RESEARCH REPORT

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Team-Based Learning in the Gross Anatomy Laboratory Improves Academic Performance and Students' Attitudes Toward Teamwork

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As the healthcare climate shifts toward increased interdisciplinary patient care, it is essential that students become accomplished at group problem solving and develop positive attitudes toward teamwork. Team-based learning (TBL) has become a popular approach to medical education because of its ability to promote active learning, problem-solving skills, communication, and teamwork. However, its documented use in the laboratory setting and physical therapy education is limited. We used TBL as a substitute for one-third of cadaveric dissections in the gross anatomy laboratories at two Doctor of Physical Therapy programs to study its effect on both students' perceptions and academic performance. We surveyed students at the beginning and completion of their anatomy course as well as students who had previously completed a traditional anatomy course to measure the impact of TBL on students' perceptions of teamwork. We found that the inclusion of TBL in the anatomy laboratory improves students' attitudes toward working with peers ($P < 0.01$). Non-TBL students had significantly lower attitudes toward teamwork ($P < 0.01$). Comparison of academic performance between TBL and non-TBL students revealed that students who participated in TBL scored significantly higher on their first anatomy practical examination and on their head/neck written examination ($P < 0.001$). When asked to rate their role in a team, a 10.5% increase in the mean rank score for Problem Solver resulted after the completion of the TBL-based anatomy course. Our data indicate that TBL is an effective supplement to cadaveric dissection in the laboratory portion of gross anatomy, improving both students' grades and perceptions of teamwork. Anat Sci Educ 00: 000–000.

Key words: gross anatomy education; team-based learning; cooperative learning; TBL; teamwork; dissection teams; anatomy grades; Doctor of Physical Therapy education; laboratory dissection

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INTRODUCTION

Human gross anatomy is an integral part of the foundational sciences for students of health science professions. Historically, gross anatomy has been taught through the use of traditional didactic lectures and laboratory dissections. The use of cadaveric dissection and prosection in gross anatomy have long been held as the gold standard for anatomy education (Older, 2004; Sugand et al., 2010). Cadaveric dissection fosters an active learning environment and develops teamwork (Older, 2004; McLachlan and Patten, 2006; Böckers et al., 2010; Hildebrandt, 2010; Cuddy et al., 2013). However, there are increasing challenges with the use of cadaveric dissection, primarily expanding curricula, diminished time for teaching, and a decline in the number of qualified instructors (Holden, 2003; Drake et al., 2009; Sugand et al., 2010). Drake et al. (2009) reported an 11% decrease in the average number of curricular hours devoted to gross anatomy across US medical schools since 2002 and a 55% decrease since 1955. Changes in health science education have brought about a need for the implementation of alternative pedagogy that is student-centered, promotes application of knowledge, facilitates teamwork, and improves academic performance. In response to these needs, anatomical teaching methodologies have incorporated more innovative modalities including digital media, imaging, simulation, and small-group learning over the last decade (Sugand et al., 2010; Johnson et al., 2012; Pluta et al., 2013; Biasutto et al., 2006; Hisley et al., 2008). These methods, however, have often been introduced at the expense of dissection (Guttmann et al., 2004; McLachlan, 2004; McLachlan et al., 2004).

Team-based learning (TBL) is a student-centered instructional strategy that allows one instructor to facilitate a large class. Developed in the 1970s for business education, TBL has since been incorporated into medical education across the United States (Michaelsen et al., 1997; Seidel and Richards, 2001; Haidet et al., 2002; Nieder et al., 2005). Team-based learning promotes small team learning in large classes, facilitates deeper learning, and has been suggested to improve knowledge retention (McInerney and Fink, 2003; Vasan et al., 2011). The literature supports the use of TBL in medical education including gross anatomy education (Nieder et al., 2005; Vasan et al., 2008, 2009); however, there is very little research on its use in physical therapy education and no evidence in the literature on its use as a replacement of dissection or prosection time in the gross anatomy laboratory.

Team-based learning uses preclass, self-directed learning with in-class, team-oriented active learning to achieve content mastery. Four main principles form the basis of TBL (Michaelsen et al., 2008; Parmelee et al., 2012; Farland et al., 2013). First, teams of students are purposefully created and managed throughout the duration of the course. This helps to ensure that students develop into highly functioning teams. Second, students are held individually accountable for their own preparation and contribution to team performance. Third, students receive immediate and frequent feedback about their performance. Finally, assignments are designed to promote learning and team development.

In 2012, the Departments of Physical Therapy at the University of Central Arkansas (UCA) and Harding University (HU) each faced a unique challenge in their respective gross anatomy courses. Because of increased enrollment and space-limited dissection facilities, students enrolled in Gross Anatomy would have been unable to participate in every dissection activity. To address this issue, our two departments, located 54 miles from one another, collaborated to identify an active learning teaching method which could be used to effectively deliver content to students who would not be able to dissect during a given laboratory. Team-based learning was chosen to meet this need due to its reported efficacy in anatomy education (Vasan et al., 2011). Here, we report the development, implementation, and evaluation of a new model for the gross anatomy laboratory curriculum that provides an active learning experience for all students. In this model, one-third of each student's cadaveric dissection experience was replaced with a team-based learning activity. The purposes of this study were (1) to assess the efficacy of this new model with respect to academic performance and knowledge retention and (2) to evaluate students' perceptions of the model.

EXPERIMENTAL PROCEDURES

Students

This study was conducted at the University of Central Arkansas and Harding University and was approved by the Institutional Review Board (IRB) of each institution. Participants in this study were first-year students enrolled in the Gross Anatomy course in the Doctor of Physical Therapy programs at both universities during the academic years 2010–2012. All students enrolled in Gross Anatomy during the fall semesters of 2010 or 2011 received a traditional lecture and laboratory curriculum and comprised the comparison group ($n = 124$). All students enrolled in Gross Anatomy during the fall semester of 2012 (experimental group, $n = 88$) received TBL during one-third of the laboratory component of the course in addition to the traditional lecture and laboratory components. The curricula for both groups are described below. All data between universities were combined in order to (1) increase sample size and (2) prevent program-specific variables from influencing the study results.

Students of the experimental group were introduced to the TBL process on the first day of class by the course directors at which time they were asked to participate in this research study and sign a consent form. Students of the comparison group were introduced to TBL by the anatomy course directors at the beginning of the 2012 fall semester. It was explained to these students that while they would not participate in TBL, their participation in the research project was important to provide comparison data. These students also consented as research subjects by signing consent forms.

Course Structure

The gross anatomy curricula for 2010–2012 at both universities were designed and implemented by the authors who served as course directors at each university. The content, course sequence, assessment materials, and examinations were jointly developed and reviewed for consistency in content and rigor between the two universities. The Gross Anatomy course is offered for a 15-week period in the fall semester of the first year in the DPT program. The course is composed of four content units: back and upper limb (3 weeks duration); thorax, abdomen, pelvis, and perineum (4 weeks duration); lower limb and vertebral column (4 weeks duration); and head and neck (4 weeks duration). For both groups (comparison and experimental), ~33% of course time was spent in traditional lecture (45 hours total), with the remaining 67% of course time spent in laboratory activities (90 hours total). Laboratory sessions were two hours in length. The only curricular difference between groups was in the structure of the laboratory activities for the course. In the comparison group, students participated in cadaveric dissection during all laboratory sessions (three times per week, 90 hours total). In the experimental group, students participated in cadaveric dissection for two of the three laboratory sessions per week (60 hours total) and a TBL session once per week (30 hours total). All students in the experimental group

Table 1.

Laboratory Activities for Experimental Group per Week

University	Day 1	Day 2	Day 3
UCA	Section A: Dissection Section B: Dissection	Section A: **TBL** Section B: Dissection	Section A: Dissection Section B: **TBL**
Harding	Section A: **TBL** Section B: Dissection Section C: Dissection	Section A: Dissection Section B: **TBL** Section C: Dissection	Section A: Dissection Section B: Dissection Section C: **TBL**

UCA, University of Central Arkansas; TBL, team-based learning.

were divided into laboratory sections (A, B, or C) and rotated between dissection and TBL activities. The laboratory structure for the experimental group in a typical week at each university is illustrated in Table 1.

For each university, there were two faculty members who delivered all lecture content and conducted all laboratory sessions for the courses. In addition, there was one faculty member who served as the facilitator of the TBL sessions for both universities. Each faculty member involved in TBL did extensive reading on the process prior to the course and participated in the development of TBL materials. The profiles of the course directors for each course and TBL facilitator are provided at the end of the manuscript (Notes on Contributors).

Team-Based Learning

For the experimental group, teams of 4–6 students (with the exception of one which had three students) were formed at the beginning of the semester to ensure an equitable distribution of males and females among teams. As described above, the course was structured such that all students had laboratory three times per week. Teams rotated between dissection and TBL such that each team participated in dissection during two of the three laboratory days with the third laboratory day devoted to TBL activities (Table 1).

The TBL sessions were structured in four phases (Table 2). For Phase 1, students were engaged in preclass individual preparation of the material. Learning objectives were distributed to students at least one week prior to the TBL session. Each set of learning objectives contained specific readings from the text, atlas, and dissector along with content-specific learning objectives to guide their studies. Learning objectives corresponded with specific dissection activities of the day.

For Phase 2 of TBL, students were engaged in the in-class readiness assurance process. They began the session with a graded individual readiness assurance test (IRAT), which contained ten multiple-choice questions assessing the learning objectives (12 minutes). Immediately following the IRAT, students convened in teams to complete the same test (group readiness assurance test [GRAT], 23 minutes) using the Immediate Feedback Assessment Technique Form (IF-AT; Epstein Educational Enterprises Inc., Cincinnati, OH). Following the IRAT and GRAT, the facilitator addressed any outstanding questions or misconceptions of the information through large group discussion and mini-lecture, and teams were allowed an opportunity to appeal individual questions.

During Phase 3 of the TBL session, students were engaged in application exercises in the form of clinical case scenarios. Cases were provided to the teams for discussion and analysis, with all teams analyzing the same case simultaneously. Cases were full or unfolding in presentation, required knowledge integral to the learning objectives, and asked teams to answer a set of multiple-choice questions. Students were allowed access to all texts and online resources during the team application activity. Teams simultaneously reported their answers to the large group, and the facilitator ensured interteam discussion until the large group reached a consensus. An example TBL module used has been published elsewhere (Brooks, et al., 2013).

During Phase 4, peer teaching was used to finalize each laboratory session. At the conclusion of Phase 3 of TBL, all students entered the cadaver laboratory, and those students who had dissected on a given day peer-taught the cadaveric anatomy to those students who had conducted TBL. Likewise, the students in the TBL team explained to the students in the dissecting team about the clinical applications that had been brought out during the TBL session.

Table 2.

TBL Model Used in Gross Anatomy Laboratory

Phase 1 Preparation (preclass)	Phase 2 Readiness assurance (in-class, 45 min)	Phase 3 Application (in-class, 1 hr)	Phase 4 Peer teaching (15 min)
Step 1: Individual study of assigned objectives	Step 2: Individual readiness assurance test (IRAT) Step 3: Group readiness assurance test (GRAT) Step 4: Faculty feedback and clarification	Step 5: Team case studies with faculty facilitation	Step 6: Peer teaching

Table 3.

Survey of Students' Perceptions of TBL and Teamwork

Question	Comparison (N = 119)	Experimental Presurvey (N = 93)	Experimental Postsurvey (N = 93)	*P*-value Comparison vs. presurvey	*P*-value Comparison vs. postsurvey	*P*-value Presurvey vs. postsurvey
TBL will help me prepare for course examinations.	4.28 (±0.70)	4.29 (±0.60)	4.52 (±0.54)	NS	0.013	0.009
TBL will help me increase my understanding of the course materials.	4.34 (±0.61)	4.38 (±0.55)	4.55 (±0.52)	NS	0.013	NS
TBL will be helpful in developing my critical thinking skills.	4.33 (±0.70)	4.30 (±0.69)	4.21 (±0.73)	NS	NS	NS
TBL will be helpful in developing my clinical thinking skills.	4.24 (±0.77)	4.37 (±0.66)	4.37 (±0.69)	NS	NS	NS
I have a positive attitude about working with my peers.	4.07 (±0.85)	4.42 (±0.65)	4.67 (±0.56)	0.002	<0.001	0.004
The ability to collaborate with my peers is necessary if I am to be a successful student.	4.14 (±0.87)	4.41 (±0.73)	4.70 (±0.51)	0.018	<0.001	0.004
Solving problems in a group is an effective way to practice what I have learned.	4.29 (±0.66)	4.48 (±0.62)	4.81 (±0.63)	NS	0.001	NS
Working well with my peers will make me a better physical therapist.	4.43 (±0.70)	–	4.81 (±0.42)	–	<0.001	–

Statistical significance was measured by a Kruskal-Wallis test and a Mann-Whitney U test post hoc with Bonferroni correction (significance level $P < 0.017$). Mean (±SD); NS, not significant; TBL, team-based learning.

Student Assessment

Examinations were developed at each university separately. The same examination questions were included in the intergroup analysis (comparison vs. experimental) within each university. Therefore, the examination questions for both groups were identical within each university, but varied between universities.

For the comparison group, students were given four multiple-choice examinations (single best answer format), four laboratory practical examinations (structure identification), one final comprehensive written examination, and other graded assignments such as quizzes, peer evaluation, and oral presentations throughout the semester. In the experimental group, students completed 10 graded sets of IRAT/GRATs in addition to the other assessment activities described above. For the first half of the semester, the IRATs and GRATs for each TBL session were weighted equally. At midterm, students voted on the desired weight distribution of the IRATs and GRATs for the remainder of the course and completed a self-evaluation and peer evaluation of team members. Case application exercises were not graded. For this study, the overall course grades were calculated and analyzed for both groups using only the data from the multiple-choice written examinations (40% of course grade), laboratory practical examinations (40% of course grade), and final comprehensive examination (20% of course grade). This was done to ensure that course grades for the experimental group were not artificially inflated due to the addition of IRAT/GRAT scores.

Evaluation of TBL

To assess the effect of TBL on students' academic performance, we compared unit examinations (written and laboratory), final examination scores, and overall course grades between the comparison (2010 or 2011) and experimental (2012) groups. An unpaired Student's t-test was used for each of these statistical comparisons using the SPSS software package.

To assess the students' various perceptions of TBL on deep learning, teamwork, and team member role, we administered a written survey that we adapted from Vasan et al. (2009) and Persky and Pollack (2011). Our survey consisted of eight statements (five of which were adopted from the Vasan survey) that assessed students' perceptions of TBL and the impact of TBL using a five-point Likert scale (Table 3). Internal consistency was determined using Cronbach's alpha coefficient, which was 0.82. In addition, the survey asked students to rank their perceived role in team function choosing between four roles: facilitator, peacekeeper, researcher, and problem solver. Students were allowed to rank each role from 1 (least applies to me) to 4 (most applies to me), using each number only once. For this study, students in the comparison group completed the survey in the fall of 2012. This time point represented either one year or two years after taking the gross anatomy course (2011 or 2010, respectively). Students in the experimental group completed the survey at the beginning of the gross anatomy course and immediately after its completion. Students' responses were compared between groups using the Kruskal-Wallis test. The Mann-

Whitney U test was used as the post hoc to compare between groups. To maintain an alpha level of 0.05 for all three comparisons and to avoid a Type I error, a Bonferroni correction was used (significance level = 0.017).

Knowledge Retention

To determine the effects of TBL on long-term retention of anatomical knowledge, we constructed a 20-question multiple-choice examination covering content from all four content units. All questions were vignette-style questions that required the application of information to a clinical situation. This retention examination was administered to the comparison group in the fall of 2012. This time point represented either one year or two years after taking the gross anatomy course (2011 or 2010, respectively). The retention examination was administered to the experimental group in the fall of 2013 (1 year following their gross anatomy course). An unpaired Student's t-test was used to compare mean scores between groups and across academic years.

RESULTS

Academic Performance

To evaluate the effects of TBL on academic performance, we compared the means of course grades, written examinations, laboratory practical examinations, and final comprehensive examinations between the comparison and experimental groups (Fig. 1A). Course grade was calculated as a weighted mean of the four written examinations (40%), four laboratory practical examinations (40%), and the final comprehensive examination (20%). No significant difference was found between groups for these mean scores; however, we noted a consistent trend toward improved performance across all assessment measures in the experimental group. To assess the distribution of course grades between groups, we binned the overall course grades into seven categories according to point value (A+ = 100–95%; A− = 94–90%; B+ = 89–85%; B− = 84–80%; C+ = 79–75%; C− = 74–70%; and D < 70%). We observed that in the experimental group, the total number of A grades increased to 5.24%, whereas the total number of C grades decreased to 3.19% and the D grades decreased to zero (Fig. 1B). Overall, there was a positive shift in students' grades for the experimental group.

When comparing academic performance by content unit, we observed significant differences between groups. The experimental group performed significantly better ($P < 0.001$) on the Unit 1 laboratory practical examination, which primarily assessed a student's ability to correctly identify anatomical structures of the back and upper limb (Fig. 2A). Students in the experimental group also demonstrated significantly improved performance on the fourth written examination in the area of head and neck anatomy ($P < 0.001$; Fig. 2B).

Retention of Content

To determine whether team-based learning in the anatomy laboratory had an impact on long-term retention of anatomical content knowledge, we administered a retention examination to the comparison group in the fall of 2012. This time point represented either one year (students enrolled in 2011, $N = 70$) or two years (students enrolled in 2010, $N = 49$) following their respective gross anatomy course. To assess retention at these two separate time points, we subdivided the comparison group into the two enrollment classes (2010 and 2011) for this analysis. There was no significant difference in examination scores between the two subgroups following completion of a traditional gross anatomy course (Fig. 3). We also administered the retention examination to the experimental group one year following their gross anatomy course ($N = 87$). Mean scores of the experimental group were 4.4 percentage points higher than the comparison group who took the examination one year postcourse (2011); however, this difference did not reach statistical significance. Mean scores of the experimental group were significantly higher than the comparison group who took the examination two years postcourse (2010, $P = 0.007$); however it is not possible to distinguish between the effects of time and TBL in this comparison (Fig. 3).

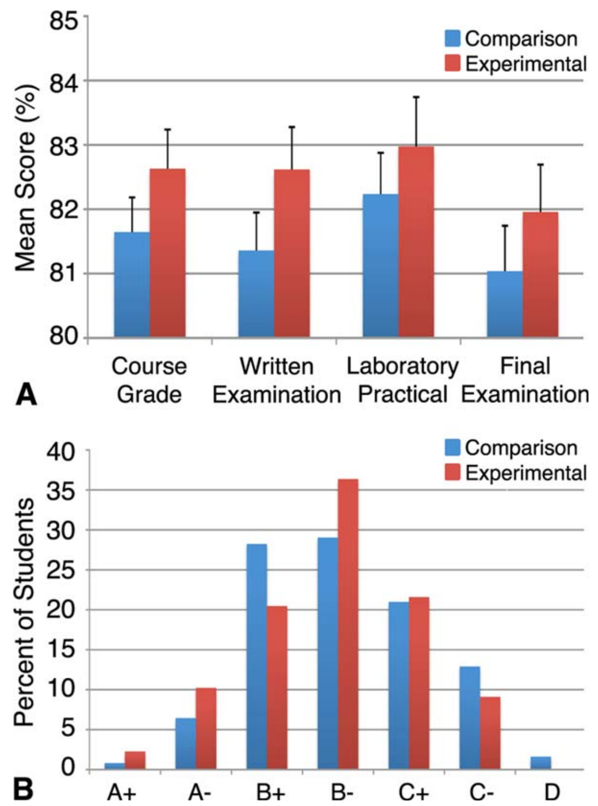

Figure 1.

Comparison of academic performance between groups. Students' academic performance was compared between a traditional gross anatomy course (Comparison) and a course in which one-third of dissection laboratories were replaced with TBL (Experimental). **A:** Course grades, written examination grades, laboratory practical examination grades, and final examination grades are plotted as mean ± standard error. **B:** The percent of students with final course grades in five point intervals are plotted for each group. A+ (95–100%), A− (90–94%), B+ (85–89%), B− (80–84%), C+ (75–79%), C− (70–74%), and D (<70%).

Perceptions About Team-Based Learning and Team Collaboration

To determine students' attitudes about the TBL process and teamwork, surveys were administered to the comparison and experimental groups as described above (Table 3). Survey

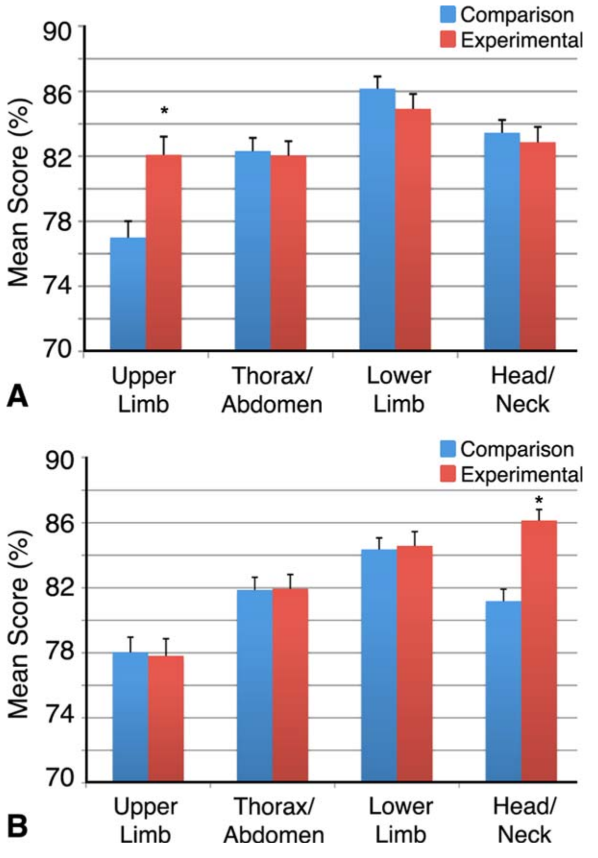

Figure 2.

Comparison of academic performance for anatomy unit examinations. **A**: Grades on each of four laboratory practical examinations are plotted as mean ± standard error for the back and upper limb; thorax, abdomen, pelvis, and perineum; lower limb; and head/neck. Scores were significantly higher on the upper limb laboratory practical examination for the experimental group ($P < 0.001$). **B**: Grades on each of four written examinations are plotted as mean ± standard error. Scores were significantly higher on the head/neck written examination for the experimental group ($P < 0.001$).

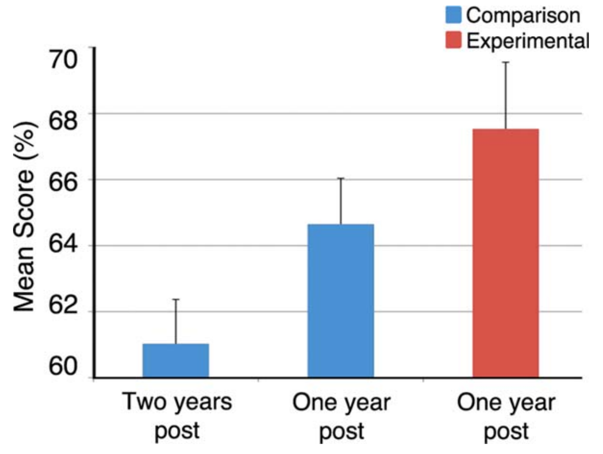

Figure 3.

Performance on anatomy retention examination. Students were administered a 20-question, multiple-choice anatomy examination covering content from all four course units for one year or two years after the start of their respective courses. Percentage scores are plotted for each group as mean ± standard error.

data indicated that students in both groups believed that TBL would help (experimental group) or would have helped (comparison group) to prepare them for course examinations and understanding of content. However, following completion of their course, students in the experimental group had significantly higher attitudes regarding the benefit of TBL in examination preparation than they had at the course onset ($P = 0.009$). Similarly, students in the experimental group had significantly higher attitudes toward the use of TBL in improvement of content understanding than the comparison group ($P = 0.013$). Interestingly, no change in the perception of TBL having helped to develop critical or clinical thinking skills was noted following course completion.

The survey also included four questions to determine students' attitudes toward team collaboration. Although students in both groups demonstrated positive attitudes toward working with peers, the experimental group agreed with the statement "I have a positive attitude about working with my peers" significantly more after completion of their gross anatomy course than at its onset ($P = 0.004$). Additionally, the experimental group agreed with a statement regarding the necessity of peer collaboration for students' success significantly higher after their TBL experience than prior to it ($P = 0.004$). It is worthy of note, however, that students who did not participate in TBL (comparison group) had significantly lower attitudes toward team collaboration ($P = 0.018$, $P < 0.001$). This suggests that in the absence of a TBL-based curriculum, students' perceptions of teamwork decline during matriculation through their physical therapy education. The experimental group also agreed with the statement "Working with my peers will make me a better physical therapist" significantly more than the comparison group ($P < 0.001$). It should be noted that the comparison group completed this survey one to two years following gross anatomy, whereas the experimental group completed the survey at the course end.

Perceptions About Role in Teams

As part of the survey that was administered to students in the experimental group before and after their TBL gross anatomy course, we asked students to rank their perceived role in team function choosing between four roles: facilitator, peacekeeper, researcher, and problem solver (Fig. 4). Students were allowed to rank each role from 1 (least applies to me) to 4 (most applies to me), using each number only once. In the precourse survey, more students ranked facilitator as a primary role than the other three roles and they ranked researcher the lowest. In the postcourse survey, a 10.5% increase in the mean problem solver rank score was observed primarily owing to a 7.1% decrease in the mean rank score for facilitator. The mean rank scores for peacekeeper and researcher showed little change.

DISCUSSION

Team-based learning was integrated into the physical therapy gross anatomy laboratories at the University of Central Arkansas and the Harding University in 2012 to address the challenge faced by each university's Physical Therapy Department regarding increased student enrollment and insufficient

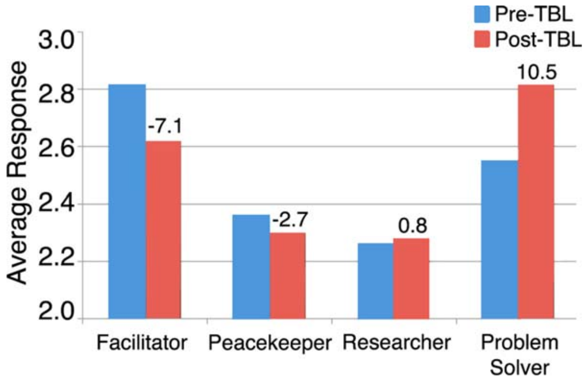

Figure 4.

Students' perceptions of role in team activity. Students were asked to rank their perceived role in a team activity, choosing between facilitator, peacekeeper, researcher, and problem solver on a scale of 1 (least applies to me) to 4 (most applies to me). Students' mean responses are plotted for TBL students at the beginning and end of their gross anatomy course. Percent changes are shown above each plot.

laboratory space. It was decided by the gross anatomy course directors at both universities to collaboratively adopt TBL as a substitute for dissection for those students who would not be able to dissect during a particular laboratory activity due to these space limitations. In the model presented here, students alternate between dissection and TBL activities with the end result being that each student participates in two-thirds of cadaveric dissections and attends a TBL session in lieu of the remaining one-third of dissections.

Nonacademic Benefits of TBL

The practical benefits of our model include a reduction in the number of cadavers necessary for a course. By only allowing 50–67% of a class to dissect at any given time, the number of donor specimen needed is reduced. This reduction in the number of students present in the laboratory also improves student–faculty ratios in the laboratory, which are traditionally high for gross anatomy laboratories. Furthermore, supplementation of traditional didactic lecture and dissection with team-based learning provides a third distinctive approach to education and one that promotes active student engagement and professional behavior development, which are rooted in adult learning theory (Hrynchak and Batty, 2012).

As noted in the "Introduction" section, cadaveric dissection is an active learning educational method that alone is effective in the development of teamwork (Older, 2004; McLachlan and Patten, 2006; Böckers et al., 2010; Hildebrandt, 2010; Cuddy et al., 2013). Team-based learning shares these qualities (Hazel et al., 2013). The question could then be posed: which is more effective at building teamwork? To our knowledge, there is no study that addresses this question. What we have done in our model is to provide an opportunity for students to engage in both team-building activities. Student teams dissect together and engage in TBL together. These separate, team-centered activities build on one another. It will be interesting to explore the separate and combined effects of each in team building in the future.

Academic Benefits of TBL

Our data indicate that students perform better on a portion of their examinations when TBL is used in addition to lecture and dissection. This is consistent with previous reports that have shown TBL to be successful in improving academic performance when compared with traditional learning formats (Wiener et al., 2009; Koles et al., 2010; Zgheib et al., 2010; Persky and Pollack, 2011; Sisk, 2011; Tan et al., 2011; Fatmi et al., 2013; Mennenga, 2013). In a recent review of knowledge outcomes of TBL in health professions education, Fatmi et al. (2013) noted that TBL led to improved or neutral changes in knowledge scores in each of 14 separate studies. This is the first report to our knowledge, although, of the use of TBL to supplement the gross anatomy laboratory experience. The most pronounced academic improvements observed were on the first laboratory practical examination and on the last written examination. Each of these examinations marks an important point in the evolution of the complexity of the course. Although laboratory practical examinations are largely identification-based assessments, PT students traditionally score the lowest marks on the first anatomy practical examination. This may be due to their lack of adequate preparation for the level of rigor that is presented in a graduate-level anatomy course. Additionally, some examinations are inherently stressful (Ng et al., 2003a, 2003b), and the time limitations of the laboratory practical examination experience may compound students' anxiety and hinder performance. Typically, however, practical examination grades rise considerably following the initial laboratory examination experience, presumably due to increased students' confidence and preparation. Our data indicate that the inclusion of TBL into the laboratory prevents the initial poor performance in students' laboratory examination scores. It is likely that providing instructor-generated learning objectives for which students are responsible before class increases their ability to correctly identify appropriate content on the examination. In addition, the inclusion of frequent formative assessments in the form of IRATs and GRATs encourages consistent study habits and prevents students from falling behind in their coverage of the material, especially in a content-heavy course such as anatomy (Nieder et al., 2005).

Written examinations contain more complex questions that require students to problem solve and use critical and clinical thinking skills to analyze patient scenarios. Our data reveal a gradual increase in written examination scores for traditional students over the course of the semester but with a slight decrease in performance on the head and neck examination. Written examination scores from the head and neck anatomy unit are traditionally lower than those from the lower limb unit, likely due to the inherent complexity of head and neck anatomy. The experimental group showed the same increased performance over the course of the semester; however, they performed significantly better than the comparison group in the last unit of the course. Similar academic improvements have been observed previously in gross anatomy courses which incorporated TBL. The New Jersey Medical School replaced its lectures with team-based learning and observed an increase in student examination grades as well as NBME subject examination scores (Vasan et al., 2009, 2011). Wright State University School of Medicine augmented their lecture time with 12 TBL sessions during the course. Although they observed no significant differences in mean examination scores, they noted a decrease in the variance of scores and a reduction in the number of students failing or requiring remediation (Nieder et al., 2005). We hypothesize that by using active learning, group communication, and peer feedback, TBL enhances students' application of content to clinical scenarios and improves reasoning skills and the ability to problem solve. Students' survey responses support this idea by reporting a perception of increased depth of knowledge and preparation for examinations. In addition, a higher percentage of students self-identified their role in group dynamics as a "Problem Solver" after completion of the TBL-based course. However, it is interesting that despite these perceptions and their improved academic performance, students did not attribute the development of critical thinking skills to the process of TBL. No differences were observed in students' perceptions of the benefit of TBL on either critical or clinical thinking skills following completion of the course.

In physical therapy education, it is essential that students and practitioners consistently recall anatomical information and be able to apply it to the evaluation and treatment of every patient. A study done by Fiebert and Waggoner (1996) found that due to the vast amount of information presented during a gross anatomy course, physical therapy students struggle to remember it. Similar trends have been reported for students of radiology (Hall and Durward, 2009). A solution to improve knowledge retention is proposed by Anderson and Conley (2000) who stated that students are more likely to remember information to which they have been exposed repeatedly, rehearsed, and used in context. According to Michaelsen et al. (2008), TBL is an approach to teaching that uses these very principles by motivating students to consistently retrieve studied information from memory to use on IRATs, GRATs, and application exercises. Additionally, repeated testing, which is a technique used in TBL, has been shown to improve information recall (Roedinger and Karpicke, 2006; Karpicke and Roediger, 2007). The results from several studies suggest that TBL does improve long-term retention of information, however, not all have been conclusive (McInerney and Fink, 2003; Persky and Pollack, 2011; Tan et al., 2011; Vasan et al., 2011). We chose to evaluate the effects of TBL on retention by administering a 20-question, vignette-style anatomy examination to students one or two years following completion of gross anatomy. Our data suggest a positive improvement with the use of TBL. It is worthy of note that there was no difference between mean scores of comparison students who took the examination one or two years following completion of gross anatomy, despite the fact that the latter were in their third professional year and had thus completed more additional, supportive coursework and more clinical rotations.

Effects of Professional Education on Perceptions of Teamwork

The second- and third-year DPT students who did not participate in TBL demonstrated significantly lower attitudes toward teamwork than entering the first-year DPT students. Likewise, higher class DPT students were significantly less agreeable with the statement "The ability to collaborate with my peers is necessary if I am to be a successful student" than the first-year students. In a separate survey, we observed a similar drop in attitudes toward teamwork between the first and second year medical students (data not shown). Parmelee et al. (2009) noted this same trend even among students who were participating in TBL. Following our physical therapy students, one additional year may provide more insight into this trend and the impact TBL has on students' perceptions with its use in the gross anatomy laboratory setting. These data suggest that simply completing a year of professional school reduces students' perceptions toward teamwork. We were able to avoid this negative trend with the inclusion of TBL in the first professional year. This observation supports the inclusion of team-based learning activities throughout the first professional year.

Feedback

Frequent feedback is an important part of the TBL process (Michaelsen et al., 2008). One key aspect of this feedback is the readiness assurance (IRAT/GRAT) phase of TBL (Gopalan et al., 2013). In our model, students take one IRAT/GRAT quiz set each week of the course and immediately receive their grades from these assessments. Gross anatomy is a content-heavy course, and it is easy for students to fall behind in their studies. We believe that the administration of these weekly quizzes played an important role in ensuring that students kept up with their studies. Indeed most students agreed or strongly agreed with the statement "IRATs were useful learning activities" (data not shown). Another feature of TBL feedback is the peer evaluation. Students completed peer evaluations of their team members at the midpoint and conclusion of the course. These provided opportunities for self-reflection and may have impacted how students viewed their role in the team.

Limitations

Although this study supports the inclusion of TBL into the gross anatomy laboratory, it is not without its own limitations. First, the experimental and comparison groups used in the analyses were in different matriculation years and participated in different gross anatomy courses. This brings several additional variables into the study including possible differences in student demographics and background as well as differences in the structure and flow of the anatomy courses. The authors/course directors made every attempt to ensure consistency in course structure and flow between years to neutralize these possible variables. Furthermore, it is unlikely that significant differences between student demographics and backgrounds existed between groups as all students underwent the same selection process to gain entrance into these DPT programs. Another limitation of the study is with regard to the timing at which surveys were administered. Students of the comparison group completed the survey one to two years following their gross anatomy course, whereas students of the experimental group completed the postsurvey immediately following their gross anatomy course. It is possible that students' perceptions of gross anatomy and TBL could vary between its completion when everything is fresh on a student's mind and one to two years later when memory is less detailed and complete.

CONCLUSIONS

In summary, TBL is an effective way to augment the traditional dissection laboratory experience. Students perform better on a portion of their examinations when TBL is used in conjunction with lecture and laboratory, which results in higher course grades. TBL may also improve long-term retention of anatomical knowledge, although more research is needed to confirm this finding. Finally, TBL improves students' perceptions about teamwork, which otherwise are decreased in second- and third-year students.

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