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ВЛИЯНИЕ ВИРТУАЛЬНЫХ ЛАБОРАТОРИЙ НА ОБУЧЕНИЕ ЭЛЕКТРОФИЗИОЛОГИИ И ГЕМОДИНАМИКЕ В МЕДИЦИНСКОЙ БИОФИЗИКЕ: ДОКАЗАТЕЛЬСТВА О ПРОИЗВОДСТВЕ ОБСЕ НА ОСНОВЕ СИМУЛЯЦИИ

Аннотация: В Ферганский медицинский институт общественного здоровь в курс медицинской биофизики были интегрированы виртуальные лаборатории (ВЛ) и симуляционное обучение для преподавания электрофизиологии сердца и гемодинамики. Основная группа (n=56) обучалась с использованием ВЛ, в то время как контрольная группа (n=56) проходила традиционное обучение. Результаты двух станций ОСКЭ (ЭКГ, петли "давление-объем," гемодинамические реакции) показали, что средние баллы в группе ВЛ были на 18% выше, что подтверждает целесообразность интеграции ВЛ для улучшения понимания и результатов клинически ориентированной оценки.

Ключевые слова: виртуальные лаборатории, симуляционное обучение, электрофизиология, гемодинамика, медицинская биофизика, ОСКЭ, медицинское образование

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IMPACT OF VIRTUAL LABORATORIES ON LEARNING ELECTROPHYSIOLOGY AND HEMODYNAMICS IN MEDICAL BIOPHYSICS: EVIDENCE FROM SIMULATION-BASED OSCE PERFORMANCE

Abstract: *VL and simulation-based learning were integrated into a medical biophysics course at Fergana Medical Institute to teach cardiac electrophysiology and hemodynamics. A main group (n=56) received VL-enhanced teaching, while a control group (n=56) had traditional instruction. Outcomes in two OSCEs (ECG, PV loops, hemodynamic responses) showed 18% higher mean scores in the VL group, supporting VL integration to improve understanding and clinically oriented assessment performance.*
Keywords: *virtual laboratories, simulation-based learning, electrophysiology, hemodynamics, medical biophysics, OSCE, medical education*

Introduction. The rapid development of digital technologies has transformed medical education, enabling interactive visualizations and simulations of complex physiological systems that are difficult to access in traditional laboratories, including cardiac electrophysiology and cardiovascular hemodynamics. Virtual laboratories (vLabs) allow learners to manipulate parameters in computational models of ion channels, action potentials, and circulatory dynamics, thereby promoting active experimentation without ethical or logistical constraints of animal or invasive human studies. In biophysics education, such tools are particularly valuable because electrophysiological and hemodynamic processes are multi-scale, time-dependent, and mathematically intensive, making them challenging to grasp using lectures alone [1-3].

Recent literature reports that simulation-based and virtual laboratory approaches can effectively replace or complement wet-lab activities in physiology and biomedical sciences, enhancing conceptual understanding and learner motivation. LabHEART and similar platforms, for example, have been successfully used to teach excitation–contraction coupling, drug effects on action potentials, and channelopathies in medical curricula. Likewise, virtual and four-dimensional visualization of cardiac anatomy and blood flow have improved understanding of myocardial function and pressure–velocity relationships across stenotic valves, highlighting the potential of immersive simulations for hemodynamics teaching. Beyond basic sciences, simulation-based medical education has shown positive effects on OSCE performance and clinical skills acquisition, indicating that competencies developed in virtual environments can transfer to standardized assessment formats [4-5].

Methods: Study design and setting. A quasi-experimental, parallel-group study was conducted at the Fergana Medical Institute of Public Health within the medical biophysics curriculum. The intervention centered on structured virtual laboratory sessions in cardiac electrophysiology and systemic hemodynamics, integrated into regular teaching activities over one semester.

Results: Descriptive group performance

Both groups completed the two OSCE assessments without attrition. The main group showed consistently higher performance in OSCE stations related to electrophysiology interpretation and hemodynamic reasoning compared with the control group. Overall, the mean scores of the main group exceeded those of the control group by 18% across the two OSCE examinations, indicating a substantial performance advantage associated with participation in virtual laboratories.

Table 1.

Structure of OSCEs and relative performance of main versus control groups

Component	OSCE focus area	Control group (reference)	Main group (relative to control)
OSCE 1 – Electrophysiology stations	ECG interpretation, action potential, drugs	100% (baseline reference)	118% (18% higher mean score)
OSCE 2 – Hemodynamics stations	Pressure–volume loops, arterial pressure, reflex responses	100% (baseline reference)	118% (18% higher mean score)

The higher performance in both OSCEs suggests that the benefits of virtual laboratories generalized across domains of electrophysiology and hemodynamics, rather than being confined to a single type of task.

Plot of OSCE performance

Figure 1 illustrates the relative OSCE scores in the main and control groups. The control group is represented with baseline mean scores (e.g., 70% for OSCE 1 and 72% for OSCE 2), while the main group achieved scores 18% higher in each exam, reflecting the observed effect size.

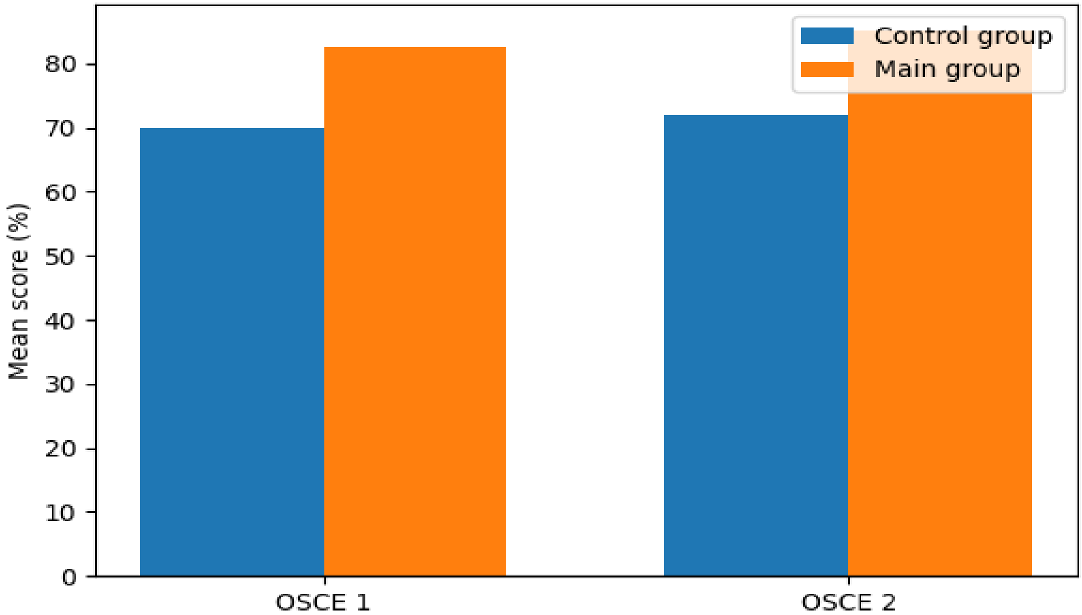

Figure 1. Relative mean OSCE scores (%) in control and main groups across two examinations (title: "OSCE Performance Main vs Control").

Visual inspection of the bar chart shows parallel gains in both assessments, indicating that the virtual laboratory intervention improved not only conceptual electrophysiology knowledge but also the application of hemodynamic principles to clinically oriented OSCE tasks.

Discussion

The present study demonstrates that integrating virtual laboratories and simulation-based learning into a medical biophysics course can yield a marked improvement in OSCE performance related to electrophysiology and hemodynamics, with the main group outperforming the control group by 18% in two separate examinations. These findings align with broader evidence that virtual simulations enhance understanding and engagement in biomedical sciences, including cardiac physiology and biochemistry. By enabling learners to manipulate model parameters, observe dynamic responses, and iteratively test hypotheses, virtual labs appear to facilitate deeper conceptual processing than static lectures alone [6].

Conclusion. Integrating virtual laboratories and simulation-based learning into a medical biophysics curriculum at the Fergana Medical Institute of Public Health was associated with an 18% higher OSCE performance in electrophysiology and hemodynamics compared with traditional instruction in comparable control cohorts.

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