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Abstract

Introduction:

Auscultation proficiency remains suboptimal among healthcare professionals, particularly in resource-limited countries. Simulation-based training is a promising measure to address this gap by offering a safe and controlled environment. This quasi-experimental study aimed to assess the efficacy of Student Auscultation Manikin II® (SAM II®)-based training and to determine the influential factors in our academic setting.

Methods:

A total of 370 third-year medical students received a single 4-hour SAM II®-based training commenced with clinical rotations. To evaluate student's performance, a test comprising 16 sounds and diagnoses was conducted at three points in time: prior to, *at the end of*, and *at a short interval after* the training. Multivariable linear regression models with intervention as a dummy variable were used to examine whether faculty qualifications and prior clinical exposure were associated with outcomes.

Results:

SAM II®-based training immediately improved student's heart and lung auscultation performance with statistical significance (Median [IQR]: 5 [4-6] vs. 4 [3-6], $p < 0.001$; 5 [4-5] vs. 3 [3-5], $p < 0.001$, respectively). Retention rates were 96.8% for cardiac and 88.1% for respiratory auscultation, with no significant difference ($p = 0.109$). Furthermore, our analysis revealed no correlation between their post-training competence, and educators' qualifications or students' prior exposure to clinical conditions.

Conclusions:

Our findings demonstrated the immediate efficacy of part-task trainers in enhancing and maintaining auscultation skills over short periods. Clinical faculties with adequate simulation training can instruct MS-3s as effectively as simulation experts. Nevertheless, it is imperative to conduct a comprehensive evaluation of simulator quality to ensure alignment with the learning objectives.

Keywords: heart auscultation, respiratory sounds, medical education, simulation training, Vietnam.

1. INTRODUCTION

Cardiovascular diseases and chronic obstructive pulmonary diseases account for major proportions of mortality worldwide, resulting in over 20 million deceases annually (1). The effectiveness of treatment strategy is contingent upon accurate and timely diagnosis, emphasizing the necessity to enhance diagnostic capacity across all clinical settings, not solely within specialty departments. Despite the availability of numerous modern diagnostic tools, auscultation remains essential for physical examination, particularly in resource-limited countries (2, 3). Stethoscopes are emblematic of healthcare profession, and not only have the most significant positive impact on the physician-patient relationship but also cost-effective instruments globally (4-6). However, attaining proficiency in auscultation remains a considerable challenge (7). Deficiency in cardiorespiratory auscultation at all levels of medical professionals has been demonstrated in recent studies (8, 9). Stefano Perlini study in 2012 with 657 participants, including medical students and residents, assessed the impact of a simulation-based cardiac auscultation tutorial using the Harvey® simulator. Despite limited faculty time and patient access, results showed significant and prolonged improvement in auscultation skills for up to three years, highlighting the effectiveness of simulation in bridging the gap between theory and clinical practice (9). Indeed, these skills cannot be perfected without clinical practice, constructive feedback, and substantial hands-on training (8). Nevertheless, in circumstances where bedside instruction frequently encounters obstacles, such as faculty shortages, unbalanced student-patient ratios, symptom unpredictability, or medical conditions unrelated to learning objectives, simulation-based training has been recognized as an effective strategy to improve physical examination ability in medical education (10). This approach enables students to acquire experiential learning in a safe, controlled, and practical environment (11).

Since 2017, the Centre for Advanced Training in Clinical Simulation (ATCS) of the University of Medicine and Pharmacy at Ho Chi Minh City (UMP-HCMC), Faculty of Medicine (FM), has been established (12, 13), and best practices in Simulation-Based Medical Education (SBME) have been adapted from the Society for Simulation in Healthcare to maintain high education and assessment standards (14). Simulation activities in the ATCS are diverse, with various modalities and fidelity levels for undergraduate and graduate students (12, 15). In the second year, medical students initiate simulated training in our center concurrently with clinical practice. During the 8-week Practice of Internal Medicine (POIM) module in the third year, a combined course on cardiology and respiratory, they receive an additional cardiorespiratory training session on a task trainer, specifically Student Auscultation Manikin II (SAM II®). SAM II® is a moderate-fidelity manikin for partial-task training, particularly cardiorespiratory auscultation skills. In the context of a low-resource condition, it is a cost-effective and appropriate modality for undergraduate education, and aligns with program settings and resources (16-18). SAM II® facilitates auscultation by producing clinically resembled sounds (19). The simulator enables the reproduction and comparison of various audios on phonocardiograms, ensuring that all students perceive the same heart and lung sounds for standardized learning experience (10). Optimally, simulation learning should precede clinical practice to mitigate risks on patient safety (20). However, with approximately 400 students per class and a congested curriculum, some groups were required to commence their clinical practice before receiving training in the simulation. Although the faculty-student ratio has improved from 1:15-1:12 to 1:5 (12, 13), the number of instructors for simulation teaching remains limited because of their engagement in other duties such as medical consultations and healthcare service delivery. To address this issue, new faculty members and resident doctors were assigned to teach at the ATCS after completing onboarding courses. This situation leads to differences in teaching quality, as junior instructors may lack experience, while senior instructors may be distracted by other tasks and may not allocate sufficient time for training (21).

In our country, the effectiveness of simulation-based auscultation training is yet to be cleared and the challenges of SBME implementation persist in the context of limited resources. Furthermore, up till the time of research implementation, we were unable to identify studies that evaluated the practical utilization of this specific task trainer in resource-limited settings or strategy to overcome educational challenges. Hence, the current study aimed to assess (a) whether SAM II® can improve and maintain auscultation skills among third-year medical students (MS-3) and (b) determine the influential factors of instructional design in our resource-limited program.

2. METHODS

2.1. Study Design

Figure 1 shows an overview of the study design. This quasi-experimental study involved the manipulation of training types administered to students using the SAM II®. Students were randomly allocated to one of 12 training groups, each comprising 24-36 participants, in accordance with course regulations and management protocols. Each group participated in a single SAM II®-based training session (Fig.1). Prior to the training session, the students completed a pre-test (T0) to establish baseline performance levels. The 4-hour training session was structured in two components: cardiac auscultation and respiratory auscultation, followed by post-test 1 (T1). To evaluate the retention rate after a short interval (2 to 8 weeks), a second post-test (T2) was conducted at the conclusion of the course. Responses to the questionnaire regarding cardiorespiratory encounters during clinical rotations were collected (Table S1). The contents of the tests administered in T0, T1, and T2 remained consistent in both order and detail (Table 1). These tests comprised ten (10) MCQs for the cardiac section and six (6) MCQs for the respiratory section. As indicated, no diagnostic questions were included for respiratory performance because of course objectives. To ensure the test quality, we have also analysed the difficulty and discrimination indices of those questions (Table S2). Each correct response was assigned one point, and the total score was calculated. The total score for cardiac auscultation skills was 10 points, while the total score for respiratory auscultation skills was 6 points. These scores reflected the maximum achievable points for correctly identifying all required findings in each respective skill set. All student responses were collected and automatically scored using the Audience Interactive Response System, which incorporated TurningPoint® software and devices (22).

[Insert Fig.1]

2.2. Participants

According to the curriculum of UMP-HCMC, students start clinical practice in the hospital in year 3. Third-year medical students (MS-3s) are required to encounter patients with heart or lung diseases. Hence, the simulation-based course at ATCS, UMP-HCMC is integrated to the curriculum before clinical practice in year 3. All MS-3s were invited to participate in our study. Excluding 37 students who were not eligible for the study due to lack of consent or missing data, a total of three hundred and seventy (370) MS-3s from the 2023-2024 academic year was enrolled in the study during the POIM module. The students were then divided into 12 teaching groups based on their class assigned by the school. The class assignment was based on entrance exam scores and sex, with even distribution per protocol. Students took courses following the overall curriculum and scheduled from the beginning of the school year. The POIM module was an 8-week clinical rotation and was scheduled in two periods in the curriculum: October–November 2023 and April-May 2024. The course included tactical teaching and clinical rotations as defined in the curriculum. The SAM II® intervention commenced with clinical rotations in the teaching hospitals. Due to the large population of each academic class and limited resources, all groups initiated their clinical practice before SAM II® training sessions with varied clinical exposure periods (Fig.1). We relied on the curriculum from the university in order to identify the prior clinical exposure periods of each MS-3 in the respiratory and cardiology wards before their SAM II® training sessions. The participants did not receive any cardiorespiratory auscultation training prior to the course. As part of this course, they underwent four hours of simulator training, in addition to their mandatory clinical rotations. The Ethical Committee of UMP-HCMC (IRB-VN) approved the study, and written informed consents were obtained from all participants prior to enrolment in the study. Students who did not attend SAM II® training sessions and tests were excluded from the study.

2.3. Training on the Student Auscultation Manikins II®

MS-3s participated in cardiorespiratory auscultation training sessions using SAM II® simulators and accompanying equipment including SimulScope® transmitters and wireless Heartman® infrared stethoscopes. To ensure a consistent listening experience, the simulated sounds emitted from SAM II® were transmitted via the transmitter through stethoscopes. Additionally, we ensured the SAM II® model and other tools were ready and well-functioned before the training sessions. The single 4-hour training session was designed based on the practical application of the stethoscope in cardiology and respiratory examinations. Students received instructions on various heart and lung sounds, adventitious sounds, and murmurs with descriptions, phonograms, electrocardiograms, and a brief lecture on explaining the mechanisms, providing a reasonable clinical diagnosis and determining the location of lesions or defects. The clinical audio database for training were similar to the database for student's assessment, but comprised different scenarios to promote critical inquiry (12) and skill transformation (23-25). A discussion session with constructive feedback was implemented until all learning objectives were achieved.

[Insert Table 1]

Each teaching group was supervised by a simulation educator or a clinical faculty member from the internal medicine department and was assisted by two residents. The coordinator of the POIM module randomly assigned simulation educators and clinical faculty members to each teaching group. All trainers were required to conduct the training sessions in accordance with the course learning outcomes to ensure the objectives were met. The teaching experience was hierarchical, ranging from junior faculty (who had only undergone pre-course training prior to simulation activities) to well-trained educators (senior faculty who had been trained in SBME and had years of experience in teaching clinical skills) and high-quality experts (simulation educators who possessed official certificates from at least one comprehensive faculty development program). During the 8-week clinical practice in the wards, students examined patients and prepared reports, and they were responsible for obtaining feedback on their findings from the clinical faculty on duty. At the conclusion of the third year, students undergo a summative OSCE stations focused on medical history inquiry and clinical examinations. Subsequently, no dedicated course solely for auscultation was assigned; however, the subject remained the focus on clinical teaching, if relevant.

2.4. Statistical Analyses

The study collected several types of variables. The dependent variables were derived from the scores of training assessments (at T0, T1 and T2). The independent variables consisted of information on gender, student distribution per teaching group, prior clinical experience, and faculty qualifications. Collinearity and confounding factors were examined during the process of multivariate regression modelling.

To ensure the validity of statistical analyses, the Shapiro-Wilk normality test was performed to assess the distribution of all variables. As the test results indicated non-normality ($p < 0.05$), nonparametric statistical methods were subsequently applied for data analysis. The Friedman test and the Cochran's Q Test were employed to compare total scores and individual item scores, respectively, across the three time points: T0, T1, and T2. For post-hoc analysis, the two-tailed Wilcoxon signed-rank test (total scores) and McNemar's Test (item scores) were conducted to compare specific assessment points in time pair-wise (T1 vs. T0, T2 vs. T0, and T2 vs. T1). To account for multiple comparisons, the significance level was adjusted using the Bonferroni correction: $\alpha' = \alpha/k$, where k represents the number of pairwise comparisons. Since three comparisons were performed for three points in time, the adjusted significance level was $\alpha' = 0.05/3 = 0.017$. Accordingly, the p-value below 0.017 was considered statistically significant. In addition, multivariable linear regression models, with intervention as a dummy variable, were used to assess whether faculty qualifications and prior clinical exposure were associated with outcomes.

For statistical analyses, we used RStudio and IBM SPSS Statistics 26. Descriptive statistics were used to summarize the collected data. Categorical variables (e.g., gender, prior clinical exposure, faculty qualifications, questionnaire responses) were summarized as frequencies and percentages. Total scores for cardiac and pulmonary auscultation skills were presented as median along with interquartile range (IQR), while individual item scores were expressed as percentage correct. Additionally, median of differences with IQR and absolute differences were used to compare total scores and percentage correct of individual items across different points of assessment. Retention rates were calculated as follows: (mean score T2/ mean score T1) × 100%. When comparing retention rates between cardiac and respiratory performance, we used the Chi-square test, with the corresponding p-value reported.

3. RESULTS

3.1. Efficacy of single simulation-based auscultation education

A total of three hundred and seventy (370) students participated in the study with a male-to-female ratio of 1.66:1. The proportion of students who had not participated to clinical practice at the cardiology ward was higher, while the opposite was true for the pulmonary ward. The number of students in each session, gender, prior exposure to cardiopulmonary clinical practice before learning SAM II®, and the quality of the instructors are described in Table S3. All students were uniformly trained in cardiorespiratory simulation scenarios related to high-prevalence diseases, including mitral stenosis with or without regurgitation, aortic stenosis with or without regurgitation, asthma, chronic obstructive pulmonary disease, and pneumonia. These training audios were used in the subsequent tests under various scenarios (Table 1).

The Friedman test results indicated a statistically significant difference in test scores across three time points ($p < 0.001$, Table 2), confirming the impact of training and subsequent clinical exposure on auscultation performance. The SAM II®-based training significantly improved the students' cardiac performance and respiratory performance immediately (Median [IQR]: 5 [4-6] vs. 4 [3-6], $p < 0.001$; 5 [4-5] vs. 3 [3-5], $p < 0.001$, respectively), and was maintained over 2 months for heart sound auscultation (5 [4-6] vs. 5 [4-6], $p = 0.051$). Conversely, lung auscultation skills decreased significantly (4 [3-5] vs. 5 [4-5], $p < 0.001$) (Fig.2; Tables 2 and S4). The rationale behind this contradictory result is addressed in the latter part of the discussion.

Although the overall cardiac performance was maintained over a short period, there was a trend toward lower identification of features associated with Atrial Septal Defect (ASD) ($p < 0.001$), Aortic Regurgitation (AR) (p=0.089), and Mitral Stenosis and Regurgitation (MSR) (p=0.659) among students (e.g., wide fixed splitting S2 in ASD, p=0.395; diastolic murmur in AR, p=0.403; and systolic and diastolic murmur in MSR, p=0.002) compared to an increasing percentage of correct identifications for Mitral Stenosis (MS) (loud S1, p=0.236; diastolic rumble, p=0.055) and gallop S3 (p=0.081 and p=0.010, respectively) (Fig.2B and C; Table 2 and S4). Notably, almost lung auscultation performances decreased significantly $p < 0.017$ (adjusted α level) after a few weeks in clinical rotations, except for coarse crackles that remained nearly unchanged. The retention rate after clinical rotations for cardiac auscultation was 96.8% (51.6/53.3), whereas that for lung auscultation was 88.1% (64.7/73.4), with no significant differences (p=0.109, Chi^2-statistics). Indeed, when comparing the test scores between T2 and T0 for both cardiac and respiratory auscultation skills, a statistically significant difference was observed, with p value < 0.001 (Tables 2 and S4).

[Insert Fig.2]

[Insert Table 2]

3.2. Simulation-based medical education in a resource-limited setting

Our findings in Table 3 indicated that educational qualifications did not significantly influence student's auscultation proficiency following SAM II® training ($p > 0.05$). This suggests that junior faculty members with minimal pre-course preparation can effectively instruct third-year medical students on auscultation techniques, performing comparably to more experienced educators. Furthermore, our analysis revealed no statistically significant correlation between students' prior exposure to clinical cardiovascular and respiratory conditions and their post-training competence, indicating that preclinical experience did not substantially affect SAM II® training efficacy.

[Insert Table 3]

Figure 3 showed that student access to appropriate cardiac cases was limited (25–55%), while exposure to respiratory conditions was more prevalent (71–91%), with the exception of patients exhibiting pleural friction rubs. Notably, students demonstrated improved cardiac auscultation skills when they were given more opportunities (>50%) to examine specific conditions (e.g., S3 gallop, accentuated S1, and diastolic rumble). Paradoxically, clinical rotations in respiratory wards were associated with decreased performance in auscultation skills (absolute differences in percentage correct between T2 and T1 ranged from 0.3 to -20.2). However, this unexpected phenomenon requires further investigation.

[Insert Fig.3]

4. DISCUSSION

In Ho Chi Minh City (UMP-HCMC) at the University of Medicine and Pharmacy, clinical training commenced early, in the second year of the curriculum. Despite institutional efforts to enhance facilities and increase the number of staff, clinical practice sessions remain overcrowded. This study demonstrated for the first empirical evidence on the efficacy of SAM II®-based training, and showed that MS3s in our academic setting exhibited significantly improved heart and lung auscultation skills after a brief training session with a part-task trainer. These findings are consistent with prior studies that have reported that simulation training plays a crucial role in enhancing clinical auscultation skills both immediately after training and over time (9, 10, 26). However, in contrast to earlier research (27-29), we did not assess student's performance in *in-situ* simulations or with real patients, which are areas that require further investigation.

Binka et al. observed a 23% improvement in the identification of heart sounds immediately after simulation intervention (30). They demonstrated a subsequent 6% decline in accuracy in the intervention group the following year. The efficacy of simulation-based education in medical training may be compromised by factors such as an insufficient faculty-to-student ratio, suboptimal remuneration, and inadequate instructor preparation. These limitations can impede the transfer of skills, particularly among novice learners who require extensive hands-on practices. Notably, our findings indicate a comparable decline in retention rates within a short period (from 2 to 8 weeks). For instance, the MS3s' ability to accurately determine heart and lung sounds decreased by 1.7% and 8.8%, respectively. One of the authors' explanations was the differences in clinical experiences across medical students, even throughout the same academic year (30). These reductions in the current study may be attributed to patient unavailability, inadequate physical state of patients for skill practice, and missing laboratory data (31). These factors could lead to the presentation of certain sounds more frequently than others. To address this issue, the regular presence of clinical faculty and the avaibility of well-defined cases in alignment with the learning objectives are essential. This approach will assist students in identifying individual abnormal sounds and in enhancing their overall auscultation skills in a clinical setting. Furthermore, conducting longitudinal studies could offer valuable insights for optimizing training protocols. Longitudinal studies would allow for the systematic assessment of skill retention over extended periods, helping to identify early signs of skill decay and determine the optimal frequency and intensity of targeted interventions (32).

In this study, we implemented a single-intervention training session based on the SAM II® within the POIM module (Fig. 1). After the session, students had the opportunity to practice cardiac and pulmonary auscultation on specific clinical cases with varying levels of engagement. Figure 2 demonstrates increased accuracy in identifying characteristics such as diastolic murmur, gallop S3, diastolic sounds, and loud S1 in the T2 test compared with the T1 test. This corresponded to a higher percentage of students correctly diagnosing mitral valve stenosis. Notably, these MS3s had more frequent access to these heart-sounds during rotation (Fig.3). This phenomenon can be attributed to the repeated practice of strengthening skills at the mastery level through deliberate effort. Indeed, a study by Høyte determined that medical students required an average of 500 repetitions of heart-sounds to demonstrate proficiency in identifying them (33). Therefore, our instructional design should emphasize the need for deliberate practice and formative assessment to provide numerous opportunities for students to practice at the edge of their abilities, share their cognitive frameworks, and discuss and learn from errors (34, 35). The balances between initial intensive training with ongoing reinforcement by periodic deliberate practices may lead to more sustainable improvements in auscultation skills, ensuring that students retain clinically relevant competencies as they progress in their medical careers (36). This method has proven beneficial for improving various trainee skills, including advanced cardiac life support (ACLS) (37), central venous catheter insertion (36), and both cardiac and respiratory auscultation (38). Altogether, implementing these measures will significantly enhance students' acquisition and retention of cardiorespiratory auscultation competencies (38, 39).

In the data analysing the acute efficacy of the training session, the students exhibited higher identification scores for pulmonary sounds than for cardiac sounds (Fig. 2). This finding aligns with a recent study on MS3s, which confirmed that recognizing lung sounds may be less challenging than recognizing cardiac sounds (40, 41). Moreover, over 75% of the students reported exposure to sounds such as alveolar rales, wheezing, rhonchi, small crackles, and large crackles in real patients. However, the students experienced difficulty in recognizing almost all lung sounds when retaking the test after their clinical rotations, with a significant reduction between T2-T1 (Fig.2A). The discrepancy in skill decay between cardiac and respiratory auscultation may stem from multiple factors. One key aspect to consider is the fidelity of the SAM II® model in replicating lung sounds. Unlike cardiac auscultation, where characteristic heart sounds are more distinct and structured, lung auscultation requires the recognition of a wider range of dynamic sounds influenced by airflow patterns and pathological variations (42). The limitations of the SAM II® model in accurately reproducing these nuances might have contributed to the observed decline in retention for respiratory auscultation but have never been reported anywhere. Indeed, feedback from cardiovascular and respiratory experts on teaching auscultation skills using the SAM II® model indicated a consensus that the authenticity of lung sounds is lower than expected, unlike that of heart sounds. This could be attributed to the fact that the fundamental aspect of these audios is generated by computer software rather than by pre-recorded sounds from real patients. Our recommendation is to assess manikin's clinical resemblance before purchasing or upgrading to newer software or data packages with realistic sounds. Another potential explanation is the cognitive processing difference between heart and lung sound recognition. Heart sounds often follow a rhythmic and repetitive pattern, making them easier to reinforce through structured learning, whereas lung sounds, particularly subtle adventitious sounds, require a more nuanced auditory discrimination, which may degrade faster without continuous practice (43).

Since 2010, the UMP-HCMC has augmented its workforce to achieve a ratio of one instructor for every five students to address the demand for curriculum innovation based on competency standards (12). However, the number of faculty members allocated to simulation-based auscultation training is limited. In a training session, one instructor guided 24-36 students with the assistance of two residents. Evidently, a larger class size reduces the faculty-to-student ratio, thereby diminishing the opportunity for direct and specific feedback from the educator, particularly given that auscultation skills are critical and require hands-on training. A more comprehensive analysis of instructor variability in intervention efficacy revealed negligible differences between cardiac and respiratory training. Teaching auscultation skills on SAM II® models to MS-3s with the primary objective of identifying and distinguishing audible sounds can be conducted by junior or other faculty members if they have previously undergone a pre-training course on teaching methods at the simulation center and learning objectives based on SAM II® models. This approach helps to alleviate the burden of human resources on other domestic medical training programs, as most are oversubscribed with students and lack comprehensive faculty development programs (17). Moreover, owing to time constraints and regulations from the Ministry of Education and the Ministry of Health, the training schedule necessitates flexible arrangements among student groups. Consequently, some groups may receive clinical training before accessing the simulation center, and vice versa. In comparison with the work of Tokuda et al. (44), our findings demonstrated that the test scores for both auscultation skills after SAM II® training did not exhibit significant differences between the two groups. Therefore, flexible scheduling options that retain educational outcomes should be considered in academic settings with congested curricular schedules, large student populations, and faculty shortages, medical schools should consider.

Overall, some positive findings from the current study support the integration of structured simulation modules that can be delivered by a broader range of educators, reducing the dependency on highly specialized faculty in curriculum design. This flexibility allows institutions to scale simulation-based programs more efficiently, ensuring wider student access to high-quality clinical skills training. From a resource allocation perspective, these findings suggest that investments should focus not solely on faculty development but also on enhancing simulation infrastructure and ensuring adequate student-to-simulator ratios. While faculty expertise remains important for advanced clinical reasoning instruction, foundational auscultation skills can be effectively taught through standardized simulation protocols with appropriate supervision. This approach optimizes resource use, particularly in settings where faculty resources are limited. Furthermore, addressing potential barriers such as suboptimal faculty-to-student ratios and inadequate instructor preparation can be achieved through targeted faculty training workshops, peer-assisted learning models, and the development of comprehensive instructor guides (45). These strategies can enhance instructional efficiency without incurring substantial additional costs. From a global perspective, standardized simulation models, such as SAM II®, can ensure consistent educational experiences across diverse settings, reducing variability in clinical skill acquisition. This is particularly valuable in regions with limited resources or varied patient populations. Future research should focus on evaluating the longitudinal impact of simulation on clinical competence and patient outcomes, as well as identifying cost-effective strategies to enhance scalability in diverse healthcare contexts.

4.1. Limitations of the study

A potential limitation of the present study was the optional nature of SAM II®-based training sessions. Although students have demonstrated an interest in practicing auscultation skills in manikins, their level of engagement during assessments may vary to some extent. Another potential limitation is the inability to measure the impact of demographic factors related to educators and students on improving their auscultation skills. Owing to the large cohort size in an academic year and the complexity of synthesizing lecturers' training backgrounds, these factors were not included in the analysis. Furthermore, the study did not assess students' performance in *in-situ* simulations or in actual patients. The current program does not incorporate *in-situ* simulations, and studies involving real patients may encounter inconsistencies on a case-by-case basis. Further research is necessary to elucidate the long-term efficacy of simulation-based training in the clinical setting. Additionally, it is imperative to evaluate the value of deliberate practice at the simulation center if it is not conducted in a single session.

5. CONCLUSION

Our findings demonstrated a significant relevance to the extant literature regarding the effectiveness of part-task trainers in simulation activities to enhance auscultation skills, both in immediate post-training assessments and over short periods. Clinical faculty who possess adequate training and experience in simulation-based education can teach third-year medical student auscultation skills as effectively as simulation experts. Nevertheless, it is imperative to conduct a comprehensive evaluation of simulator quality to ensure alignment with the learning objectives and program outcomes. Notably, a single training session is insufficient for a profession that demands a high technical proficiency. While simulation-based training holds great promise for improving clinical skills globally, its long-term effectiveness depends on strategic curricular integration, ongoing reinforcement, and adaptive models that address resource disparities.

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Ethical Approval

The study was approved by the Ethics Committee for Biomedical Research, University of Medicine and Pharmacy at Ho Chi Minh City (No 682/HĐĐĐ-ĐHYD, 20th July, 2023. Protocol # IRB-VN1002/IORG0008603/FWA00023448). The study was conducted in accordance with the local legislation and institutional requirements.

Availability of data and material

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Supplementary Materials

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REFERENCES

1. NCD Countdown 2030: worldwide trends in non-communicable disease mortality and progress towards Sustainable Development Goal target 3.4. Lancet (London, England). 2018;392(10152):1072-88.
2. Bediang G, Baran À Zock A, Doualla FG, Nganou-Gnindjio C. Evaluation of a digitally enhanced cardiac auscultation learning method in Cameroon: results of a controlled study. BMC Med Educ. 2024;24(1):560.
3. Hiatt MD. Of White Coats and Stethoscopes. JAMA. 1999;281(5):474-.
4. Mangione S, Nieman LZ, Gracely E, Kaye D. The teaching and practice of cardiac auscultation during internal medicine and cardiology training. A nationwide survey. Annals of internal medicine. 1993;119(1):47-54.
5. Jiwa M, Millett S, Meng X, Hewitt VM. Impact of the Presence of Medical Equipment in Images on Viewers' Perceptions of the Trustworthiness of an Individual On-Screen. J Med Internet Res. 2012;14(4):e100.
6. Mc Loughlin MJ, Mc Loughlin S. Cardiac auscultation: Preliminary findings of a pilot study using continuous Wave Doppler and comparison with classic auscultation. International Journal of Cardiology. 2013;167(2):590-1.
7. Butter J, McGaghie WC, Cohen ER, Kaye M, Wayne DB. Simulation-based mastery learning improves cardiac auscultation skills in medical students. Journal of general internal medicine. 2010;25(8):780-5.
8. Patrizio HA, Phyu R, Kim B, Brolis NV. Utilization of Simulation to Teach Cardiac Auscultation: A Systematic Review. Cureus. 2023;15(7):e41567.
9. Perlini S, Salinaro F, Santalucia P, Musca F. Simulation-guided cardiac auscultation improves medical students' clinical skills: the Pavia pilot experience. Internal and emergency medicine. 2014;9(2):165-72.
10. McKinney J, Cook DA, Wood D, Hatala R. Simulation-based training for cardiac auscultation skills: systematic review and meta-analysis. Journal of general internal medicine. 2013;28(2):283-91.
11. Smith SN, Crocker AF. Experiential learning in physical therapy education. Advances in medical education practice. 2017:427-33.
12. Tran TD, Vu PM, Pham HTM, Au LN, Do HP, Doan HTT, et al. Transforming medical education to strengthen the health professional training in Viet Nam: A case study. The Lancet regional health Western Pacific. 2022;27:100543.

13. Tuan TD. The First Annual National Vietnam Medical Education Conference “Preparing the 21st Century Physician”. MedPharmRes. 2018;2(1):1-2.
14. SIM Center Directory. Sim Center Asia: Society Simulation in Healthcare; 2024.
15. Carey JM, Rossler K. The How When Why of High Fidelity Simulation. In: StatPearls [Internet]: Treasure Island (FL): StatPearls Publishing; 2024 Jan-; Updated 2023 May 1.
16. Alessi SM. Fidelity in the design of instructional simulations. 1988;15(2 %J J. Comput. Based Instruct.):40–7.
17. Kaminsky J, Bianchi R, Eisner S, Ovitsh R, Lopez AM, Smith L, et al. Respiratory Auscultation Lab Using a Cardiopulmonary Auscultation Simulation Manikin. MedEdPORTAL : the journal of teaching and learning resources. 2021;17:11107.
18. Quinn A, Kaminsky J, Adler A, Eisner S, Ovitsh R. Cardiac Auscultation Lab Using a Heart Sounds Auscultation Simulation Manikin. MedEdPORTAL : the journal of teaching and learning resources. 2019;15:10839.
19. Ward JJ, Wattier BA. Technology for enhancing chest auscultation in clinical simulation. Respiratory care. 2011;56(6):834-45.
20. Jabaay MJ, Marotta DA, Aita SL, Walker DB, Grcevich LO, Camba V, et al. Medical Simulation-Based Learning Outcomes in Pre-Clinical Medical Education. Cureus. 2020;12(12):e11875.
21. Brownell SE, Tanner KD. Barriers to faculty pedagogical change: lack of training, time, incentives, and...tensions with professional identity? CBE life sciences education. 2012;11(4):339-46.
22. Lymn JS, Mostyn A. Audience response technology: engaging and empowering non-medical prescribing students in pharmacology learning. BMC Med Educ. 2010;10:73.
23. Diaz-Navarro C, Armstrong R, Charnetski M, Freeman KJ, Koh S, Reedy G, et al. Global consensus statement on simulation-based practice in healthcare. Advances in Simulation. 2024;9(1):19.
24. Lembo D, Abate Daga F, Calì C, Garbossa D, Manfredi M, Odetto L, et al. Early introduction of simulation in the medical curriculum: the MedInTo perspective. Frontiers in medicine. 2023;10:1280592.
25. Murakami T, Yamamoto A, Hagiya H, Obika M, Mandai Y, Miyoshi T, et al. The effectiveness of simulation-based education combined with peer-assisted learning on clinical performance of first-year medical residents: a case-control study. BMC Medical Education. 2023;23(1):859.

26. Bernardi S, Giudici F, Leone MF, Zuolo G, Furlotti S, Carretta R, et al. A prospective study on the efficacy of patient simulation in heart and lung auscultation. BMC Med Educ. 2019;19(1):275.
27. de Giovanni D, Roberts T, Norman G. Relative effectiveness of high- versus low-fidelity simulation in learning heart sounds. Medical education. 2009;43(7):661-8.
28. Sverdrup Ø, Jensen T, Solheim S, Gjesdal K. Training auscultatory skills: computer simulated heart sounds or additional bedside training? A randomized trial on third-year medical students. BMC Medical Education. 2010;10(1):3.
29. Fraser K, Wright B, Girard L, Tworek J, Paget M, Welikovich L, et al. Simulation training improves diagnostic performance on a real patient with similar clinical findings. Chest. 2011;139(2):376-81.
30. Binka EK, Lewin LO, Gaskin PR. Small Steps in Impacting Clinical Auscultation of Medical Students. Global pediatric health. 2016;3:2333794x16669013.
31. Ewy GA, Felner JM, Juul D, Mayer JW, Sajid AW, Waugh RA. Test of a cardiology patient simulator with students in fourth-year electives. Journal of medical education. 1987;62(9):738-43.
32. Arrogante O, González-Romero GM, López-Torre EM, Carrión-García L, Polo A. Comparing formative and summative simulation-based assessment in undergraduate nursing students: nursing competency acquisition and clinical simulation satisfaction. BMC Nursing. 2021;20(1):92.
33. Høyte H, Jensen T, Gjesdal K. Cardiac auscultation training of medical students: a comparison of electronic sensor-based and acoustic stethoscopes. BMC Med Educ. 2005;5(1):14.
34. Madireddy S, Rufa EP. Maintaining Confidentiality and Psychological Safety in Medical Simulation. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan; [Updated 2023 May 1].
35. Torralba KD, Jose D, Byrne J. Psychological safety, the hidden curriculum, and ambiguity in medicine. Clinical rheumatology. 2020;39(3):667-71.
36. Barsuk JH, Ahya SN, Cohen ER, McGaghie WC, Wayne DB. Mastery learning of temporary hemodialysis catheter insertion by nephrology fellows using simulation technology and deliberate practice. American journal of kidney diseases : the official journal of the National Kidney Foundation. 2009;54(1):70-6.
37. Wayne DB, Butter J, Siddall VJ, Fudala MJ, Wade LD, Feinglass J, et al. Mastery learning of advanced cardiac life support skills by internal medicine residents using

simulation technology and deliberate practice. Journal of general internal medicine. 2006;21(3):251-6.
38. Barrett MJ, Kuzma MA, Seto TC, Richards P, Mason D, Barrett DM, et al. The power of repetition in mastering cardiac auscultation. The American journal of medicine. 2006;119(1):73-5.
39. Spatz ES, LeFrancois D, Ostfeld RJ. Developing cardiac auscultation skills among physician trainees. International Journal of Cardiology. 2011;152(3):391-2.
40. Mangione S, Nieman LZ. Pulmonary auscultatory skills during training in internal medicine and family practice. American journal of respiratory and critical care medicine. 1999;159(4 Pt 1):1119-24.
41. Mangione S, O'Brien MK, Peitzman SJ. Small-group teaching of chest auscultation to third-year medical students. Academic medicine : journal of the Association of American Medical Colleges. 1997;72(10 Suppl 1):S121-3.
42. Sarkar M, Madabhavi I, Niranjan N, Dogra M. Auscultation of the respiratory system. Annals of thoracic medicine. 2015;10(3):158-68.
43. Arts L, Lim EHT, van de Ven PM, Heunks L, Tuinman PR. The diagnostic accuracy of lung auscultation in adult patients with acute pulmonary pathologies: a meta-analysis. Scientific Reports. 2020;10(1):7347.
44. Tokuda Y, Matayoshi T, Nakama Y, Kurihara M, Suzuki T, Kitahara Y, et al. Cardiac auscultation skills among junior doctors: effects of sound simulation lesson. International journal of medical education. 2020;11:107-10.
45. Kohan M, Changiz T, Yamani N. A systematic review of faculty development programs based on the Harden teacher’s role framework model. BMC Medical Education. 2023;23(1):910.

Table 1. Cardiorespiratory scenarios, simulated sounds and diagnosis used in pre and post-test

Scenario	Simulated Sound	Diagnosis*
Cardiac		
A. A 28-year-old female patient, regular health check-up. Patient occasionally feels tired and shortness of breath when exerting. ECG shows right bundle branch block, referred to a cardiologist.	1. Wide fixed splitting S2	1. ASD
B. A 26-year-old male patient was admitted to the hospital due to sudden, severe chest pain while playing soccer. In the emergency department, the patient had pale skin, was sweating, and complained of difficulty breathing.	2. Gallop S3 3. Diastolic murmur	2. AR
C. A 51-year-old female patient was examined for shortness of breath. For about 3 months, the patient had a hoarse voice and difficulty swallowing. For the past 2 weeks, the patient had shortness of breath and chest pain when exerting.	4. Loud S1 5. Diastolic rumble	3. MS
D. A 57-year-old male patient presented with shortness of breath. The patient had a history of rheumatic heart disease at age 12. He was hospitalized for treatment but did not return for follow-up.	6. Systolic and diastolic murmurs	4. MSR
Respiratory		
A. A 26-year-old man came for a routine health check-up and had his lungs examined.	1. Normal vesicular breath sounds	
B. A 25-year-old female patient presented with shortness of breath. She reported coughing and choking while eating, followed by difficulty breathing.	2. Wheeze Low pitched Rhonchi	
C. A 60-year-old male patient presented with shortness of breath. He had a 30-pack-year smoking history and was diagnosed with chronic obstructive respiratory disease.	3. Wheeze End Expiratory	
D. A 45-year-old male patient came to the clinic because of a persistent cough with green sputum. History of respiratory tuberculosis 5 years ago.	4. Crackles - Very Coarse	

E. A 65-year-old male patient presented with fever and right chest pain. History of type 2 diabetes mellitus for 10 years. Fever, cough with green sputum and chest pain for about 1 week.	5. Pleural Rub 6. Crackles - Fine

* No required diagnosis for respiratory performance. ASD - Atrial Septal Defect; AR - Aortic Regurgitation; MS - Mitral Stenosis; MSR - Mitral Stenosis and Regurgitation.

Table 2. The acute and short-term efficacy of the SAM II®-based training

		Cardiac	Respiratory
Pre-test (T0)	Median [IQR]	4 [3 – 6]	3 [3–5]
Post-test 1 (T1)	Median [IQR]	5 [4–6]	5 [4–5]
Post-test 2 (T2)	Median [IQR]	5 [4–6]	4 [3–5]
Friedman[#]	P value	<0.001	<0.001
(T1–T0)[a]	Median [IQR]	1 [-1–2]	1 [0–2]
	P value	<0.001	<0.001
(T2–T0)[b]	Median [IQR]	1 [-1–2]	0 [-1–2]
	P value	<0.001	<0.001
(T2–T1)[c]	Median [IQR]	0 [-2–1]	0 [-2–1]
	P value	0.051	<0.001

[#] *The Friedman test was used to compare T0, T1, and T2. Significant level: $p < 0.05$ (α level).*
[a] *The differences in the scores measured at posttest 1 (right after the SAM II®-based training) and pretest.*
[b] *The differences in the scores measured at posttest 2 (after 2 months of clinical rotations) and pretest.*
[c] *The differences in the scores measured at posttest 2 (after 2 months of clinical rotations) and posttest 1 (right after the SAM II®-based training).*
[a, b, c]*: The Wilcoxon signed ranks test (two-tailed) was conducted to compare pairwise time points.*
Significant level: $p < 0.017$ (adjusted α level).

Table 3. The effect of educator qualifications and prior clinical exposure on auscultation performance

	Total	**Prior clinical exposure**	
	(N=370)	**Yes (N=169)**	**No (N=201)**
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Cardiac			
Clinical Faculties	-0.15 (0.33) (p-value=0.64)	-0.33 (0.46) (p-value=0.47)	0.45 (0.53) (p-value=0.39)
Simulation Educators	0.33 (0.44) (p-value=0.45)	0.09 (0.61) (p-value=0.88)	1.05 (0.69) (p-value=0.13)
	R-squared=0.05	R-squared=0.09	R-squared=0.03
Respiratory			
Clinical Faculties	0.12 (0.22) (p-value=0.58)	0.32 (0.31) (p-value=0.30)	0.03 (0.37) (p-value=0.94)
Simulation Educators	-0.23 (0.28) (p-value=0.42)	-0.14 (0.38) (p-value=0.70)	-0.39 (0.45) (p-value=0.39)
	R-squared=0.01	R-squared=0.03	R-squared=0.01

Model adjusted for groups of students and sex

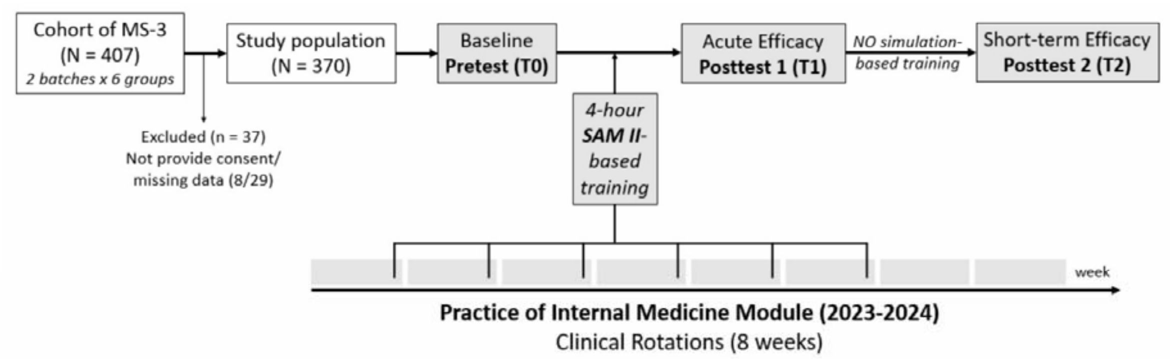

Fig.1. The present study design with SAM II®-based training. The Practice of Internal Medicine Module comprised an 8-week clinical rotation and was scheduled for two batches of students. In each batch, the students were divided into six teaching groups and received a single SAM II® intervention (represented by thin vertical lines inserted into the shaded area). MS-3: Third-Year Medical Students.

Fig.1.The present study design with SAM II based training

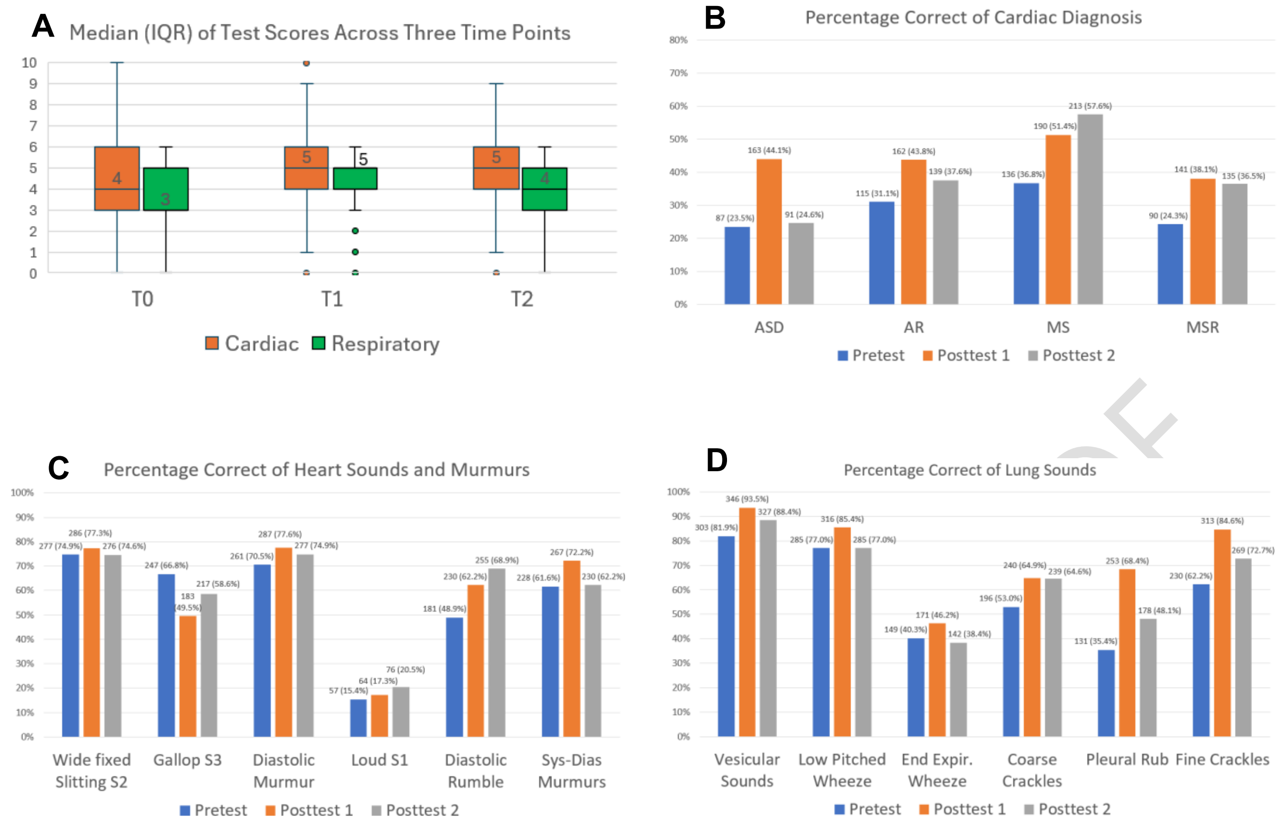

Figure 2. Accuracy rates of cardiorespiratory findings and diagnoses. Pre-test, Post-test 1, and Post-test 2 refer to T0, T1, and T2, respectively, as described in the text. **(A)** Median (IQR) of test scores across three time points for cardiac (orange) and respiratory (green) auscultation performance. Boxes represent the IQR, the horizontal line within the box and value indicates the median, and dots outside the whiskers denote outliers. **(B)** Frequency and percentage correct % of cardiac diagnosis based on scenarios and auscultation findings in (C), including atrial septal defect (ASD); aortic regurgitation (AR); mitral stenosis (MS); mitral stenosis and regurgitation (MSR). **(C-D)** Frequency and percentage correct % of cardiac and respiratory auscultation performance. The data are summarized in Table 2 and S4.

A

B

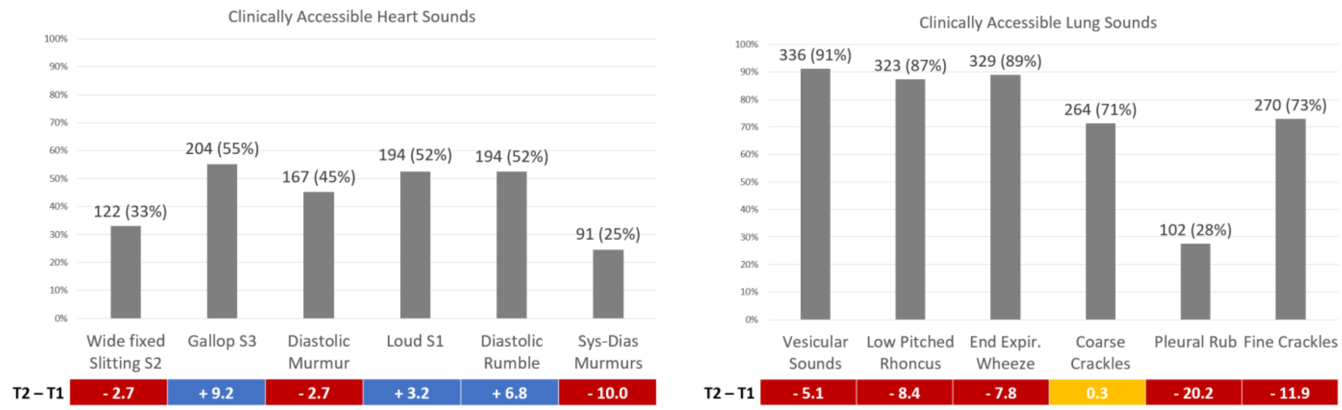

Figure 3. Accessible heart and lung sounds in clinical rotations. (A-B) Frequency and percentage of students who could access patients with clinically relevant conditions. Absolute differences in percentage correct between posttest 2 (T2) and posttest 1 (T1) were depicted under diagrams with increased (blue), unchanged (orange), and decreased (red). The questionnaire of clinical encounters was described in the text and Table S1.