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Impact of 3D Virtual Reality on Teaching and Learning Human Anatomy Among Undergraduate Students

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Author`s Contribution

[1]Provided concept/research design, data collection, responsibility and is accountable
[2,3]Edit of manuscript, critical revision of the manuscript for important intellectual content
[4,5]statistical analysis and manuscript writing

Funding Source: None
Conflict of Interest: None

Received: Feb 04, 2024
Accepted: June 07, 2024

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ABSTRACT

Objective: To assess how impact 3D-VR is in improving the retention of human anatomy knowledge among undergraduate students compared to traditional methods.

Methodology: This convergence mixed method study was carried out in anatomy department of HBS Medical and Dental College, Islamabad, from February to December 2023. The study was evaluated learning outcomes, specifically knowledge retention score in short-term and long-term, in undergraduate students by 3D-VR vs traditional models. Additionally, it sought to capture experience of students and perspectives by 3D-VR teaching and learning method.

Results: The post-test score (indicative of short-term knowledge retention) by 3D-VR in both groups of male and female was significant high than traditional method ($p \leq 0.001$). 3D-VR also achieved significant high follow-up score (indicative of long-term knowledge retention) in both groups compared to traditional method. While the knowledge score in all tests of 3D-VR and traditional method for females was high than males. Post-test score (indicative of short-term knowledge retention) and follow-up score (indicative of long-term knowledge retention) in 3D-VR method of females was significant high than males ($p \leq 0.001$).

Conclusion: 3D-VR is effective method for knowledge retention in short-term and long-term in undergraduate students. Undergraduate students demonstrated 3D-VR as a learning method that offers substantial advantages for studying human anatomy versus traditional method.

Keywords: Anatomy education, Curriculum, Three-Dimensional.

Cite this article as: Jawed S, Zia MS, Iqbal TA, Muzafar S, Imran S. Impact of 3D Virtual Reality on Teaching and Learning Human Anatomy Among Undergraduate Students. Ann Pak Inst Med Sci. 2024; 20(3):222-226. doi. 10.48036/apims.v20i3.1072.

Introduction

Inadequate knowledge retention is a significant factor contributing to undergraduate medical student attrition and a major concern in education. Advocates have promoted the use of teaching and learning methods such as three-dimensional virtual reality (3D-VR) in medical education to improve student learning results. There is a noticeable decline in medical students' retention of human anatomy knowledge, highlighting the need for evaluation and review.[1] Inadequate retention of knowledge in human anatomy is believed to be a contributing factor to this issue, posing a significant concern in education.[2] The implementation of updated curriculum in medical and allied health institutions has opened avenues for enhanced student gaining knowledge in human anatomy. This improvement is facilitated by integrating technology into teaching, particularly through computer-generated simulations.[3] As a result, the use of three-dimension virtual reality (3D-VR) in medical education is advocated to enhance student learning.

The development of 3D models is enabled the orientation of various anatomical structure and simplified challenging task in learning and teaching method, in contrast to traditional method.[4] These developments have decreased

the required teaching and laboratory hours for human anatomy. Consequently, students have more time for individual study, leading to a deeper understanding and mastery of human anatomy.[5]

The challenges faced by medical students during classroom and practical lessons, where they rely on 2D images from reference materials to visualize 3D nature of anatomical features, can impact their retention of knowledge and understanding of the functions of these structures.[6] For instance, student may fail to identify the caudate lobe of the liver as structure is shifted to various positions. Therefore, 3D-VR enables students to manipulate structures in various positions, enhancing their comprehension of anatomical concepts.[7]

The ability to visualize and mentally manipulate 3D structures is crucial in medicine for accurately identifying anatomical structures.[8] While 3D tools offer benefits for student knowledge and learning gain, several studies have shown no difference in students gaining knowledge of human anatomy when comparing dissection, latest 3D learning methods, and 2D traditional methods.[9] Nonetheless, research conducted at various colleges in Pakistan has indicated that 3D-VR is an effective teaching methodology for enhancing students' retention of human anatomy knowledge.[10]

The study objective to assess how impact 3D-VR is in improving the retention of human anatomy knowledge among undergraduate students compared to traditional methods.

Methodology

This convergence mixed method study was carried out in anatomy department of HBS Medical and Dental College, Islamabad, from February to December 2023. Human anatomy, plastic models were used as control group intervention, while human anatomy, 3D-VR models installed on iPads were used for experimental group. Retention of knowledge impact of these methods on short-term and long-term on students was evaluated. Afterward, focus group discussion was held to gather experience and perspective of undergraduate students on 3D-VR as learning and teaching method for human anatomy. The students included 250 first- and second-year MBBS and first-year BDS in the clerkship rotation. The students' sample for the two groups (male and female), which was of unequal size, were calculated. WHO sample size calculator was used with the following parameters: a 95% confidence interval, 80% test power, and 5% alpha error. Pakistan Medical and Dental Council (PM&DC) allocated a batch of 100 MBBS and 50 BDS students to HBS. The 80 male undergraduate students were split into experimental and control groups (each group, n=40). 170 female undergraduate students were also split into experimental and control groups (each group, n=85).

The study intervention as the following; bones, ligaments, and joints models of plastic (total 10 models of different human anatomy) were used as teaching method for control group, while experimental group used human anatomy on a 3D-VR software platform installed on iPads. Before the intervention, a senior anatomist delivered two hours lecture to experimental and control groups. Pre-test and post-test were administered to two groups to evaluate the short-term knowledge retention of students. The follow-up test was administered to assess the long-term knowledge retention of students after one month.

The OSPE comprised of 10 slides. There were two questions on each slide, making 20 questions of total. The total duration of OSPE was 20 minutes. All questions underwent validation by three professors of anatomy to ensure the validity of text. The focus group discussion, involving 100 students split into 10 groups, were conducted by a professor of anatomy. These students volunteered to participate from experimental group. The group discussion, focusing on personal experience of students and views regarding 3D-VR utilization as learning and teaching method, were recorded and transliterated precisely.

The quantitative data was coded and analyzed by SPSS v 25. Descriptive analysis, including mean ± SD, were applied as pre-test, post-test, and follow-up score. Paired t test was conducted to ascertain whether there existed a discrepancy between pre-test and post-test score, thereby assessing students' retention knowledge in short-term. Paired t test was utilized to evaluate whether there existed a discrepancy between post-test and follow-up score, thereby assessing the long-term knowledge retention of students. Additionally, independent t test was utilized to compare the score of experimental and control groups. The p-value ≤ 0.05 was considered to be significant. Thematic analysis was conducted on qualitative data collected from focus group discussion regarding personal experience and views of students on 3D-VR as learning and teaching method. Themes and subthemes were recognized, and text was defined.

Results

In this study, 250 students of first- and second-year MBBS and first-year BDS were included. The female-to-male ratio was 1:2.1, with females comprising 68% (n=170) and males 32% (n=80) of the sample. In all statistical tests, knowledge score of male and female both groups utilizing 3D-VR was high compared to those traditional method (Table I). Upon additional analysis, post-test score (indicative of retention knowledge short-term) of male and female groups utilizing 3D-VR was significant high from traditional method ($p \leq 0.001$) (Table I). The male and female both groups utilizing 3D-VR also achieved significant high follow-up score (indicative of retention knowledge long-term) compared to those traditional method (Table 1). While the knowledge score in all tests of 3D-VR and traditional method for females was high than males (Table II). Post-test score (indicative of retention knowledge short-term) and follow-up score (indicative of retention knowledge long-term) in 3D-VR method of females was significant high than males (Table II).

Table I: Compare the knowledge score between 3D-VR and traditional in male & female group

Test	3D-VR group (n=40)	Traditional group (n=40)	p-value
	Mean ± SD	Mean ± SD	
Male Students			
Pre test	6.3±1.8	5.7±1.4	.091
Post test	7.1±1.6	5.5±1.5	.001
Follow up	7.5±1.6	6.1±1.9	.001
Female Students			
Pre test	6.3±1.6	.088	.088
Post test	7.1±2.0	.001	.001
Follow up	7.5±1.9	.001	.001

Table II: Compare the knowledge score between male and female group using traditional method and 3D-VR.

Test	Female group (n=85)	Male group (n=40)	p-value
	Mean ± SD	Mean ± SD	
Traditional method			
Pre test	6.4±1.6	6.3±1.9	.754
Post test	7.4±2.0	7.1±1.6	.514
Follow up	7.7±1.9	7.5±1.6	.737
Utilizing 3D-VR			
Pre test	6.3±1.6	6.3±1.9	1.00
Post test	8.4±2.0	7.1±1.6	.001
Follow up	8.3±1.9	7.3±1.6	.001

Thematic analysis was conducted, themes arose from focus group discussion regarding the utilization of 3D-VR as a method for learning and teaching human anatomy in undergraduate students. The focus group discussions on 3D-VR revealed the following themes: the features of 3D-VR assist the learning process, information of 3D-VR is highly accessible and available, 3D-VR offers a realistic experience of learning that enhances engagement between students and teachers, 3D-VR can complement traditional cadaver models as learning method, 3D-VR has its limitations, and the use of 3D-VR poses health risks (Table III).

Table III: Thematic analysis of 3D-VR method.

Codes	Themes	Sub-themes
Learning	Features of 3D-VR assist the learning process	- Presentation and display - Purpose and usage - Information source
Information	Highly available and accessible	- No time and usage limitation - Speed up - Access from anywhere
Teacher-student engagement	Realistic learning experience	- Comprehensive functional representation of an organ
Complement usage of 3D-VR	Traditional cadaver model learning method	- Combining direct interaction with cadavers and utilization 3D-VR could enhance understanding and retention.
Limitations	Challenges encountered when using the application	- Battery storage
Health risk	Eye strain, eye pain, headache	Application affected concentration

Students explained that using 3D-VR enabled enhanced visual anatomy parts and related structure, resulting in improved understanding. Students explained how software of 3D-VR was intended to allow them to view the anatomy parts and related structure from any angle they chosen. 3D-VR provides a comprehensive organ view and related structure from multiple angles, and to achieve a more focused examination on organ through observation from various anatomy planes, such as anterior and posterior.

Discussion

Recently, a variety of teaching methods are established to enhance the teaching efficiency in human anatomy, including 3D-VR learning, computer-aids, applications of mobile devices, and web-based technology.[11] These methods are achieved significant results in teaching human anatomy.[12] Among the innovative teaching methods, 3D-

VR is latest, and its precise utilization in retention knowledge is not fully assessed in students.

Currently, 3D-VR is utilized in medical education to illustrate and demonstrate structure of human body as virtually.[13] It increases retention knowledge as included multisensory learning, which enhances engagement of students compared to traditional models including cadavers or plastic models.[14] The qualitative findings of study demonstrate that the use of 3D-VR engagement between students and teachers. While many students reported positive experience with 3D-VR learning in human anatomy, some believed that traditional cadaver models alongside 3D-VR would result in a more effective learning and teaching process. The effect of 3D-VR as learning and teaching method was noted in females. Using 3D-VR resulted in high score of knowledge of short-term and long-term compared to those traditional method.

This study also found a significant association between 3D-VR and retention knowledge of short-term or long-term in females. More studies are suggested to revalidate and compare the effects of 3D-VR over longer intervals, with a suggested 4 weeks interval between intervention and long-term examination. Assessing the retention of knowledge in human anatomy requires a specific time period between intervention and examination. It is recommended that to obtain consistent findings, a time period of 6 months is necessary.[15] In this study, a one-month time frame was chosen instead of 6 months due to following factors: the study's time frame was limited to 2 months because of students' heavy academic schedule. While 3D-VR is demonstrated to be effective for learning and teaching human anatomy, particularly retention knowledge in students in many colleges of Pakistan.[16]

This study recognized several limitations of 3D-VR, including students' unfamiliarity with how to use the application, its impact on battery life, absence of direct interaction, and some students' preference to continue using cadaver or plastic model alongside 3D-VR for improved retention knowledge. These issues must be resolved prior to considering the integration of 3D-VR learning and teaching methods into the human anatomy curriculum in medical education.

Conclusion

The study demonstrated that 3D-VR is an effective learning method for short-term and long-term retention knowledge in undergraduate medical students. The students characterized 3D-VR as a learning method with significant advantages for studying human anatomy compared to traditional method. This method enhanced their retention knowledge, fostered learning engagement between students and teachers, and enabled students to realistic, learning experience of self-directed.

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