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Effectiveness of Anatomage Virtual Dissection as a Teaching Tool in Neuroanatomy for Physiotherapy Students

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ABSTRACT
Background & Objectives*: Comprehensive anatomical knowledge and understanding are fundamental aspects of physiotherapy education and practice. The utilization of innovative tools such as Anatomage has been demonstrated to be highly effective for anatomical study. The purpose of the study was to assess the effectiveness of Anatomage virtual dissection as a teaching tool in comparison to traditional dissection in Neuroanatomy for 3rd year Physiotherapy Students*
Methods*: Quasi experimental study design, in this study, there were 100 subjects who are 3rd year physiotherapy students and were divided into two groups randomly. The subjects in Group A (n = 50) were taught using virtual dissection table and Group B (n = 50) were taught using traditional cadaveric method. Teaching sessions were taken to participants 3 days a week for 6 weeks.*
Results*: Independent t' test was used to compare the mean significance difference between continuous variables. Paired 't' test was used to assess the statistical difference between pre and post test scores of Anatomage dissection table. Statistical analysis of this data revealed that, both groups significantly improved in understanding of neuroanatomy when compared within groups, but when compared between groups, the Anatomage virtual dissection table group improved better than the conventional cadaveric method group.*
Conclusion*: The findings of this study indicate that both the Anatomage virtual dissection table group and the cadaveric dissection group exhibited significant improvements in understanding and knowledge attention related to Neuroanatomy. Nevertheless, it was observed that the group instructed through Anatomage virtual dissection tables demonstrated greater effectiveness compared to the conventional cadaveric method group. This underscores the importance of integrating Anatomage virtual dissection teaching into the Anatomy curriculum as a valuable supplement in addition to traditional cadaveric dissection.*
Keywords*: Neuroanatomy, Virtual Dissection Table, Anatomage, Cadaver.*

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I. INTRODUCTION

Knowledge of anatomy is essential for physiotherapy clinical diagnosis, treatment effectiveness and safe practice[1].Anatomical knowledge and understanding are key components of physiotherapy education and practice. Physiotherapy education spans four years, with anatomy being a fundamental component taught in the

first year of university[2]. Physiotherapists recognize the critical importance of a comprehensive understanding of anatomy for ensuring safe and effective clinical treatment practices [3].

Anatomy is foundational in healthcare education, essential for healthcare professionals to excel in their fields. In disciplines like physiotherapy, students develop a deep understanding of human anatomy through practical experiences, including extensive peer examinations and exposure to living anatomy throughout their program [4].

Currently, the physiotherapist is present in several specialties, which requires a more accurate knowledge of human anatomy, as it is essential for professional qualification[3]. Targeted anatomy education for physiotherapy students can aid learning and retention of anatomical knowledge necessary for effective and safe clinical practice [5].

Neuroanatomy defines as the science that studies the macroscopic and microscopic structures of the Nervous System, which is composed by the Central Nervous System and the Peripheral Nervous System [6]. Neuroanatomy stands as one of the most difficult subjects for students. One reason is the complexity of the study contents related to the CNS and PNS, which include the pathways involved in each neurophysiological process [7]. The other reason is the shortage of anatomical tools, including neuroanatomy models, handbooks or software at universities. For these two reasons it is imperative that teachers pre-explain or provide instructions to students along with the study material[8].

An exhaustive study of neuroanatomy and neurophysiology, as well as the most prevalent neurological disorders, their clinical manifestations and their therapeutical management is essential for the correct training of students as future physiotherapists[9].

From time immemorial, cadaveric dissection has been commonly employed as a method of practical teaching and learning for anatomical education globally. Conventionally, cadaveric dissection has been embraced and widely accepted as the best fit for comprehensive and gross teaching in anatomy education, thus placing an undue rise in cadavers' demands[10].

The study of anatomy through the dissected cadaver is viewed as the uniquely defining feature of medical courses, which involves exposure and description of internal body organs and structures. It consists of dismembering the body of a deceased human to study the anatomical structure and it is typically conducted in an anatomy lab[11].

In cadaveric dissection, the learner plays the central role of the teaching process and to view structures in their natural location. Cadaveric dissection is however perceived as tedious and time consuming by most students which influence their perception and attitude towards the teaching method [12]. Nevertheless, as dissection alone cannot provide uniform learning experience hence needs to be complemented with other innovative learning methods in the future education model of anatomy [13].

In the midst of a potential paradigm shift facilitated by new insights and technologies, tools like Anatomage have been developed, offering an additional dimension to anatomy teaching[14]. It is crucial to provide Physiotherapy students access to such tools for enhanced learning of neuroanatomy [15]. Overcoming barriers of social and educational isolation is imperative, and the integration of new technologies for studying anatomical content is key to surmounting these challenges [16,17].

Most medical and health science schools adopt innovative tools to implement the teaching of anatomy to their undergraduate students. The increase in technological resources for educational purposes allows the use of virtual systems in the field of medicine, which can be considered decisive for improving anatomical knowledge, a requisite for safe and competent medical practice. Among these virtual tools, the Anatomage virtual dissection table represents, to date, a pivotal anatomical device for student education and training medical professionals [18].

Introduced in the fall of 2015, the Anatomage Table is a cutting-edge teaching technology that uses a state-of-the-art method to represent the human body's structures. The Anatomage Table is equipped with life-sized interactive images that are taken from actual human cadavers and transformed into 3D images that can be rotated 360 degrees, increased or decreased in size, and cut in multiple sections and planes [19].

Anatomage table is a technologically advanced anatomy visualization system for anatomy education and it is being adopted by many of the world's leading medical schools and institutions[20]. Anatomage combines stereoscopic images of the whole body with software in order to build a 3-D reconstruction of the different human body parts (taken initially from two cadavers: male and female) that allows for virtual dissection and reconstruction. This computerized body-size table features a 7 by 2.5-foot screen and combines the technology of CT scan, X-Ray, ultrasound and MRI to reconstruct the human body [21].

The use of virtual dissection technology seems to have a promising role in future educational training[21]. The Anatomage table is an anatomical visualization system that projects male and female gross anatomical structures from human cadavers onto a life-sized touchscreen table [22], it is used for digital dissection, prosection, functional anatomy demonstration, virtual simulation of certain functions, and interactive digital teaching aid [23]. This innovative dissection method enables to practice dissections over and over again to be effective anatomy learning tool than any other techniques[24].

The anatomy education literature suggests blended-learning approaches as more effective. The advancements of technologies have developed anatomical education into a new era[25]. The teaching of Neuroanatomy is an integral part of the curriculum as anatomy is one of the key building blocks necessary to effectively evaluate and treat patients [26]. Traditionally, neuroanatomy is taught through a series of classroom lectures followed by examination of prosected specimens of brain and spinal cord in the dissection hall[27].

The study endeavours to evaluate the performance of physiotherapy students as they engage with both traditional cadaveric specimens and the innovative Anatomage table to grasp the complexities of Neuroanatomy[28]. Neuroanatomy stands as a cornerstone in the education of physiotherapy students, shaping their understanding and practice in the field[29]. Traditionally, this subject has been taught through cadaveric methods, but the emergence of technologies like Anatomage has heralded a transformative shift[30]. The research aims to explore how this transition from traditional to technological methods impacts students' comprehension and learning outcomes [31].

II. MATERIALS AND METHODS

Study Design: Quasi Experimental Study design.

Ethical Clearance and Informed Consent: The study protocol was approved by the Ethical Committee of GSL Medical College & General Hospital (Annexure-I), the investigator explained the purpose of the study and given the student information sheet. The participants were requested to provide their consent to participate in the study (Annexure-II). All the participants signed the informed consent and the rights of the included participants have been secured.

Study Population: Subjects of 3rd year bachelors of physiotherapy pursuing students were included.

Study Setting: The study was conducted at GSL Smart Lab and GSL Anatomy Dissection Hall, Rajamahendravaram, Andhra Pradesh, India.

Study Duration: Study was conducted for a period of one year.

Teaching Duration: 6 weeks, 6 hours for each group (3 hours of lecture followed by 3 hours of practical) for 3 days in a week.

Study Sampling Method: Convenience Sampling

Sample Size: All the hundred 3rd Year physiotherapy are included in the study. All recruited students are briefed about the study's purpose and significance. Following informed consent and meeting criteria, 100 subjects were evenly divided into two groups: 50 in the teaching by Virtual Dissection group and 50 in the Cadaveric Dissection teaching group.

GROUP A: Exposed to Anatomage Virtual Dissection teaching (n = 50).

GROUP B: Exposed to Cadaveric dissection teaching (n = 50).

GROUP	NO. OF SUBJECTS	TEACHING TOOL
GROUP – A	50	ANATOMAGE DISSECTION TABLE
GROUP – B	50	CADAVER

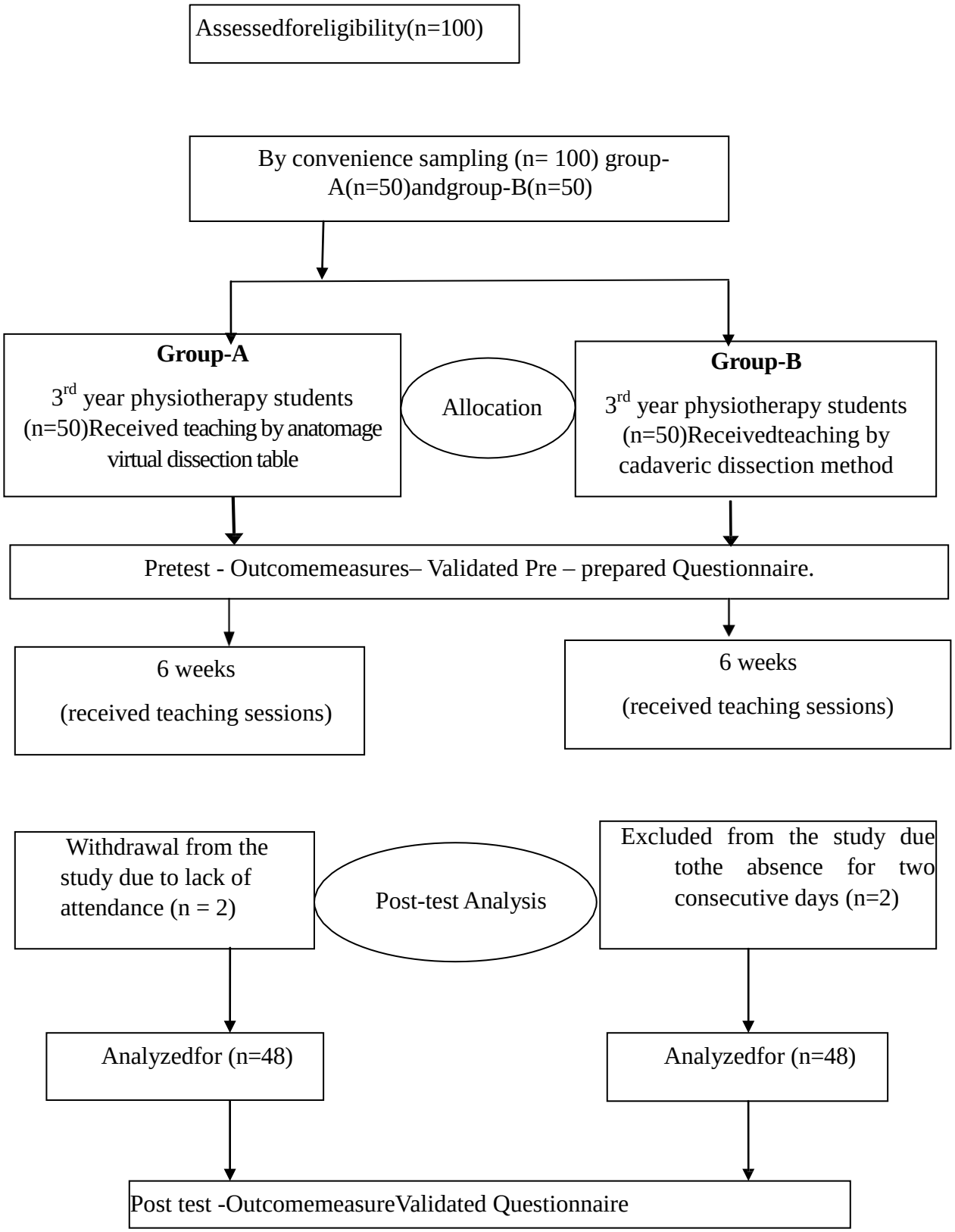
III. MATERIALS USED

Anatomage Virtual Dissection Table: This innovative technology provides students with a realistic, interactive platform to explore neuroanatomy digitally. The table allows for detailed visualization and manipulation of anatomical structures, facilitating active learning and engagement.

Cadaver: Traditional cadaveric dissection remains indispensable in anatomical education, offering students a hands-on experience with real human anatomy. It provides a tactile understanding of spatial relationships and structural variations not easily replicated in virtual environments.

Examination Forms – Questionnaire: Customized examination forms and questionnaires were designed to assess students' perceptions, confidence levels, and comprehension following exposure to both virtual and cadaveric dissection methods. This quantitative and qualitative data collection aims to evaluate the effectiveness and student preferences.

FLOW CHART


Assessedforeligibility(n=100)
By convenience sampling (n= 100) group-A(n=50)andgroup-B(n=50)
Group-A
3rd year physiotherapy students (n=50)Received teaching by anatomage virtual dissection table
Allocation
Group-B
3rd year physiotherapy students (n=50)Receivedteaching by cadaveric dissection method
Pretest - Outcomemeasures– Validated Pre – prepared Questionnaire.
6 weeks
(received teaching sessions)
6 weeks
(received teaching sessions)
Withdrawal from the study due to lack of attendance (n = 2)
Post-test Analysis
Excluded from the study due tothe absence for two consecutive days (n=2)
Analyzedfor (n=48)
Analyzedfor (n=48)
Post test -OutcomemeasureValidated Questionnaire

IV. PROCEDURE

Following approval from the Institutional Ethics Committee (IEC) and obtaining consent from the participating students, the study was conducted. The topics of the study centered on the anatomy of cerebrum, cerebellum, brainstem, venous drainage and blood supply of the brain as the topics of learning, selected from the syllabus for 3rd year bachelors of physiotherapy as per the university guidelines.

The selection process for participants in the study involved several steps to ensure the enrollment of eligible third-year physiotherapy students. Next the 100 selected students are divided into two groups using convenience sampling, resulting in two groups of 50 subjects each. Group A, designated to undergo teaching sessions utilizing the Anatomage virtual dissection table and Group B to undergo sessions on cadaveric specimens.

The Questionnaire administered in this study comprised 20 multiple-choice questions (MCQs) of single correct answer type. These MCQs are carefully selected and validated to ensure their reliability and accuracy in assessing the participants' understanding of the material. Prior to their use in the study, all questions underwent a rigorous validation process for construct validity.

The validation process involved the assessment of each question by four faculty members from the Department of Anatomy. These experts thoroughly reviewed the questions to ensure that they accurately measured the intended learning outcomes and are appropriate for assessing the participants knowledge of the topics under study. Additionally, the experts scrutinized the clarity, relevance, and appropriateness of each question to ensure that they were free from ambiguity or bias.

Furthermore, the experts evaluated the alignment of each question with the learning objectives and content covered in the instructional materials. By employing a comprehensive validation process involving multiple experts, the study ensured the reliability and validity of the pre and post-test instruments. This approach helped to enhance the credibility and robustness of the study findings by ensuring that the assessment tools accurately measured the participants knowledge levels before and after the intervention.

GROUP A

TEACHING ON ANATOMAGE VIRTUAL DISSECTION TABLE

FIG 3: DEMONSTRATION OF THE FEATURES OF ANATOMAGE VIRTUAL DISSECTION TABLE

Before the commencement of the study, a demonstration showcasing the utility and features of the Anatomage virtual dissection table was provided to familiarize the students with the technology. Through its innovative features, Anatomage empowers students to explore anatomy with precision and clarity, bridging the gap between theoretical knowledge and practical application in healthcare education. Additionally, a pre-test was administered to assess the baseline understanding of neuroanatomy among the students in Group A.

FIG 4: TEACHING ON ANATOMAGE VIRTUAL DISSECTION TABLE

The curriculum for Group A consisted of teaching topics related to the anatomy of the cerebrum, cerebellum, brainstem, and venous and blood supply of the brain. These topics were allocated a total of 18 hours of lecture time, followed by practical sessions facilitated by subject experts. Each lecture session lasted for one hour, and the students attended three sessions per week on alternate days. Subsequently, an hour-long practical session followed each lecture, allowing students to apply theoretical knowledge in a hands-on manner.

S No	Name of the topic	No. of Lecture hours	No. of Practical hours
1	Cerebrum	3hrs.	3hrs.
2	Cerebellum	3hrs.	3hrs.
3	Midbrain	2hrs.	2hrs.
4	Pons	2hrs.	2hrs.
5	Medulla Oblongata	2hrs.	2hrs.
6	Venous drainage of the brain	2hrs.	2hrs.
7	Blood supply of the brain	4hrs.	4hrs.

TABLE 1: SYLLABUS OF NEUROANATOMY (18Hrs)

FIG 5: TEACHING SSESSION ONANATOMAGE VIRTUAL DISSECTION TABLE

The lecture sessions were conducted by a subject expert with 10 years of experience in teaching neuroanatomy to medical professionals. Upon the completion of all 18 lectures and practical sessions, a post-test was administered to Group A using the same questionnaire utilized in the pre-test.

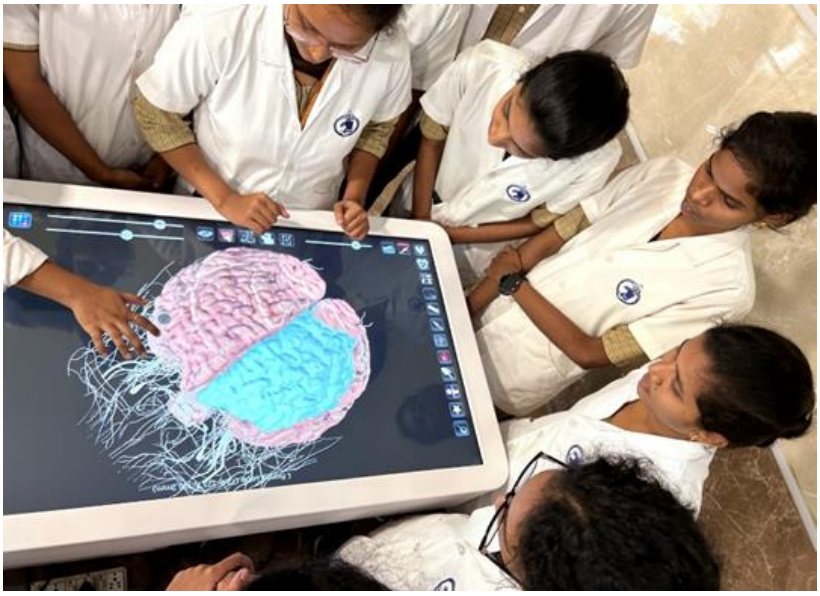


FIG 6: STUDENTS PRACTICING ON ANATOMAGE

GROUP B
CADAVERIC DISSECTION TEACHING

Before the study, Group B received a briefing session, pre-test, and a demonstration of the cadaveric specimens is done. The briefing on cadaveric specimens encompassed safety protocols crucial for their handling, emphasizing adherence to stringent safety parameters. Students were instructed on proper techniques for holding and maneuvering the specimens to minimize risks of injury or contamination. Emphasis was placed on maintaining a sterile environment and utilizing appropriate personal protective equipment throughout the

dissection process. Clear instructions were provided regarding the handling of sharp instruments and disposal of biological materials to ensure the safety of both students and faculty. By prioritizing safety measures, students were equipped with the necessary skills to conduct cadaveric dissections effectively and responsibly in anatomy education.

FIG 7: DEMONSTRATION ON CADAVERIC SPECIMENS

The curriculum for Group B included topics such as cerebrum, cerebellum, brainstem, venous drainage, and blood supply of the brain, totaling 18 hours of lecture and practical sessions. Lectures were conducted three times a week, followed by practical sessions. Sessions were led by a subject expert with 10 years of teaching experience. After completing all sessions, Group B underwent a post-test comprising 20 validated multiple-choice questions.

FIG 8: TEACHING SESSION ON CADAVERIC SPECIMENS

FIG 9:PRACTICAL SESSION ON CADAVERIC SPECIMENS

To address ethical concerns, a crossover in teaching methods is implemented, with Group B instructed using Anatomage virtual dissection, while Group A is taught through the traditional cadaveric approach, ensuring equitable exposure to both methodologies.

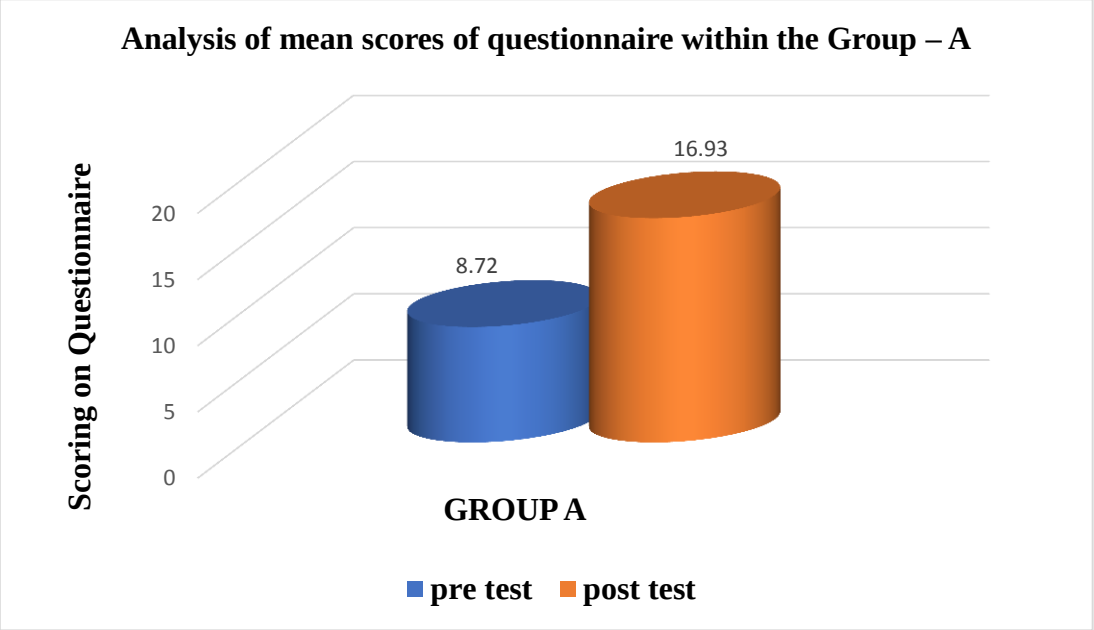
V. RESULTS

- The performance of the students was assessed using the questionnaire of multiple-choice questions for a total of 20 marks.
- Both the groups were assessed prior to the study by conducting a pre-test.
- Post-test was conducted for both the groups immediately after the study to assess the students understanding.
- A total of 100 students were assessed for the study and out of which each group was assigned with 50 each, all the students were made to take the pretest. After excluding two students from Group A for attendance deficiencies and two from Group B due to consecutive absences, a post-test was administered to 48 participants from each group (Groups A and B) to assess the effectiveness of the teaching interventions.

Analysis of mean scores of Questionnaires within the Group – A

Groups		Mean	Standard Deviation	P-value	Inference
Group – A	Questionnaire Pretest	8.72	2.13	0.001	Highly Significant
	Questionnaire Post test	16.93	1.19		

TABLE -2



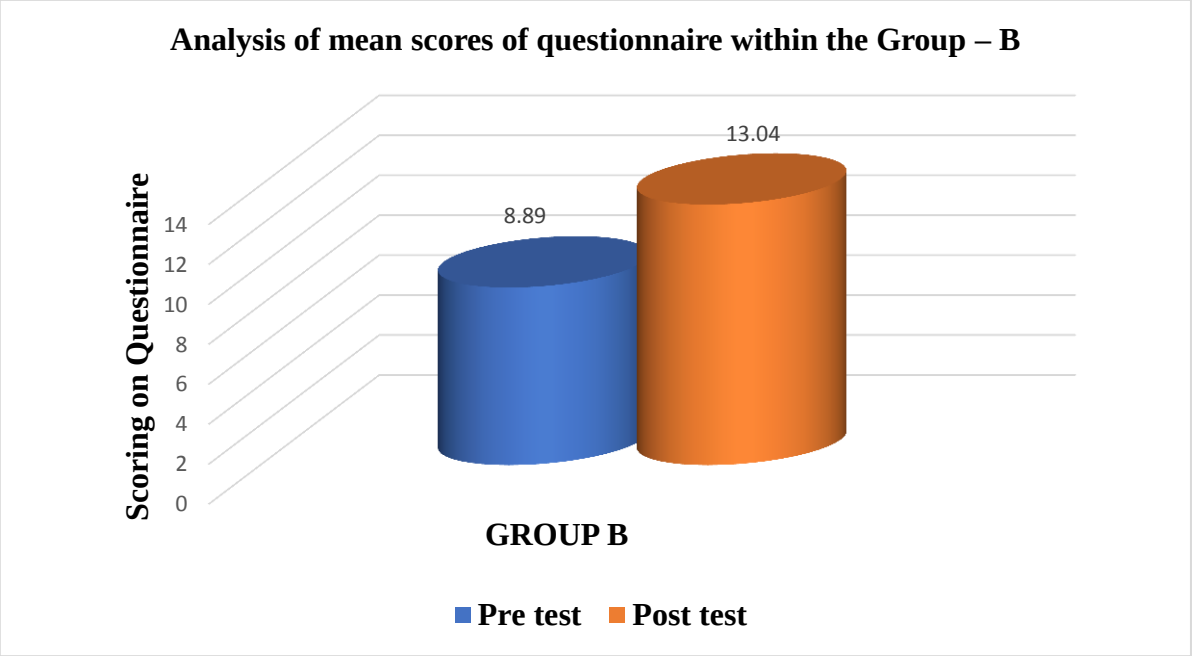
GRAPH – 1

RESULTS: The above table and graph depict the mean scores of questionnaires within the Group – A were found to be statistically significant ($P < 0.005$).

Analysis of mean scores of Questionnaires within the Group – B

Groups		Mean	Standard Deviation	P-value	Inference
Group – B	Questionnaire Pretest	8.89	2.47	0.001	Highly Significant
	Questionnaire Post test	13.04	2.29		

TABLE – 3



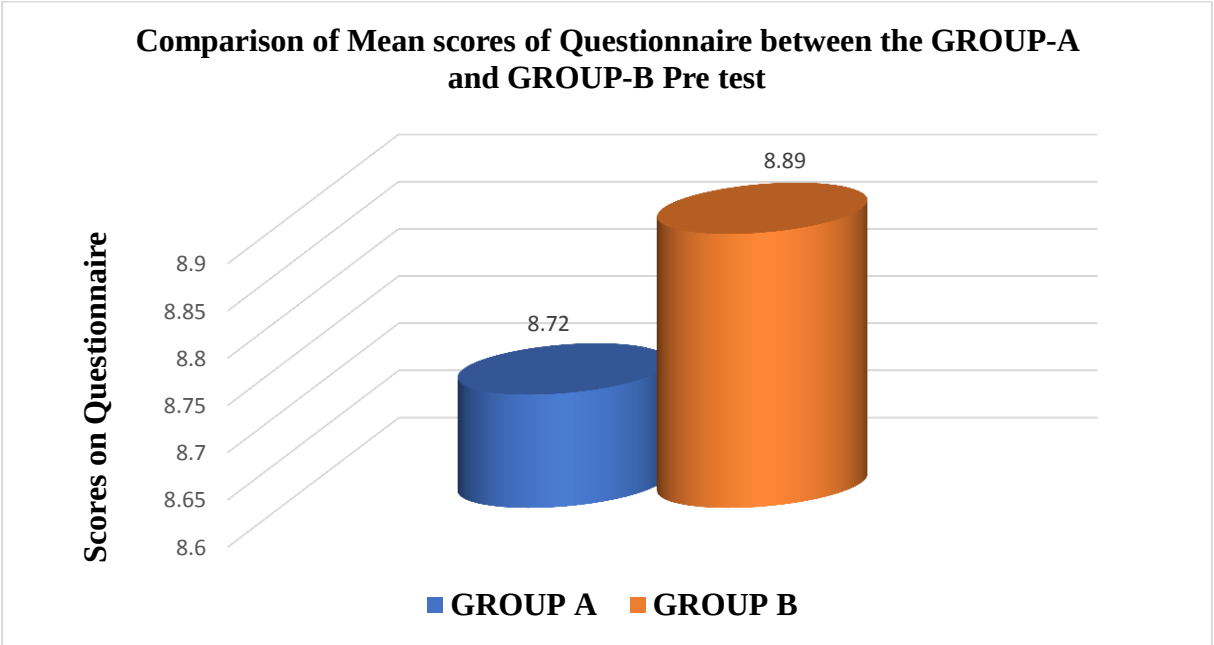
GRAPH - 2

RESULTS: The above table and graph depict the mean scores of questionnaires within the Group – B were found to be statistically significant (P < 0.005).

Comparison of mean scores of Questionnaires between the groups
Group A & B (Pre-Test)

Groups		Mean	Standard Deviation	P-value	Inference
QUESTIONNAIRE Pre-Test	Group - A	8.72	2.13	0.7246	Insignificant
	Group - B	8.89	2.47		

TABLE – 4



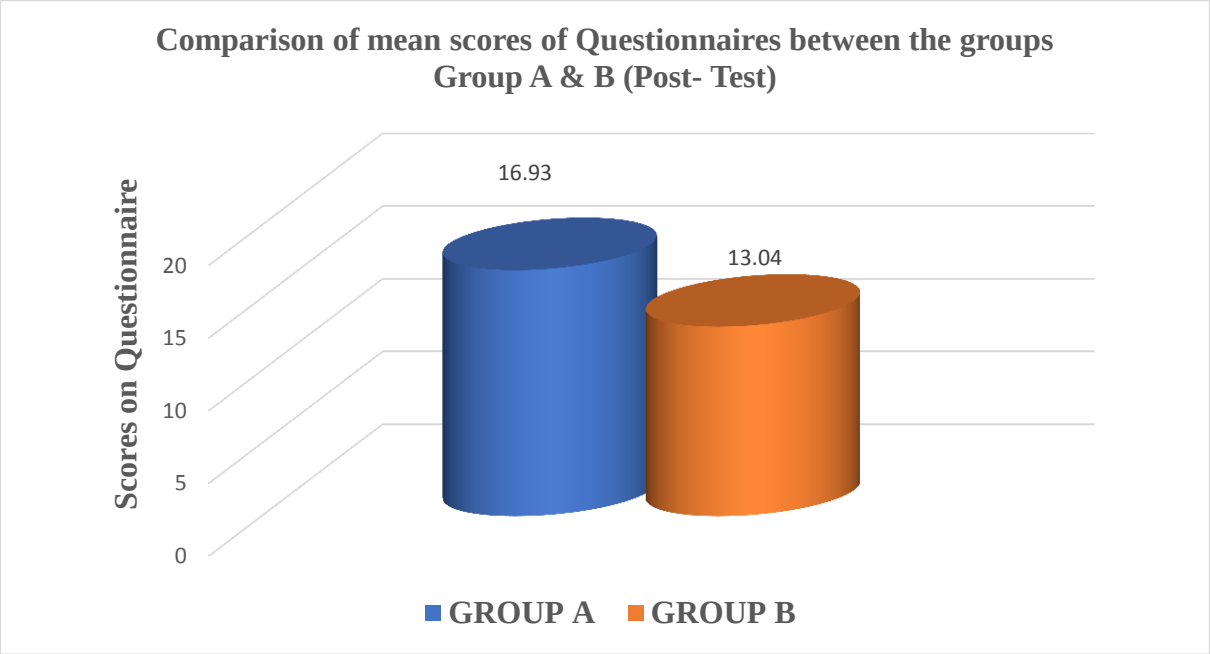
GRAPH - 3

RESULTS: The above table and graph depict the baseline measurement of scores on Questionnaire in Group–A(8.72)and Group–B (8.89)were found to be statistically insignificant.

Comparison of mean scores of Questionnaires between the groups
Group A & B (Post-Test)

Groups		Mean	Standard Deviation	P-value	Inference
QUESTIONNAIRE Post-Test	Group - A	16.93	1.19	0.0001	Highly Significant
	Group - B	13.04	2.29		

TABLE – 5



GRAPH – 4

RESULTS: The above table and graph depict the baseline measurement of scores on Questionnaire in Group – A (16.93) and Group – B (13.04) were found to be statistically significant

VI. DISCUSSION

The study aimed to evaluate the efficacy of Anatomage as an instructional aid for neuroanatomy among third-year physiotherapy students. The findings revealed that Group A, who underwent instruction via the virtual dissection table, demonstrated significantly better performance in the post-test evaluation compared to Group B. This outcome underscores the potential effectiveness of virtual dissection as a pedagogical tool for facilitating enhanced learning outcomes in the field of neuroanatomy among physiotherapy students. In Group-A there is statistically a more significant improvement in understanding (P=0.001).

Advancements in technology (AT) have revolutionized the way anatomical structures are visualized and dissected. This transformation is particularly evident in the realm of Anatomage virtual dissection. Notably, the integration of interactive elements, such as the blood flow tool, which allows the students to simulate physiological processes, gaining a deeper understanding of how anatomical components function within the body and animated depictions of anatomical structures and processes which offer a level of detail and clarity that is often difficult to achieve through static diagrams or cadaveric dissections has significantly enhanced the educational experience withing Group A. These visualizations can highlight complex relationships and spatial orientations, aiding students in conceptualizing anatomical structures more effectively. Unlike traditional classroom teaching methods, these features empower students to engage in independent learning and self-assessment of their understanding of anatomy.

Importantly, the inclusion of interactive features in virtual dissection platforms promotes active learning. Students are encouraged to manipulate virtual anatomical models, identify structures, and observe how they interact with each other. This hands-on approach fosters critical thinking and problem-solving skills, essential for healthcare professionals. Additionally, virtual dissection offers flexibility in learning, as students can access educational materials remotely and at their own pace. This flexibility accommodates diverse learning styles and schedules, making it easier for students to engage with the material and reinforce their understanding of anatomy.

In brief, virtual dissection, enriched with interactive features, represents a significant advancement in anatomical education. By providing a dynamic and engaging learning experience, it empowers students to independently explore and understand complex anatomical structures and processes, ultimately enhancing their proficiency in anatomy and preparing them for careers in healthcare.

Studies by Boscolo-Berto et al.,[34] Alasmari et al.,[35] Baratz et al.,[36] and Narnaware YR, Neumeier M. et al.,[37] collectively underscore the profound impact of incorporating virtual dissection technology, particularly Anatomage, into anatomical education. Boscolo-Berto et al. found that students integrating virtual dissection were over three times more likely to succeed in post-gross-dissection tests compared to peers relying solely on textbooks. Alasmari et al. noted the significant preference among students for supplementing cadaveric dissection with the Anatomage tool, citing its substantial benefits in enhancing the learning process. Baratz et al.'s observations revealed superior performance among Anatomage users in musculoskeletal quizzes, indicating the efficacy of virtual dissection for short-term information retention. Moreover, Narnaware YR, Neumeier M. et al. demonstrated marked improvements in class averages across multiple examinations with virtual dissection integration. Collectively, these studies highlight the tangible advantages of incorporating virtual dissection technology like Anatomage into anatomy education, suggesting its potential to revolutionize learning outcomes and enhance student performance in the field.

Group A Students are granted the capability to zoom in and out, manipulate, and observe anatomical structures from various perspectives, enabling them to discern the intricate relationships and connections between them. This functionality allows for the rotation, enlargement, and reduction of organs and minute structures from numerous angles and planes. Additionally, virtual dissection facilitates the ability for learners to section the body in any desired direction and seamlessly merge views of structures across different spatial planes: sagittal and parasagittal, coronal, and transverse. Moreover, users have the flexibility to select specific body parts—such as muscles, nerves, vessels, ligaments, or bones — and examine them from multiple 3D perspectives, with the option to rectify any errors made during virtual dissection or revert to previous views of the structure. Furthermore, the images are color-coded and resilient to damage caused by inexperienced dissection, mitigating issues commonly associated with improper preparation and handling of cadavers.

Consequently, the integration of Anatomage virtual dissection table (AVDT) fosters both independent and collaborative learning, nurturing students' knowledge and skill development. Moreover, the utilization of AVDT imposes no limitations or prerequisites, as it eliminates exposure to sharp objects or accidental injuries—a common concern in traditional cadaver dissection. Unlike traditional methods, virtual dissection via AVDT does not necessitate the use of embalming agents or specialized facilities to accommodate anatomical tables.

In contrast, traditional cadaver dissection often entails exposure to noxious chemical odors and discomfort stemming from embalming solutions like formalin. Importantly, AVDT eliminates the emotional attachment typically associated with cadaveric models, as it presents learners with inert objects within a virtual realm, distinct from authentic human cadavers. This aspect offers a distinct advantage over traditional methods, where emotional engagement with physical corpses may pose challenges to some learners.

While Anatomage has demonstrated numerous advantages as a supplementary educational tool, it cannot fully supplant cadaveric dissection due to the intricacies of anatomy instruction. Nevertheless, Anatomage offers a forward-thinking approach to anatomy education, harnessing technological advancements to enhance learning outcomes. Its integration with traditional medical training methods, including cadaveric dissection, amplifies the efficacy of virtual dissection instruction. Anatomage thus assumes a critical role in future education programs, serving as an indispensable resource for adequately preparing future healthcare professionals. By combining the benefits of virtual dissection with established teaching methods, Anatomage contributes to a comprehensive and innovative approach to anatomical education, ensuring that students receive the necessary training to excel in their respective fields of healthcare practice.

VII. CONCLUSION

In this study, though the Anatomage table proves to be an effective tool for teaching neuroanatomy, it cannot entirely replace the traditional cadaveric method. Instead, it serves as a valuable supplementary resource, augmenting the learning experience when used in conjunction with cadaveric dissection. The Anatomage table offers unique advantages, such as interactive visualization and manipulation of anatomical structures, which enhance students' understanding of neuroanatomy. However, the tactile experience and depth of learning provided by cadaveric dissection remain unparalleled. Therefore, integrating the Anatomage table alongside cadaveric dissection can enrich students' learning by offering diverse perspectives and reinforcing concepts. This combination allows students to benefit from the strengths of both methods, maximizing their comprehension and retention of neuroanatomical knowledge. Thus, while the Anatomage table holds significant promise in modern anatomical education, its role as a supplementary tool alongside cadaveric dissection is essential for providing students with a comprehensive and well-rounded learning experience in neuroanatomy.

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