weaknesses, this review provides support for the use of several different teaching methods, specifically patient educators and small group interactive learning. In doing so, it serves as a springboard for future research into how and why these strategies are effective. In addition, the review may help guide medical curriculum developers as they design programs with the aim of producing physicians who are competent in MSK clinical skills.

Background

Musculoskeletal (MSK) complaints make up 12-20% of primary health care visits in Canada (Badley, Rasooly, & Webster, 1994; Badley, Webster, & Rasooly, 1995; Pinney & Regan, 2001; Wang & Badley, 2003) and are a source of significant health care expenditures (Yelin, Herrndorf, Trupin, & Sonneborn, 2001; Yelin et al., 2004) and population morbidity (Badley et al., 1995; Badley & Wang, 2001; Leroux, Dionne, Bourbonnais, & Brisson, 2005). Current data project increases in both the prevalence of arthritis related diseases and associated disability as the population ages (Badley & Crotty, 1995; Badley & Wang, 1998). Increasing levels of obesity are also likely to alter the future prevalence of MSK related disorders. Despite this, MSK examination is often neglected in clinical practice (Ahern, Soden, Schultz, & Clark, 1991; Crotty, Ahern, McFarlane, & Brooks, 1993; Doherty, Abawi, & Pattrick, 1990; Rigby & Oswald, 1987), in contrast to near 100% documentation of cardiovascular, respiratory and gastrointestinal systems' examination (Crotty et al., 1993; Doherty et al., 1990).

Several previous studies and reports have raised concerns regarding the inadequacy of MSK clinical skills teaching including recent reports from the American Association of Medical Colleges (AAMC) and the Collège des Médecins du Québec that have identified MSK clinical skills as areas of weakness in medical school curricula and among practicing physicians (Association of American Medical Colleges, 2005; College des Medecins du Quebec Practice Enhancement Division, 1999). In addition, consensus statements from the UK (Dacre, Griffith, & Jolly, 1996), the USA (R. C. Anderson, Fagan, & Sebastian, 2001) and the International League Against Rheumatism (Dequeker

& Rasker, 1998) underscore the need for not only more general physical exam teaching, but specifically more MSK physical exam (PE) teaching in medical school. As Woolf describes, “there is a range of specialties involved in the management of the spectrum of MSK conditions, including rheumatology, orthopedics, pain physicians, geriatrics, sports medicine, and occupational medicine” (Woolf 1995), however MSK clinical skills are seldom taught in an intra-disciplinary manner. As there have been no publications to date reviewing the strategies employed to teach MSK clinical skills within medicine, the authors chose to perform a review at this level of inquiry to provide a comprehensive evidence-base in this area for medical curriculum developers. As part of the Bone and Joint Decade, the Association of American Medical Colleges published a detailed report in 2005 highlighting the under representation of MSK in medical school curricula, specifying recommended objectives that should be part of all medical school MSK curricula and providing some broad suggestions of how they may be achieved (Association of American Medical Colleges, 2005). Almost concurrently in 2005, the Alliance for the Canadian Arthritis Program (ACAP), published a report stating that "all relevant health professionals must be able to perform a valid, standardized, age appropriate musculoskeletal screening assessment” (Alliance for the Canadian Arthritis Program, 2006).

In addition to consensus statements, several surveys have demonstrated poor confidence by trainees in MSK clinical skills. For example, Clawson performed one of the largest surveys of trainees entering residency in the USA and found that those from allopathic medical schools described themselves as poorly prepared to assess and treat common

MSK complaints (Clawson, Jackson, & Ostergaard, 2001). Another recent survey of medical students at Harvard University revealed that although the students considered MSK medicine as the third most important topic to their future medical career, they described low to average levels of confidence in MSK examination skills; further, when these students were administered Freedman's nationally validated MSK basic competency short answer exam, only 26% of fourth year students passed (Day, Yeh, Franko, Ramirez, & Krupat, 2007). Even when this exam was given to another population of trainees who came from a school with a longstanding dedicated MSK program, still a little more than 50% of the trainees failed the exam (Schmale, 2005).

There are two issues that emerge from this data. First, there is little doubt that the teaching of MSK clinical skills in current undergraduate medical school curricula needs to be improved. However, simply adding teaching hours does not guarantee improvement in students' MSK clinical skills. This can only be achieved through better understanding of what teaching strategies are most effective at achieving competency in MSK clinical skills.

Small group learning has long been employed as a strategy for imparting clinical skills from expert clinicians to medical trainees. Such teaching sessions often have a range of objectives and may take place in a variety of environments, from the classroom to the bedside. However, all are grounded in the notion that Ericsson's educational principle of deliberate practice with expert feedback is more consistently executed in a small group rather than large class setting (Ericsson, 2004).

Within the past 25 years, many medical curricula have adapted small group interactive teaching sessions as one way to incorporate patients as educators. Many institutions now use patient educator programs, wherein trained patients take on an active role in the training of medical students and residents. This teaching strategy is well aligned with the educational concept of a patient centred approach to clinical skills teaching. A recent review of this subject found that the rationale for such programs is largely based upon the theoretical concept of the patient as an expert in their disease, which renders them a suitable and valuable teacher while also providing a meaningful clinical context for the material (Jha, Quinton, Bekker, & Roberts, 2009).

Traditional curricula have further evolved in response to advancing technological capacity, resulting in the development of computer assisted learning programs (CAL). CAL refers to the use of computer based programs for the enhancement of student knowledge and performance, often through interactive teaching strategies. Authors have noted that CAL is considered a beneficial tool because it is flexible and convenient, offers unique presentation of information and encourages personalized and self directed learning (Greenhalgh, 2001). Researchers have generally concluded that CAL is an intervention that is equal to or better than traditional teaching methods in terms of student satisfaction and knowledge gain (McNulty, Sonntag, & Sinacore, 2009).

While there is a large volume of literature regarding patient educators, small group learning interventions, and CAL, there has not been a systematic evaluation of these

interventions specific to the teaching of MSK clinical skills. We undertook a systematic review to identify and describe the research evaluating the effectiveness of different teaching strategies for MSK clinical skills.

Methods

Research question:

The objective of this systematic review is to identify which structured educational interventions lead to competence in musculoskeletal clinical skills for medical trainees including undergraduates, residents and practicing physicians. The following outcomes were chosen a priori according to Kirkpatrick's model (Kirkpatrick, 2006) to assess the effectiveness of educational strategies: patient outcomes, change in behaviour, change in skills, change in knowledge and change in attitudes/perceptions. Reviewers aligned the outcomes of included studies according to this model.

For the purpose of this review the MSK system is defined as the peripheral and axial skeleton and associated bone, muscle, tendon, ligament, joint, bursa and cartilage. Clinical skills are defined as patient history and physical examination, and do not include diagnostic imaging interpretation or procedural skills such as joint injection techniques.

Search Strategy:

A comprehensive search strategy was developed by a medical librarian (SC) in consultation with the remaining authors to identify relevant studies in the online databases listed in Table 1.

The specific terms and search strategies can be found in Table 2. In addition, the reference lists of all included studies were hand searched, as were those of relevant reviews that were identified during the title screening procedure described below. We also hand-searched the conference proceedings for the Association of American Medical Colleges and the Association of Medical Education in Europe from 2006-2008. A separate cited reference search was also conducted using Web of Science for each included study looking for papers that cited it and that it cited. The primary authors of all included studies were contacted by email to determine if they knew of any unpublished, recently published, or ongoing studies relevant to the review. The contact information used was extracted from the included papers or from the university directories associated with the primary authors.

Screening and selection of studies:

The titles and abstracts generated from the electronic database searches were independently collected in a Refworks reference management database. They were then screened by two reviewers (AEO and AOO) to exclude those that obviously did not meet the inclusion criteria or address the question under study. The full texts of the remaining studies were retrieved and a pre-approved inclusion form was applied to each to identify relevant studies. This was done independently by two reviewers (AEO and AOO), and any disagreements that arose were resolved through discussion, or with the aid of a third reviewer (LH) as required.

The inclusion criteria are detailed in Table 3. These were applied to each potentially relevant study to evaluate whether the study should be included in the review. This review primarily focused on medical trainees who experienced structured teaching interventions as evaluated by controlled studies.

Assessment of methodological quality:

The methodological quality of included studies was evaluated independently by two reviewers (LH and AOO) using well-recognized tools specific to different study designs. The Cochrane Risk of Bias tool was used for controlled trials (Higgins & Green, 2006). The Newcastle-Ottawa Scale (NOS) was used for cohort studies (Wells et al.,). These tools had been piloted in a previous systematic review performed by the authors (Hartling, Spooner, Tjosvold, & Oswald, 2010). Discrepancies were resolved through consensus.

The methodological quality of the included studies was summarized by grouping according to study design (cohorts vs. trials), and identifying common and methodologically significant areas of weakness.

Data Extraction:

Electronic data extraction forms were developed and piloted in a previous systematic review performed by the authors (Hartling et al., 2010). These forms were further revised and tailored to the current review through discussion within the review group after data from a sample of initial articles' was extracted. One reviewer extracted data (AOO), but to ensure accuracy and consistency of the process a sample of 20% of the

articles was randomly selected for extraction by a second reviewer (AEO). The data extracted by the two reviewers were then compared and no significant discrepancies or errors were detected. Age and gender were not recorded at the data extraction level, as the included studies did not consider these variables in their design other than as a measure of baseline characteristics among participant groups.

Analysis:

The included studies were found to be too heterogeneous in terms of design, interventions and outcome assessments to be combined for quantitative statistical analysis. As a result, the included studies were qualitatively described by intervention as these subgroups provided homogeneity that allowed for useful comparison of relative effectiveness. Each intervention was further subdivided by comparators and outcomes assessed according to Kirkpatrick levels to give greater context to the results (Table 4). To give a sense of overall efficacy, each intervention was summarized by combining all comparators and outcomes assessed. The descriptive analysis was meant to bring clarity to studies identified by previously described inclusion and exclusion criteria, but was not in itself part of the screening or exclusion process for the primary studies. Evidence tables detailing study characteristics (including population, intervention, comparison, outcomes and design), results and authors' conclusions are provided. See Tables 4, 5 and 6.

Results

Overview of Included Studies

Figure 1 presents a flow diagram of the study selection process. 5089 studies were identified by electronic database searches and 354 studies were identified by reference and hand searches. Title and abstract screening identified 265 potentially relevant studies. Inclusion forms were applied with full text review of these 265 studies and this identified twenty-four studies that were relevant to our investigation. Of these, twelve were Randomized Controlled Trials (RCTs), four were non-concurrent cohort studies, and eight were prospective cohort studies. Ten of the twenty-four studies were conducted in the United States, with the remainder based in the United Kingdom (n=7), Australia (n=4), Canada (n=2) and Switzerland (n=1). Eighteen of the twenty-four studies were concerned with undergraduate medical education, while five investigated residents (n=3) or both undergraduates and residents (n=2). Only one study's participants were practicing physicians. Although participants in the majority of included studies included uni-professional medical trainees or physicians, the teachers and intervention facilitators represented a variety of professions including medicine, physiotherapy and the lay public. Several included studies assessed more than one level of Kirkpatrick learning outcomes. Within all the included studies one of twenty-four assessed a change in behaviour, twenty-one of twenty-four assessed change in skill, five of twenty-four assessed change in knowledge and four of twenty-four studies assessed a change in attitudes or perceptions. None of the studies evaluated patient outcomes. In total, over 2500 participants were involved in the included studies.

Methodological Quality and Risk of Bias of Included Studies

Quality and Risk of Bias tools were applied to all twenty-four included studies and none were excluded subsequently on the basis of their quality assessment scores. The methodological quality of the studies varied, however several weaknesses were common to particular designs. Over half of the RCTs did not describe their randomization process (n=7) and the majority (n=10) did not attempt or describe the process of allocation concealment. Five trials did not attempt to blind participants to their intervention groups and the outcomes being measured , and an additional five trials did not adequately blind participants Moreover, two trials did not adequately blind all outcome assessors, and two others did not state whether evaluators were blinded to participant intervention. In half of the trials (n=6) outcome data was either incomplete or inadequately addressed. One trial was found to be at risk of selective outcome reporting. Five trials did not present any baseline characteristics of the groups being compared, and two trials described only the age and sex of their participants. Finally, one trial used a cluster randomization process and inappropriately analyzed data on an individual basis.

A limitation common to the majority of both prospective and non-concurrent cohorts was an unclear or absent description of whether outcome assessors were blinded to intervention groups (n=9). In addition, only four of twelve studies took into account the comparability of cohorts and controlled for participants' level of relevant education (including year of residency and completion of related electives) or learning style. Moreover, in three of the cohort studies the exposed group was a select group of student volunteers and in three cases the derivation of the non-exposed cohort was inadequately described or derived from a different source. Three cohort studies did not clearly present

data for participant follow-up and another provided no statement regarding extent of follow-up. One cohort study did not have adequate follow-up of participants, as its loss to follow-up rate was greater than 10% of study participants and there was an incomplete description of those lost.

Characteristics of Included Studies

Table 4 provides a summary of the interventions, comparators, outcomes measured and main findings of all included studies. The outcomes of interest varied among studies, however fifteen of twenty-four studies utilized Objective Structured Clinical Examination (OSCE) scores as a primary measure of students' skill in performing the musculoskeletal physical exam. Tables 5 and 6 detail the characteristics and results of all included studies. The following provides a narrative overview of the results grouped according to intervention.

Patient Educators

Nine studies involving 492 participants investigated the effectiveness of patient educators as teachers compared to a standard curriculum (n=3), a video (n=1) or sessions led by a general practitioner (n=1) or expert in rheumatology (n=4). Of these, three were observational studies and the remainder were RCTs. Three studies compared patient educators to a standard curriculum: one RCT (27 participants) and one observational study (19 participants) found significant differences in terms of skill favouring the patient educator while another observational study (unclear number of participants) found no difference. Four studies compared patient educators to experts in rheumatology. All

studies assessed changes in skill and found very different results with one RCT (23 participants) favouring the patient educator, a cluster RCT (62 participants) favouring the rheumatology expert, and two RCTs (130 participants) finding no difference. One observational study (37 participants) compared patient educators to sessions lead by a general practitioner and showed a change in skills favouring the patient educators. Finally, one RCT (181 participants) compared patient educators to a video: results for skill, knowledge and confidence favoured the patient educator. Overall, eight of nine studies showed patient educators to be no different (n=3) or better than (n=5) their comparators across a variety of outcomes (Table 4).

Interactive, Small Group Learning

Five studies involving 499 participants compared interactive small group sessions or a curriculum with emphasis on this teaching strategy to didactic teaching styles and traditional curricula. Four of these studies were observational and one was an RCT. The majority (including the RCT) favoured the small group teaching style, with findings of improved skill, knowledge and confidence. Only one observational study (145 participants) showed discrepant results, favouring the traditional curriculum over the small group, interactive curriculum in terms of skill acquisition. This study had a considerably unequal distribution of teaching time; students in the traditional curriculum received twenty hours of clinical teaching, whereas those in the small groups-oriented program received only three hours of instruction. In comparable studies the teaching time was equal, lengthier in the small groups curricula or was not noted (See Table 5). The differences in instruction time may be responsible for these conflicting results.

Computer-Assisted Learning (CAL)

Three RCTs and one observational study involving 529 participants evaluated the effectiveness of computer-assisted learning (CAL). Two studies compared CAL to traditional curricula: one cluster RCT (354 participants) found a difference in skill favouring CAL but found no difference in confidence, while one observational study (197 participants) found no difference in knowledge. One study compared CAL to bedside teaching (27 participants) and found no difference in skill acquisition. Another study (61 participants) compared CAL to a textbook and found a significant difference favouring CAL in terms of change in skill. The same study also compared CAL to experts in rheumatology, and found no difference.

Other Interventions

The interventions, comparators and outcomes of the remaining six included studies varied considerably. Peer-assisted learning was assessed in two studies involving 310 participants. One observational study (64 participants) found no difference in skill change for peer-assisted learning compared to instruction by a physiotherapist. This same study, and another observational study (310 participants) compared peer-assisted learning to the standard curriculum and found differences favouring peer-assisted learning in terms of skill change. One cluster RCT (264 participants) compared instruction by a general practitioner versus a physiotherapist and found no difference in skills between groups. Likewise, one RCT (144 participants) compared standardized physical exam associates versus physician faculty and found no difference in skills. One observational study (11

participants) examined the use of reminder sheets pre-patient interview versus standard curriculum and found that reminders significantly changed behaviour. Finally, one observational study compared a new GALS teaching approach to a traditional curriculum and found changes in skill (264 participants) and confidence (218 participants) favouring GALS.

Discussion

All stages of medical training were represented in this review although the majority of studies (eighteen of twenty-four) focused on undergraduate medical education. A variety of teaching interventions were evaluated among the included studies. The findings of this review resonate overall with larger adult learning theory as represented by Spencer's progressive learning philosophy. In this theoretical framework, teachers strive to engage and guide students through learning experiences that are educative, stimulating and yet purposeful and contextually relevant (Spencer, 1998).

Patient Educators:

For example, in the case of patient educators, learners encounter a highly contextually relevant experience that is likely to represent one of their first independent patient encounters. Jha et al. also note that the use of patients as teachers was advantageous for students as it allowed for immediate feedback, and facilitated a non-threatening learning environment (Jha et al., 2009). Further, they note that students consider the method to be "stimulating and satisfying", a finding that was echoed by the authors of several studies included in our review of MSK clinical skills teaching techniques (Haq, Fuller, & Dacre,

2006; Hendry, Schrieber, & Bryce, 1999). The current review found the use of patient educators to be an effective teaching method in terms of skill, knowledge and confidence improvement. Eight of the nine patient educator related studies found no difference or superiority of patient educators to their comparators, which included experts in rheumatology, general practitioners, video and the standard curriculum.

Our findings regarding the relative effectiveness of patient educators are consistent with a 2009 review on this subject (Jha et al., 2009). They found that the use of patient educators resulted in "improved proficiency in clinical skills" in eight of nine studies concerned with musculoskeletal, cardiopulmonary and general chronic disease physical examination and history taking. Their review also found that only one study reported a negative impact (Humphrey-Murto, Smith, Touchie, & Wood, 2004). In that study, students taught by rheumatology faculty passed more OSCE stations and had significantly higher scores at two out of nine stations. Our review also identified this study as one of nine that favoured a comparator over patient educators for number of OSCE stations passed; however, for this trial's stated primary outcome of overall OSCE score there was no significant difference between the two groups.

Standardized Physical Exam Associates (SPEAs):

In addition to patient educators, some institutions have explored other non-faculty dependent modes of education. One review of simulation in psychiatric education, found both videotapes and live interaction with standardized patients (SPs) to be effective in teaching interviewing skills in clerkship and junior residency years of training (McNaughton, Ravitz, Wadell, & Hodges, 2008). Our review identified one RCT

investigating the use of standardized physical exam associates (which included some SPs as well as other community members), which found no differences in skill for students instructed by associates compared to physician faculty.

Small group interactive learning:

The surprising paucity of literature evaluating large versus small group physical exam teaching may be due to the fact that most authors support Ericsson's theory that deliberate practice with specific feedback is critical to the mastery of skills (Ericsson, 2004). It is likely that most authors presume that small group settings are more likely than large group demonstrations to facilitate clinical skills learning and thus few studies have been performed. The findings of this review resonate with this learning principle in their support of small group clinical skills teaching. Four of five studies favoured a small group interactive teaching style for the instruction of clinical skills over a traditional, didactic form of teaching.

Computer-assisted learning (CAL):

Where CAL is less contextually grounded than patient educator or small groups interactive teaching strategies, it still provides stimulating and self-directed learning opportunities in keeping with progressive adult learning theory, and the findings of this review suggest that it may be an effective method of teaching MSK clinical skills. However, a meaningful and comprehensive analysis of CAL was problematic, due to the heterogeneity of CAL applications in the included studies. .A review of CAL for medical education concluded that at the undergraduate level the gain of knowledge was variable

among programs (Hammoud et al., 2006). A similar variety among studies was noted in the current review. Two of four studies found CAL to be better than its comparator for at least one outcome, while the remaining studies showed no difference. Our findings thus agree with previous reviews, and further suggest that CAL may be an effective means of promoting MSK clinical skills transfer. An additional review of web-based continuing medical education programs found them to be equivalent to traditional teaching methods in effecting knowledge change (Wutoh, Boren, & Balas, 2004). Recent reviewers have further determined that CAL for continuing medical education effectively induces change in practice patterns lasting up to 12 months (Lam-Antoniades, Ratnapalan, & Tait, 2009).

The authors commented that further research is required to elucidate which components of CAL are most effective in order to maximize their usage. A recent longitudinal study of a CAL program for an undergraduate medical course determined that the type of CAL used by students was related to gender, personality preference and learning style (McNulty et al., 2009). This finding coincides with previous research (Chumley-Jones, Dobbie, & Alford, 2002; Cook, 2005) and suggests that the most effective CAL programs will offer a variety of tools and teaching methods. In the future, such results may be applied in designing CAL interventions for teaching MSK clinical skills.

Limitations:

By prospectively determining our search strategy and having two authors screen papers for inclusion we minimized inclusion bias, and believe our review to be inclusive of all relevant studies. However, the review is limited by the methodological quality of included studies. Both RCTs and observational studies were at a high risk of bias due to

inadequate blinding of participants and/or outcome assessors. In addition, many included trials did not present complete outcome data, or did so in an unclear manner. Either of these flaws may result in an overestimation of an intervention's effects. Similarly, few RCTs presented adequate baseline data to allow the authors to confirm balance between the groups and few cohorts accounted for differences in learning style or level of education.

Another limitation relates to the fact that only three studies provided power calculations. As a result, for most studies, it is not possible to determine if observations of no difference between the interventions being compared represents actual equivalence or simply points to insufficient statistical power (i.e. Type II errors). We recommend that future publications in this field include power calculations to allow for more meaningful conclusions to be drawn.

The review is also limited by weaknesses inherent to the field of investigation, many of which have been previously discussed. As with any evaluation of teaching strategies, one cannot entirely control for variables such as teaching skill, student-teacher relationships and confounding exposures that have occurred in the learning cohorts. Schmidt *et al.* (1987) have thoroughly outlined the difficulty in controlling for extraneous variables that may affect outcomes, particularly in studies that extend over a period of time. Authors have also detailed the struggle of identifying and isolating the relative contributions of different curricular components that may affect outcomes (Schmidt, Dauphinee, & Patel, 1987; Schmidt et al., 1996; Tamblyn et al., 2005). As there is a lack of "gold standard

teaching modalities" against which interventions may be compared and as most studies did not provide validation analyses of their outcome measures, it is difficult to draw conclusions regarding the absolute effectiveness of the strategies presented rather than their relative merit. Additionally, existing outcomes and measurement tools may ineffectively assess important areas of physician competence (Berkson, 1993; Distlehorst, Dawson, Robbs, & Barrows, 2005; Vernon & Blake, 1993).

For example, none of the included studies evaluated patient outcomes and thus we are unable to conclude whether one teaching method is superior in terms of this important outcome. One study assessed the efficacy of using reminder sheets prior to commencing a relevant patient interview; the reminder sheets prompted house officers to apply MSK history taking and physical exam recommendations they had previously been taught (Mazzuca, Brandt, & Katz, 1993). Investigators found that trainees asked appropriate questions and performed specific MSK physical exam maneuvers on suitable patients with more frequency when they received a reminder sheet. This study demonstrated a change in behaviour in a clinical context and the authors noted that "at least 65% of arthritis patients with chronic joint pain received thorough physical examinations to rule out disorders other than arthritis," suggesting that as a result, patients may have received an improved quality of care.

Finally, the heterogeneity of populations, designs, interventions, comparators and outcomes measured prohibits the deduction of a single most efficient teaching method.

For the same reasons, the findings cannot be generalized to medical trainees of all levels or differing education settings.

Advantages of non-traditional teaching methods:

Many authors of studies included in this review commented that patient educators and CAL are resources that could be applied to teach MSK clinical skills while minimizing educational costs in terms of physical space and faculty tutor time (Averns, Maraschiello, van Melle, & Day, 2009; Hasle, Anderson, & Szerlip, 1994; P. Vivekananda-Schmidt, Lewis, & Hassell, 2005). These interventions are relatively inexpensive and have been found to be no different or better in terms of confidence, knowledge and skill outcomes. Vivekananda-Schmidt *et al.* (2005) investigated the efficacy of a "Virtual Rheumatology CD", and found no difference in confidence and superior OSCE scores for students using the CD, versus those exposed to the traditional curriculum only. The cost of the program was $22 045, which arose primarily from CD production. Given current technology, this is much less of an issue, as demonstrated by Averns *et al.* (2009), whose research group created a similar rheumatology web-based resource at minimal cost. This tool was found to be equivalent to a teaching session by an expert in rheumatology and superior to a textbook. Hasle *et al.* (1994) analyzed the costs and benefits of using standardized patients to help teach clinical exam skills, as opposed to faculty alone. They determined that it was less costly to train and employ SPs to teach the physical exam, and also found no difference in students' performance on OSCEs. Similarly, patient educators who often teach on a voluntary basis are also a cost-effective use of resources.

Conclusions

This review is the first of its kind to consider broad MSK clinical skills teaching in medicine and provides supportive evidence for the use of interventions that maximize engagement and realistic context for medical trainees and physicians. Several instructional strategies were found to be an effective means of teaching MSK clinical skills with most studies supporting patient educators, interactive small group learning and computer-assisted learning. Furthermore, our findings highlight the need for future studies to elucidate how and why these interventions are effective, and provide guidance regarding study design and quality for investigators in the field of MSK clinical education.

As curricula evolve, interest in the use of alternate instructional methods is increasing, and many may be more efficient and cost-effective than traditional strategies. Our findings provide support for curriculum planners who are already implementing the strategies reviewed with limited access to evidence behind them, and may also direct teaching methodology choices, as educators strive to maximize teaching efficiency with limited instruction time.

Practice Points

- Interventions that maximize active engagement and realistic context are most supported by the literature
- Of the interventions studied patient educators and small group interactive learning were supported by the literature
- Opportunities for future research into the pedagogical underpinnings of these methods is discussed

Glossary

AAMC: American Association of Medical Colleges

ACAP: Alliance for the Canadian Arthritis Program

BEME: Best Evidence in Medical Education

CAL: Computer-assisted Learning

GALS: Gait Arms Legs Spine

GPs: General Practitioners

MSK: Musculoskeletal

NOS: Newcastle-Ottawa Scale

OSCE: Objective Structured Clinical Examination

PE: Physical Exam

PT: Physiotherapists

RCT(s):Randomized Controlled Trial(s)

SPs: Standardized Patients

SPEAs: Standardized Physical Exam Associates

Figure 1

Flow diagram of included studies

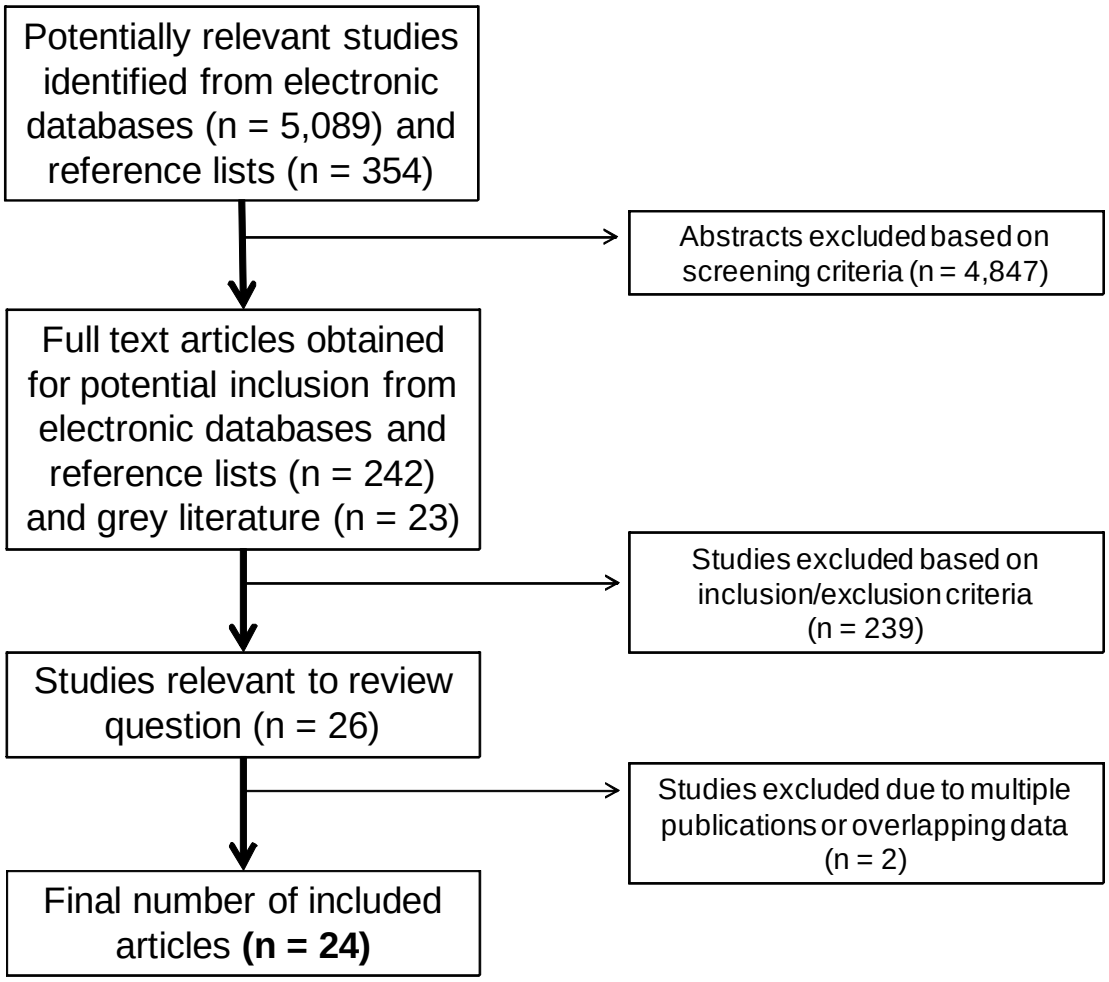

Table 1

Included online databases

Databases – note that all searches were limited to 1970 to current (August, 2009).

Medline (1950-present)	Cochrane Library (various dates – present)
EMBASE (1980 – present)	SCOPUS (1823 - present)
PubMed (1950 – present)	Web of Science (1956 - present)
CINAHL (1937- present)	ERIC (1966 - present)
Sport Discus (1970- present)	OpenSigle (various years - present)
Google (dates of content vary – present)	Proquest Dissertations and Theses (content dates vary – present)

Table 2

Search terms and strategy

Search Strategy

Concept 1	AND Concept 2	AND Concept 3
medical education methods	clinical	musculoskeletal
exp Teaching/mt [Methods] or exp Medical Education / [Methods] or exp Programmed Instruction as Topic/ or exp Educational Measurement/ or exp Curriculum/ or instructional methods.mp. or exp Computer-Assisted Instruction/	Exp Clinical Competence/ or clinical.mp.	musculoskeletal.mp. or exp Musculoskeletal System/ or exp Musculoskeletal Development/ or exp Musculoskeletal Abnormalities/ or exp Musculoskeletal Manipulations/ or exp Musculoskeletal Diseases/ osteopathic medicine/ or exp orthopedics/ or exp Rheumatology/ or exp Physical Medicine/ or exp Podiatry/
Limits: English language Human 1970 to current		

Table 3

Inclusion and exclusion criteria applied to potentially relevant studies to determine suitability for systematic review purposes

	Inclusion Criteria	**Exclusion Criteria**
Population	Medical Students Residents Physicians	Nurses Physiotherapists Other Allied Professionals
Intervention	Lectures Workshops Physician-led small group learning sessions Standardized patient teachers Patient educators Peer teachers Structured clinical interviews Teaching OSCEs Simulations Videos Textbook/print materials Computer assisted learning Other structured teaching activities or materials	Clinical rotations Shadowing/mentoring Clinical experience Practice audits Feedback alone (unless provided in conjunction with another educational intervention)
Comparator	Any teaching method described under the inclusion criteria for **Intervention** section Any "standard curriculum"	
Outcome (Based on modified Kirkpatrick's 1967 model of hierarchical outcomes)	As it relates to MSK physical examination: Change in attitudes/perceptions Confidence self ratings Comfort self ratings Change in knowledge Written exam scores Change in skills OSCE scores Observed assessment scores Change in behaviour Inclusion of skill in clinical practice Patient Outcomes	Learner Reaction Satisfaction with teaching method Satisfaction with instructor Procedural Skills outcomes such as injection and aspiration techniques
Study Type	Comparative studies which	Studies reporting on needs

	provide primary data for any of the outcomes listed above, including the following designs: Randomized controlled trials Non-randomized control trials Controlled before and after studies Interrupted time series English language (Morrison A et al., 2009)	assessments for MSK Teaching Studies reporting the prevalence of MSK skills teaching Opinion Papers Uncontrolled before and after studies Articles not in the English language

Table 4

Condensed summary of findings

Intervention	Comparator	Outcome	Findings	Study Design and Number of Participants Enrolled
Patient educators	Standard curriculum	Skill	Favours patient educator	1 RCT (n=32*), 1 observational study (n=19)
			No difference	1 observational study (n=unclear)
	Expert in rheumatology	Skill	Favours patient educator	1 RCT (n=24*)
			Favours expert in rheumatology	1 cluster RCT (n=62)
			No difference	2 RCT (n=50, n=80)
		Knowledge	No difference	1 RCT (n=50)
		Confidence	No difference	1 RCT (n=41*)
	General practitioner	Skill	Favours patient educator	1 observational study (n=37)
	Video	Skill	Favours patient educator	1 RCT (n=181)
		Knowledge	Favours patient educator	1 RCT (n=181)
		Confidence	Favours patient educator	1 RCT (n=181)
Interactive, small groups learning	Didactic teaching	Skill	Favours small groups	1 cluster RCT (n=75) 1 observational study (n=22)
		Knowledge	Favours small groups	1 cluster RCT (n=22)
New curriculum emphasizing small group, interactive learning	Traditional curriculum	Skill	Favours traditional curriculum	1 observational study (n=145)
			Favours new curriculum	1 observational study (n varied with outcome assessed = 65 or 86*)
		Knowledge	Favours new curriculum	1 observational study (n=197)
		Confidence	Favours new curriculum	1 observational study (n varied with outcome assessed = 39 or 67*)
Computer- assisted learning	Traditional curriculum	Skill	Favours computer-based learning	1 cluster RCT (n=354)
		Knowledge	No difference	1 observational study (n=87)
		Confidence	No difference	1 cluster RCT (n=354)
	Textbook	Skill	Favours computer-based learning	1 RCT (n=99*)
	Expert in rheumatology	Skill	No difference	1 RCT (n=99*)
	Bedside teaching	Skill	No difference	1 RCT (n=28*)

Peer-assisted learning	Standard curriculum	Skill	Favours peer-assisted learning	2 observational studies (n=64) and (n=246)
	Physiotherapist	Skill	No difference	1 observational study (n=64)
General physician	Physiotherapist	Skill	No difference	cluster RCT (n=264)
Standardized physical exam associates	Physician faculty	Skill	No difference	1 RCT (n=144)
Reminder sheets pre-patient interview	Standard curriculum	Change in behaviour	Favours reminders	1 observational study (n=11)
New GALS teaching approach	Traditional curriculum	Skill	Favours GALS approach	1 observational study (n=264)
		Confidence	Favours GALS approach	1 observational study (n=218)

GALS: Gait, arms, legs and spine screening examination
* the number of participants enrolled in the study did not equal the number of participants analyzed for outcome assessment

Table 5

Study Characteristics

Citation	Institution	Design	Population	Research Question/Purpose	Intervention	Comparator	Primary Outcomes
Patient Educators							
(Hendry et al., 1999)	Faculty of Medicine, University of Sydney	cluster RCT	undergraduates	To assess whether students taught by trained patients acquire the same levels of competence in musculoskeletal examination skills for arthritis as students taught by consultant rheumatologists.	Trained arthritis patient educators (80min session with 7-8 students per group)	Consultant rheumatologists (80 min session with 7-8 students per group)	Skill: physical exam skills assessed by an arthritis educator
(Humphrey-Murto et al., 2004)	Faculty of Medicine, University of Ottawa	cluster RCT	undergraduates	To evaluate the teaching effectiveness of patient educators compared to rheumatology faculty using the musculoskeletal examination	Trained arthritis patient educators (3, 3hour sessions with 6-7 students per group)	Consultant rheumatologists (3,3 hour sessions with 6-7 students)	Skill: 9 station OSCE

(Branch, Graves, Hanczyc, & Lipsky, 1999)	University of Texas, Southwestern Medical Center	RCT	internal medicine PGY2 and PGY3 residents	To assess the examination skills of residents and determine whether an intervention by trained arthritis educators could have a greater impact on their physical examination skills than participation in an ambulatory care training experience alone	Standard exposure at an arthritis clinic (1/2 day per week, 6 week rotation) + hands-on interactive demonstration of the musculoskeletal examination by the arthritis educator (length of time not stated).	Standard exposure at an arthritis clinic (1/2 day per week, 6 week rotation). The residents evaluated approximately 6 patients per week under the direct supervision of an attending rheumatologist.	Skill: physical exam skills assessed by an arthritis educator
(Branch & Lipsky, 1998)	University of Texas, Southwestern Medical Center	RCT	undergraduates	To determine whether an intervention by trained persons with arthritis could have a positive impact on retention of information, confidence, and examination skills of medical students as compared to viewing an instructional video alone	Trained arthritis educators (90 min) + video (40min)	Video (40 min)	Skill: physical exam skills assessed by an arthritis educator
(Raj, Badcock, Brown, Deighton, & O'Reilly, 2006)	Derbyshire Royal Infirmary and Postgraduate Dental and Medical Education School of Community and Health Sciences, University of Nottingham	RCT	undergraduates	To compare the core hand and knee examination skills gained by undergraduates taught either by trained patient educators or by doctors.	Trained arthritis patient educators (2, 1 hr sessions with 25 students per group)	Consultant rheumatologists + an untrained Pt (2, 1 hr sessions with 25 students per group)	Skill: 2 station OSCE

(Haq et al., 2006)	Centre for Rheumatology, University College Hospitals and Academic Centre for Medical Education, Royal Free and University College Medical School London	prospective cohort	undergraduates	To assess the impact of teaching about back pain to medical students using trained patient partners.	Standard curriculum + trained patient educators (2, 75 min sessions with 12-15 students per group)	Standard curriculum 5 week block (attendance at rheumatology clinics, problem-solving exercises and seminars)	Skill: 1 station OSCE
(M. D. Smith, Henry-Edwards, Shanahan, & Ahern, 2000)	School of Medicine, Flinders University of South Australia	RCT	undergraduates	To evaluate the effect of 2 different teaching methods on MSK PE exam outcomes	Small group sessions by arthritis Pt. educators (size of groups and length of sessions not stated)	Small group sessions by rheumatology fellows (size of groups and length of sessions not stated)	Skill: 1 station OSCE
(Schrieber, Hendry, & Hunter, 2000)	Dept. of Rheumatology Royal North Shore Hospital, St. Leonards and the Faculty of Medicine, University of Sydney	prospective cohort	undergraduates	To assess whether students taught by trained patients acquire the same levels of competence in musculoskeletal physical exam skills as students taught by non specialist doctors.	Trained patient educators (duration of session not stated, 3-4 students per group)	Non-specialist physicians (duration of session not stated, 3-4 students per group)	Skill: physical exam skills assessed by an arthritis educator and a rheumatologist

(K. K. Anderson & Meyer, 1978)	University of Wisconsin-Madison, Center for Health Sciences	prospective cohort	undergraduates	To compare the physical exam skills of students taught by instructor-patients, to those taught by physicians	Patient led physical examination skills session (2.5 hours, 4 students per group)	Traditional curriculum - details not stated	physical exam skills assessed by physicians
Small groups, interactive learning							
(C. C. Smith, Newman, Davis, Yang, & Ramanan, 2005)	Harvard Medical School	non-concurrent cohort	internal medicine and primary care PGY2 and PGY3 residents	To create and implement a comprehensive clinical skills teaching model, and to evaluate its effects on residents' knowledge and diagnostic skills.	2 new curricular series, the painful shoulder and the painful knee, with: group discussion, case presentation, question and answer opportunity, interactive lectures, role-playing, and one-on-one teaching (each series consisted of 3, 50-minute educational sessions).	Traditional curriculum	Skill: 2 station OSCE

(Bilderback et al., 2008)	Louisiana State University School of Medicine and the College of Medicine, University of Florida	non-concurrent cohort	undergraduates	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.	Elements of objectives-based and problem centered curricular models. Each clinical lecture was preceded by pertinent anatomy lectures and dissections to provide a context for the clinical information presented in the lecture.	Historical curriculum	knowledge: Freedman-Bernstein basic competency exam
(Berendonk, Perrig, & Beyeler, 2008)	Institute of Medical Education, Assessment and Evaluation Unit, University of Bern	prospective cohort	undergraduates	To evaluate student awareness of clinical skills development and to assess the impact of a teaching intervention	Standard clerkship + session with a rheumatologist and an internal medicine inpatient (6, 1 hour sessions, "small groups" but number of students per group not stated)	Standard clerkship only	Skill: 1 station OSCE

(Hergenroeder, Chorley, Laufman, & Fetterhoff, 2002)	Baylor College of Medicine, and Wyle Laboratories, Life Sciences Systems and Services	cluster RCT	practicing pediatricians	To compare the effect of 2 methods of teaching the physical examination of the ankle and knee on the knowledge and skills of pediatricians.	Videotape showing correct performance of the ankle and knee physical examinations (18 minutes) + a physical exam skills building session (duration of session not stated)	videotape only (18 minutes)	Skill: Clinical Skills Assessment Examination
(M. D. Smith et al., 2002)	School of Medicine, Flinders University of South Australia	non-concurrent cohort	undergraduates	To assess student evaluation, satisfaction, and examination outcomes for a new method of teaching musculoskeletal medicine clinical skills, structured clinical instruction modules, and to compare with the outcomes of a traditional method of teaching clinical skills (small group bedside tutorials) in rheum and orthopedic outpatient sessions	Structured clinical instruction modules - station staffed by a senior consultant in rheumatology and orthopedic surgery, with a relevant patient (6, 30 min stations with 24-26 students per group)	Small bedside group tutorials (~20hours with 9-10 students per group)	Skill: 2 station OSCE
Computer-assisted Learning							

(P. Vivekananda-Schmidt, Lewis, Hassell, & ARC Virtual Rheumatology CAL Research,Group, 2005)	Keele University School of Medicine	cluster RCT	undergraduates	To identify whether there was measurable impact of a specific computer-assisted learning package, "Virtual Rheumatology," on the learning of musculoskeletal examination skills by medical students.	Virtual Rheumatology CD - includes illustrations of anatomic terms and living anatomy, photographs of the skeleton, and digital video sequences to demonstrate examination techniques. Self-assessment component available	Standard curriculum	Skill: 1 station OSCE
(Averns et al., 2009)	School of Medicine, Queens University	RCT	undergraduates	To evaluate the effectiveness of an online module in the development of medical students' clinical hand examination skills.	Web-based module (unlimited time)	Rheumatologist led tutorials (with presentation and patient, physical exam practice time - duration of session not stated, 18 students per group)	Skill: 1 station OSCE

(Hull, Chaudry, Prasthofer, & Pattison, 2009)	Worcestershire Royal Infirmary, Heart of England Foundation Trust and University Hospital Coventry and Warwickshire	RCT	undergraduates	To establish the most effective order in which to deliver teaching to medical students when using both bedside teaching and computer-based learning.	Computer-based-learning package of a PowerPoint presentation with written and pictorial slides and video clips of a physician performing the examination techniques with commentary followed by 1 hour bedside teaching by an orthopedic specialist	1 hour bedside teaching by the same orthopedic specialist, followed by the computer-based-learning package	Skill: 1 station OSCE
(Bridges et al., 1993)	University of Missouri-Columbia School of Medicine	non-concurrent cohort	undergraduates and residents doing a rheumatology elective	To assess the effectiveness of A11LEARN/Rheumatology, a computer-controlled interactive videodisc system for teaching.	Virtual Rheumatology CD - includes illustrations of anatomic terms and living anatomy, photographs of the skeleton, and digital video sequences to demonstrate examination techniques. Self-assessment component available	Traditional didactic lectures	Knowledge: multiple choice exam with slides of physical findings

Peer-assisted Learing							
(Graham, Burke, & Field, 2008)	University of Glasgow, Faculty of Medicine	prospective cohort	undergraduates	To assess whether medical students using peer-assisted learning can deliver training comparable with didactic teaching provided by a specialist (physiotherapist).	Peer-assisted learning (2 hour session with 11-19 students per group)	Physiotherapist led didactic teaching (2 hour session with 19 students per group)	Skill: 1 station OSCE
(Burke, Fayaz, Graham, Matthew, & Field, 2007)	University of Glasgow, Faculty of Medicine	prospective cohort	undergraduates	To evaluate whether peer-assisted learning can be used to improve students' clinical examination skills.	Peer-assisted learning (2, 3 hour sessions with 14 students per group)	Standard curriculum	Skill: 1 station OSCE
Other							
(McGaghie et al., 1993)	University of North Carolina, School of Medicine	cluster RCT	undergraduates	To evaluate the effectiveness of general physicians vs. physical therapists as instructors of the musculoskeletal physical exam	Physical therapists as instructors of the physical exam (2, 2 hr sessions with a maximum of 20 students per group)	General internists or general practitioners as instructors of the physical exam (2, 2 hr sessions with a maximum of 20 students per group)	Skill: 4 station OSCE
(Mazzuca et al., 1993)	Indiana University School of Medicine	prospective cohort	internal medicine house officers	To assess whether the use of reminder sheets would increase house officers' adoption of care recommendations taught in a didactic conference	1 hour didactic lecture on diagnosis and treatment of arthritis, with practice physical exam + reminder sheet in chart when seeing patients with	1 hour didactic lecture + practice physical exam only	change in behaviour: observation of interaction with patient by a trained research assistant

					chronic knee or shoulder pain		
(Fox, Dacre, Clark, & Scotland, 2000)	University College Medical School, the Whittington Hospital, and Chelsea and Westminster Hospital	non-concurrent cohort	undergraduates and pre-registration house officers	To assess the impact of GALS locomotor screen teaching to all 3rd year medical students at a British medical school	1 hour small group session (size not stated) during the general practice or rheumatology firm attachment where GALS is taught as a screening tool	Curriculum wherein students are not taught GALS as part of locomotor screening	Skill: 1 station OSCE
(Barley, Fisher, Dwinnell, & White, 2006)	University of Colorado at Denver and Health Sciences Center, School of Medicine	RCT	undergraduates	To determine differences in the physical exam skills of first-year medical students learning physical exam exclusively from standardized physical examination teaching associates or physician faculty.	Standardized physical examination associates (standardized patients, community members) led physical exam session (duration of session not stated, one-on-one teaching)	Physician faculty led physical exam session (duration of session not stated, 6 students per group)	Skill: 1 station OSCE

OSCE - Objective Structured Clinical Exam

PGY - Post-Graduate Year

Table 6

Main findings of the review

Citation	Outcome	Quantitative Results	Author's Conclusions	Stated limitations
Patient Educators				
(Hendry et al., 1999)	Skill: physical exam skills assessed by an arthritis educator (hand and wrist)	Students taught by patient educators achieved a mean score of 36.18/42 whereas those taught by faculty achieved a mean score of 32.4/42. Authors did not state the statistical significance of these findings, nor did they provide the standard deviation so the P-value could not be calculated.	Students learned slightly better when taught by patient educators than faculty so trained patients are at least as competent teachers as physician faculty.	Though they were blinded, patient educators assessed student examination skill which may have biased the overall outcome
(Humphrey-Murto et al., 2004)	Skill: 9 station OSCE	No significant difference for overall score between rheumatology taught and patient taught students, which was 62.1% and 66.5% respectively. Five patient taught students failed the exam whereas zero faculty taught students failed (P=0.02).	Rheumatology faculty appear to be more effective teachers of the musculoskeletal physical exam than patient educators	NS

(Branch et al., 1999)	Skill: PE skills assessed by an arthritis educator	At baseline there was no difference in the mean scores between groups (P=0.370). Post-intervention, the arthritis educator group had a mean score of 50.5/85, whereas the group with only the standard clinic experience had a mean score of 41.9/85 (P=2.15 x 10 ^ -5). The arthritis educator intervention group improved significantly in 23 of the 85 evaluation items (27%). By contrast, the group that received the clinic-only experience showed significant improvement in only 5 of the 85 (6%) evaluated manoeuvres.	"An intervention by arthritis educators significantly improved the musculoskeletal examination skills of internal medicine residents more effectively than the standard clinical teaching in a rheumatology outpatient clinic". These effects lasted at least five weeks.	NS
(Branch & Lipsky, 1998)	Skill: PE skills assessed by an arthritis educator, Knowledge: Matching terms and definitions, Confidence: 1-5 Likert scale	Students taught by an arthritis educator achieved a score of 51.6/85 on the physical skills exam, whereas those that watched the video alone had a score of 32.6/85 (P<0.000). Although there was no difference between groups pre-intervention, post-intervention students taught by arthritis educators scored significantly higher on their written exam (P= 6 x 10 ^ -8) and ranked their self-confidence higher (P = 2 x 10 ^ - 48) than those who only watched the video.	"An intervention by arthritis educators improved the retention of information, confidence and examination skills of second-year medical students significantly compared with the standard educational approach". These effects lasted at least two weeks.	It is possible that the added length of the intervention (an extra 90 min), versus its actual content, affected the outcome. It was also the students' first formal exposure to patients in medical school, which may be why the sessions had such a heavy impact.

(Raj et al., 2006)	Skill: 2 station OSCE (hand and knee)	At the hand OSCE station, students taught by arthritis educators achieved a mean score of 18.04/28, whereas those taught by rheumatology faculty scored 17.16/28. At the knee OSCE station, students taught by arthritis educators achieved a mean score of 15.66/25, whereas those taught by rheumatology faculty scored 15.38/25. No significant difference was detected between groups at either OSCE station.	Patient educators can "deliver clearly structured undergraduate skills, teaching with equivalent learning outcomes to those of rheumatology consultants".	Contamination from other teaching sources (although students recruited before their MSK module started to avoid this).
(Haq et al., 2006)	Skill: 1 station OSCE (ankylosing spondylitis)	No significant difference was found between the OSCE scores of the groups of students exposed to the standard curriculum only (75.8%) and those who had additional training with patient educators (79.3%).	"Using patient partners with back pain to teach medical students has a positive effect on student learning and patient well-being. The effects on examination performance are small but significant".	NS

(M. D. Smith et al., 2000)	Skill: 1 station OSCE (hand and wrist)	No significant difference was found in the OSCE scores between students in the rheumatology fellow led group (68.1%), and the patient educator led group (68.9%).	"Patient partners are as effective as rheumatology fellows in teaching MSK physical examination skills".	NS
(Schrieber et al., 2000)	Skill: formative assessment - physical exam skills scored by a consultant rheumatologist and a patient educator.	Students trained by arthritis patient partners scored significantly higher on their formative assessment than those trained by general physicians in 7/14 physical exam skills categories ($P<0.05$) rated by both sets of scorers. They also scored higher overall with an average score of 36.4/56 vs. 28.2/56 when rated by a rheumatologist, and 43.9/56 and 33.2/56 when rated by a patient educator.	"Patient partners are superior or equal to non-specialist doctors in the teaching of MSK physical exam skills".	Consultants and patient partner assessors were not blinded to student training

(K. K. Anderson & Meyer, 1978)	Skill: physical exam observed and assessed by physicians, and % of manoeuvres/elements omitted on physical exam	Students who received training by patient educators in addition to the standard curriculum scored significantly higher on the physical exam assessment than did those who were exposed to the standard curriculum only (3.07/7 vs. 4.21/7 - best score being 1.0), P<0.001. However, no significant difference was detected between groups for the mean percent of omitted manoeuvres (35.3% for the group exposed to the standard curriculum only vs. 21.8% for the group that received an additional session with a patient educator).	"Evaluation of students' physical exams demonstrated that the two groups have comparable technical skills after training". The group with additional training by patient educators performed a more thorough physical exam, though not necessarily more skillful.	Intervention groups were volunteers, they were also aware of their testing (Hawthorne effect)
Small groups, interactive learning				
(C. C. Smith et al., 2005)	Skill: 2 station OSCE (shoulder and knee)	Students exposed to the new curricular series scored significantly higher than their historical counterparts at both the shoulder (78% vs. 51%) and knee (95% vs. 55%) OSCE stations, with a significance of P=0.005 and P=0.0014 respectively.	Students participating in the new curriculum "demonstrate a greater improvement in the knowledge and performance of the skills needed in diagnosing and treating common shoulder and knee complaints as compared to the control group".	The number of residents involved in the single station OSCEs was relatively small compared to the number who participated in the curricula. the faculty who evaluated the residents were not blinded to whether the residents participated in the curricula. Also, unbalanced teaching time for new vs. old curriculum.

(Bilderback et al., 2008)	Knowledge: Freedman Bernstein basic competency exam	Students exposed to the objectives-based, PBL curriculum scored higher on the Freedman Bernstein basic competency exam (77.8%) than the control group exposed to a historical, didactic curriculum did (59.6%), with a significance of P<0.05.	"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".	The historical comparison group consisted of eighty-five medical and surgical residents who were in their first postgraduate year. Authors don't state which curriculum these participants were exposed to, and there was likely variance among them
(Berendonk et al., 2008)	Skill: 1 station OSCE	Students who received training in small groups with rheumatology faculty performed significantly better on the OSCE than those that received standard clerkship training alone, with a mean group score of 3.3/4 vs. 2.83/4 (P<0.05)	"The intervention students significantly improved their skills (from 2.78 ± 0.36 to 3.30 ± 0.36, p<0.05) in contrast to the control students (from 3.11 ± 0.58 to 2.83 ± 0.49, n.s.)".	NS

(Hergenroeder et al., 2002)	Skill: physical exam skills assessed by a Clinical Skills Assessment Examination (CSAE) (ankle and knee) Knowledge: written exam	Pediatricians that viewed the instructional video and were taught in small groups scored significantly higher on the CSAE for both the ankle and knee than those who viewed the video alone (P=0.002 and P=0.003 respectively). The pediatricians with additional small group training also scored higher on the written exam.	"Pediatricians' skills were lacking at baseline. Both teaching interventions were associated with improved skills and knowledge".	Professional familiarity between investigators and participants may have favourably biased the outcomes, as the pediatricians may have had more of an incentive to demonstrate their knowledge and skills than they would have to investigators whom they would be unlikely to interact with again.
(M. D. Smith et al., 2002)	Skill: 2 station OSCE (hand and knee)	For the hand station no significant difference was found between overall mean score for groups that received the structured clinical instruction modules (64.3%), versus those that were trained using traditional bedside teaching (62.6%). However, at the knee station, students taught with the traditional bedside manner scored significantly higher than their SCIM-trained peers (P=0.028). The clinical significance is questionable as the difference in scores was <10%.	"SCIM is an effective method of teaching clinical skills in MSK medicine, comparable with patient partners and traditional registrar based bedside teaching methods, but it is less resource intensive".	The study relies on 2 MSK stations out of a total of 11 (1997) or 12 (2000) OSCE stations to compare 2 methods of teaching.
Computer-assisted Learning				

(P. Vivekananda-Schmidt et al., 2005)	Skill: 1 station OSCE Confidence: self-confidence in performing physical exam	Both the London and Newcastle sites found that students using the Virtual Rheumatology CD scored significantly higher on the OSCE compared to students exposed to the standard curriculum only. At London the CD intervention group scored 15.1/17 versus the control group which scored 14.1/17 (P= 0.040). At Newcastle the CD intervention group scored 20.5/28 versus the control group which scored 18.1/28 (P= 0.002). No significant difference in confidence levels was found between groups.	"The Virtual Rheumatology CD has a positive impact on the acquisition of musculoskeletal examination skills in medical students".	Not all students underwent the OSCE in Newcastle, but there was little reason to suspect that these students were a select sample of the study population. Furthermore, the true effect size of CD use might have been underestimated by the intention-to-teach analysis, because only 50% of the participants in the intervention group actually used the CD.
(Averns et al., 2009)	Skill: 1 station OSCE (hand and wrist)	The group of students using the online module did not have significantly different OSCE scores than those who were taught by rheumatology faculty. However, the group using the online module did have significantly higher OSCE scores than the group using the textbook, 73.2% vs. 60.5% (P=0.003).	The web-based module is "an effective tool in the teaching of musculoskeletal examination skills, and provides some advantages over tutor-led teaching in terms of knowledge retention".	Student knowledge of upcoming OSCE as a motivator (Hawthorne Effect).Unbalanced teaching time i.e. unlimited access to the web module and textbook.

(Hull et al., 2009)	Skill: 1 station OSCE (scored on 2 separate occasions)	On the first OSCE testing, no significant difference was found between groups. The group using CAL achieved a mean score of 11/96/14, whereas the group exposed to bedside teaching achieved a mean score of 12.19/14. In the second OSCE, groups that used the CAL package prior to the bedside teaching session performed significantly better on their OSCE (12.79/14) than did students who received the bedside teaching session first, followed by the CAL package (11.81/14) (P = 0.038).	The findings suggest that "CBL is as effective as bedside teaching because there was no statistically significant difference between the groups in results on the first OSCE". Thus, the CAL package is a useful tool and is most effective if used before bedside teaching, as significant improvement in student OSCE scores was observed.	NS
(Bridges et al., 1993)	Knowledge: physical finding slides on multiple choice exam	No significant difference was detected between groups using the AI/LEARN/Rheumatology program and those exposed to traditional didactic lectures (58.2 vs. 56.4 - maximum score not stated).	"The results showed that AI/ LEARN/Rheumatology was as effective as traditional lectures in teaching rheumatology and showed a trend (P = 0.10) toward improved learning".	The authors "recognize the existence of a possible testing effect, i.e., that post-test scores may be artificially inflated because of prior experience with the test…[however, they] assume that pre-test effects were constant across groups".
Peer-assisted Learning				

(Graham et al., 2008)	Skill: 1 station OSCE	In the peer-taught group 39/45 students passed the MSK OSCE station, and 16/19 physiotherapist-taught students passed the station. There was no significant difference between the groups. After standard curriculum training, 111/181 (61%) achieved a pass at the MSK station. Following additional training, the pass rate rose for the students who had undertaken extra training, which rose 87% after peer-assisted learning and 84% after specialist training.	"Peer assisted learning (PAL) is a useful adjunct to musculoskeletal clinical skills training. Students using PAL techniques offered a comparable level of training with that provided by an expert".	The participants were volunteers and self-selection may have encouraged the more gifted or the more challenged students to apply for extra training.
(Burke et al., 2007)	Skill: 1 station OSCE	26/28 (93%) students that received extra peer assisted training passed the MSK OSCE station, whereas 146/218 (67%) of the students that received the standard curriculum only, passed the station. This is a significant difference of P<0.005 and examination results for other clinical skill stations showed no difference in performance between the two groups.	"This study shows that peer-assisted learning is a useful adjunct to MSK training, and could be incorporated into medical curricula to enhance clinical skills".	NS
Other				
(McGaghie et al., 1993)	Skill: 4 station OSCE (knee, shoulder, back, general - each student was tested at 3 of the 4 stations)	No significant difference was found between physical therapist - led groups and physician trained groups, except at one OSCE station (the overall MSK exam), where the physician trained students performed better in one year of the study (54.06 vs. 49.57 - maximum score not stated).	"Physicians and physical therapists were equally effective teachers" of the musculoskeletal exam.	NS

(Mazzuca et al., 1993)	Change in behaviour: observation of resident interaction with patient by a trained research assistant - looking for particular shoulder and knee physical exam techniques and specific questions on history	Residents who were provided with reminders were found to perform 4/5 physical examination techniques more frequently than those without reminders ($P<0.05$). For the knee residents with reminders performed an appropriate PE and history 75% of the time, versus those without reminders who performed an appropriate PE and history 35.2% of the time. For the should, residents with reminders performed an appropriate PE and history 76.5% of the time, versus those without reminders who performed an appropriate PE and history 36.8% of the time.	"Specific questioning about a recent history of knee or shoulder pain and the performance of 4/5 recommended PE manoeuvres were increased significantly by reminder sheets in patient's charts".	Small number of participants in trial, small number of observed patient encounters and direct observation may have caused atypical behaviour.
(Fox et al., 2000)	Skill: 1 station OSCE (screening locomotor system examination) Confidence: self-rated physical exam skills	Students that were taught the GALS locomotor screen scored significantly higher on the OSCE, 16.0/20 than did the pre-registration house officers that did not undergo GALS training, 5.0/20 ($P<0.0001$). Students that were taught the GALS screen also rated their self-confidence significantly higher than the PRHOs ($P<0.05$).	"Students who are taught the GALS screen as part of their curriculum perform it well at an end of year OSCE to a higher standard than PRHOs".	Not an RCT

(Barley et al., 2006)	Skill: 1 station OSCE (upper extremity)	No significant difference in OSCE scores was detected between groups trained by standardized physical exam associates (SPEAs) (86.8%) and those trained by physician faculty (83.9%).	The findings suggest that "lay teaching associates can effectively teach foundational physical examination skills at the equivalent and sometimes better performance level as physician faculty".	The limitations of this study include it being a single-institution, single-year study. Another limitation might be that the groups were different sizes. This was done because faculty needed pairs of students to teach with, while SPEAs needed time to allow the three students to practice on his/her body. Potentially the time spent observing students practicing on each other by faculty could have impacted their ability to teach the competencies.

NS – none stated

References

Ahern, M. J., Soden, M., Schultz, D., & Clark, M. (1991). The musculo-skeletal examination: A neglected clinical skill. *Australian & New Zealand Journal of Medicine, 21*(3), 303-306.

Alliance for the Canadian Arthritis Program. (2006). *Report for the summit on standards for arthritis prevention and care*

Anderson, K. K., & Meyer, T. C. (1978). The use of instructor-patients to teach physical examination techniques. *Journal of Medical Education, 53*(10), 831-836.

Anderson, R. C., Fagan, M. J., & Sebastian, J. (2001). Teaching students the art and science of physical diagnosis. *American Journal of Medicine, 110*(5), 419-423.

Association of American Medical Colleges. (2005). *Report VII contemporary issues in medicine: Musculoskeletal medicine education, medical school objectives project* No. VII)

Averns, H., Maraschiello, M., van Melle, E., & Day, A. (2009). Evaluation of a web-based teaching module on examination of the hand. *Journal of Rheumatology, 36*(3), 623-627.

Badley, E. M., & Crotty, M. (1995). An international comparison of the estimated effect of the aging of the population on the major cause of disablement, musculoskeletal disorders. *Journal of Rheumatology, 22*(10), 1934-1940.

Badley, E. M., Rasooly, I., & Webster, G. K. (1994). Relative importance of musculoskeletal disorders as a cause of chronic health problems, disability, and health care utilization: Findings from the 1990 ontario health survey.see comment. *Journal of Rheumatology, 21*(3), 505-514.

Badley, E. M., & Wang, P. P. (2001). The contribution of arthritis and arthritis disability to nonparticipation in the labor force: A canadian example. *Journal of Rheumatology, 28*(5), 1077-1082.

Badley, E. M., & Wang, P. P. (1998). Arthritis and the aging population: Projections of arthritis prevalence in canada 1991 to 2031. *Journal of Rheumatology*, *25*(1), 138-144.

Badley, E. M., Webster, G. K., & Rasooly, I. (1995). The impact of musculoskeletal disorders in the population: Are they just aches and pains? findings from the 1990 ontario health survey. *Journal of Rheumatology, 22*(4), 733-739.

Barley, G. E., Fisher, J., Dwinnell, B., & White, K. (2006). Teaching foundational physical examination skills: Study results comparing lay teaching associates and physician instructors. *Academic Medicine, 81*(10 Suppl), S95-7.

Berendonk, C. H., Perrig, M., & Beyeler, C. (2008). Further concerns about self-assessment: Are medical students aware of their progress in clinical skills during clerkship? *Association for medical education in europe*, Prague, Czech Republic,

Berkson, L. (1993). Problem-based learning: Have the expectations been met? *Academic Medicine, 68*(10 Suppl), S79-88.

Bilderback, K., Eggerstedt, J., Sadasivan, K. K., Seelig, L., Wolf, R., Barton, S. et al. (2008). Design and implementation of a system-based course in musculoskeletal medicine for medical students. *Journal of Bone & Joint Surgery - American Volume, 90*(10), 2292-2300.

Branch, V. K., Graves, G., Hanczyc, M., & Lipsky, P. E. (1999). The utility of trained arthritis patient educators in the evaluation and improvement of musculoskeletal examination skills of physicians in training. *Arthritis Care & Research, 12*(1), 61-69.

Branch, V. K., & Lipsky, P. E. (1998). Positive impact of an intervention by arthritis educators on retention of information, confidence, and examination skills of medical students. *Arthritis Care & Research, 11*(1), 32-38.

Bridges, A. J., Reid, J. C., Cutts, J. H.,3rd, Hazelwood, S., Sharp, G. C., & Mitchell, J. A. (1993). AI/LEARN/Rheumatology. A comparative study of computer-assisted instruction for rheumatology. *Arthritis & Rheumatism, 36*(5), 577-580.

Burke, J., Fayaz, S., Graham, K., Matthew, R., & Field, M. (2007). Peer-assisted learning in the acquisition of clinical skills: A supplementary approach to musculoskeletal system training. *Medical Teacher, 29*(6), 577-582.

Chumley-Jones, H. S., Dobbie, A., & Alford, C. L. (2002). Web-based learning: Sound educational method or hype? A review of the evaluation literature. *Academic Medicine, 77*(10 Suppl), S86-93.

Clawson, D. K., Jackson, D. W., & Ostergaard, D. J. (2001). It's past time to reform the musculoskeletal curriculum. *Academic Medicine, 76*(7), 709-710.

College des Medecins du Quebec Practice Enhancement Division. (1999). *Clinical practice guidelines: The musculoskeletal system*

Cook, D. A. (2005). Learning and cognitive styles in web-based learning: Theory, evidence, and application. *Academic Medicine, 80*(3), 266-278.

Crotty, M., Ahern, M. J., McFarlane, A. C., & Brooks, P. M. (1993). Clinical rheumatology training of australian medical students. A national survey of 1991 graduates. *Medical Journal of Australia, 158*(2), 119-120.

Dacre, J. E., Griffith, S. M., & Jolly, B. C. (1996). Rheumatology and medical education in great britain. *British Journal of Rheumatology, 35*(3), 269-274.

Day, C. S., Yeh, A. C., Franko, O., Ramirez, M., & Krupat, E. (2007). Musculoskeletal medicine: An assessment of the attitudes and knowledge of medical students at harvard medical school. *Academic Medicine, 82*(5), 452-457.

Dequeker, J., & Rasker, H. (1998). High prevalence and impact of rheumatic diseases is not reflected in the medical curriculum: The ILAR undergraduate medical education in rheumatology (UMER) 2000 project. together everybody achieves more. international league of associations for rheumatology. *Journal of Rheumatology, 25*(6), 1037-1040.

Distlehorst, L. H., Dawson, E., Robbs, R. S., & Barrows, H. S. (2005). Problem-based learning outcomes: The glass half-full. *Academic Medicine, 80*(3), 294-299.

Doherty, M., Abawi, J., & Pattrick, M. (1990). Audit of medical inpatient examination: A cry from the joint. *Journal of the Royal College of Physicians of London, 24*(2), 115-118.

Ericsson, K. A. (2004). Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Academic Medicine, 79*(10 Suppl), S70-81.

Fox, R. A., Dacre, J. E., Clark, C. L., & Scotland, A. D. (2000). Impact on medical students of incorporating GALS screen teaching into the medical school curriculum. *Annals of the Rheumatic Diseases, 59*(9), 668-671.

Graham, K., Burke, J. M., & Field, M. (2008). Undergraduate rheumatology: Can peer-assisted learning by medical students deliver equivalent training to that provided by specialist staff?. *Rheumatology, 47*(5), 652-655.

Greenhalgh, T. (2001). Computer assisted learning in undergraduate medical education. *BMJ, 322*(7277), 40-44.

Hammoud, M., Gruppen, L., Erickson, S. S., Cox, S. M., Espey, E., Goepfert, A. et al. (2006). To the point: Reviews in medical education online computer assisted instruction materials. *American Journal of Obstetrics & Gynecology, 194*(4), 1064-1069.

Haq, I., Fuller, J., & Dacre, J. (2006). The use of patient partners with back pain to teach undergraduate medical students. *Rheumatology, 45*(4), 430-434.

Hartling, L., Spooner, C., Tjosvold, L., & Oswald, A. (2010). Problem-based learning in pre-clinical medical education: 22 years of outcome research. *Medical Teacher, 32*(1), 28-35.

Hasle, J. L., Anderson, D. S., & Szerlip, H. M. (1994). Analysis of the costs and benefits of using standardized patients to help teach physical diagnosis. *Academic Medicine, 69*(7), 567-570.

Hendry, G. D., Schrieber, L., & Bryce, D. (1999). Patients teach students: Partners in arthritis education. *Medical Education, 33*(9), 674-677.

Hergenroeder, A. C., Chorley, J. N., Laufman, L., & Fetterhoff, A. (2002). Two educational interventions to improve pediatricians' knowledge and skills in performing ankle and knee physical examinations. *Archives of Pediatrics & Adolescent Medicine, 156*(3), 225-229.

Higgins, J. P. T., & Green, S. (2006). *Cochrane handbook for systematic reviews of interventions 4.2.6*John Wiley & Sons, Ltd: Cochrane Collaboration.

Hull, P., Chaudry, A., Prasthofer, A., & Pattison, G. (2009). Optimal sequencing of bedside teaching and computer-based learning: A randomised trial. *Medical Education, 43*(2), 108-112.

Humphrey-Murto, S., Smith, C. D., Touchie, C., & Wood, T. C. (2004). Teaching the musculoskeletal examination: Are patient educators as effective as rheumatology faculty? *Teaching & Learning in Medicine, 16*(2), 175-180.

Jha, V., Quinton, N. D., Bekker, H. L., & Roberts, T. E. (2009). Strategies and interventions for the involvement of real patients in medical education: A systematic review. *Medical Education, 43*(1), 10-20.

Kirkpatrick, D. L. (2006). In Kirkpatrick D. L., Kirkpatrick J. D.(Eds.), *Evaluating training programs: The four levels* (third edition ed.). San Francisco: Berrett-Koehler Publishers.

Lam-Antoniades, M., Ratnapalan, S., & Tait, G. (2009). Electronic continuing education in the health professions: An update on evidence from RCTs. *Journal of Continuing Education in the Health Professions, 29*(1), 44-51.

Leroux, I., Dionne, C. E., Bourbonnais, R., & Brisson, C. (2005). Prevalence of musculoskeletal activity limitation and associated factors among adults in the general

population in the 1998 quebec health survey. *Journal of Rheumatology, 32*(9), 1794-1804.

Mazzuca, S. A., Brandt, K. D., & Katz, B. P. (1993). Improved training of house officers in a rheumatology consult service. *Arthritis Care & Research, 6*(2), 59-63.

McGaghie, W. C., Kowlowitz, V., Renner, B. R., Sauter, S. V., Hoole, A. J., Schuch, C. P. et al. (1993). A randomized trial of physicians and physical therapists as instructors of the musculoskeletal examination. *Journal of Rheumatology, 20*(6), 1027-1032.

McNaughton, N., Ravitz, P., Wadell, A., & Hodges, B. D. (2008). Psychiatric education and simulation: A review of the literature. *Canadian Journal of Psychiatry - Revue Canadienne De Psychiatrie, 53*(2), 85-93.

McNulty, J. A., Sonntag, B., & Sinacore, J. M. (2009). Evaluation of computer-aided instruction in a gross anatomy course: A six-year study. *Anatomical Sciences Education, 2*(1), 2-8.

Pinney, S. J., & Regan, W. D. (2001). Educating medical students about musculoskeletal problems. are community needs reflected in the curricula of canadian medical schools? *Journal of Bone & Joint Surgery - American Volume, 83-A*(9), 1317-1320.

Raj, N., Badcock, L. J., Brown, G. A., Deighton, C. M., & O'Reilly, S. C. (2006). Undergraduate musculoskeletal examination teaching by trained patient educators--a comparison with doctor-led teaching. *Rheumatology, 45*(11), 1404-1408.

Rigby, J. C., & Oswald, A. G. (1987). An evaluation of the performing and recording of physical examinations by psychiatric trainees. *British Journal of Psychiatry, 150*, 533-535.

Schmale, G. A. (2005). More evidence of educational inadequacies in musculoskeletal medicine. *Clinical Orthopaedics & Related Research,* (437), 251-259.

Schmidt, H. G., Dauphinee, W. D., & Patel, V. L. (1987). Comparing the effects of problem-based and conventional curricula in an international sample. *Journal of Medical Education, 62*(4), 305-315.

Schmidt, H. G., Machiels-Bongaerts, M., Hermans, H., ten Cate, T. J., Venekamp, R., & Boshuizen, H. P. (1996). The development of diagnostic competence: Comparison of a problem-based, an integrated, and a conventional medical curriculum. *Academic Medicine, 71*(6), 658-664.

Schrieber, L., Hendry, G. D., & Hunter, D. (2000). Musculoskeletal examination teaching in rheumatoid arthritis education: Trained patient educators compared to nonspecialist doctors. *Journal of Rheumatology, 27*(6), 1531-1532.

Smith, C. C., Newman, L., Davis, R. B., Yang, J., & Ramanan, R. (2005). A comprehensive new curriculum to teach and assess resident knowledge and diagnostic evaluation of musculoskeletal complaints. *Medical Teacher, 27*(6), 553-558.

Smith, M. D., Henry-Edwards, S., Shanahan, E. M., & Ahern, M. J. (2000). Evaluation of patient partners in the teaching of the musculoskeletal examination. *Journal of Rheumatology, 27*(6), 1533-1537.

Smith, M. D., Walker, J. G., Schultz, D., Ash, J., Roberts-Thomson, P., Shanahan, E. M. et al. (2002). Teaching clinical skills in musculoskeletal medicine: The use of structured clinical instruction modules. *Journal of Rheumatology, 29*(4), 813-817.

Spencer, B. (1998). *The purposes of adult education*. Toronto: Thompson Educational Publishing Inc.

Tamblyn, R., Abrahamowicz, M., Dauphinee, D., Girard, N., Bartlett, G., Grand'Maison, P. et al. (2005). Effect of a community oriented problem based learning curriculum on quality of primary care delivered by graduates: Historical cohort comparison study. *BMJ, 331*(7523), 1002.

Vernon, D. T., & Blake, R. L. (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine, 68*(7), 550-563.

Vivekananda-Schmidt, P., Lewis, M., & Hassell, A. B. (2005). Cluster randomized controlled trial of the impact of a computer-assisted learning package on the learning of musculoskeletal examination skills by undergraduate medical students. *Arthritis & Rheumatism: Arthritis Care & Research, 53*(5), 764-771.

Vivekananda-Schmidt, P., Lewis, M., Hassell, A. B., & ARC Virtual Rheumatology CAL Research,Group. (2005). Cluster randomized controlled trial of the impact of a computer-assisted learning package on the learning of musculoskeletal examination skills by undergraduate medical students. *Arthritis & Rheumatism, 53*(5), 764-771.

Wang, P. P., & Badley, E. M. (2003). Consistent low prevalence of arthritis in quebec: Findings from a provincial variation study in canada based on several canadian population health surveys. *Journal of Rheumatology, 30*(1), 126-131.

Wells, G. A. et al. *The newcastle-ottawa scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses.* Retrieved April/26, 2010 from http://www.ohri.ca/programs/clinical_epidemiology/oxford.htm

Wutoh, R., Boren, S. A., & Balas, E. A. (2004). eLearning: A review of internet-based continuing medical education. *Journal of Continuing Education in the Health Professions, 2*4(1), 20-30.

Yelin, E., Cisternas, M. G., Pasta, D. J., Trupin, L., Murphy, L., & Helmick, C. G. (2004). Medical care expenditures and earnings losses of persons with arthritis and other rheumatic conditions in the united states in 1997: Total and incremental estimates. *Arthritis & Rheumatism, 5*0(7), 2317-2326.

Yelin, E., Herrndorf, A., Trupin, L., & Sonneborn, D. (2001). A national study of medical care expenditures for musculoskeletal conditions: The impact of health insurance and managed care. *Arthritis & Rheumatism, 4*4(5), 1160-1169.