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The segmental-based approach during anatomy coursework presents better results than the systems-based approach

Thalles Guilarducci Costa[1,7], Mario Hebling Campos[1], Ana Claudia Ferreira Barros[1], Marilia Santos Andrade[2], Rodrigo Luiz Vancini[3], Ricardo Borges Viana[4], Thomas Rosemann[5], Katja Weiss[5], Beat Knechtle[5,6*] and Claudio Andre Barbosa de Lira[1]

Abstract

Traditionally, there are two pedagogical approaches to teaching human anatomy. The first is the systems-based approach (study of body systems – bones, muscles, organs – separately) gross anatomy courses and the second is the segmental-based approach (study of body segments – upper and lower limbs and trunk – separately); both are highly recommended. However, to the best of our knowledge, less is known about academic performance comparing the two approaches. Thus, in this study, we evaluate undergraduate students' academic performance in human anatomy courses using systems- or segmental approaches, also, evaluate attendance, the impact of missing class on performance, the course evaluations (specific to the professor) and the student perceptions of the different coursework. The final grade and class attendance of 141 undergraduate students, from the sports and exercise science program, undertaking the anatomy course, were evaluated. Seventy students participated in the systems-based gross human anatomy approach (SYS), and 71 students participated in the segmental-based gross human anatomy approach (SEG). Students in SEG (median [interquartile range (IQR]: 7.3 [2.0]) performed better academically, with higher final grades ($U = 1{,}804.5$, $p = 0.005$; $r_B = 0.274$ [95% confidence interval (CI): 0.09–0.44]; medium effect) than SYS (median [IQR]: 6.6 [1.6]). SEG had higher class attendance (median [IQR]: 60 [8]) than SYS (median [IQR]: 60 [7]; $U = 1{,}919.5$, $p = 0.015$; $r_B = 0.228$ [95%CI: 0.040–0.399]; small effect). Students in SEG rated the professor's performance more highly than SYS ($U = 78.0$, $p = 0.001$; $r_B = 0.616$ [95%CI: 0.332–0.797]; large effect). The segmental-based gross human anatomy approach leads to better academic performance and higher attendance in the gross anatomy course than SYS.

Keywords Education methodology, Anatomy and medical education, Human anatomy, Anatomy teaching

*Correspondence:
Beat Knechtle
beat.knechtle@hispeed.ch
[1]Faculdade de Educação Física e Dança, Universidade Federal de Goiás, Goiânia, Brasil
[2]Departamento de Fisiologia, Universidade Federal de São Paulo, São Paulo, Brasil
[3]Centro de Educação Física e Desportos, Universidade Federal do Espírito Santo, Vitória, Brasil
[4]Instituto de Educação Física e Esportes, Universidade Federal do Ceará, Fortaleza, Brasil
[5]Institute of Primary Care, University of Zurich, Zurich, Switzerland
[6]Medbase St. Gallen Am Vadianplatz, St. Gallen, Switzerland
[7] Unidade Universitária de Itumbiara, Universidade Estadual de Goiás, Itumbiara, Brazil

Introduction

Human anatomy is the study of the structure in which life events occur; consequently, understanding the structure is necessary to know its function [1]. As a result, human anatomy is primordial for undergraduate health science courses, such as medicine [2], physical therapy [3], nursing [4], and sports and exercise-related programs, including physical education and exercise physiology [5]. Human anatomy study dates back to the century II AD when Galeno started dissecting pigs and monkeys, but it was not until 1539 that Andreas Vesalius examined the first human bodies [6].

The gross human anatomy course is important in undergraduate sports and exercise programs because it provides knowledge about the locomotor apparatus, body movements, and responses and adaptations to exercise, which is important for professionals to prescribe effective physical training [5]. The human anatomy course in the third semester of the sports and exercise science undergraduate program at the Federal University of Goiás (UFG), located in Brazil, focuses on the locomotor apparatus [7].

Traditionally, there are two approaches to teaching gross human anatomy of the locomotor apparatus. The first is the systems-based approach, which consists of studying the fundamental systems that work together to perform the movement; therefore, the course focuses on teaching osteology, arthrology, and myology separately [6]. Osteology is the study of bones, arthrology is the study of joints and ligaments that connect bones to muscles, and myology is the study of the muscles that perform the movement [1]. This approach focuses on an organ's organizational properties, structure, and supply [8].

Another teaching approach is the segmental-based approach, which involves studying human body segments, such as the upper body (head, neck, arms, trunk, abdomen, and back) and lower body (pelvic, legs, and feet). As a result, the course focuses on teaching the segments separately, showing bones, joints, and muscles from the same segment [1]. This approach is concerned with position, as in spatial relationship within the body, and relations, as in relationship with adjacent organs [8]. This method is widely used in cadaver dissection teaching [9], and evidence suggests that it is crucial for safe practices among medical professionals [10].

Both approaches are equally recommended for theoretical gross human anatomy courses [11]. However, the segmental-based approach can accumulate details and isolated facts; in other words, understanding the body as a whole is limited, whereas the systems-based approach could be purely sequential and linear without showing important relationships between neighboring structures [8]. Many medical schools in the United States have been changing their programs to an organ-system approach [2]. Additionally, among physical therapists, the segmental-based approach to studying anatomy is the preferred and most commonly used method in physiotherapy programs [11, 12]. This is noteworthy because the physical therapy curriculum is closely related to sports and exercise programs. However, to the best of our knowledge, no study was conducted to investigate which teaching strategy improves students' academic performance, which includes the final grade of the students, the class attendance, and the professor evaluation by the student.

Another important point is related to class attendance. Previous studies showed that class attendance affects student performance [13]. Hidayat et al. [14] found an inverse association between the number of class hours missed by students and their academic performance in therapeutic courses. Class attendance is influenced by various aspects, such as motivation, prior grade point average, student self-financing, hours spent on employment, quality of teaching, and nature of class lectures [15]. Therefore, a study comparing segmental and systems-based approaches to class attendance is warranted. Furthermore, considering that teaching quality is an intervening factor, a study examining professor performance as perceived by students is also warranted.

Therefore, the primary aim of this study was to assess the academic performance of undergraduate students enrolled in human anatomy courses taught using a systems-based or segmental-based approach. The secondary aims were to compare undergraduate students' class attendance, professor performance evaluated by students, and student's perceptions of coursework between teaching approaches and assess the influence of class absenteeism on final grades. Our hypothesis, grounded in empirical observations, posits that students enrolled in an anatomy course using the segmental-based approach would achieve higher final grades, exhibit greater class attendance, and report higher satisfaction with professor performance compared to those in the systems-based approach.

Materials and methods

Participants

A total of 204 sports and exercise science undergraduate students from the UFG who attended the functional human anatomy of the locomotor apparatus coursework were recruited to participate in the study, the inclusion criteria were: i) participating in the anatomy course as student of the Sports and Exercise program. The exclusion criteria were: (i) not reaching the minimum of class attendance to pass in the course (The Brazilian educational system permits students to miss up to 25% of the total class hours of a course) and (ii) not taking one of the six tests of the coursework. The course lasted 16 weeks,

with four class hours per week for 64 class hours. Data from students enrolled between 2015 and 2019 were analyzed. Because the evaluation process differed from the other years, 2016 was excluded from the grade analysis, but maintained in the professor evaluation by the student analysis. The 2015 professor evaluation survey was excluded from the analysis as it did not contain the same questions used in subsequent years. Sixty-three students were excluded from the study because they did not finish the evaluation process (they did not take at least one of the tests). Therefore, the total sample size was 141 students. The sample was divided into two groups based on the approach taken by the student (systems-based approach versus segmental-based approach). The systems-based approach group (SYS) had 70 students and the segmental-based approach group (SEG) had 71 students. From 2015 to 2017, the systems-based approach was offered, and from 2018 to 2019, the segmental-based approach was offered.

Participants responded to the professor's performance regarding didactics, methodological approach, use of instructional technologies, and their perceptions of the coursework. The response was from an online questionnaire and the answers were anonymous and the students could attribute grades to the professor on the topics previously mentioned. Furthermore, class attendance was also evaluated, considering that a well-evaluated class by students could lead to higher attendance during lectures.

The coursework in both approaches was taught by the same experienced professor (M.H.C.). All experimental procedures were approved by the UFG Ethics Committee and were in accordance with the principles outlined in the latest version of the Declaration of Helsinki in 2013.

The bachelor's in sports and exercise science program

The sports and exercise program is eight semesters long. It is designed to provide students with a scientific background in human and exercise physiology, gross anatomy, biomechanics, nutrition, and physical training. Graduates of the program are employed in gyms, fitness centers, and public health services [5, 7].

Professor performance assessment

The survey assessing professor performance was standardized by the institution and distributed to students via an online system at the end of the semester, prior to the release of final grades. The students completed a nine-item questionnaire about how the professor conducted the coursework, which included the following items: 1—attend classes; 2—respect the course schedule; 3—comply with the teaching plan; 4—establish a relationship between the theoretical topic and professional practice; 5—has dominance and clarity of the matter; 6—use different and inspiring learning methodologies; 7—the evaluation process is coherent; 8—returns the evaluations and clarify the doubts; and 9—is polite with the students. The student may give each item a grade ranging from 0 to 10; the mean was calculated to attribute a final grade to the professor for the course. The participation in the survey was voluntary, which resulted in a majority of students not responding. Students did not have access to their peers' scores, and the professor did not know the identities of the respondents. The 2015 survey was excluded from the analysis because it did not include the same questions as the other years. However, data from 2016 was incorporated into the analysis despite being excluded from the grade analysis. This exclusion of grade analysis was due to a higher number of tests administered during that semester, which altered the testing pattern compared to other years. Importantly, the instructional approach in 2016 remained consistent with the other years, justifying its inclusion in the broader analysis.

The systems- and segmental-based approaches and process of evaluation

The systems-based approach focused on the musculoskeletal system, divided into four main sections: introduction, skeletal system, articular system, and muscle system. The skeletal system included topics such as bone classification, morphology, and the skeletal division. The articular system covered joint types, movements, and structures (e.g., ligaments, bursas, tendons). The muscle system addressed concepts of muscle anatomy, classification, and functions (e.g., the biceps brachii's origin and insertion). An introductory section covered general anatomy concepts, nomenclature, planes, sections, and body divisions. The final grade was computed as the arithmetic mean of all test scores. For each topic (skeletal system, articular system, and muscle system), one theoretical test and one practical test were applied; therefore, a total of six tests were conducted. The segmental-based approach examined the body in segments, with four main sections: introduction, functional anatomy of the lower limb, trunk, and upper limb. The functional anatomy sections emphasized the identification of bones, joints, muscles, and movements within each segment (e.g., the humerus as a long bone, its articulations, and its muscle attachments). The trunk section included the spine's anatomy and functionality. An introductory unit, similar to the systems-based approach, included general anatomy concepts. The final grade was calculated as the arithmetic mean of all test scores. For each topic (lower limb, trunk, and upper limb), one theoretical test and one practical test were applied; therefore, a total of six tests were conducted. Over the years, the same professor (M.H.C.) touched on both approaches, and classes were divided into theoretical (lectures with basic anatomic information and terminology) and practical

(demonstration in plastic-made body parts [3B Scientific, Hungary] and radiological imaging) classes. Theoretical classes took up 48 h, and practical classes took up 16 h. Students have access to content complementation via virtual platforms. Near-peer teaching, when students who already completed the course helped other students in the process [5], was also available for interested students. The final grade required for approval was 6.0 out of 10.0. The theoretical tests had 15 multiple-choice questions and two essay questions. The practical tests comprised anatomical structure naming problems. Considering the different nature of the two approaches, the methodological appraisal was different in the perspective of content. However, the tests were developed by the same professor and covered identical concepts, subjects, and difficulty levels. As stated previously in this manuscript, the number of tests was the same (three theoretical tests and three practical tests) and the tests were conducted at the same time points within the 16 weeks.

Attendance evaluation

Class attendance was confirmed at the beginning of each class day; if a student did not respond to name-calling during the present conference, one foul was assigned to their name. The maximum number of fouls allowed was 25% of total classes (four of 16 class days), and each class day had four class hours; that is, the student received 4 h of absence for each class day missed.

Statistical analysis

The data were analyzed in the Jeffreys's Amazing Statistics Program (JASP, 0.18.1.0, Amsterdam University, Netherlands). The data distribution was analyzed using the Shapiro–Wilk test. Because no variable had normal values, presenting skewed distribution, therefore the data were presented as medians and interquartile ranges (IQRs) (e.g. 7.3 [2.0]), unless otherwise stated. The final grade was evaluated using a non-parametrical Mann–Whitney test between groups and class attendance. The final grades were compared using a Kruskal–Wallis test based on the number of class hours attended (48, 52, 56, 60, and 64 h), and the Dunn *post hoc* analysis was used to identify differences between medians, with Bonferroni corrections for multiple comparisons.

Furthermore, the rank biserial correlation (r_B) was used as the effect size for the Mann–Whitney test and the *post hoc* analysis of the Kruskal–Wallis test, with the following classifications: small effect ($r_B < 0.24$), medium effect ($0.24 \leq r_B < 0.37$), and large effect ($r_B \geq 0.37$). The eta squared (n^2) was used as the Kruskal–Wallis effect size, with the following classifications: small effect ($n^2 < 0.13$), medium effect ($0.13 \leq n^2 < 0.26$), and large effect ($n^2 \geq 0.26$).

A Spearman correlation was conducted, controlling for the type of approach (approach partial out), to examine the relationship between academic performance and class attendance while excluding the influence of the instructional methods. The Fisher's z effect size was used with the following classifications: small effect: $z \leq 0.3$, medium effect: $0.3 < z \leq 0.5$, and large effect $z > 0.5$.

Results

Differences between approaches

The Mann–Whitney test ($U = 1{,}804.5$, $p = 0.005$; $r_B = 0.274$ [95% confidence interval (CI): 0.09–0.44]; medium effect) showed that students enrolled in SEG (median [IQR]: 7.3 [2.0]) had better academic performance (i.e., received a higher final grade) than students enrolled in SYS (median [IQR]: 6.6 [1.6], Fig. 1), (Δ median [SEG – SYS] = 0.7). Simultaneously, the Mann–Whitney test ($U = 1{,}919.5$, $p = 0.015$; $r_B = 0.228$ [95%CI: 0.040–0.399]; small effect) showed that SEG had higher class attendance (median [IQR]: 60 [8]) than SYS (median [IQR]: 60 [7], Fig. 2).

Differences in final grades based on class attendance

One hundred forty-one students completed the functional human anatomy of the locomotor apparatus course between 2015 and 2019 (excluding 2016). A total of 49 students had full class attendance (64 h), 45 had 60 h of class attendance, 33 had 56 h of class attendance, six had 52 h of class attendance, and eight had 48 h of class attendance. The Kruskal–Wallis test showed that class attendance affected final grades (H [4] = 34.842, $p < 0.001$; $n^2 = 0.33$; large effect). Dunn's *post hoc* analysis showed that those with full attendance (64 h, median [IQR]: 7.9 [2.1]) had higher final grades than those with 56 h ($p_{bonf} = 0.037$, median [IQR]: 6.7 [1.5]), 52 h ($p_{bonf} = 0.001$, median [IQR]: 5 [3.0]), and 48 h ($p_{bonf} < 0.001$, median [IQR]: 3.8 [4.5]) of class attendance; those with 60 h (median [IQR]: 7.0 [1.2]) of class attendance had higher final grade than 48 h ($p_{bonf} = 0.007$); and the those with 56 h of class attendance had higher final grade than who had the minimal hours (48 h) of class attendance ($p_{bonf} = 0.037$) class attendance (Fig. 3). Spearman's correlation, with the type of approach partial out, showed a significant negative correlation between final grade and missing classes ($r = -0.304$; 95%CI (-0.145; -0.463); $p < 0.001$, Fisher's z effect size= -0.314; medium effect), with missing classes accounting for 34.3% of the variance in final grade.

Professor performance assessment by the student

In the 2015–2019 school years, 44 students responded to the questionnaires, 29 from the SYS and 14 from the SEG. The Mann–Whitney test ($U = 78.0$, $p = 0.001$; $r_B = 0.616$ [95%CI: 0.332–0.797]; large effect) showed that SEG students scored higher (median [IQR]: 9.9 [0.4])

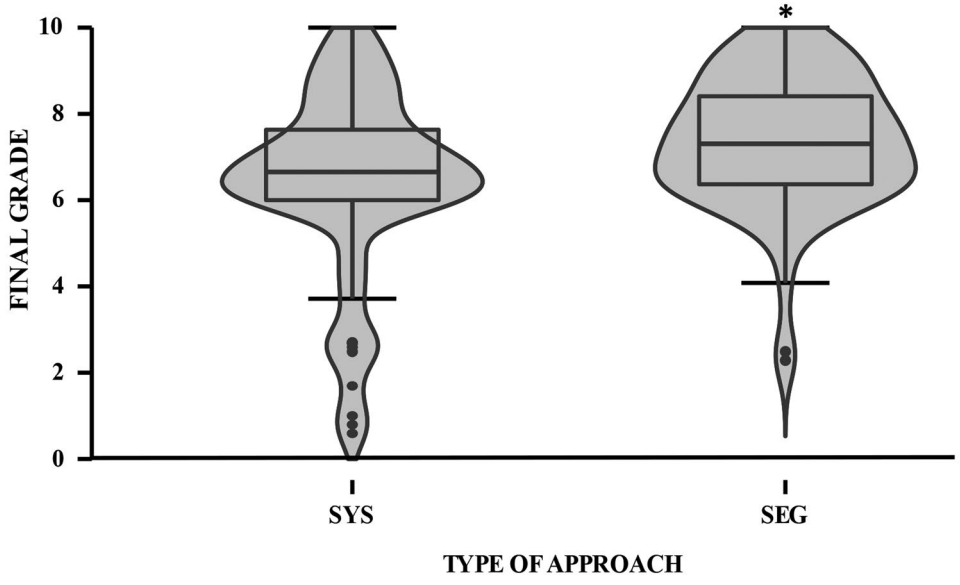

Fig. 1 Boxplot with violin element of the comparison of final grade between students from the systems-based approach group (SYS, $n=70$) and segmental-based approach group (SEG, $n=71$). *SEG higher than SYS

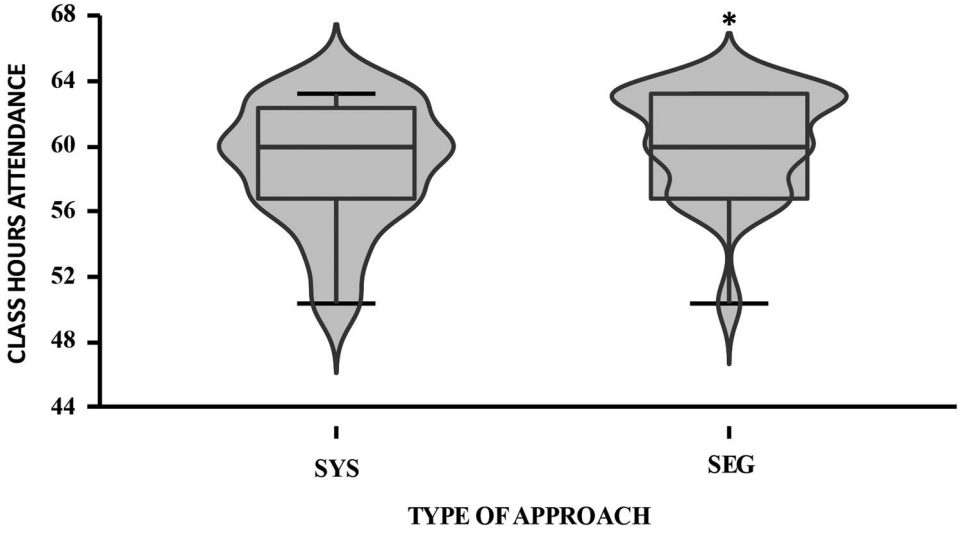

Fig. 2 Boxplot with violin element comparison of class attendance between the systems-based approach group (SYS, $n=70$) and segment-based approach group (SEG, $n=71$). *SEG higher than SYS

than SYS students (median [IQR]: 8.7 [2.3]; (Δ median [SEG - SYS] = 1.2) (Fig. 4). Supplementary analyses for individual questions are presented in supplementary material 1.

Discussion

We evaluated the difference in academic performance (assessed by final grade) between the two teaching human anatomy approaches, hypothesizing that students enrolled in a segmental-based anatomy course would achieve higher final grades, attend more classes, and report greater satisfaction with professor performance, compared to those in a systems-based approach. Our key finding was that students who in the segmental-based approach achieved higher final grades than those in the systems-based approach. Additionally, students in the segmental-based course attended more classes and rated professor performance more positively. Therefore, our initial hypothesis was confirmed.

In terms of final grades, SEG students had higher final grades than SYS students. To the best of our knowledge, this is the first study that compared academic performance between different human anatomy teaching approaches, particularly in sports- and exercise-related undergraduate programs. Consequently, our ability to compare our results with previous studies is limited.

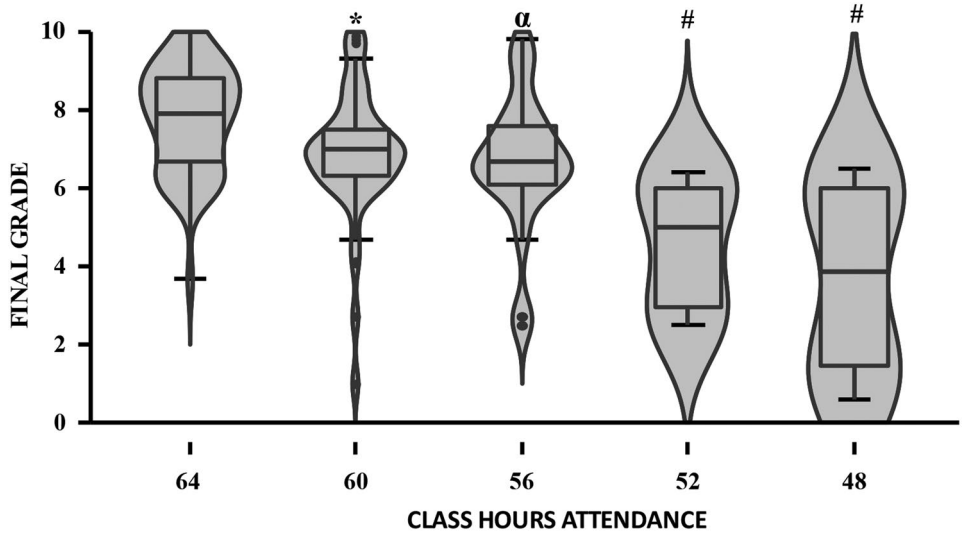

Fig. 3 Boxplot with violin element comparison of final grade between 64 h ($n=49$), 60 h ($n=45$), 56 h ($n=33$), 52 h ($n=6$), and 48 h ($n=8$) of class hours attendance. *Final grade higher than 48. αFinal grade lower than 64 and higher than 48. #Final grade lower than 64

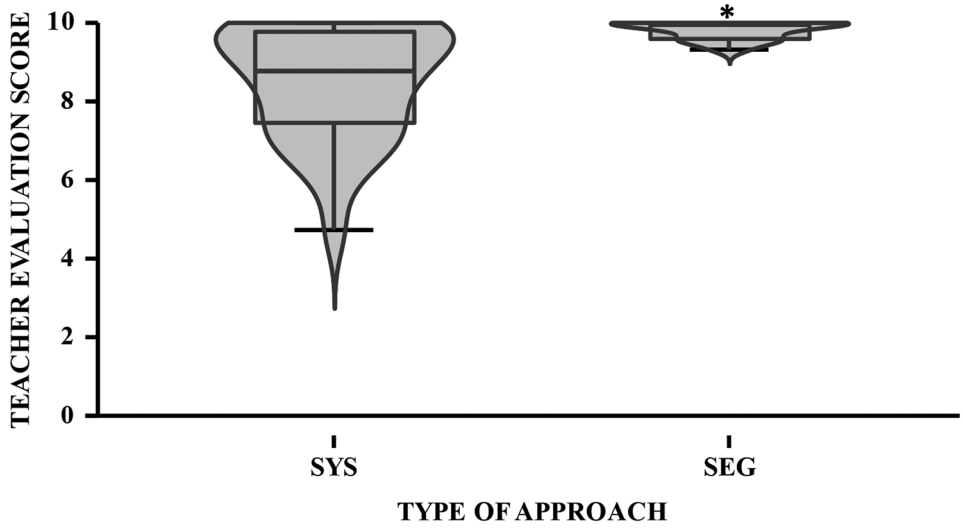

Fig. 4 Boxplot with violin element comparison of professor evaluation by the student between the systems-based approach group (SYS, $n=29$) and segment-based approach group (SEG, $n=14$). *SEG higher than SYS

Moreover, professor performance assessed by students enrolled in SEG was better than that in SYS, and students from SEG had higher class attendance than students from SYS.

According to Dezee et al. [2], many medical schools in the United States have been changing their programs to an organ-system approach rather than a discipline approach since 2005, but the focus on medical schools is also changing to small-group case-based education, moving away from lecture-based instruction. However, the authors point out that research on the benefits of this curricular change is limited. In this case, it is worth noting that lecture-based instruction remains important in Brazil, mainly due to the difficulties in obtaining cadavers [16]. The use of cadavers in human anatomy courses in sports- and exercise-related programs is becoming rare, whereas the use of synthetic anatomical models to teach human anatomy is becoming more widespread. Furthermore, lectures incorporating radiological imaging and the use of virtual educational platforms were shown to be more technically and economically viable than dissection and surgery watching, particularly in low- and middle-income countries [17]. Therefore, our results should be interpreted with caution when compared to other methodological perspectives in the study of anatomy. Future studies should also consider analyzing different approaches in anatomy courses, such as small-group case-based education or problem-solving methods.

Regarding the difference in grades based on class attendance, students with full attendance (64 h) had higher grades than those with 48–56 h of attendance and studentes with 60 h of attendance had higher grades than those with 48 h of attendance. Similar results regarding the positive association between grades and class attendance were found in other studies in medical [13, 18] and pharmacy [14] programs. Therefore, our results are consistent with the literature. In general, the Brazilian educational system allows for 25% class absences of the total class hours of the course. Therefore, in a 64-hours course, the student may miss 16 h. At UFG, the final grade for approval is 6.0; this grade was only achieved by students (based on the median) who missed no, one, or two class day. Therefore, our results suggest that the university could allow one or two class day absence in the human anatomy course, equating to 6.25–12.5% of the total course. This is important because class attendance affects academic performance [18]. Therefore, our results are consistent with the literature. Corroborating this finding, the Spearman's correlation, with the type of approach partial out, showed a significant negative correlation between final grade and missing classes.

It is worth noting that many factors can influence attendance, including a class period (morning or afternoon), examination preparation, and the professor's poor lecturing skills [19], as well as the student's interest in the subject of the course [20]. Because the Sport and Exercise Science Undergraduate Course at UFG is only offered in the afternoon, this was not an intervening factor in the results presented here. Additionally, the correlation results indicated that more missed classes are associated with lower grades, regardless of the teaching approach, highlighting the critical role of attendance in understanding the material and achieving better academic performance. Regarding the professor's academic skill, the participants from SYS and SEG evaluated the professor with median grades of 8.7 and 9.9, respectively; therefore, it is acceptable to assume that the professor's skill did not influence the results presented here.

While it is indeed possible that some aspects of the segmental approach to gross anatomy may be more accessible or memorable, we did not conduct a specific analysis to address this, as it was not within the scope of our research questions. However, we hypothesize that certain features of segmental approach could offer educational advantages compared to the systemic approach. In segmental approach, students examine all structures within the same segment, emphasizing their intimate anatomical relationships. For instance, understanding the origin, insertion, and function of the biceps brachii is facilitated by studying all associated structures together. This includes the humerus—the bone from which the biceps brachii originates (e.g., from the supraglenoid tubercle of the scapula for the long head and from the apex of the coracoid process for the short head)—as well as its insertion on the radial tuberosity, and its connective interactions within the humeroulnar, humeroradial, and glenohumeral joints. In contrast, we propose that systemic approach may inadvertently introduce redundancy, requiring students to revisit structures from the same segment multiple times across different systems. It is important to note that the systemic division of the human body is a didactic construct, while the body itself functions as an integrated whole. Future studies should explore this matter further, using more qualitative research questions. Moreover, we believe that students who are more satisfied with the course content delivery and who can comprehend the material more easily are likely to rate the professor's performance more positively.

Our study has a few limitations. First, it focused exclusively on sports and exercise science undergraduate students from one single institution. Therefore, our findings should be extrapolated with caution for other academic courses. Nonetheless, we believe this limitation does not undermine the study's conclusions. Second, we did not assess the students' prior academic levels, which might have provided a more comprehensive understanding of the impact of different anatomy teaching approaches. Therefore, we recommend that future research incorporate pre- and post-tests to compare different teaching methodologies and provide deeper insights. However, since all students were at comparable academic levels, we assume their baseline performance was similar. Third, the tests did not have an external reviewer to validate the assessments. However, we believe this limitation does not compromise the validity of our findings. The professor responsible for the course has extensive experience in teaching anatomy and was meticulous in ensuring that the concepts, content, and difficulty levels were equivalent across both approaches. Therefore, we are confident that the assessments applied allowed for a fair and accurate comparison of the student's academic performance. Fourth, that teaching improvements due to experience may have influenced the results, as the two cohorts (SEG vs. SYS) were evaluated in different years. However, the transition between approaches occurred in consecutive years, with no gap for significant improvements in teaching methodology. Additionally, the professor had no prior experience with the SEG approach, which contrasts with their extensive experience teaching SYS. Based on this, we would have expected less favorable outcomes for SEG, yet the results demonstrated the opposite. This supports the robustness of our findings, as the SEG approach yielded higher grades and better academic evaluations despite the professor's initial unfamiliarity with it. Moreover, using the same professor for both approaches eliminated potential biases that might arise from varying

teaching styles or perspectives. Fifth, while better academic performance in the SEG cohort might be partially attributed to higher attendance rates, it is important to note that the students' evaluations of the professor were also more favorable in the SEG group. This suggests that the SEG approach not only improved comprehension but also positively impacted student engagement, which may, in turn, have influenced attendance and grades. However, our study cannot establish the direction of this relationship. Future research should explore this connection further, as it is plausible that students are more motivated to attend classes when the material is presented in a more accessible manner. Despite these limitations, we believe our findings are robust and provide valuable insights into the effectiveness of different anatomy teaching approaches.

Future studies should apply the methodology to replicate the results in other science programs, such as medicine, physical therapy, and nursing across multiple institutions. Other than that, professors of anatomy courses should be aware of the valuable implications of the study, such as, there is a method that seems to be more effective to teach anatomy. Furthermore, future studies should associate the better performance with standard tests taking pre and after the anatomy course, to compare the two approaches; also, innumerous other methodologies have the potential to fit in to the segmental approach, for instance, problem-based learning, cardboard games, active learning, and others.

In conclusion, we showed that the academic results among the undergraduate students from the Sport and Exercise Science Undergraduate Course enrolled in human anatomy coursework using a segment-based approach were higher than those enrolled using a systems-based approach. We also showed that students who did not attend for more than 4 h presented a lower academic performance in human anatomy coursework. Our results can be used by faculty and deans to improve human anatomy coursework.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-024-06541-5.

Supplementary Material 1

Supplementary Material 2

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Author contributions
T.G.C: data analysis, interpretation and manuscript preparation, study concept and design; M.H.C: Project administration, study concept and design, review and editing; A.C.B.F: data acquisition and manuscript preparation; M.S.A: Writing – review and editing; R.L.V: Writing – review and editing; R.B.V: Writing – review and editing; T.R: Writing – review and editing; K.W: Writing – review and editing; B.K: Writing – review and editing; C.A.B.L: Study concept and design, writing – review and editing, project administration and final approved of the manuscript. All authors read and approved the final manuscript.

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Data availability
All data generated or analysed during this study are included in this published article as supplementary information file.

Declarations

Inform consent
An inform consent was obtained from all subjects to permit the participants to enter the study. Information about study objectives, location of data collection, requirements to engage, possible risks, rights of the participants, guarantees of data privacy, and the possibility to withdraw of the study in any time. The consent was sign at the presence of one researcher.

Competing interests
The authors declare no competing interests.

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