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ORIGINAL ARTICLE

Knowledge transfer of spinal manipulation skills by student-teachers: a randomised controlled trial

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Abstract
Purpose To assess the use of peer-assisted learning (PAL) of complex manipulative motor skills with respect to gender in medical students.
Methods In 2007–2010, 292 students in their 3rd and 4th years of medical school were randomly assigned to two groups [Staff group (SG), PAL group (PG)] led by either staff tutors or student-teachers (ST). The students were taught bimanual practical and diagnostic skills (course education module of eight separate lessons) as well as a general introduction to the theory of spinal manipulative therapy. In addition to qualitative data collection (Likert scale), evaluation was performed using a multiple-choice questionnaire in addition to an objective structured clinical examination (OSCE).
Results Complex motor skills as well as palpatory diagnostic competencies could in fact be better taught through professionals than through ST (manipulative OSCE grades/diagnostic OSCE score; SG vs. PG; male: $P = 0.017$/$P < 0.001$, female: $P < 0.001$/$P < 0.001$). The registration of theoretical knowledge showed equal results in students taught by staff or ST. In both teaching groups (SG: $n = 147$, PG: $n = 145$), no significant differences were observed between male and female students in matters of manipulative skills or theoretical knowledge. Diagnostic competencies were better in females than in males in the staff group ($P = 0.041$) Overall, students were more satisfied with the environment provided by professional teachers than by ST, though male students regarded the PAL system more suspiciously than their female counterparts.
Conclusions The peer-assisted learning system does not seem to be generally qualified to transfer such complex spatiotemporal demands as spinal manipulative procedures.

Keywords Peer teaching · Gender differences · Randomised controlled trial · Complex motor skills · Spinal manipulative therapy

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Introduction

Although spinal manipulative (SM) therapy continues to be increasingly used, there remain many unanswered questions with respect to training and competence at the present time. Peer-assisted learning (PAL) has become an increasingly popular strategy to support staff members, but little is known about the acceptance and outcome of PAL in the field of demanding bimanual manipulative motor skills. The results of PAL appear comparable to those offered by health-care professionals [1–6], but there exist some doubts concerning the universality of the results when applied to more complicated bimanual skills and learning objectives that necessitate high levels of sensory/motor coordination and confidence [3, 4]. Viewed from a motor learning perspective, SM performance is a demanding bimanual task that requires confidence [7]. Characterised by a dynamic thrust of high velocity, low amplitude, specific anatomical contact and direction associated with an audible cavitation [8], it can be perceived as a task requiring high-speed,

low-amplitude precision with mechanical consequences [9]. Several authors have investigated the effects of various feedback strategies and learning tools to improve chiropractic teaching techniques, and have underlined the necessity of including motor learning principles as early as possible [10]. Clinical experience aside, it remains possible that students may not possess the pedagogical skills to teach fellow students the more difficult aspects of complex motor skills [11]. Thus far, however, neither PAL strategies nor gender differences with regard to this learning process have been investigated in this context. The research of the role of biological sex and sociological gender has added important results for treatment strategies, clinical research and career planning of physicians, but the results in the area of clinical performance have not been consistent, with respect to advantages for female or male students [12–15]. To test this hypothesis, the study attempts to combine the PAL concept with SM therapy searching for a gender-related outcome difference. The correlation between personally reported confidence in newly learnt skills and the objective performance measures remains questionable [16]. We therefore conducted the present prospective randomised study to answer two questions:

1. Can the demanding bimanual tasks of complex SM motor skills be successfully taught equally to both genders by student-teachers?
2. Do female and male students assess the SM knowledge transfer by student-teachers and their learning environment equally?

Methods

Informed consent was obtained from each student and participation was voluntary (ethical approval EK 178/09). Recruitment of students was achieved via flyers posted on bulletin boards, as well as by e-mail. Participants were assured that all data collected would remain anonymous and confidential and performance would bear no impact on later evaluations or other assessments. A randomised study (RCT) was completed that was able to measure both the quantitative and qualitative parameters.

Six separate cohorts of medical students (2007–2010) were enrolled in the study ($n = 304$). Students were representative of the normal student population as a whole. All students included in the study denied any previous experience with SM therapy as well as any previous didactic or pedagogical training in a preliminary questionnaire. From this group, 12 willing students were chosen at random to serve as student-teachers (ST). The remainder of the students ($n = 292$) were then randomly assigned to a PAL group (PG) or a Staff group (SG). The SG was taught SM performances by two experienced physicians (both male orthopaedic surgeons), possessing at least 7 years of SM experience.

Teacher training

The ST were representative of the general student population. Each was given a 90-min introduction to the diagnostic and practical aspects of SM therapy by the two experienced orthopaedic surgeons in addition to 2 weeks of full-time preparation with the appropriate background literature [17, 18]. During this time and also during the period of the 8-week course, they had the opportunity to assist in SM manoeuvres in ambulant treatment everyday including autonomous practice of the SM techniques. Students volunteered as test objects in this context.

Student training

Students were divided into smaller teaching groups, each containing 6–12 students. Each treatment platform was shared by two students. The exposure took place in eight separate lessons (8 weeks), each lasting approximately 120 min. Traditionally, complex chiropractic techniques are taught beginning with theoretical aspects of SM (first 30 min), including bimanual motor learning principles. Topics included indications/contraindications, differences between mobilisation and manipulation, diagnostics, patient positioning, hand placement, specific anatomical contact, preload, thrust phases and the direction of force. Thereafter, students participated in a 90-min practical session in which they were able to practice specific manipulative and diagnostic techniques of the whole spine, including the sacroiliac joint. Duration and content of the teaching sessions for SG and PG were absolutely comparable because of the existence of a predefined curriculum, as defined by the German Society for Manual Medicine (DGMM) (three manipulative techniques of the cervical spine, two of the thoracic and lumbar spine each, three of the sacroiliac joint).

Evaluation

A multiple-choice questionnaire (MCQ: 20 questions, maximal 10 points) and an objective structured clinical examination (OSCE) were used to assess the learning effect at the end of the 8-week course. The final practical examination included a realistic patient scenario where fellow students played the part of the patient. The manipulative skills (positioning of the volunteer, hand placement, specific anatomical contact, preload, thrust phases and direction/level of force) were rated by using a school grading system (1 = excellent, 6 = fail), while students

could achieve an OSCE score between zero and six for their palpatory diagnostic competencies assessing the functional musculoskeletal disturbances in the patient scenario. The students were separately evaluated (grades) by three external objective graders (all male orthopaedic surgeons, average determination) who were blinded as to which group the medical student was in, using a standardised rubric for manipulative skills (according to the standardised phases of manipulation technique). Points for diagnostic competencies (0–6 points) were awarded according to the number of correctly demonstrated steps to diagnose joint dysfunction in the cervical spine (soft tissue irritation, segmental mobility check, functional behaviour of segmental irritation) and focusing on the sacroiliac joint (including sacroiliac tests; Table 1).

Reciprocally, each student assessed the quality of teaching they received using items rated on a 5-point Likert scale (5 = agree, 1 = disagree). Of primary interest was teacher competency, subjective evaluation of personal confidence in the newly learnt skills and the evaluation of the PAL system with respect to SM therapy. The knowledge transfer was again rated using the school grading system (1 = excellent, 6 = fail).

Statistics

Analysis was performed using SPSS™ 17.0 (SPSS Inc., Chicago, IL, USA). In the cases where a normal distribution was present (MCQ, OSCE), a student *t* test was carried out; otherwise (assessment by Likert scale), non-parametric test methods such as the Mann–Whitney Wilcoxon test were used.

Table 1 OSCE tasks including diagnostic and manipulative competencies

Diagnostic OSCE score (0–6 points)
Palpatory competencies, cervical spine (0–2 points)
Functional tests, sacroiliac joint (0–2 points)
Palpatory competencies, sacroiliac joint (0–2 points)
Manipulative skills (grades: 1 = excellent, 6 = fail)[a]
Rotation-traction technique, cervical spine
Cross-hand technique, thoracic spine
Rotation-manipulative technique, lumbar spine
"Panther's-jump" technique, sacroiliac joint (cranialisation sacrum/caudalisation ilium)

[a] Manipulative skills, rubric focused on positioning of the volunteer, hand placement, specific anatomical contact, preload, thrust phases and direction/level of force

Results

Study population

The 292 students and 12 ST were selected from a population of 304 medical students in years 3 and 4 who had completed a mean of 6.2 semesters (mean age (SD) 23.1 (2.3) years, 184 female, 108 male). The mean age of the 12 ST was 23.7 (2.6) years; 6 were female and 6 were male. Staff group (SG, $n = 147$) and PAL group (PG, $n = 145$) had the same population characteristics.

Table 2 shows the distribution of the student collective.

Quantitative objective parameters (MCQ, OSCE)

The registration of the students' theoretical grasp of the topic showed no difference between the teaching groups (PG compared to SG; Table 3). The standardised manipulative manoeuvres could in fact be better taught through professionals than through ST. Here, the mean OSCE performance grades as well as the grades for the most particular manipulative techniques (1 = excellent, 6 = fail) showed superior results for the staff-led group in both genders (mean OSCE performance mark; SG vs. PG: male: 3.1 vs. 3.6, $P = 0.017$; female: 3.2 vs. 3.6, $P < 0.001$). The OSCE results in registration of the palpatory diagnostic competencies were better in students taught by professionals as well (diagnostic OSCE score (0–6 points); SG vs. PG: male: 4.0 vs. 3.4, $P < 0.001$; female: 4.4 vs. 3.7, $P < 0.001$).

Focusing on potential gender effects, no differences emerged between female and male students of the SG [mean MCQ scores (0–10 points): 5.9 vs. 5.5; $P = 0.207$] or the PG (5.8 vs. 5.6; $P = 0.567$) assessing the theoretical knowledge (Table 3). Similarly, no significant differences were seen between the two gender groups during the practical manipulative assessment (mean OSCE performance mark; SG: $P = 0.830$, PG: $P = 0.616$; Table 3). Statistically relevant differences were observed between

Table 2 Study population

Group	Number of students		Semester [mean (SD)]		Age [mean (SD)]	
	Female	Male	Female	Male	Female	Male
Staff group (SG, $n = 147$)	94	53	5.8 (1.7)	6.3 (1.7)	22.7 (2.3)	23.4 (1.9)
PAL group (PG, $n = 145$)	90	55	6.1 (1.5)	6.4 (1.8)	22.9 (2.2)	23.7 (2.3)
Total	184	108	6.0 (1.6)	6.4 (1.6)	22.8 (2.3)	23.6 (2.1)

Table 3 Comparison of groups: theory and OSCE scores expressed in mean (SD)

	Staff group (SG, $n = 147$)			PAL group (PG, $n = 145$)		
	Female	Male	P value	Female	Male	P value
Theory (MCQ, 20 questions, 10 points)	5.9 (1.9)	5.5 (1.9)	0.207	5.8 (1.8)	5.6 (1.8)	0.567
OSCE performance mark (grades 1–6)[a]	3.2 (0.9)#	3.1 (0.9)*	0.830	3.6 (0.9)	3.6 (1.0)	0.616
Rotation-traction technique, cervical spine	3.7 (1.4)°	3.4 (1.5)°	0.194	4.6 (1.4)	4.2 (1.5)	0.146
Cross-hand technique, thoracic spine	3.0 (1.1)°	3.2 (1.2)	0.432	3.4 (1.3)	3.4 (1.1)	0.918
Rotation-manipulation technique, lumbar spine	3.1 (1.2)°	3.0 (1.3)°	0.658	3.5 (1.2)	3.5 (1.4)	0.934
"Panther's-jump" technique, sacroiliac joint	2.8 (0.9)°	2.8 (1.0)	0.407	3.1 (1.1)	3.0 (1.0)	0.749
Diagnostic OSCE score (maximal 6 points)	4.4 (1.3)#	4.0 (1.5)#	0.041	3.7 (1.1)	3.4 (1.8)	0.101

[a] Grades: 1 = excellent, 6 = fail

* $P = 0.017$ compared to PG

# $P < 0.001$ compared to PG

° $P < 0.05$ compared to PG

female and male students in the SG in terms of the palpatory diagnostic OSCE score (SG; female vs. male: 4.4 vs. 4.0; $P = 0.041$). A summary of all results can be found in Table 3.

Subjective parameters (course evaluation)

Evaluation of the lessons as well as assessment of the quality of the learning environment is shown in Table 4. Of note is the fact that students in the SG rated the global knowledge transfer (Grade 2), the competency of their teachers, the fun of the lessons as well as the group interaction positively (Likert scale $\geq$4.1). In contrast to the overall positive reaction in the SG, students in the PG rated the global knowledge transfer, competency of their teachers (ST) and their time management significantly lower than those in the SG, irrespective of gender (Table 4; $P < 0.05$). As a whole, the peer-led group felt that they were left with more unanswered questions and the students would rather have been in the staff-led group ($P < 0.001$).

In the PG, significant gender differences emerged with regard to perceptions of the learning environment. Female students rated the global knowledge transfer (grades: 1 = excellent, 6 = fail) better than did their male colleagues (PG; female vs. male: 2.5 vs. 3.4; $P = 0.028$). Female students tended to be more satisfied with the competence of their ST (PG; female vs. male: 3.8 vs. 3.1 points of Likert scale; $P = 0.002$), the interaction between ST and students ($P = 0.026$) and with the group size ($P = 0.022$) than male students. Furthermore, they found the lessons more enjoyable ($P = 0.033$), subjectively felt that they learnt more ($P = 0.011$) and would indicated that they would act as an ST themselves ($P = 0.013$). Only male students of the PG were definitively convinced that SM performances ought to be learnt under the guidance of an experienced professional (PG: female vs. male, 3.0 vs. 4.0; $P = 0.008$; Table 4).

Discussion

Studies with qualitative and quantitative data collection are required to compare PAL to training by experts in the field of musculoskeletal medicine [5]. In the past, PAL programme student-teachers were shown not only to be effective, but also equally effective in teaching the required competencies for complicated technical skills (musculoskeletal ultrasound) as experienced physicians using self-teaching learning strategies [6]. Two different studies have shown the efficacy of PAL in the realm of technical skills with variable degrees of difficulty and also observed no differences to the results found in the traditionally staff-led teaching [3, 4], indicating a dependency of the results upon the difficulty of the skills being assessed [3]. However, to date, objective quantitative and qualitative data detailing the aspects of demanding manipulative techniques are lacking.

Our objective results show that such complex bimanual tasks of SM performances that require high levels of sensory/motor coordination and confidence could in fact be better taught through experienced professionals than through student-teachers. Contradicting the finding of a previous study [6], it was shown that subjective results of students correlate with this objective OSCE performance measures showing more unsatisfactory ratings under the PAL students. Significant gender differences were only seen in palpatory diagnostic competencies in the staff-led group and in the subjective evaluation data of the peer-led group. Female students seem to be more open to the knowledge transfer by student-teachers regarding complex spatiotemporal demands, while male students seem to regard it more critically.

Table 4 Responses from trainees who had lessons by peers with those who had lessons by physicians depending on their gender [Likert scale, mean (SD)]

	Staff group (SG, $n = 147$)			PAL group (PG, $n = 145$)		
	Female	Male	P value	Female	Male	P value
Rating of knowledge transfer (grades 1–6)[a]	2.0 (0.7)	2.1 (0.6)	0.543	2.5 (0.9)°	3.4 (1.1)°	0.028
The teacher was competent	4.5 (0.7)	4.4 (1.2)	0.565	3.8 (1.2)°	3.1 (1.1)°	0.002
The lessons were enjoyable	4.5 (0.9)	4.4 (0.8)	0.788	4.0 (0.9)	3.2 (1.2)°	0.033
I was able to learn a lot	3.7 (1.0)	3.6 (0.9)	0.808	3.2 (1.2)	2.5 (1.4)°	0.011
I was able to directly apply what I learnt	2.1 (1.0)	1.9 (1.2)	0.391	1.6 (1.0)	1.5 (0.8)	0.912
Theory and practice were well combined	3.7 (1.0)	3.8 (1.1)	0.745	3.3 (1.2)	3.3 (1.0)	0.473
I would rather have been in a different group	1.7 (1.1)	1.5 (0.9)	0.489	3.0 (1.2)°	3.6 (1.5)°	0.076
Group size was optimal	3.6 (1.3)	3.3 (1.4)	0.426	4.4 (0.8)°	3.7 (1.2)	0.022
I would act as a teacher	2.4 (1.3)	2.7 (0.9)	0.289	3.0 (1.2)	2.2 (1.2)	0.013
Interaction students/teacher was good	4.2 (0.9)	4.2 (0.8)	0.692	4.6 (0.8)*	4.0 (1.1)	0.026
There were many unanswered questions	2.5 (1.1)	2.6 (1.1)	0.722	3.3 (1.2)°	3.8 (1.0)°	0.284
Only a doctor could teach this	3.3 (1.2)	2.5 (1.4)	0.078	3.0 (1.3)	4.0 (1.1)°	0.008
Time was tight	3.6 (1.2)	3.7 (1.1)	0.528	2.8 (1.4)°	2.6 (1.1)°	0.693

5-point Likert scale: 5 = agree, 1 = disagree

[a] Grades: 1 = excellent, 6 = fail

* $P < 0.05$ compared to SG

° $P < 0.01$ compared to SG

Limited success rate of PAL-students using student-teachers in the field of complex motor skills

Despite adequate results regarding the theoretical aspects, our data show that instructor-guided SM training is superior to PAL dealing with demanding bimanual coordination patterns. PAL strategies with a limited student-teacher training seem unable to take the place of traditional training for coordinative demanding motor skills through experienced physicians, in contrast to technically oriented procedures [6]. These results prove the theories of different authors, who postulated that an exclusive and comprehensive training of the student-teachers including didactic components is an absolute necessity for success [2, 3, 19, 20]. However, existing guidelines offer no indication as to the comprehensiveness of training necessary or for the standard of competence that should be attained. Motor tasks requiring whole body coordination are especially challenging because they depend on the coordination of trunk and limb movements [21]. Because of the long learning curve and the required clinical background, we believe that teaching of SM procedures by an experienced instructor is a basic prerequisite for goal-orientated training. However, it is possible that same-year student-teachers may not possess the pedagogical skills to teach fellow students the more coordinative demanding aspects of special motor skills [11]. It has been shown that peer teaching in surgical skills training with novices can even worsen the training outcome [22]. To what extent these basic SM results could be affected by a larger time investment or by exposure to didactic trained student-teachers remains to be seen in further studies. Thus, an early implementation of training musculoskeletal examination and motor skill techniques during medical school education would be highly beneficial, especially considering the fact that medical students do not feel adequately prepared in musculoskeletal medicine [23]. However, learning SM requires a basic set of fundamental skills that, when properly mastered, can be generalised to a larger span of therapeutic procedures [10]. It is possible that this could lead to a more thorough and regular application of complex motor skills in clinical routine, as well as provide the opportunity to implement alternate teaching means such as quantitative augmented feedback strategies [24, 25] or special manikin or simulator training [24]. There is little data with regard to the minimum time necessary to become an experienced SM operator. We believe that the early learning of these basic practical skills could present the first step in the never-ending and complex SM training.

Significant gender differences existed only in terms of diagnostic competencies and in subjective perception results regarding knowledge transfer by student-teachers

Our work represents the first study that details objective and subjective parameters for an estimation of PAL teaching quality and outcome in female versus male students with regard to complex motor skills that require

confidence. Female students were viewed as significantly less confident and more anxious than their male counterparts [12], but results in the realm of clinical performance have not been consistent, regarding an advantage for either female or male students [13–15, 26]. Despite an advantage of females regarding palpatory diagnostic competencies in our study, students of both genders achieved comparable results during practical manipulative assessment. Recently, Kolozsvari et al. [27] stated that gender does not affect the learning curve for a bimanual demanding motor skill (laparascopic task), while surgical interest and perceptual abilities influence the early outcome. All students were less satisfied with the teaching of the student-teachers compared to professionals, but female students consistently rated the knowledge transfer by student-teachers better than male students. In contrast to other centres, our study deliberately left out any didactic and pedagogical training of student-teachers, which could have reinforced male students' prejudices [28, 29]. It remains possible that male students tend to overestimate their abilities and are more likely to apply greater force than female students in SM training, implying that they may need closer supervision by experienced professionals [30]. In contrast, female students tend to underestimate their abilities, report more anxiety about their performance, greater stress over competency issues and less confidence in their abilities [12], issues which the PAL environment could diminish.

Strengths and limitations

The strengths of the present study include the high number and the controlled randomisation process of the participants and the fact that the primary outcome was available in all cases. An additional strength is the fact that the external objective graders were blinded to the teaching method using a standardised rubric for diagnostic and manipulative skills. Duration and content of the sessions for both teaching groups were absolutely comparable because of the existence of a predefined curriculum. Our study has several limitations: Pre-training assessment to determine the students' existing skill level in SM skills and as a means of measuring the direct learning success was not performed. Pre-existing SM abilities were at least denied by all of the students included by means of a preliminary questionnaire. In addition, the selection process of student-teachers may have influenced the results obtained. A group of volunteer students without a comprehensive SM or didactic training were used, who may have had an extraordinary level of motivation to teach, but it is possible that they may not possess the clinical and pedagogical skills to teach fellow students the more coordinative demanding aspects of SM skills. In addition, it must be noted that the subjective course evaluation is limited by the inability to blind the medical students as to which group was teaching them. Physicians may inherently garner more respect by appearance alone.

Conclusions

Teaching complex spatiotemporal demands to students using the PAL system showed inferior results in relation to conventional lessons. Overall, students were more satisfied with the learning environment provided by professionals than by student-teachers, but male students regarded the PAL more suspiciously than female students. Of interest would be the optimal didactic and pedagogical training modules for the student-teachers and the optimal difference in education level between student-teachers and students regarding the effect on the overall learning curve. Focusing on outcome measures, medical educators should invest time and resources in programs designed to educate the student-teachers and to improve their confidence in the field of demanding manipulative skills. Such training, however, could severely stress the already tight staff and resources, which the PAL system tries to preserve. Maybe the PAL system is not qualified to transfer such demanding bimanual motor skills and professionals' clinical backgrounds might be of greater importance. However, guidelines offering some indication as to the comprehensiveness of SM training necessary or for the standard of competence are mandatory.

Ethical approval (EK 178/09) was obtained from the Ethics Committee, Medical Faculty, RWTH Aachen University (Chairman G. Schmalzing).

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Conflict of interest None to declare.

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