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Education

Teaching gross anatomy during the Covid-19 pandemic: Effects on medical students' gain of knowledge, confidence levels and pandemic-related concerns

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ABSTRACT

For medical students the dissection course is the preferred method to learn gross anatomy. However, the added value of active cadaver dissection on knowledge gain in multimodal curricula offering a diversity of e-learning resources is unknown. The Covid-19-related lockdown forced educators to replace the dissection course by e-learning resources. At the end of the summer term 2020 loosening of pandemic-related regulations allowed offering a compact, voluntary active dissection course of the head-neck region to first-year medical students at Hannover Medical School. A study was conducted comparing a dissection group (G1, n = 115) and a non-dissection group (G2, n = 23). Knowledge gain and confidence level were measured with a multiple-choice (MC-)test. The use of e-learning resources was recorded. A questionnaire measured motivation, interest and level of concern regarding Covid-19 and anatomy teaching. No differences between groups were found regarding motivation and interest in anatomy of the head-neck region. G2, however, had significantly higher concerns regarding the Covid-19 pandemic than G1. Neither before nor after the educational intervention, differences in the scores of the MC-test were found. However, after the course G1 answered more MC-questions with highest confidence level than G2 (6.7 ± 6.0 vs. 3.6 ± 4.6, $p < 0.05$) and demonstrated by trend an increased improvement in the scores of image-based questions (30.8 ± 18.2 % vs. 17.1 ± 14.8 %, $p = 0.06$). In general, frequent users of online quizzes, a part of the e-learning resources, scored significantly better in the knowledge test. Active dissection improves self-assurance to identify anatomical structures and should be re-implemented in multimodal, blended-learning-based anatomical curricula in the post-pandemic era.

1. Introduction

Anatomical curricula are usually placed in the first two years of education of health care professionals in German medical schools. The overall aim is to study the normal composition of the human body. Gross anatomy involves those structures which can be identified with the naked eye, and is complemented by microscopic anatomy and embryology. In gross anatomy the structures are arranged in systems and regions so that the curriculum aims to convey knowledge and understanding in topographic anatomy, systematic and functional anatomy (Louw et al., 2009). In particular, imparting sustainable knowledge and understanding in topographic (spatial) anatomy represents a challenge for both the students and educators since this is highly dependent on the spatial ability of students (Rochford, 1985). Furthermore, knowledge and understanding three-dimensional topographic anatomy is of utmost importance for the daily life of clinicians, e.g., considering clinical examination, clinical imaging and surgery (Older, 2004; Turney, 2007; Arráez-Aybar et al., 2010). In this context it has been shown that clinical reasoning during physical examination of patients is often based on actively applying anatomical knowledge retrieved from memory by visual representations (Vorstenbosch et al., 2016). Also, three-dimensional (3D) objects, such as anatomical structures and their spatial interrelationships are usually represented in the memory as images which are mentally rotated to derive the corresponding 3D information (Bülthoff et al., 1995; Garg et al., 2001). Hence, anatomical science education has to work with two- and three-dimensional visualization of organs and course of conduction paths, ideally in a clinical context, to prepare future physicians.

In order to face these educational challenges in teaching gross anatomy, a diversity of educational methods within the frame of a

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multimodal curriculum are usually applied (Estai and Bunt, 2016). Demonstration preparations dissected by prosectors, plastic models or e-learning modules including 3D anatomy software have been used to visualize spatial anatomy in medical education (Lewis et al., 2014). Except for 3D anatomy software these methods to engage with spatial anatomy allow participants to apply different sensory perceptions such as the visual and tactile system and this is perceived by the students as a beneficial learning experience linked with an authentic learning environment (Attardi et al., 2016). Furthermore, based on a survey of anatomists across Europe, active cadaver dissections still remain an important educational method to teach gross anatomy (Patel and Moxham, 2008). Active dissection of cadavers has also been shown to be the students' first preference to learn anatomy in a medical school in Greece. In that study active cadaver dissection was superior to demonstration of preparations (prosections), plastic models or e-learning resources of the 3D anatomy (Zibis et al., 2021). The added value in terms of objective learning outcomes of active cadaver dissection in comparison to demonstration and active investigation of prosections, however, is not that clear although there is a trend in favor of active dissection (Winkelmann, 2007). Nevertheless, in the context of neuroanatomy and the anatomy of the upper limb, recent randomized and controlled studies demonstrated that active dissections are superior to prosections or plastic models with regard to objective gain in anatomical knowledge (Li and Zuo, 2020; Zibis et al., 2021). On the other hand active cadaver dissection and the use of 3D anatomy software demonstrated comparable efficiency in imparting knowledge and understanding of anatomy (Zibis et al., 2021). However, whether or not active cadaver dissection as an educational method is in terms of objective gain in knowledge differs from "modern" computer-based 3D visualization of anatomical structures is a matter of debate (Chytas et al., 2020).

The severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) has disrupted medical education in March 2020. Due to the threats of the SARS-CoV-2 pandemic many medical schools around the world were challenged to replace face-to-face by distance teaching within a very short time frame (Rose, 2020). Also, concepts to deal with SARS-CoV-2 positive donors had to be developed (Lemos et al., 2021). In many medical schools one of the most efficient teaching methods preferred by students as well as teachers/instructors, the active cadaver dissection in small groups (Ghosh, 2017), had to be abandoned and replaced by other formats which were in compliance with the concept of social distancing (Brassett et al., 2020; Cuschieri and Calleja Agius, 2020; Wolniczak et al., 2020; Taylor et al., 2022). Thus, anatomy had to be taught without the access to practical-based learning materials which stimulate the tactile and visual system of the learner to understand anatomy. The cancellation of the dissection course in many universities not only complicated the gain of anatomical knowledge and understanding but also the development of professionalism and motor skills of the students (Boeckers and Boeckers, 2016; Kumar Ghosh and Kumar, 2019) so that it is not astonishing that students were worried about the quality of their education and future careers (Cuschieri and Calleja Agius, 2020; Franchi, 2020).

In Germany, face-to-face teaching was also reduced to a minimum and lectures as well as seminars were held online as live events or delivered as videos for streaming and asynchronous use. Some universities offered interactive quizzes in between the lectures and seminars. The dissection course was reduced in time and group size (e.g., 1–3 students per group and time point) in many medical schools and complementary self-produced video-demonstrations were offered (Böckers et al., 2021). Hence, the available time per student for active dissection was considerably reduced in the summer term 2020 in many universities around the world including Hannover Medical School. However, the very precious, reduced dissection time might be utilized very efficiently by the students to gain knowledge and understanding of anatomical structures in three dimensions. This is particularly true since students spent approximately 1/3 of the time for active dissection in a regular dissection course while the rest of the time is utilized for investigation of prosections or cadaver-unrelated activities (Winkelmann et al., 2007).

The aim of the present study was therefore to evaluate the effect of a six-hour dissection course in groups of two students to acquire knowledge and understanding of the head-neck region. First-year medical students at Hannover Medical School were offered participation in a voluntary and shortened dissection course of head and neck at the end of the summer term 2020. This made it possible to perform a controlled study with non-dissecting controls, while under normal circumstances the dissection course at Hannover Medical School was mandatory for all medical students. The students were already experienced in active dissection from the time before the lock-down and had access to compatible online learning material six weeks before the dissection course. Before and after this educational intervention a knowledge test containing text and image-based multiple-choice questions was conducted to measure the topographical knowledge of the head-neck region. Furthermore, a self-assessment addressing anatomy in general, the dissection course in particular, use of teaching material and concerns regarding the Covid-19 pandemic was employed. Students who did not participate in the voluntary dissection course but participated in the surveys served as controls.

2. Methods

2.1. Teaching anatomy at Hannover Medical School

The anatomy module for medical students took place during the whole first year of study and was separated into three blocks of ten weeks each (tertials). For gross anatomy, each block of ten weeks had specific topics: In the first tertial general anatomy and the topographical regions back, upper limbs and neck were taught. The second tertial contained situs, pelvis, genital organs and lower limbs and the third tertial dealt with the head-neck region.

The first two tertials (10/2019–03/2020) were conducted as previously described by Koop et al. (2021).

In the upcoming third tertial (summer term) the head-neck region was taught. To give a better structure for home-based learning, a specific topic was given each week, e.g., cranium and spine for the first week. The students had access to sound-recorded lectures and lecture slides as pdf-files (1–2 uploads/day), videos of anatomical specimen demonstration (1–2x/week), exercise material (1x/week), an online learning quiz (1x/week) and an online photographic anatomy atlas. All learning materials were provided on the online portal "ILIAS".

In June 2020 a voluntary dissection course, which was in line with the hygiene regulations could be offered to the students. It was set at the end of the tertial, within two weeks before the final written examination. Small groups of two students were allowed to dissect the head-neck region of their body donors for two hours each on three consecutive days. One anatomist per hall supervised the courses, but was not allowed to help the students for content questions due to hygiene regulations. No student tutors were involved. Therefore, the students received a checklist of important structures which were likely to dissect in the given time for guidance (Suppl. Mat.).

2.2. Participants and evaluation

281 first-year medical students were registered for the anatomy module and 210 students attended the voluntary dissection course. Of these, a maximum of 115 students participated in the study

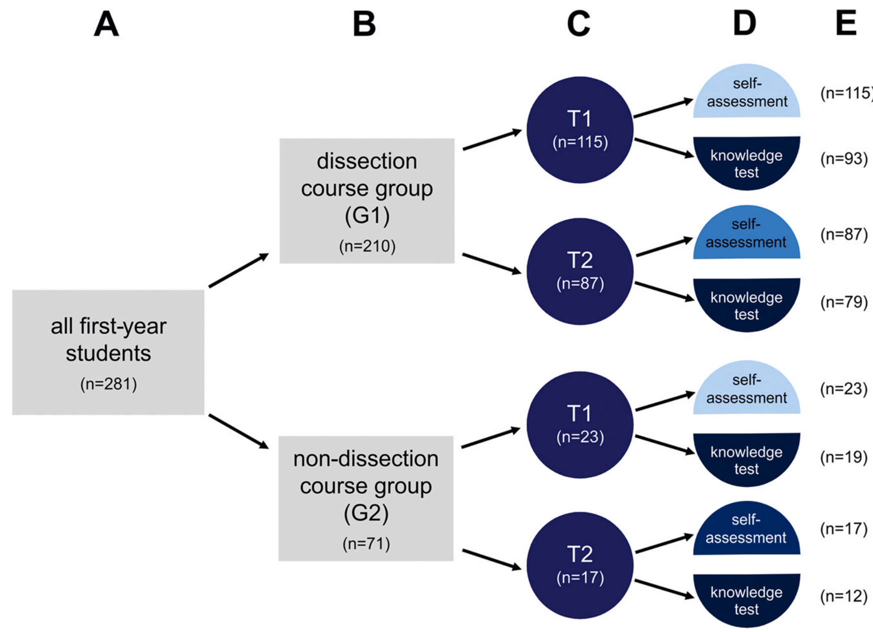

Fig. 1. Study design and participants. All first-year medical students were allowed to participate in the surveys. The survey at time point 1 (T1) was conducted before the voluntary dissection course (baseline), whereas the survey at time point 2 (T2) was conducted afterwards. The surveys included two parts: First a self-assessment and second an anatomical knowledge test. Participants were only included in the analyses if they at least finished the self-assessment part. For analysis of the second part only data of completely finished knowledge tests were included.

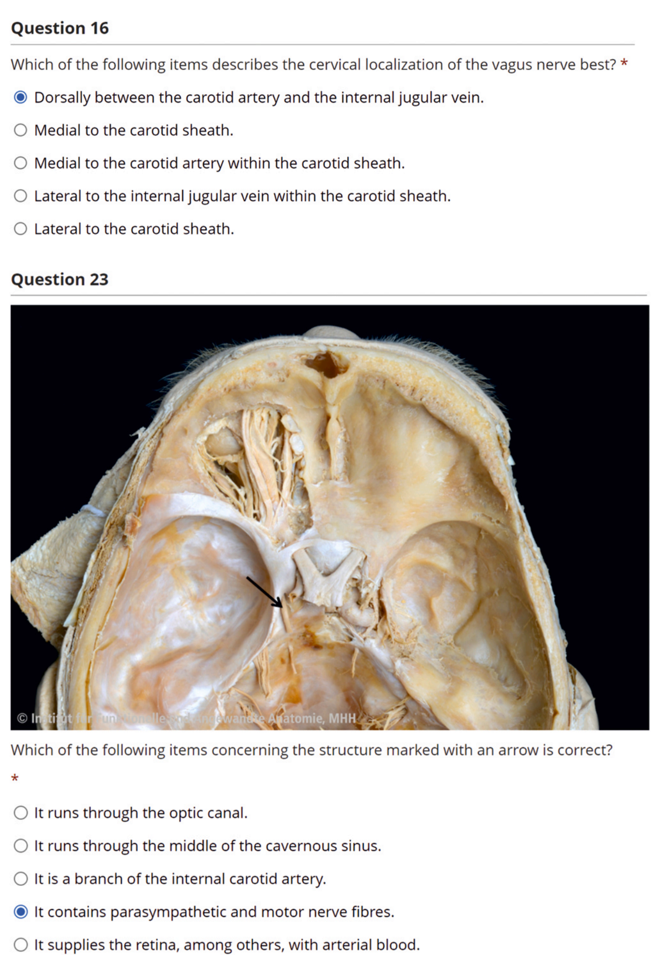

Fig. 2. Representative examples of text-based and image-based multiple-choice questions. Correct answers are marked with a blue dot.

(intervention, dissection course group, G1), varying at the different time points and parts of the study (Fig. 1). Of the 71 students who decided not to participate in the dissection course, a maximum of 23 students took part in the study (control, non-dissection course group, G2). The study consisted of two surveys conducted on the online portal "ILIAS" and every first-year medical student at MHH had access to them. The first survey at time point 1 (T1) was open for execution right before the dissection course for two days, whereas the second survey at time point 2 (T2) was activated right after the last dissection course for three days. An anonymized participation was guaranteed, but participating students had to give a consistent personal nickname at the beginning of each survey to eventually match the results during analyses. Furthermore, they were asked to name their gender as male (m), female (f), diverse (d) or no answer (N/A) at T1. Each survey consisted of two parts: A self-assessment and a knowledge test.

In the first part, the participants were asked to self-assess items concerning interest, motivation and knowledge of anatomy in general and the topographic anatomy of the head-neck region in detail (G1/G2 at T1). Therefore, a six-point Likert scale was used. The items were taken and adapted from Knudsen et al. (2018), a publication in which internal consistency of items had been demonstrated using Kendall´s tau and Cronbach´s alpha. Furthermore, items regarding concerns about the Covid-19 pandemic (G1/G2 at T1/T2) and regarding the voluntary dissection course (G1 at T2) had to be rated by a Likert scale-based self-assessment. The six-point Likert scales were described as 1 = strongly disagree to 6 = strongly agree. At last, the participants were asked to specify the frequency of teaching material use on a five-point Likert scale. The items were described as 1 = never, 2 = infrequently (< 1x/week), 3 = occasionally (1x/week), 4 = frequently (> 1x/week) and 5 = daily. For every Likert scale it was possible to give no answer (N/A).

The second part of the surveys consisted of an objective knowledge test on the topographic anatomy of the head-neck region. As such, 15 text-based and image-based multiple-choice questions each were created by an experienced anatomist, resulting in a total of 30 questions. One text-based question was excluded from data analysis because of two possible right answers in retrospect. Text-based and image-based questions were set alternating in the examination. Pictures for the image-based questions were taken from the online photographic anatomy atlas. One representative example for each question type is shown in Fig. 2. The same examination was used for all participants and both time points. After every question, the participants were asked to rate their level of confidence for answering the question on a six-point Likert scale, described as 1 = 0 % to 6 = 100 %. All first-year medical students were given the opportunity to perform the knowledge test without participating in the study. In this case, no personal data or survey data was obtained. Before participants gave informed consent, they were informed about the objectives of the study, instructed to answer the questions without any help and asked not to share the questions and answers with others.

The study was conducted according to good clinical practice and was approved by the Ethical Review Board of Hannover Medical School, Germany (reference number: 9120 BO K 2020).

2.3. Statistical analyses

The data of all participants, regardless of the participation at any time point (T1 only, T2 only, T1 and T2), were included in the analyses, resulting in different numbers of participants per group at both time points (Fig. 1C). Furthermore, the participants were able to abort the surveys at any time. Only fully completed survey parts were included. So, in case of an incomplete knowledge test part, the completed self-assessment was included. These in-survey drop-outs resulted in different numbers of participants within one group at one time point (Fig. 1E). The internal consistency of the knowledge test scores was tested by calculating Cronbach's alpha, differentiating the scores of image-based (15 questions), text-based (14 questions) and all questions (29 questions) (Möltner et al., 2006). Cronbach's alpha was also assessed to test for internal consistency of the items regarding knowledge, gain in knowledge, promotion of interest, intrinsic motivation (T2) and pandemic concerns in the self-assessments. For correlation analysis of the items related to interest and intrinsic motivation (T1) Kendall's tau was calculated.

For group comparisons at each time point, means of knowledge test results and confidence levels were tested by Student's t-test in case of normally distributed data. Not normally distributed or not equally varied data was tested by Mann-Whitney Rank Sum test. The identical procedure was conducted for the Likert scale-based self-assessments and a subgroup analysis of knowledge test results differing by the teaching material using frequency. To test for group and time effects of the mean confidence levels at right and wrong answers, a 2-way-ANOVA was performed. For calculation of the mean absolute change of correctly answered questions, the results of the participants who completed the knowledge tests at both time points were matched. This procedure led to a decreased number of participants for the analysis (number data shown in Table 3). Statistical analyses were performed using SigmaPlot® software, version 13.0.0.83 (SYSTAT® Software Inc.) and Real Statistics Resource Pack©, version 7.7.1 in Microsoft Excel 2019. Cohen's effect size was calculated and used for a post-hoc power analysis using G*Power statistic software, version 3.1. Differences were considered significant if p-values < 0.05 and as tendency if $0.05 \le p < 0.1$.

3. Results

3.1. Internal consistency of self-assessment and knowledge test

Regarding the self-assessment, Cronbach's alpha of the item ratings related to knowledge, gain in knowledge, promotion of interest, intrinsic motivation (T2) and pandemic concerns (T1) were 0.79, 0.84, 0.63, 0.74 and 0.66, respectively. Items regarding interest and intrinsic motivation (T1) showed a significant correlation with a Kendall's tau of 0.14 ($p = 0.048$) and 0.45 ($p < 0.0001$). The internal consistency of the knowledge test results at T1 was also assessed, resulting in a Cronbach's alpha of 0.73 for the scores of image-based questions, 0.52 for text-based questions and 0.78 for all questions.

3.2. Group characteristics before the dissection course

The participation rates of the dissecting students´ group in the study-related evaluations were 54.8 % before (T1) and 41.4 % after the dissection course (T2). In the group of non-dissecting students, these rates were lower and amounted to 32.4 % and 23.9 %, respectively (Fig. 1B and C). Due to the voluntary participation in the dissection course, no systematic randomization between the dissection course (G1) and non-dissection course group (G2) could be applied. Yet, despite no randomization, the gender distribution appeared quite matching in the dissection course and non-dissection course groups (m / f / d / N/A = 34.8 % / 62.6 % / 0 % / 2.6 % for G1 and 34.8 % / 60.9 % / 0 % / 4.3 % for G2, both at T1). Furthermore, the frequency of teaching material use did show only minor differences between the study groups (Fig. 3). The frequency of using teaching material appeared to follow their upload frequency. For example, a majority of the participants used daily uploaded, sound-recorded lecture slides daily, whereas exercise materials were used mainly one time per week (Fig. 3). There were no significant differences between both groups in items regarding interest, intrinsic motivation and knowledge in the self-assessment at T1 (Table 1). Nevertheless, G1 tendentially had a higher promotion of interest in topographic anatomy of the head-neck region than G2 (4.9 ± 1.3 vs 4,6 ± 1.3, $p = 0.084$), whereas G2 rated the complexity of the topic significantly higher than G1 on the six-point Likert scale (4.7 ± 0.7 vs. 4.3 ± 0.5, $p = 0.008$).

The results of the knowledge tests before the dissection course did not differ significantly between the groups, neither did the mean confidence levels at correct or wrong answers (Table 2, Fig. 4A). There were also no significant differences in the mean results of image- or text-based questions.

3.3. Results after the dissection course

The main study goal was to test for knowledge and confidence level differences between dissecting (G1) and non-dissecting students (G2) after the dissection course (T2). No statistically significant differences were found between G1 and G2 neither for the results of the complete knowledge test (59.9 % ± 20.1 for G1 vs. 52.6 % ± 15.4 for G2, $p = 0.232$) nor after differentiation of the test in image- or text-based questions (Table 2). For text-based questions, however, G1 tended to achieve better results than G2 (53.3 % ± 19.9 vs. 42.9 % ± 16.7, $p = 0.09$). Furthermore, G1 showed a tendency to a greater improvement of correctly answered image-based questions from T1 to T2 ($p = 0.062$, Table 2). Of note, only participants who took part in both surveys were included for this analysis focusing on the gain in knowledge between T1 and T2. While there were no group differences in the confidence levels for rightly or wrongly answered questions before the dissection course, the dissection course group rated their confidence levels significantly higher ($p = 0.049$) than G2 in the context of rightly answered questions afterwards (Table 2). On the other hand, G1 tended to rate their confidence levels for incorrectly answered questions higher than G2, as well ($p = 0.066$). Analyzing correctly and incorrectly answered questions as a function of the confidence level (based on the six-point Likert scale), G1 was found to rate significantly more often as "100 % confident" (6 on the Likert scale) for rightly answered questions after the dissections course (Fig. 4B).

For the self-assessment after the dissection course (T2) only participants of G1 were asked to rate their knowledge, gain in knowledge, understanding and confidence as well as the promotion

Table 1
Self-assessments regarding interest, motivation, knowledge, confidence in general anatomy and anatomy of head-neck region before the dissection course (T1). Rating from 1 = strongly disagree to 6 = strongly agree, except for two items (scales described at items directly). Self-assessment for both dissection (G1) and non-dissection course (G2) groups. Statistical analyses of group results were performed by Student's t-test or Mann-Whitney Rank Sum test. SD = standard deviation.

Item	Category	G1mean (± SD)	G2 mean (± SD)	P-value
I am very interested in topographic anatomy of the head-neck region.	Interest	4.8 (0.9)	4.6 (1.0)	0.612
Complexity of topic: 1 = way too easy, 6 = way too difficult.	Complexity of topic	4.3 (0.7)	4.7 (0.5)	0.008
I enjoy working on topographic anatomy of the head-neck region.	Intrinsic motivation	4.3 (1.0)	4.3 (0.8)	0.497
I am glad if I do not have to work on topographic anatomy of the head-neck region.	Intrinsic motivation (reversed)	2.7 (1.3)	2.7 (1.3)	0.803
I would like to increase my knowledge of topographic anatomy of the head-neck region.	Promotion of interest	4.9 (1.3)	4.6 (1.3)	0.084
I am well able to understand the spatial anatomy of head and neck.	Knowledge and understanding	3.9 (1.2)	4.3 (0.7)	0.254
I feel confident in identifying anatomical structures at prosections.	Knowledge and understanding	2.5 (1.2)	2.6 (1.3)	1
I feel confident in identifying anatomical structures on sectional images.	Knowledge and understanding	3.0 (1.2)	3.2 (1.0)	0.336
I think that my present knowledge of topographic anatomy of the head-neck region is very good.	Knowledge and understanding	2.6 (1.4)	2.7 (1.4)	0.573

of interest and the intrinsic motivation relating to the dissection course. At T1, the dissection course group (G1) rated their interest and intrinsic motivation regarding topographic anatomy of the head-neck region as 4.8 ± 0.9 and 4.3 ± 1.0 on the six-point Likert scale, whereas the "knowledge and understanding" items were rated below 4 in average (Table 1). Despite the non-significant differences in the examination results between G1 and G2, the participants of G1 rated the items concerning "gain in knowledge" after the dissection course (T2) higher than 5.0 in average (Table 3). The gain in confidence after attending the dissection course was evaluated as 5.0 ± 1.1 on the six-point Likert scale. Furthermore, the dissection course-related intrinsic motivation was assessed as ≥5.4. The general rating of the voluntary dissection course was 5.8 ± 0.6.

3.4. Subgroup analysis of teaching material using frequency and examination results

A subgroup analysis was conducted to address the question, whether the frequency of using online teaching material, especially the online photographic anatomy atlas, affected knowledge test results before the dissection course (T1). It appeared to be possible that students who used the online atlas frequently could do better in the examination, especially at image-based questions. Therefore, the data of all participants at T1 which completed the self-assessment and the knowledge test were sorted for their using frequency of the teaching material. The examination results of participants which used a teaching material less than or one time a week (low frequency group) were compared to those who used a teaching material more than one time a week (high frequency group). This sorting was performed regardless of the status of dissection course participation. A Student's t-test or a Mann-Whitney Rank Sum test were performed, testing for differences in examination results of the groups for each teaching material. The examination results were categorized into "all questions" as well as the question types "image-based" and "text-based".

The analysis showed no significant differences in examination results depending on the using frequency of the online photographic anatomy atlas. Same results occurred for the anatomical demonstrations, sound-recorded lectures and exercise material. However, using the online quiz more often resulted in significantly better

Table 2
Results of multiple-choice knowledge tests, confidence levels and absolute changes of results from T1 (before the educational activity) to T2 (after the educational activity). Examination results of study group participating in dissection course (G1) and non-dissection course group (control, G2). Confidence level scale from 1 = 0 % to 6 = 100 %. For analyses of absolute changes only participants executing both knowledge tests at T1 and T2 were included. This resulted in lower numbers of participants which are displayed in the table. All absolute changes are positive. Statistical analyses of group results at each time point were performed by Student's *t*-test or Mann-Whitney Rank Sum test. n = number, SD = standard deviation.

	Before dissection course (T1)		After dissection course (T2)		P-value	
	G1	**G2**	**G1**	**G2**	**T1**	**T2**
Mean result of all questions [%] (± SD)	37.2 (17.5)	41.6 (19.0)	59.9 (20.1)	52.6 (15.4)	0.417	0.232
Mean result of image-based questions [%] (± SD)	38.3 (21.3)	46.3 (23.5)	66.1 (23.2)	61.7 (18.2)	0.156	0.433
Mean result of text-based questions [%] (± SD)	36.1 (17.3)	36.5 (17.5)	53.3 (19.9)	42.9 (16.7)	0.981	0.09
Mean confidence level at correct answers [1–6] (± SD)	2.92 (1.14)	3.21 (1.03)	4.5 (0.96)	4.05 (0.81)	0.308	0.049
Mean confidence level at wrong answer [1–6] (± SD)	2.35 (0.8)	2.26 (0.67)	3.61 (0.95)	3.13 (0.71)	0.807	0.066
	G1 (n = 53)		**G2** (n = 7)		**P-value**	
Mean absolute change of all correct questions [%] (± SD)	24.7(14.4)		15.3(11.8)		0.105	
Mean absolute change of correct image-based questions [%] (± SD)	30.8(18.2)		17.1(14.8)		0.062	
Mean absolute change of correct text-based questions [%] (± SD)	18.1(19.2)		13.3(11.2)		0.522	

Table 3
Self-assessments regarding interest, motivation, knowledge, confidence in general anatomy, anatomy of head-neck region and dissection course after the dissection course (T2). Rating from 1 = strongly disagree to 6 = strongly agree, except for one items (scales described at items directly). Self-assessment for dissection course group (G1). SD = standard deviation.

Item	Category	G1mean (± SD)
Previous knowledge: 1 = not enough to follow the course, 6 = everything has been known, participation unnecessary.	Knowledge	3.5 (0.8)
I have learned something useful and important by the active dissection during the course.	Gain in knowledge	5.4 (0.8)
I have increased my knowledge of topographic anatomy of the head-neck region through participation in the dissection course.	Gain in knowledge	5.5 (0.9)
The dissection course has increased my interest in this topic.	Promotion of interest	5.1 (0.9)
My functional understanding of the anatomy of the head-neck region has been improved due to the dissection course.	Gain in knowledge and understanding	5.2 (1.0)
My spatial sense of the anatomical structures of the head-neck region has been improved by the dissection course.	Gain in knowledge and understanding	5.4 (0.9)
My confidence regarding knowledge of topographic anatomy of the head-neck region has improved by the active dissection.	Gain in confidence	5.0 (1.1)
The dissection course motivates me to continue to work on the topics of topographic anatomy.	Promotion of interest	4.8 (1.0)
I felt bored during the dissection course.	Promotion of interest (reversed)	1.4 (0.8)
The voluntary dissection course was too demanding.	Demand	2.6 (1.2)
Dissecting without a student tutor was unproductive.	Student tutor	3.1 (1.2)
The time during the voluntary dissection course really dragged.	Intrinsic motivation (reversed)	1.4 (0.8)
I enjoyed being able to actively take part in the voluntary dissection course.	Intrinsic motivation	5.7 (0.6)
For me this way of working on topographic anatomy is very interesting.	Interest	5.5 (0.7)
The dissection course motivates thinking about the topic.	Promotion of interest	5.4 (0.8)
Attending the voluntary dissection course was worthwhile.	General rating	5.8 (0.6)

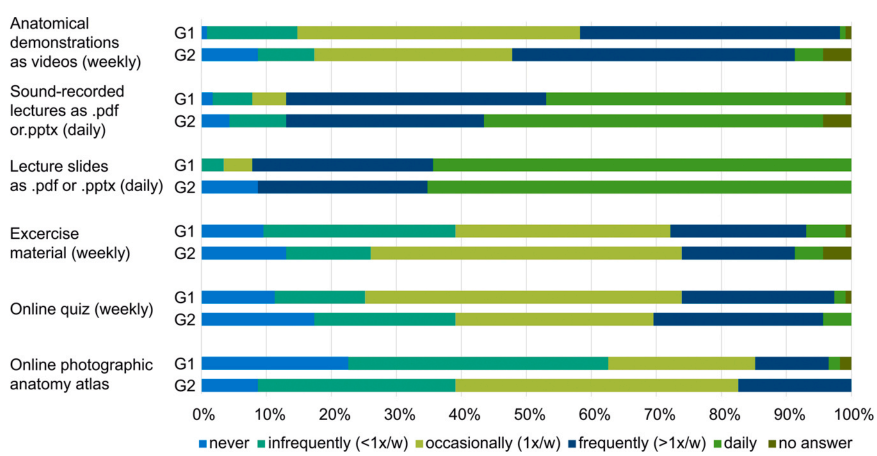

Fig. 3. Use of teaching material. Percentage rates of dissection course (G1) and non-dissection course group (G2) regarding the use of online teaching material. Upload frequency of teaching material is indicated in brackets. w = week.

examination results independent of the question type (Table 4). Furthermore, a better result in text-based questions was detected at a higher using frequency of lecture slides.

3.5. Covid-19 pandemic-related effects on attending voluntary dissection course

The study was conducted in June 2020 when Covid-19 was known for nearly half a year. However, the situation with a nation-wide lockdown in Germany due to the pandemic lasted for less than three months. In order to evaluate possible concerns regarding the effects of Covid-19 on first-year medical students and their attendance at the voluntary dissection course, the surveys consisted of five pandemic-related questions each. There were significant differences between the two study groups in four of the five items (Fig. 5). At both time points, the non-dissection course group (G2) had a significant higher mean rating than G1 regarding the concerns about infecting themselves while dissecting ($p < 0.001$ at T1, $p = 0.002$ at T2) and infecting others ($p < 0.02$ at T1, $p < 0.001$ at T2) with Covid-19. Furthermore, participants of G2 would have rather stayed at home than attending face-to-face teaching than those of G1 ($p < 0.001$ at T1, $p < 0.001$ at T2) and stated higher concentration problems while attending a dissection course in this situation ($p < 0.001$ at T1, $p = 0.004$ at T2). No significant group differences

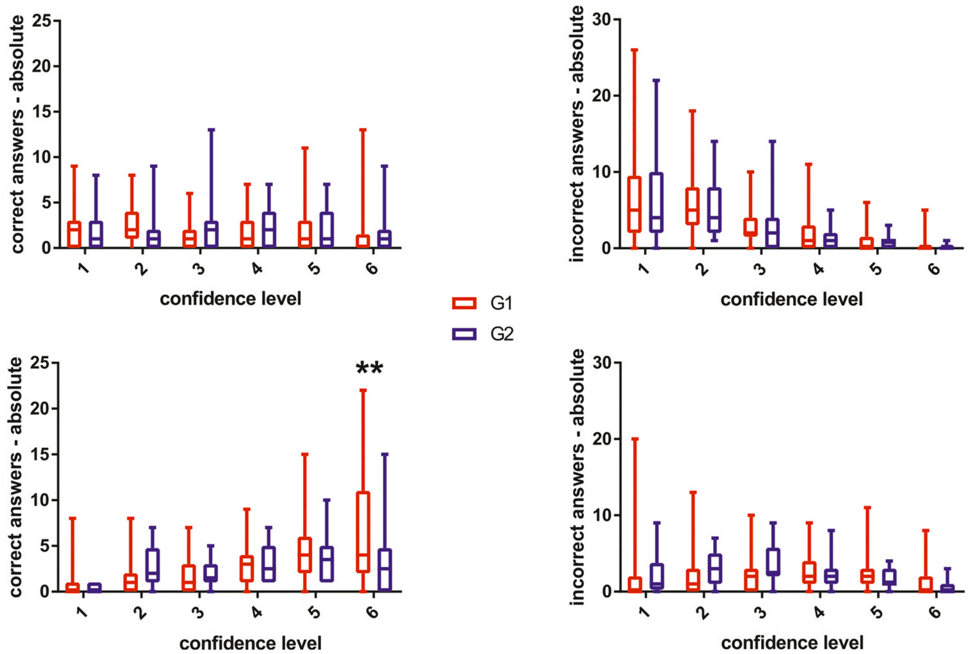

Fig. 4. Confidence levels of correct and incorrect answers at time point 1 (T1: upper row) and time point 2 (T2: lower row) for the dissection course (G1) and non-dissection course group (G2). The survey at T1 was conducted before the voluntary dissection course, whereas the survey at T2 was conducted afterwards. Confidence level ranged from 1 = 0 % to 6 = 100 %.**p < 0.01 between G1 and G2. Statistical analysis was performed by a two-way ANOVA.

were detected for the item regarding concerns of disadvantages in their studies due to Covid-19 at both time points (p = 0.533 at T1, p = 0.781 at T2).

4. Discussion

The Covid-19 pandemic had considerable effects on the anatomical science education in universities around the world for two years after its beginning. Face-to-face teaching was replaced by or at least reduced in favor of distance teaching (Ross et al., 2020; Darici et al., 2021). In many universities in Germany the number of students allowed to be present in the dissection lab at the same time was minimized in order to comply with the hygiene and confidence measures. As a consequence, the time per student for active cadaver dissection was reduced. This reduced dissection time in the lab was complemented by e-learning resources such as streaming videos of demonstration of anatomical structures (Böckers et al., 2021).

In summer term 2020, the active cadaver dissection at Hannover Medical School was completely skipped from March to the end of June. Instead, the students could watch videos in which the teachers demonstrated already dissected anatomical preparations of the head and neck region. When the shutdown regulations were eased, in view of the approaching final examination in anatomy, it was decided to offer the students a brief and intensive active dissection course of the head-neck region on a voluntary basis for a total duration of 6 h. This was a quite unique situation since during the weeks before this voluntary dissection course the students could prepare the content of the curriculum very intensively using a

Table 4

Subgroup analysis of using frequency of different teaching material and knowledge test results. Matched results of knowledge test and of Likert scale-based rating of teaching material using frequency. All data of participants with completed self-assessments and knowledge examination (G1 and G2) at T1 were included and sorted by using frequency (≤ 1x/week vs. > 1x/week). Statistical analyses of subgroup results for each teaching material were performed by Student's t-test or Mann-Whitney Rank Sum test. SD = standard deviation, w = week.

Teaching material	Exam results of all questions		Exam results of image-based questions		Exam results of text-based questio	
Using frequency	≤ 1x/w	> 1x/w	≤1x/w	> 1x/w	≤1x/w	> 1x/w
Anatomical demonstrations [%] (± SD)	36.3 (18.7)	40.8 (16.0)	37. 5 (22.1)	43.0 (21.3)	35.1 (18.4)	38.4 (14.9)
P-value	0.131		0.163		0.259	
Sound-recorded lectures [%] (± SD)	37.6 (17.5)	38.3 (17.6)	42.2 (21.0)	39.7 (21.7)	32.7 (16.8)	36.8 (17.2)
P-value	0.819		0.667		0.380	
Lecture slides [%] (± SD)	28.8 (12.8)	39.0 (17.9)	32.7 (16.7)	40.4 (22.2)	24.7 (12.9)	37.4 (17.2)
P-value	0.091		0.510		0.015	
Exercise material [%] (± SD)	37.0 (18.1)	41.8 (16.1)	38.8 (22.5)	42.6 (19.7)	35.0 (17.1)	40.9 (16.4)
P-value	0.204		0.357		0.130	
Online quiz [%] (± SD)	35.6 (17.7)	45.6 (15.9)	37.1 (22.4)	47.4 (18.5)	34.0 (16.9)	43.6 (15.8)
P-value	0.005		0.009		0.009	
Online photographic atlas [%] (± SD)	37.2 (16.9)	44.4 (21.4)	38.9 (20.5)	45.8 (28.8)	35.5 (16.7)	42.9 (18.3)
P-value	0.234		0.435		0.119	

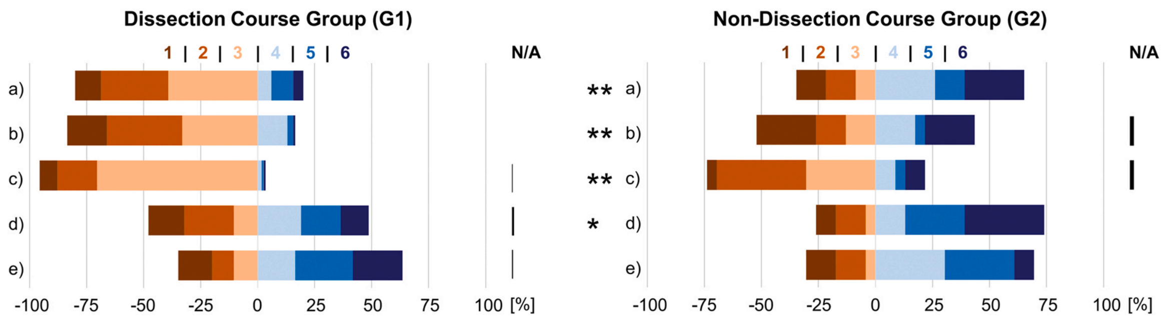

Fig. 5. Covid-19 pandemic-related self-assessment before dissection course (T1). Same significance levels for every item at T2 (detailed results not shown in this figure). Items: a)I would rather stay at home due to the Covid-19 pandemic, even if hygiene standards were fulfilled during active participation. b)I am worried about getting infected with SARS-CoV2 during the dissection course. c)I could not focus on the dissection course due to concerns about Covid-19. d)I am worried about infecting others (e.g., relatives) with SARS-CoV2. e)I am worried that my studies will be negatively affected by the Covid-19 pandemic. The survey at time point 1 (T1) was conducted before the voluntary dissection course (baseline), whereas the survey at time point 2 (T2) was conducted afterwards. Likert scale range from 1 = strongly disagree to 6 = strongly agree.*p < 0.05 or **p < 0.01 between G1 and G2. Statistical analyses were performed by Student's t-test or Mann-Whitney Rank Sum test.

diversity of teaching methods except for active corpse dissection. While before the Covid-19 pandemic the active cadaver dissection represented the mainstay in teaching gross anatomy at Hannover Medical School, it was in the summer term 2020 a complementary offer only. Under these circumstances it was the aim of this study to investigate the added value of a brief and intensive active cadaver dissection lesson in small groups of two students with respect to subjective and objective gain of knowledge of the anatomy of the head-neck region. The authors were not able to design a randomized, controlled study for ethical reasons since this voluntary active cadaver dissection course was offered during the period of exam preparation. A cross-over design was not feasible due to shortage of time with the advance of the exam. In general, the offer was well accepted by the students and approximately 75 % of first year medical students attended. The remaining 25 % were offered to participate in the survey including also the knowledge test and served therefore as a control group. The quite high proportion of volunteers indicates that active cadaver dissection is the preferred way to learn gross anatomy by medical students, an observation which has been reported by many investigators around the world (Cuschieri and Calleja Agius, 2020; Franchi, 2020; Wolniczak et al., 2020; Cheng et al., 2021; Zibis et al., 2021). Of note, those students who did not volunteer for participating in the active dissection course were characterized by a higher degree of anxiety since their agreement with the statement that they preferred to stay at home or were afraid to be infected with SARS-CoV-2 was much higher compared to the dissection course group (Fig. 5). Otherwise, there were hardly any differences in the evaluation regarding the interest for the topic, the intrinsic motivation and subjectively perceived prior knowledge and understanding of the anatomy of the head-neck region (Table 1). Hence it appears to be very likely that the increased level of anxiety was the main reason why students did not opt for participation in the dissection activity. In this context it is not astonishing that several studies have revealed a quite high degree of anxiety among medical students linked with the Covid-19 pandemic before (Cuschieri and Calleja Agius, 2020). Furthermore, it is of note that the concern regarding infecting themselves during the dissection course were constant for the dissection course group before and after the dissection course (2.3 on the six-point Likert scale at T1 and T2). This underlines the reasoned implementation of a hygiene concept in the dissection course and during a pandemic on a subjective level.

Although it was not a randomized study, there were no differences in prior knowledge between the students entering the educational intervention and those representing the control group based on self-assessment (Table 1) and the objective knowledge test (Table 2). After the dissection activity, however, no differences in the scores of knowledge tests could be observed, neither for the text-based nor for the image-based questions (Table 2). Both groups improved their knowledge with time. It has to be pointed out that all students were in preparation for the written examination which took place one week after the second survey. So, there was a high degree of extrinsic motivation in both groups to deal with the content of the curriculum and this might have diluted the effect of the educational intervention in the present study. Moreover, the control group was challenged with the questions of the knowledge test as well and this might have triggered a more specific learning. The use of quizzes for self-assessment has been demonstrated to improve performance in summative evaluations in several studies (Kibble, 2007; Kibble et al., 2011). In the context of anatomical science education, challenging students over time repetitively with slightly changed questions resulted in a progressive increase in the score (Logan et al., 2011). Hence, the gain in knowledge in the active cadaver dissection group of the present study can also in part be explained by the repetitive, study-related surveys. In line with this reasoning is the observation that independent from the study group the frequency of participating in voluntary quizzes during the course of the summer term before entering our study had a significant effect on the scores in the knowledge tests: frequent participation in the online quizzes was associated with better results (Table 4). This finding reproduces in part previous studies in anatomical and physiological science education (Kibble, 2007; Logan et al., 2011; McNulty et al., 2015).

In general, under the given circumstances our study took place, it is also very likely that a ceiling effect plays a role, since medical students are a group of high performers in which the educational effort of six hours hands-on dissection course might have had only a small impact. This phenomenon has been described before in studies investigation the effect of e.g., problem-based learning (Albanese, 2000; Winkelmann, 2007). Comparing the results between our study groups after the educational intervention shows a slightly higher score in the dissection group and formal calculation of Cohen´s effect size D can at best be considered to be small (0.39). Provided that there is an effect on knowledge gain attributable to active cadaver dissection, the statistical power to detect that effect was in the range of 31 % in our study.

However, comparing the results before and after the educational intervention of those students who took part in both knowledge tests showed that the mean individual improvement with respect to the image-based questions was tendentially higher in the dissection course group and this difference appears to be of relevance (30.8 % vs. 17.1%, Table 2). The images for these questions were taken from the online atlas to which the students had access during the whole term. In the dissection group the students had to actively search for those anatomical structures (muscles, vessels, nerves) which were demonstrated in the videos and not only the auditory/verbal and visual channel was addressed but also the tactile system. In addition, students could link new information obtained during active dissections with their prior knowledge they had acquired by utilizing the e-learning resources including anatomical demonstrations and they had the opportunity to investigate variations of anatomical structures (Ross et al., 2020). In other words, students in the dissection group were confronted with different "versions" of the topographic regions of interest. Hence, the larger improvement with regard to the image-based questions after hand-on cadaver dissection can be linked with diverse aspects associated with active cadaver dissection. One of these aspects is the repetitive confrontation with different specimens (e.g., anatomical demonstration videos and specimens in the dissection lab) and this can be considered as a kind of training, which distinguishes an experienced from a less-experienced expert (Norman et al., 2007; Sibbald et al., 2017; Knudsen et al., 2018). Moreover, in our study, the scores of the image-based questions were in general better than those of the text-based questions. Similar observations have been described by others before and explained by the cognitive theory of multimedia learning: words in conjunction with images facilitate processing of information in the working memory and images facilitate knowledge retrieval (Sagoo et al., 2021).

Each question of the knowledge test was combined with an additional question for rating of the self-confidence the students perceived when choosing a distractor. At baseline there were no significant differences in the rating of confidence between the study groups (Fig. 4). With learning progress for the approaching exam and after repetitive challenge of students with the knowledge test questions both study groups gained self-confidence. However, after the educational intervention the confidence rating was in general significantly higher and significantly more correctly answered questions were rated with the highest degree of confidence in the dissection course group while this was not the case for incorrectly answered questions (Fig. 4). Hence, it can be concluded that active cadaver dissection results in a higher degree of confidence for real anatomical knowledge and understanding. These observations are in line with previous studies reporting a subjective loss of confidence in anatomy of first year medical students linked with the cancellation of active cadaver dissection (Singal et al., 2021). In our study a higher degree of self-confidence suggests a deeper knowledge and understanding of anatomy as a consequence of active cadaver dissection, and it might be linked with a higher sustainability and longer half-live of anatomical knowledge. A high sustainability of anatomical knowledge combined with high self-confidence has been observed in prior studies where medical imaging was used as an authentic approach to learn anatomy in the context of image-based questions (de Barros et al., 2001; Knudsen et al., 2018). Unfortunately, in the present study it was not possible to organize a follow-up evaluation to investigate whether the higher self-confidence immediately after the active cadaver dissection was associated with a higher half-life of anatomical knowledge.

5. Limitations

This study was integrated into the regular curriculum so that the study design represents a compromise with inherent limitations. There was no randomization of students into the two study groups. Instead, those not volunteering the additional activity in the dissection lab represented the control group. Hence, the comparability of the study groups can not entirely be taken for granted. We found significant differences in the Covid-19 related anxiety level, and also the perception of the complexity of the anatomy of the head-neck region (Table 1). Nevertheless, there was no difference in the prior knowledge, confidence in answering the knowledge test questions, interest in and motivation for the topic so that we think that the primary read-out parameter, the knowledge test scores after the educational intervention, is meaningful and useful for comparison between the study groups. Due to the fact that the hands-on dissection activity was well accepted by the students, the control group was much smaller, and this was linked with a quite low statistical power of the study to detect between group differences provided that these exist. In addition, a selection bias cannot be excluded. Among those joining the dissection course approximately 2/3 participated in the study-related surveys while among those who did not join the dissection activity only 1/3 of students did so. These differences in the willingness to attend the surveys might be due to differences in the motivation in these two cohorts of students. On the other hand, it might also be possible that those students who did not opt for taking part in dissection course did not expect any added value, e.g., because they felt already very confident concerning their knowledge in anatomy of the head-neck region. Due to the voluntary character of the study, we were unfortunately not able to characterize the cohort of non-participants in more detail to understand the underlying reasons for refusing attendance of the additional learning activity. In this regard it was also not possible to compare the results in the final official exam between participants and non-participants as data acquisition was anonymous. Nonetheless, with a high participation quota in the dissection course (74.7 % of all first-year students) it can be assumed that the course was perceived as a beneficial educational intervention. This is supported by the subjectively perceived high gain in knowledge as a consequence of the course in the group G1 (Table 3). In addition, since participation of students in the surveys was completely voluntary there was a quite high fraction of drop-outs within the study and the individual surveys. Regarding the two study groups, the fraction of drop-outs within a survey was comparable and in the range of 15–17 %. Moreover, the proportion of students only participating in the survey after (T2) but not before (T1) the educational intervention was comparable between the study groups (13.9 % in G1 vs. 16.9 % in G2) so that a bias in the data at T2 due to between groups differences in the exposure to the questions at T1 appear to be unlikely. Due to the fact that we used an online-based survey to measure students´ knowledge which was accessible for several days for all students who gave informed consent, there is a risk of content leakage. Hence, it cannot be excluded that students shared the questions and answers with each other e.g., via social media or looked-up the correct answers during the completion of the surveys. In an attempt to mitigate this, the authors informed the students about the protocol as well as the objectives of the study. Also, students were instructed to answer the questions without any assistance and they were asked not to share the questions with others. An on-site knowledge test would have been the optimal scenario to avoid any kind of exchange among the students or the use of other learning resources by the students during answering the questions. However, in the context of the present study we expected that for the control group in particular, the threshold to come to the university for an on-site knowledge test would have been very high thereby reducing the number of participants and increasing the number of drop-out. Therefore, we decided to offer a low-threshold way of testing the knowledge for the purpose of the present study.

6. Conclusion

After a period of self-directed learning using a diversity of e-learning resources, a brief and intensive cadaver dissection course of the head-neck region in groups of two students did not result in better scores in the knowledge test compared to a control group. Nevertheless, there was a trend for a notable improvement of the gain in knowledge with regard to image-based questions, a finding which should motivate further and sufficiently powered studies.

Although the knowledge test scores in the dissection group were not higher compared to the control group, students had a higher degree of self-confidence when answering knowledge questions correctly after the active cadaver dissection. This finding gives reason to speculate that the active cadaver dissection results in consolidation and therefore a longer half-live of anatomical knowledge, a hypothesis which should also be tested in randomized, controlled studies in the future. In the literature there is a very controversial debate of the future of the active cadaver dissection course after the Covid-19 pandemic (Ross et al., 2020). In this context, the authors think that the provided data are of relevance for organizing future anatomical curricula, also, in view of the fact that many universities in Germany started reimplementation of the dissection courses in winter term 2020/2021 and summer term 2021 (Tschernig et al., 2022). In multi-modal anatomical curricula using a diversity of e-learning resources such as quizzes, anatomical demonstrations, computational 3D models and medical imaging an intensive dissection activity is effective in consolidating anatomical knowledge. Such blended-learning approaches are more and more commonly used in anatomical education with promising results (Yoo et al., 2021). Based on our data it might be reasonable and justifiable to offer brief and more intensive sessions of active cadaver dissection in very small groups (e.g., n = 2–3) more often instead of longer sessions of larger groups. Such curricular adjustment should be complemented by appropriate e-learning resources.

Ethical Statement

The study (including its study protocol) entitled “Makroskopische Anatomie mit und ohne Präparierkurs während Corona-bedingter Einschränkungen” has been reviewed and approved by the institutional ethic committee of Hannover Medical School in 2020 prior to the conductance of the study. The approval number is 9120_BO_K_2020.

CRediT authorship contribution statement

Henri Schulte: Conceptualization, Data curation, Formal analysis, Methodology, Software, Visualization, Writing – original draft. **Andreas Schmiedl:** Conceptualization, Project administration, Resources, Writing – review & editing. **Christian Mühlfeld:** Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Resources, Supervision, Writing – review & editing. **Lars Knudsen:** Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Software, Supervision, Visualization, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.aanat.2022.151986.

References

Albanese, M., 2000. Problem-based learning: why curricula are likely to show little effect on knowledge and clinical skills. Med. Educ. 34, 729–738.
Arráez-Aybar, L.A., Sánchez-Montesinos, I., Mirapeix, R.M., Mompeo-Corredera, B., Sañudo-Tejero, J.R., 2010. Relevance of human anatomy in daily clinical practice. Ann. Anat. 192, 341–348.
Attardi, S.M., Choi, S., Barnett, J., Rogers, K.A., 2016. Mixed methods student evaluation of an online systemic human anatomy course with laboratory. Anat. Sci. Educ. 9, 272–285.
de Barros, N., Rodrigues, C.J., Rodrigues Jr., A.J., de Negri Germano, M.A., Cerri, G.G., 2001. The value of teaching sectional anatomy to improve CT scan interpretation. Clin. Anat. 14, 36–41.
Böckers, A., Claassen, H., Haastert-Talini, K., Westermann, J., 2021. Teaching anatomy under COVID-19 conditions at German universities: recommendations of the teaching commission of the anatomical society. Ann. Anat. 234, 151669.
Boeckers, A., Boeckers, T.M., 2016. The dissection course - a psychological burden or an opportunity to teach core medical competencies: a narrative review of the literature. Eur. J. Anat. 20 (4), 287–298.
Brassett, C., Cosker, T., Davies, D.C., Dockery, P., Gillingwater, T.H., Lee, T.C., Milz, S., Parson, S.H., Quondamatteo, F., Wilkinson, T., 2020. COVID-19 and anatomy: stimulus and initial response. J. Anat. 237, 393–403.
Bülthoff, H.H., Edelman, S.Y., Tarr, M.J., 1995. How are three-dimensional objects represented in the brain? Cereb. Cortex 5, 247–260.
Cheng, X., Chan, L.K., Pan, S.Q., Cai, H., Li, Y.Q., Yang, X., 2021. Gross anatomy education in China during the Covid-19 Pandemic: a national survey. Anat. Sci. Educ. 14, 8–18.
Chytas, D., Piagkou, M., Salmas, M., Johnson, E.O., 2020. Three-dimensional digital technologies in anatomy education: better than traditional methods, but are they better than cadaveric dissection? Clin. Anat. 33 (1), 25–33.
Cuschieri, S., Calleja, Agius, J., 2020. Spotlight on the shift to remote anatomical teaching during Covid-19 pandemic: perspectives and experiences from the University of Malta. Anat. Sci. Educ. 13, 671–679.
Darici, D., Reissner, C., Brockhaus, J., Missler, M., 2021. Implementation of a fully digital histology course in the anatomical teaching curriculum during COVID-19 pandemic. Ann. Anat. 236, 151718.
Estai, M., Bunt, S., 2016. Best teaching practices in anatomy education: a critical review. Ann. Anat. 208, 151–157.
Franchi, T., 2020. The impact of the Covid-19 pandemic on current anatomy education and future careers: a student's perspective. Anat. Sci. Educ. 13, 312–315.
Garg, A.X., Norman, G., Sperotable, L., 2001. How medical students learn spatial anatomy. Lancet 357, 363–364.
Ghosh, S.K., 2017. Cadaveric dissection as an educational tool for anatomical sciences in the 21st century. Anat. Sci. Educ. 10, 286–299.
Kibble, J., 2007. Use of unsupervised online quizzes as formative assessment in a medical physiology course: effects of incentives on student participation and performance. Adv. Physiol. Educ. 31, 253–260.
Kibble, J.D., Johnson, T.R., Khalil, M.K., Nelson, L.D., Riggs, G.H., Borrero, J.L., Payer, A.F., 2011. Insights gained from the analysis of performance and participation in online formative assessment. Teach. Learn Med. 23, 125–129.
Knudsen, L., Nawrotzki, R., Schmiedl, A., Mühlfeld, C., Kruschinski, C., Ochs, M., 2018. Hands-on or no hands-on training in ultrasound imaging: a randomized trial to evaluate learning outcomes and speed of recall of topographic anatomy. Anat. Sci. Educ. 11 (6), 575–591.
Koop, C, Marschollek, M, Schmiedl, A, Proskynitopoulos, P, Behrends, M, 2021. Does an audiovisual dissection manual improve medical students' learning in the gross anatomy dissection course? Anat. Sci. Educ. 14 (5), 615–628.
Kumar Ghosh, S., Kumar, A., 2019. Building professionalism in human dissection room as a component of hidden curriculum delivery: a systematic review of good practices. Anat. Sci. Educ. 12, 210–221.
Lemos, G.A., Araújo, D.N., de Lima, F.J.C., Bispo, R.F.M., 2021. Human anatomy education and management of anatomic specimens during and after COVID-19 pandemic: ethical, legal and biosafety aspects. Ann. Anat. 233, 151608.
Lewis, T.L., Burnett, B., Tunstall, R.G., Abrahams, P.H., 2014. Complementing anatomy education using three-dimensional anatomy mobile software applications on tablet computers. Clin. Anat. 27, 313–320.
Li, L., Zuo, Y., 2020. A hands-on organ-slicing activity to teach the cross-sectional anatomy. Anat. Sci. Educ. 13, 732–742.
Logan, J.M., Thompson, A.J., Marshak, D.W., 2011. Testing to enhance retention in human anatomy. Anat. Sci. Educ. 4, 243–248.
Louw, G., Eizenberg, N., Carmichael, S.W., 2009. The place of anatomy in medical education: AMEE Guide no 41. Med. Teach. 31, 373–386.
McNulty, J.A., Espiritu, B.R., Hoyt, A.E., Ensminger, D.C., Chandrasekhar, A.J., 2015. Associations between formative practice quizzes and summative examination outcomes in a medical anatomy course. Anat. Sci. Educ. 8, 37–44.
Möltner, A, Schellberg, D, Jünger, J, 2006. Basic quantitative analyses of medical examination. GMS Z. Med. Ausbild., 23:Doc53.
Norman, G., Young, M., Brooks, L., 2007. Non-analytical models of clinical reasoning: the role of experience. Med. Educ. 41, 1140–1145.
Older, J., 2004. Anatomy: a must for teaching the next generation. Surgeon 2, 79–90.
Patel, K.M., Moxham, B.J., 2008. The relationship between learning outcomes and methods of teaching anatomy as percieved by professional anatomists. Clin. Anat. 21 (2), 182–189.
Rochford, K., 1985. Spatial learning disabilities and underachievement among university anatomy students. Med. Educ. 19, 13–26.
Rose, S., 2020. Medical student education in the time of COVID-19. JAMA 323, 2131–2132.

Ross, C.F., Pescitelli, M.J., Smith, H.F., Williams, J.M., 2020. Teaching anatomy with dissection in the time of COVID-19 is essential and possible. Clin. Anat. 34 (8), 1135–1136.
Sagoo, M.G., Vorstenbosch, M.A.T.M., Bazira, P.J., Ellis, H., Kambouri, M., Owen, C., 2021. Online assessment of applied anatomy knowledge: the effect of images on medical students' performance. Anat. Sci. Educ. 14 (3), 342–351.
Sibbald, M., Sherbino, J., Preyra, I., Coffin-Simpson, T., Norman, G., Monteiro, S., 2017. Eyeballing: the use of visual appearance to diagnose 'sick'. Med. Educ. 51, 1138–1145.
Singal, A., Bansal, A., Chaudhary, P., Singh, H., Patra, A., 2021. Anatomy education of medical and dental students during COVID-19 pandemic: a reality check. Surg. Radio. Anat. 43, 515–521.
Taylor, L., Dyer, T., Al-Azzawi, M., Smith, C., Nzeako, O., Shah, Z., 2022. Extended reality anatomy undergraduate teaching: a literature review on an alternative method of learning. Ann. Anat. 239, 151817.
Tschernig, T., Bechmann, I., Meier, C., Paulsen, F., Waschke, J., Westermann, J., Bräuer, L., 2022. Anatomy in times of pandemia - impact on teaching and body donations. Ann. Anat. 239, 151792.
Turney, B.W., 2007. Anatomy in a modern medical curriculum. Ann. R. Coll. Surg. Engl. 89, 104–107.
Vorstenbosch, M.A., Kooloos, J.G., Bolhuis, S.M., Laan, R.F., 2016. An investigation of anatomical competence in junior medical doctors. Anat. Sci. Educ. 9, 8–17.
Winkelmann, A., 2007. Anatomical dissection as a teaching method in medical school: a review of the evidence. Med. Educ. 41, 15–22.
Winkelmann, A., Hendrix, S., Kiessling, C., 2007. What do students actually do during a dissection course? First steps towards understanding a complex learning experience. Acad. Med. 82, 989–995.
Wolniczak, E., Roskoden, T., Rothkötter, H.J., Storsberg, S.D., 2020. Course of macroscopic anatomy in Magdeburg under pandemic conditions. GMS J. Med. Educ. 37, 65.
Yoo, H, Kim, D, Lee, YM, Rhyu, IJ, 2021. Adaptations in anatomy education during COVID-19. J. Korean. Med. Sci. 36 (1), e13.
Zibis, A., Mitrousias, V., Varitimidis, S., Raoulis, V., Fyllos, A., Arvanitis, D., 2021. Musculoskeletal anatomy: evaluation and comparison of common teaching and learning modalities. Sci. Rep. 11, 1517.