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Research Article

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The Efficiency of Digital Anatomy Teaching Strategies

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Abstract

Background: *In medical school, the teaching of anatomy is both time-consuming and complicated. As more schools allot less time to this subject, there is a growing need to restructure anatomy teaching methodologies. This paper examines digital dissection resources and identifies how and when they were implemented in the classroom.*

Methods: *An online survey tool was sent to osteopathic medical schools throughout the United States to determine the resources and methods being used and to assess how students were performing in corresponding anatomy courses. The anatomy director at each school was given a predetermined set of questions to enable an evaluation of the curriculum and performance of the students.*

Results: *After data were collected from the medical schools, the results were analyzed and indicated that the use of digital anatomy resources resulted in better overall performance and grades.*

Conclusion: *Although the small sample size precluded proper hypothesis testing, several strong trends emerged that should be investigated with a larger sample. Most notably, these trends included strong associations among the prevalence of digital anatomy training, teaching using cadavers, and student competence.*

Keywords: Anatomy, educational technology, medical school, medical education, cadaver

Introduction

Medical school programs tend to have rigorous curricula that include in-depth, fast-paced anatomy courses. Many colleges have reduced the amount of time that is allotted for teaching these courses; thus, there is a need to understand the most effective approach for teaching the curriculum [1]. As computer technology has progressed, there has been a push to transition to digital approaches in anatomy courses. Some schools implement combined methods that include both cadavers and digital anatomy resources, while others use solely digital resources. This paper aims to examine how the use of digital anatomy resources impacts student performance.

Study Justification

As stated above, time is very limited with respect to the amount of information that must be learned in medical school, particularly in regard to anatomy. Thus, it is important to identify the most effective teaching methods and resources for this subject. This paper reports on how schools are approaching the problem of time constraints in teaching anatomy, as well as the types of resources that are currently being used.

Theoretical Perspective

Current perspectives lean toward the belief that at the graduate level of education, students should be able to retain critical, high-yield data regardless of the manner in which the data are presented. While cadaveric dissection is the most common approach to teaching anatomy and has several benefits as a teaching method, it has limitations as well; [2] for example, with this method, learning is limited to the dissection lab. Subsequently, other resources are needed to allow for learning outside of the anatomy lab.

Literature Review

Overview

Dissection has been the primary method for teaching anatomy for more than 400 years [3]. Cadaveric dissection has many advantages over other approaches, including preparing students for clinical practice, familiarizing medical students with death, practicing manual skills, and clarifying relationships between patients' symptoms and associated pathologies [3]. Although cadaveric dissections may always be necessary for anatomical instruction, there is a need for more effective methods to allow for the shorter time that is being allotted to these courses.

Problems and Their Implications for Research

The medical school curriculum has been under constant pressure for many years to teach more information in less time. As anatomy classes usually have many hours that are dependent on laboratory time, this situation has had a strong impact on anatomy courses [4], resulting in a need to identify the most effective methods for presenting and teaching anatomy to students. Many medical schools have maintained traditional teaching methods, focusing on cadaveric dissections supplemented with two-dimensional images from books and PowerPoint presentations. Some schools have transitioned to a combination of cadaveric dissections supplemented with three-dimensional digital imaging, while a few medical schools now rely solely on three-dimensional digital imaging to teach anatomy to medical students.

Supporting Logic

While it is too early to determine whether teaching methods based solely on digital resources are superior, such approaches have many promising advantages. For example, in contrast to cadaver-based instruction, digital resources enable students to quickly find a structure, watch an animation showing its function, read its label, and listen to its pronunciation, all with only a few keystrokes [5]. Digital resources also have more viewing angles and overlays, with all essential structures clearly labeled, and may be more accurate than cadaver-based learning options [5].

Need for New Research

As stated previously, few researchers are investigating optimal approaches for teaching anatomy, and thus, the most effective strategy has not yet been determined. There is a need to collect data on how students are performing in medical school, which can then enable data analyses to determine the best approach for teaching anatomy in medical school.

Materials and Methods

Research Questions

1. Does increased use of digital anatomy technology result in higher grades?
2. Do lower grades occur with the use of increased digital anatomy technology?
3. Is there any correlation between higher grades and increased digital anatomy technology use?

In this work, the research questions address the type of digital anatomy resources that are currently used by medical schools. The questions also focus on when these resources were first used in the curriculum. In this paper, we interpret the collected data to determine which instructional approach is the most effective for teaching anatomy at the medical-school level of education. We hypothesized that medical schools that implemented digital resources earlier in their curriculum would have the highest scores in the retention of information and overall knowledge in anatomy courses.

Materials

To best support students in becoming capable future providers, universities need accurate information on the effectiveness of digital anatomy technology and its influence on student performance. In this work, we investigated the use and effectiveness of digital anatomy technology using surveys. A systematic review of the literature was performed to answer the question posed above. For this review, we collected several articles from the online database PubMed. We then complemented this research by utilizing an online survey tool that was sent to 34 osteopathic medical schools, followed by statistical analysis.

Research Design

The design of this study involved a questionnaire that was completed by all participants. The poll was administered to institution and faculty members to help determine whether digital anatomy technology in the classroom enhances or diminishes student performance. This study was both quantitative and qualitative. The independent variable was the question within the survey, and the dependent variable was the answer provided by each participant.

Variables

The independent variables focused on the methods by which anatomy information is presented to the students: cadaveric dissections, cadaveric prosections, all-digital presentations, or a combination of both cadaveric and digital methods. The dependent variable was the performance of the students on questions that were designed to determine which method helped to achieve the greatest retention of anatomy information.

Procedures

Each participant was asked to complete a survey that would assess their defining characteristics and their institutions. These responses were then collected and analyzed using parametric statistics based on the dependent t-test, also known as the paired t-test, and analysis of variance (ANOVA) statistical tests for within-subject comparisons. The statistical analysis tested the relationship between two variables: student progress (grades) and the use of digital anatomy technology. ANOVA was also used to compare more than three groups for statistical significance. The null hypothesis of ANOVA states that all groups from a given osteopathic faculty population are random. Because the response variable was the students' performance based on education with or without digital anatomy technology, a fixed-effects ANOVA model was used. The fixed-effects model allowed the statistician to approximate the range of response variables (i.e., grades A–F) generated by the use of digital anatomy technology [6]. The dependent t-test was used to compare two different observations for a given population. Touro University Nevada's statistician performed all statistical analyses.

Survey Instrument Development

The model for our survey was developed by Touro University Nevada to investigate the anatomy curriculum with and without digital anatomy technology in Doctor of Osteopathic degree programs. The data collection categories included (a) Doctor of Osteopathic program demographics, (b) descriptive information regarding digital anatomy technology, (c) faculty demographics and experiences, and (d) students' experience with digital anatomy technology. Many anatomy professors who teach osteopathic medicine students, who have considerable clinical experience marked by cadaver dissections and some digital anatomy technology training, provided an initial review of the survey. After feedback was provided, the survey was revised and sent to another panel of experts who also had experience in teaching with digital anatomy technology. The survey was then finalized based on their assessments (see Appendix).

Participants

The American Osteopathic Association's Commission on Osteopathic College Accreditation recognizes 34 Doctor of Osteopathic Medicine degree programs in the United States, and the surveys were sent to the faculty of these institutions. The survey was sent directly to the anatomy program faculty member; if the faculty member was not known, the survey was emailed to program directors with instructions to forward the survey to the primary faculty member teaching and coordinating the anatomy component of the curriculum.

Survey Administration

After the institutional review board of Touro University Nevada approved the protocol of this study, the survey was emailed as an attachment to the degree programs in 2019. The survey's introduction described the study's purpose, emphasized the results being reported, assured the anonymity of individual answers, and affirmed that involvement was voluntary. The surveys were number-coded to track non-responders and to facilitate follow-up communication. Four weeks after the survey was distributed, a follow-up email with an attached survey was sent to the non-responders. At five weeks, a final email was delivered to the non-responders.

Results

Data Analysis

The data were hand-entered into a Microsoft Excel spreadsheet by two research assistants. To ensure accuracy, the assistants routinely met with the lead author to clarify the interpretation of survey responses. Furthermore, each assistant completed an independent review of the other assistant's previously entered data, and the lead author compared survey responses to previously entered datasets for 30% of the surveys. Descriptive statistics (ANOVA and dependent t-test) were calculated to determine the demographics of the osteopathic programs and participating faculty and the status of their digital anatomy technology. ANOVA allowed the statistician to associate the participants (anatomy faculty) with the use or non-use of digital anatomy technology and the subsequent effect on students' grades. The ANOVA test was used to determine the significance of the results[6] and helped establish whether the null hypothesis could be rejected [6]. The dependent t-test was used for comparisons among a single set of participants and allowed the statistician to determine how the participants were affected by the presence or absence of digital anatomy technology [7].

Analysis Approach and Limitations

Due to the limited sample size (nine respondents) and the optional nature of their responses, statistical analysis was limited to primarily investigating correlations among factors. In some cases, categorical responses were numerically operationalized to allow for the identification of trends. Given the potentially limited generalizability of this group and the preclusion of more rigorous hypothesis testing due to the small sample, all outlined results were interpreted with the intent of revealing potentially replicable trends for a more extensive future investigation. Many of the relationships exhibited strong trends, potentially warranting a broader investigation rather than merely suggesting findings. Replicating these results in a more comprehensive sample would not only address hypotheses regarding the direct impact of digital anatomy training on the competence of students (both academic and practical), it would also allow for more robust analytical approaches. For example, with a larger sample, clustering methods might reveal groups of anatomical regions that are associated with particular tiers of competence, and combined with multivariate regression, the relative influence of digital versus practical anatomy training on expertise in these regions might be further explored. We hope that these preliminary findings will set the groundwork for such an investigation.

Class Sizes and Teaching Methods

Respondents indicated that, on average, 233 students (standard deviation [SD] = 99.03, n = 9) were enrolled in first-year anatomy courses. These courses included an average of 14.29% digital content (SD = 10.58%, n = 7), and 58.33% of the courses were devoted to cadaver studies (SD = 30.62%, n = 9). There was a moderate negative correlation between class size and the proportion of digital course content (r = -0.27), as well as the proportion taught with cadavers (r = -0.38). This finding suggests that as class size increased, the reliance on both techniques was reduced, and conventional teaching methods (lectures, textbooks) were more likely employed. Unsurprisingly, there was also a strong negative correlation between the proportion of the course that was taught digitally as opposed to that taught with cadavers (r = -0.65), suggesting that, for a constant class size constant, instructors tend to prefer one method over the other.

When asked how instructors assessed competence in digital anatomy instruction (practical examination, written examination, or both), those who used practical examination or both (n = 7) were more likely to teach using cadavers (averaging 68% of course content) than those who used written assessments or both (50% of course content, n = 7). When excluding those who responded "both," this gap widened to 75% for those who relied solely on practical examinations (n = 3) and 25% for those who used only written examinations (n = 2); thus, instructors with a preference for practical teaching were more likely to include practical assessments as well, and vice versa.

Contributors to Student Competence

The respondents were asked to evaluate the competence of their students in seven categories: upper limb, lower limb, thorax, abdomen, perineum and pelvis, back, and head and neck. The competence in each area was captured in five categories: F (< 60), D (60–69), C (70–79), B (80–89), and A (90–100). No respondents indicated a competence level of F in any category. Thus, to enable analysis, the responses were coded in a linear numeric fashion, maintaining the linear spacing of grading tiers. Averages and correlations were coded using values of 100 (A), 66.67 (B), 33.33 (C), and 0 (D). This transformation has no impact on the strength of the associations, but it does enable the testing of associations. In addition to individual categories, an overall competence was calculated based on the average of all responses, provided that an individual responded for at least three of the seven categories.

The responses suggest that any possible association between class size and overall competence is negligible (r = -0.02). However, moderate to strong associations emerged between the competence of students in each of the seven categories (including overall competence) and the proportion of courses taught digitally or using cadavers (**Table 1**). Overall, the proportion of digital anatomy teaching was negatively associated with competence (r = -0.52). This negative association was reflected in each of the seven individual categories to varying degrees. However, the responses in two categories, i.e., upper limb and lower limb, did not exhibit sufficient variability among respondents for a correlation to be calculated.

Table 1. Correlations Between Competence and Teaching Method

Competence Area	Average (0–100)	Digital teaching (r)	Cadaver teaching (r)
Upper Limb	*71.13*	*N/A*	*0.61*
Lower Limb	*71.13*	*N/A*	*0.61*
Thorax	*71.00*	*-0.43*	*-0.06*
Abdomen	*66.86*	*-0.43*	*0.60*
Perineum and Pelvis	*45.88*	*-0.54*	*0.71*
Back	*81.67*	*-0.23*	*0.52*
Head and Neck	*54.13*	*-0.08*	*0.18*
Overall	*65.99*	*-0.52*	*0.55*

Conversely, the proportion of a course taught using cadavers was positively associated with overall competence (r = 0.55), with each of the seven individual categories reflecting varying degrees of this positive association. While a negative association was found only for the thorax, this correlation was so weak as to be considered negligible (r = -0.06). In all cases, the significance of these correlations could not be evaluated due to sample size, but their strengths warrant a more extensive investigation.

Taken together, these findings suggest substantial benefits for the use of cadavers in teaching and, among those surveyed, a potentially negative impact of digital anatomy training on student competence. The small survey sample and the employed teaching and assessment methods may have influenced these associations. While digital anatomy training was negatively associated with competence in this sample, further investigation may reveal factors that support positive implementation and may indicate how the influence of digital anatomy training on student competence might be improved. For example, instructor experience and training in digital anatomy and the use of assessment methods more suited to digital teaching may reveal different trends.

Furthermore, there was a notable variability in the competence of students among the seven categories evaluated. Interestingly, the category with the lowest competence (perineum and pelvis) showed the strongest positive association with teaching using cadavers (r = 0.71) and the strongest negative association with digital anatomy instruction (r = -0.54). This finding suggests a particular benefit of cadaver-based teaching for this region. Replication in a larger sample may aid in the generalizability of this finding, supporting ideal testing methods for this and other areas that are associated with relatively lower competence. In addition, a more in-depth investigation of factors contributing to competence in each region may identify more effective methods for implementing digital anatomy training.

Beliefs Regarding Competence Improvement

Although this sample does not support a correlation between digital anatomy teaching and increased competence, when asked about the most beneficial ways to increase students' knowledge of anatomy, respondents expressed a conspicuous belief that increased availability of digital technology would be successful (33.33% of respondents). This finding is related to an increasing emphasis on digital anatomy during clinical affiliations. Of the four choices given, increased laboratory hours were believed to present the most benefit (55.56% of respondents). However, it should be noted that the respondents were allowed to identify more than one category (**Figure 1**). Interestingly, none of the respondents who preferred an increased availability of digital technology had experience with digital technology during their entry-level professional education.

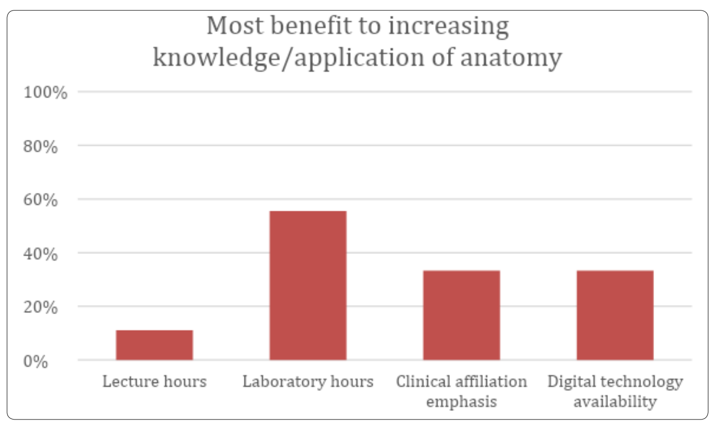

Figure 1: Factors Believed to Most Strongly Contribute to the Knowledge/Application of Anatomy

Regarding methods for enhancing expertise in teaching digital anatomy, on a five-point Likert scale (not helpful to very helpful), similar results were obtained for continuing education (3.56) and group settings with the product developer (3.34). Furthermore, those who had experience with digital anatomy during their education were more likely to choose group settings with the product developer (4.50), while those who did not have this type of experience were more likely to choose continuing education (3.83). These results indicate that one's experience with digital anatomy training may impacts one's beliefs concerning its usefulness and implementation, which should be further investigated in a larger sample.

Discussion

This analysis represents a preliminary investigation into methods of anatomy teaching, competence of students in different areas of anatomy, and beliefs surrounding the implementation of digital anatomy training. While the small sample size precluded proper hypothesis testing, several strong trends emerged, which should be investigated with a larger sample. Most notably, these trends included strong associations among the prevalence of digital anatomy training, teaching using cadavers, and student competence.

The present survey tool may be used in a larger sample to more fully clarify the impact of an instructor's experience and attitude on the competence of their students in anatomy training. Most notably, applying the competence scale to a larger sample would enable the use of multivariate regression to analyze the effect of an instructor's experience with digital anatomy training toward its implementation on students' competence, both overall and in specific areas. Moreover, areas of relatively lower or higher competence might be specifically investigated to identify which facets contribute to high competence or might bolster competence in lower areas. These data suggest some potentially interesting trends that warrant further investigation.

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