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Simulation-Based Learning Enhances Sport Massage Competence in Physical Education Students: A Quasi-Experimental Study

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ABSTRACT

Background & objective: This study aimed to examine the effectiveness of simulation-based learning (SBL) in improving sport massage competencies among Physical Education students, with particular emphasis on psychomotor skill development and applied performance outcomes.

Materials and methods: A quasi-experimental one-group pretest–posttest design was employed. Thirty undergraduate Physical Education students (18 males, 12 females) enrolled in a Sport Massage course participated in the study. The intervention consisted of four simulation-based learning sessions designed to replicate authentic sport massage scenarios. Sport massage competence was assessed using a validated observation rubric covering massage technique, procedure sequence, pressure and rhythm control, and therapeutic communication. Data were analyzed using descriptive statistics, paired-sample t-tests, Cohen's d effect size, and normalized gain (N-Gain) analysis at a significance level of $\alpha = .05$.

Results: The results demonstrated a statistically significant improvement in overall sport massage competence following the SBL intervention ($t(29) = -12.46, p < .001$). The mean score increased from 68.40 (SD = 6.32) at pretest to 84.27 (SD = 5.41) at posttest, yielding a large effect size (Cohen's $d = 2.28$). Component-level analysis revealed significant gains across all assessed skills ($p < .001$), with the largest improvements observed in pressure and rhythm control and massage technique. The overall N-Gain score was 0.70, indicating high learning effectiveness, with 96.67% of participants achieving moderate-to-high learning gains.

Conclusions: Simulation-based learning is a highly effective instructional approach for enhancing sport massage competencies among Physical Education students. By providing realistic, structured, and repetitive practice opportunities, SBL facilitates meaningful psychomotor skill acquisition, improves performance consistency, and supports professional readiness. The integration of simulation-based strategies is strongly recommended for sport massage instruction in higher education physical education programs.

Keywords

simulation-based learning; sport massage; physical education students; psychomotor skills; skill acquisition.

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INTRODUCTION

Global and Theoretical Context

Sport massage has become an important component of sports and exercise-related care, particularly in contexts involving athlete recovery, physical readiness, and management of exercise-related muscular discomfort. Previous reviews have reported that massage may influence aspects of recovery, muscle soreness, flexibility, and sport or exercise performance, although the magnitude of its effects varies according to the outcome, timing, and characteristics of the intervention (Best et al., 2008; Brummitt, 2008; Dakić et al., 2023; Sriwongtong et al., 2020). The increasing use of manual interventions in sport settings creates a corresponding need for Physical Education graduates to develop appropriate practical competence so that sport massage techniques can be performed systematically, accurately, and safely.

Sport massage competence is not exclusively a theoretical construct. Effective performance requires the integration of

procedural knowledge and psychomotor abilities, including accurate hand positioning, appropriate massage movements, control of pressure and rhythm, adherence to procedural sequences, and professional communication with the recipient. Fundamental techniques such as effleurage, petrissage, friction, and tapotement require repeated practice to achieve precision, consistency, and appropriate movement control (Brummitt, 2008; Moraska, 2005). Therefore, students may understand the theoretical principles of sport massage without necessarily being able to demonstrate competent manual performance. The development of competence requires instructional conditions that allow learners to observe correct procedures, perform the techniques repeatedly, receive feedback, and correct performance errors.

Conventional approaches to teaching practical skills commonly involve lecturer explanation, demonstration, guided practice, peer practice, and laboratory activities. Although these approaches provide important foundations for learning, they may

not consistently provide sufficient opportunities for repeated and standardized practice. In technical and health-professions education, differences in the amount of supervised practice and feedback may influence the development of procedural skills (Bederson et al., 2024; Surabenjawong et al., 2020). This issue is particularly relevant to sport massage because incorrect pressure, inappropriate movement, poor sequencing, or inadequate communication may compromise the quality and safety of the procedure.

Simulation-based learning (SBL) provides an instructional environment in which learners can practice realistic procedures under controlled conditions. Simulation allows students to repeatedly perform target skills, receive immediate or structured feedback, identify errors, and refine their performance without immediately exposing actual clients to unnecessary risks (Bradley, 2006; Lateef, 2010). Simulation has consequently been incorporated into various health-professions curricula for the development of technical, procedural, communication, and clinical competencies. Evidence from physical therapy education indicates that simulation can provide structured opportunities for students to develop practical skills and professional readiness (Mori et al., 2015; Stockert et al., 2022).

The theoretical mechanism of SBL is particularly relevant to procedural and psychomotor learning. Repeated practice within a structured environment provides opportunities for learners to coordinate movement, reduce performance errors, and improve consistency. Research on simulator-based procedural training suggests that structured practice can support the progression from initial understanding of a procedure toward more efficient and consistent execution (Shahriari-Rad et al., 2017; Shanks et al., 2010). Similarly, physical practice has been shown to contribute to clinical skill learning in kinesiology education (Perreault et al., 2019). Applied to sport massage, these mechanisms suggest that simulation may facilitate competence by repeatedly exposing students to authentic massage procedures while allowing them to refine technique, pressure, rhythm, sequence, and communication.

Critical Review of Existing Evidence

Although simulation-based learning has received increasing attention in health-professions education, the existing evidence is heterogeneous in terms of participants, intervention characteristics, outcome measures, and research designs. Hough et al. (2019), for example, examined simulation-based education among physiotherapy students and reported improvements in student self-efficacy related to pediatric assessment and management. This finding supports the educational value of simulation but primarily reflects a confidence-related outcome rather than objectively assessed manual performance. Similarly, (Stedje & Herzog, 2021) examined simulated experiences among athletic training students and reported changes in self-confidence and perceptions of learning. These findings suggest potential benefits of simulation but also demonstrate that outcomes may depend on whether competence is assessed through self-report or direct performance measures.

More rigorous comparative evidence has also produced important insights. Sandoval-Cuellar et al. (2021) conducted a randomized controlled trial involving physiotherapy students and compared simulated-patient and role-playing approaches for clinical decision-making related to low back pain. The study demonstrated improvements in the assessed learning outcomes, but the findings also indicate that different simulation formats may produce different educational experiences. This suggests that the

term simulation-based learning should not be treated as a uniform intervention; its effectiveness may depend on scenario design, instructional guidance, practice opportunities, feedback, and the outcome being measured.

Evidence from physical therapy education further supports the potential role of simulation while demonstrating considerable methodological variation. Mori et al. (2015) reviewed simulation learning experiences within physical therapy entry-to-practice curricula and identified simulation as a potentially useful strategy for developing practical competencies. Stockert et al. (2022) similarly documented the growing application of simulation-based education in physical therapist professional education. However, the reviewed studies varied in simulation modality, educational objectives, assessment procedures, and outcome measures. (Dairo et al., 2024) also examined simulation-based learning in physiotherapy practice placement, illustrating the potential contribution of simulation to students' knowledge, attitudes, and performance. Nevertheless, evidence derived from physiotherapy education cannot automatically be generalized to Physical Education students learning sport massage because the educational context, skill requirements, and performance criteria differ.

The evidence directly related to sport massage education is more limited. Tisna et al. (2022) reported that project-based e-learning improved cognitive and psychomotor learning achievement in a sports massage course. Tisna et al. (2024) likewise reported improvements in cognitive learning and sports massage skills following a project-based blended learning model. These studies are important because they demonstrate that active, technology-supported, and student-centered approaches can improve sport massage learning outcomes. However, project-based e-learning and blended learning are conceptually different from simulation-based learning. They do not necessarily provide the same combination of realistic procedural scenarios, repeated performance, controlled practice, and structured feedback that characterizes SBL.

Research Gap, Novelty, and International Contribution

Although previous studies show that simulation-based learning can support practical learning and that project-based or blended learning can improve sport massage outcomes, it remains unclear whether structured simulation-based learning can improve multidimensional sport massage competence among undergraduate Physical Education students when competence is assessed through direct performance across multiple skill domains.

The present study addresses this unresolved issue by applying four structured simulation-based learning sessions specifically designed around authentic sport massage scenarios. Unlike previous sport massage studies that primarily examined project-based e-learning or project-based blended learning (Tisna et al., 2022, 2024), the present intervention emphasizes simulated performance situations in which students repeatedly practice sport massage procedures. The study also evaluates competence using a structured performance-based observation rubric covering four domains: massage technique, procedure sequence, pressure and rhythm control, and therapeutic communication.

This study contributes to the international evidence base by linking simulation pedagogy with multidimensional manual-skill assessment in Physical Education, extending evidence beyond medical and physiotherapy education. It provides quantitative evidence of performance changes following a structured four-session simulation intervention and examines the transferability

of simulation-based learning to sport massage instruction.

The novelty lies in integrating structured simulation, authentic sport massage scenarios, repeated practical performance, and multidimensional assessment. By assessing four technical and applied domains, the study identifies not only overall performance changes but also which competency components improve most, providing a more comprehensive understanding of simulation-supported sport massage learning.

Objectives and Hypotheses

The primary objective was to determine whether four

structured simulation-based learning sessions improved overall sport massage competence among undergraduate Physical Education students. A secondary objective was to examine changes in four competence domains: massage technique, procedure sequence, pressure and rhythm control, and therapeutic communication. It was hypothesized that posttest competence scores would be significantly higher than pretest scores for overall sport massage competence and for each of the four assessed domains..

MATERIALS AND METHODS

Participants

The study cohort consisted of 30 fourth-semester Physical Education students (18 males, 12 females) enrolled in the Sports Massage course at a university in Indonesia. Participants were recruited via purposive sampling, with the inclusion criterion of having completed basic courses in anatomy and physiology of sports. Data collection occurred during the even semester of the 2024/2025 academic year at the Physical Education and Health Laboratory.

Study Organization

This study adopted a quasi-experimental design featuring a one-group pretest-posttest framework to evaluate improvements in students' sports massage skills before and after simulation-based learning implementation. This approach is suitable for educational interventions lacking full randomization or control over extraneous variables, such as practical lectures.

Test and Measurement Procedures

Sport massage competence was assessed using a structured performance-based observation instrument designed to evaluate students' practical skills in sport massage application. The instrument was developed based on established principles of sport massage practice and relevant learning outcomes of the Sport Massage course. It comprised four core skill components: (1) massage technique, (2) procedure sequence, (3) pressure and rhythm control, and (4) therapeutic communication

Table 1. Sport Massage Competence Assessment Instrument

Skill Component	Indicators Assessed	Description of Measurement	Scoring Scale
Massage Technique	Hand positioning, movement accuracy, technique execution	Assesses the correct application of fundamental sport massage techniques (effleurage, petrissage, friction, tapotement), including hand placement, movement precision, and smoothness	0–100
Procedure Sequence	Order of techniques, continuity, protocol adherence	Evaluates the logical and systematic sequence of massage procedures in accordance with standard sport massage protocols	0–100
Pressure and Rhythm Control	Pressure consistency, rhythm stability, adaptability	Measures the appropriateness, consistency, and control of applied pressure and	0–100

Therapeutic Communication	Verbal interaction, non-verbal cues, professionalism	movement rhythm during massage performance Assesses clarity of communication, client interaction, safety instructions, and professional demeanor throughout the massage session	0–100
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Note. Higher scores indicate better sport massage performance. The instrument was validated through expert judgment ($n = 3$) and demonstrated high internal consistency (Cronbach's $\alpha = 0.87$).

The pedagogical experiment followed a structured three-stage protocol: 1) Preparation Stage: Formulation of the Semester Learning Plan, development of sports massage skills observation instruments, and lecturer training on SBL application. 2) Implementation Stage: Delivery of SBL across four sessions, enabling students to practice massage techniques via simulated real-world scenarios. 3) Evaluation Stage: Conduct of pretest and posttest assessments, with skills evaluated using a performance rubric.

Statistical analysis

Data were analyzed using SPSS Statistics version 25. Descriptive statistics included means, standard deviations, minimum and maximum values, and 95% confidence intervals. Assumptions were assessed using the Shapiro–Wilk test for normality and Levene's test for homogeneity, with $\alpha = .05$. Intervention effects were evaluated using paired-sample t-tests comparing pretest and posttest scores for overall sport massage competence and its four components: massage technique, procedure sequence, pressure and rhythm control, and therapeutic communication. Mean differences, t-values, degrees of freedom, p-values, 95% confidence intervals, and Cohen's d were reported, with effect sizes interpreted as small (0.20), medium (0.50), or large (0.80). Learning gains were additionally assessed using normalized gain (N-Gain), categorized as high (≥ 0.70), moderate (0.30–0.69), or low (< 0.30). Frequencies and percentages were calculated for each category. All tests were two-tailed, with statistical significance set at $p < .05$.

Ethical Considerations

This study obtained ethical endorsement from the Universitas Pembangunan Masyarakat Indonesia Approve Number UPMI/Research-LPPM-7798 (ethics committee). Procedures complied with established ethical guidelines, including informed consent from participants, voluntary involvement, confidentiality, and adherence to the Declaration of Helsinki.

RESULTS

This section presents the findings of the study examining the effectiveness of simulation-based learning (SBL) in enhancing sport massage competencies among Physical Education students ($n = 30$). The results are organized into six subsections:

descriptive statistics, assumption testing, inferential analysis using paired-sample t-test, per-component skill comparisons, normalized gain (N-Gain) analysis, and the distribution of individual learning gains. All statistical analyses were performed

using SPSS version 25 with a significance level set at $\alpha = .05$.

Descriptive Statistics of Sport Massage Skill Performance

Table 2 presents the descriptive statistics of the overall sport

massage skill scores measured before (pretest) and after (posttest) the implementation of simulation-based learning. The scores were based on a validated observation rubric covering four skill components: massage technique, procedure sequence, pressure and rhythm, and therapeutic communication.

Table 2. Descriptive Statistics of Sport Massage Skill Scores (n = 30)

Measurement	Mean	SD	Min	Max	95% CI
Pretest	68.40	6.32	55	78	[66.04, 70.76]
Posttest	84.27	5.41	75	95	[82.25, 86.29]
Gain Score	15.87	6.97	—	—	[13.26, 18.47]

Note. SD = standard deviation; CI = confidence interval. Scores are based on a 100-point rubric scale.

As presented in Table 2, the mean pretest score was 68.40 ($SD = 6.32$), which increased to 84.27 ($SD = 5.41$) following the intervention, yielding a mean gain of 15.87 points (95% CI [13.26, 18.47]). The non-overlapping 95% confidence intervals between pretest and posttest means provide preliminary evidence of a meaningful shift in performance. Additionally, the reduction in standard deviation from 6.32 to 5.41 suggests that simulation-based learning not only elevated the overall performance level but also reduced inter-individual variability, indicating more consistent skill acquisition across participants.

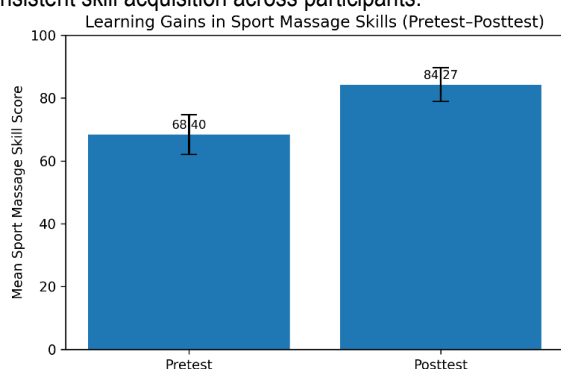


Figure 1. Learning gains in sport massage skills before and after the simulation-based learning intervention.

The bar chart illustrates a substantial increase in mean posttest scores compared to pretest scores, indicating meaningful improvements in overall sport massage performance following the intervention.

Testing of Statistical Assumptions

Prior to conducting the paired-sample t -test, the requisite statistical assumptions of normality and homogeneity of variance were examined. The Shapiro-Wilk test was employed to assess the normality of score distributions, while Levene's test was used to evaluate the equality of variances between the pretest and posttest conditions. The results of these diagnostic tests are summarized in Table 3.

Table 3. Results of Normality and Homogeneity Assumption Tests

Test	Variable	Statistic	p-value	Decision
Shapiro-Wilk	Pretest	0.958	.283	Normal
	Posttest	0.951	.167	Normal
Levene's Test	Pre-Post	1.478	.231	Homogeneous

Note. Normality assessed using the Shapiro-Wilk test ($\alpha = .05$). Homogeneity assessed using Levene's test ($\alpha = .05$).

The Shapiro-Wilk test indicated that both pretest ($W = 0.958$, $p = .283$) and posttest ($W = 0.951$, $p = .167$) score distributions did not significantly deviate from normality. Furthermore, Levene's test confirmed the homogeneity of variance between the two measurement conditions ($F = 1.478$, $p = .231$). Given that both assumptions were satisfied, the use of a parametric paired-sample t -test was deemed appropriate for the subsequent inferential analysis.

Paired-Sample t -Test Analysis

A paired-sample t -test was conducted to determine whether the mean difference between pretest and posttest scores was statistically significant. To complement the significance testing, Cohen's d was calculated as a measure of practical effect size. The results are presented in Table 4.

Table 4. Paired-Sample t -Test Results with Effect Size

Comparison	Mean Diff	SD Diff	t	df	p (2-tailed)	Cohen's d	95% CI of Diff
Pre-Post	-15.87	6.97	-12.46	29	< .001***	2.28	[-18.47, -13.26]

Note. *** $p < .001$. Cohen's d : 0.20 = small, 0.50 = medium, 0.80 = large (Cohen, 1988). CI = confidence interval of the mean difference.

The paired-sample t -test revealed a statistically significant improvement in sport massage skill scores following the simulation-based learning intervention ($t(29) = -12.46$, $p < .001$, 95% CI [-18.47, -13.26]). The effect size, as measured by Cohen's $d = 2.28$, exceeds the threshold for a large effect ($d \geq 0.80$), indicating that the intervention produced a substantial and practically meaningful improvement in students' sport massage competencies. This result provides strong quantitative evidence that simulation-based learning significantly enhances psychomotor skill performance among Physical Education

students.

Comparison of Pretest and Posttest Scores Across Skill Components

To provide a more granular understanding of the intervention's impact, paired-sample t -tests were conducted separately for each of the four assessed skill components. This component-level analysis allows for the identification of specific areas where simulation-based learning was most effective. The results are summarized in Table 5.

Table 5. Pretest-Posttest Comparison by Skill Component (n = 30)

Skill Component	Pretest		Posttest		Mean Difference	t	p
	M	SD	M	SD			
Massage Technique	66.83	7.14	85.50	5.28	18.67	-10.84	< .001
Procedure Sequence	69.17	6.88	83.00	5.93	13.83	-9.72	< .001
Pressure & Rhythm	67.50	6.51	86.33	4.87	18.83	-11.38	< .001
Therapeutic Comm.	70.10	5.76	82.23	5.48	12.13	-8.56	< .001

Note. M = mean; SD = standard deviation. All comparisons significant at $p < .001$ (two-tailed). $df = 29$ for all tests.

As illustrated in Table 5, all four skill components demonstrated statistically significant improvements following the intervention (all $p < .001$). The largest mean difference was observed in pressure and rhythm control ($M\Delta = 18.83$), followed closely by massage technique ($M\Delta = 18.67$). These two components showed the most pronounced improvements, suggesting that the tactile and kinesthetic practice afforded by simulation was particularly effective in refining manual dexterity and pressure calibration. Procedure sequence ($M\Delta = 13.83$) and therapeutic communication ($M\Delta = 12.13$) also improved significantly, though with relatively smaller gains, which may reflect the more cognitively complex nature of these skill domains.

Normalized Gain (N-Gain) Analysis by Skill Component

To evaluate the magnitude of learning improvement relative to the maximum possible gain, normalized gain (N-Gain) scores were calculated for each skill component using (Hake, 1998) formula: $g = (\text{posttest score} - \text{pretest score}) / (\text{maximum score} - \text{pretest score})$. The N-Gain scores were categorized according to established benchmarks: high ($g \geq 0.70$), moderate ($0.30 \leq g < 0.70$), and low ($g < 0.30$). The results are presented in Table 6.

Table 6. Average Normalized Gain (N-Gain) Scores by Skill Component

Skill Component	Average N-Gain	SD	Category	Interpretation
Massage Technique	0.72	0.11	High	$g \geq 0.70$
Procedure Sequence	0.68	0.13	Moderate	$0.30 \leq g < 0.70$
Pressure & Rhythm	0.74	0.10	High	$g \geq 0.70$
Therapeutic Communication	0.65	0.14	Moderate	$0.30 \leq g < 0.70$
Overall	0.70	0.09	High	$g \geq 0.70$

Note. N-Gain categories: High ($g \geq 0.70$), Moderate ($0.30 \leq g < 0.70$), Low ($g < 0.30$), based on (Hake, 1998).

The overall average N-Gain score of 0.70 ($SD = 0.09$) falls within the high effectiveness category, confirming that simulation-based learning produced educationally meaningful improvements across all skill dimensions. At the component level, pressure and rhythm control achieved the highest N-Gain ($g = 0.74$), followed by massage technique ($g = 0.72$), both classified as high. Procedure sequence ($g = 0.68$) and therapeutic communication ($g = 0.65$) fell within the moderate category, though they approached the upper boundary, indicating substantial learning gains in these areas as well.

DISCUSSION

Principal Findings

The present study examined changes in sport massage competence following structured simulation-based learning (SBL) among undergraduate Physical Education students. Overall competence increased from 68.40 ($SD = 6.32$) at pretest to 84.27 ($SD = 5.41$) at posttest, yielding a mean improvement of 15.87 points. The paired-samples t-test showed a significant difference, $t(29) = 12.46$, $p < .001$, with a large within-person effect ($d = 2.28$). These findings support the primary hypothesis and indicate substantial improvement in sport massage performance following the four-session SBL intervention. The results further suggest that structured, realistic practice may enhance manual dexterity and procedural accuracy by connecting theoretical knowledge with practical application. (Sukowati et al., 2026, p. 216).

Improvement was observed across all four competence domains. Massage technique increased by 18.67 points, procedure sequence by 13.83 points, pressure and rhythm

Distribution of Individual Learning Gains

To examine the spread of individual-level improvement, the overall N-Gain scores of all 30 participants were classified into three categories. Table 7 presents the frequency distribution of these individual gains.

Table 7. Frequency Distribution of Individual N-Gain Scores ($n = 30$)

N-Gain Category	Criteria	Frequency (n)	Percentage (%)	Cum. %
High	$g \geq 0.70$	17	56.67	56.67
Moderate	$0.30 \leq g < 0.70$	12	40.00	96.67
Low	$g < 0.30$	1	3.33	100.00
Total		30	100.00	

Note. Cum. % = cumulative percentage. Classification based on (Hake, 1998).

The distribution analysis reveals that the majority of participants ($n = 17$, 56.67%) achieved high N-Gain scores, while 12 students (40.00%) demonstrated moderate gains. Only one student (3.33%) fell within the low gain category. Cumulatively, 96.67% of participants achieved at least moderate learning gains, indicating that the simulation-based learning intervention was effective for the vast majority of the sample. These findings further reinforce the robustness of the intervention, demonstrating that its positive effects were not limited to a subset of high-performing students but were broadly distributed across the participant group.

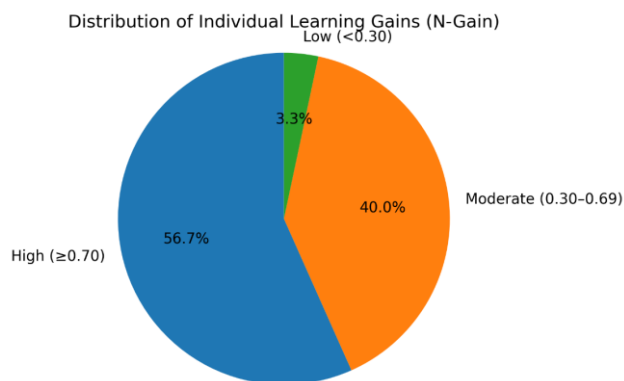


Figure 2. Distribution of individual learning gains based on normalized gain (N-Gain) categories.

The pie chart illustrates that more than half of the participants achieved high learning gains, while nearly all students reached at least a moderate level of improvement following the simulation-based learning intervention.

control by 18.83 points, and therapeutic communication by 12.13 points; all changes were statistically significant ($p < .001$). Thus, all secondary hypotheses were supported. The larger gains in pressure and rhythm control and massage technique may reflect the benefits of repeated physical practice, tactile calibration, movement coordination, and immediate correction of procedural errors. These findings suggest that SBL can strengthen both technical execution and applied communication skills in sport massage training (Reeves et al., 2019, p. 20).

Statistical significance should not be equated with clinical or professional competence. Although the large effect size indicates substantial improvement relative to within-participant variability, it does not demonstrate that students achieved a predefined competency threshold or were ready for independent practice. Because the study did not compare performance with established professional standards or practicing sport massage professionals, the findings should be interpreted as evidence of

substantial short-term improvement in assessed educational performance rather than proof of professional competence. The overall normalized gain was 0.70, with 56.67% of students showing high gain, 40.00% moderate gain, and 3.33% low gain. This distribution suggests that improvement occurred across most participants. However, N-Gain depends on baseline and maximum scores and should therefore be regarded as a descriptive indicator of learning gain rather than independent evidence of intervention effectiveness.

Comparison with International Evidence

The present findings are broadly consistent with the international literature indicating that simulation can support practical learning in health-professions and allied-health education, but the magnitude and interpretation of the present findings should be considered in light of differences in population, intervention dose, assessment, and research design.

Evidence from physical therapy education provides an important comparison. Mori et al. (2015, p. 201), in a systematic review of simulation learning experiences in physical therapy entry-to-practice curricula, found evidence that simulation can support specific skill acquisition and learner preparation, while also emphasizing that relatively few studies used randomized designs and validated outcome measures. Their review reported that simulator-based feedback could facilitate learning of specific practical skills and that simulated learning could contribute to clinical education without necessarily impairing learning outcomes. The present study extends this literature to a different educational population—Physical Education students—and to sport massage competence rather than general physiotherapy competencies. This distinction is important because sport massage involves highly tactile and movement-dependent skills that may respond particularly strongly to repeated physical practice. Additionally, current research underscores the timing of these interventions, noting that students who receive targeted simulation-based training immediately prior to clinical placements often achieve higher assessment marks than their peers (Tuttle & Horan, 2019, p. 17). Moreover, the integration of structured simulation tasks has been shown to reduce learner uncertainty, reinforcing the link between targeted practice and increased professional confidence (Kiernan, 2018, p. 49). More recent evidence also indicates substantial heterogeneity in simulation implementation. Stockert et al. (2022) reviewed SBE in physical therapist professional education and found that simulation was increasingly used across different content areas and clinical settings. However, the review identified frequent use of non-validated outcome measures and limited reporting or application of published simulation standards of best practice. The present study responds partially to this methodological concern by using a structured performance-based observation instrument, developed around four predefined domains, with expert judgment from three specialists and reported internal consistency of Cronbach's $\alpha = .87$. Nevertheless, internal consistency should not be equated with inter-rater reliability or construct validity; these issues remain relevant to interpretation.

The findings are comparable with Sandoval-Cuellar et al. (2021), who reported improved clinical decision-making among 42 physiotherapy students following simulation-based approaches, with no clear advantage of simulated patients over role-playing. However, their randomized two-group design differs from the present one-group study of 30 Physical Education students. Therefore, the larger within-group improvement observed here should not be interpreted as evidence that SBL is superior to other teaching methods. Collectively, the findings

suggest that structured simulation can support learning, while its comparative effectiveness may depend on the learning objectives and implementation context. Dairo et al. (2024) similarly reported potential benefits of simulation-based placement for preparing physiotherapy students for clinical practice, while emphasizing authenticity, interaction with service users, and adequate contact time. In contrast, the present study used a shorter four-session intervention and assessed directly observed sport massage performance rather than subsequent clinical placement outcomes. Thus, the current findings support short-term improvement in practical skills but do not establish whether these gains transfer to authentic athlete-care settings. Tisna et al. (2022) provide a contextually relevant comparison, reporting higher cognitive and psychomotor outcomes following project-based e-learning in an Indonesian sport massage course. Unlike their two-class, non-equivalent control-group design, the present study used a within-participant pretest–posttest design focused on structured simulation. Together, the findings suggest that active, practice-oriented approaches can support sport massage learning, but they do not establish that SBL is superior to project-based learning.

Differences across studies may partly reflect intervention dose and measurement sensitivity. Recent systematic evidence suggests that simulation frequency may influence learning outcomes, with greater performance improvements reported in studies using approximately 12–13 simulation experiences compared with those using 6–7 experiences (Wolden et al., 2025). Despite only four sessions, the present study showed substantial short-term improvement, possibly because sport massage competence relies heavily on repetitive motor practice. However, this interpretation remains tentative because simulation dose was not experimentally manipulated.

Differences in outcome measurement may partly explain variation across SBE studies. Reported measures range from self-efficacy and knowledge tests to OSCEs and direct performance assessment, limiting cross-study comparison Stockert et al. (2022). The direct performance rubric used here is appropriate for assessing manual competence, but the absence of blinded raters and objective biomechanical measures means that assessor or testing effects may have influenced the observed improvement.

Contextual differences are also important. Unlike much international SBL research conducted in physiotherapy and other health-profession programs, this study involved Indonesian Physical Education students in a sport massage course. Differences in curriculum, prior practical experience, educator preparation, resources, and professional expectations may affect implementation and learning outcomes. Thus, the findings extend the disciplinary and geographical evidence base but should not be assumed to generalize across educational contexts.

Theoretical, Methodological, and Practical Implications

The findings provide qualified support for skill-acquisition theories emphasizing progression through repeated practice, feedback, and increasingly coordinated performance. The strongest gains occurred in massage technique and pressure/rhythm control, which are directly dependent on physical repetition and sensorimotor coordination (Pacheco et al., 2019, p. 1892; Pasquier et al., 2023, p. 41). This pattern is compatible with the logic of progressive procedural skill acquisition: learners initially need explicit attention to task components and subsequently refine coordination and consistency through repeated practice. Simulator-based

procedural education has similarly emphasized the value of structured practice and feedback in developing procedural performance (Bosse et al., 2015, p. 22; Shanks et al., 2010, p. 79).

The findings also extend this theoretical perspective by showing that simulation may support domains beyond purely technical motor execution. Procedure sequence and therapeutic communication also improved significantly. This suggests that sport massage competence should not be conceptualized solely as manual dexterity. Instead, competence encompasses coordinated technical, procedural, interpersonal, and safety-related behaviors. Simulation provides a pedagogical context in which these dimensions can be practiced together. By integrating multifaceted scenarios, educators can ensure that students develop the necessary proficiency to navigate the complexities of real-world therapeutic encounters (Feruzakhan et al., 2025, p. 98). Consequently, educators should prioritize the inclusion of service users and authentic stakeholders in curriculum design to further bridge the gap between classroom-based simulations and unpredictable clinical settings (Dairo et al., 2024; Mulhall et al., 2025).

Methodologically, the study contributes by combining a structured intervention with multidimensional performance assessment. The assessment instrument included massage technique, procedure sequence, pressure and rhythm control, and therapeutic communication, and was subjected to expert judgment and internal-consistency analysis. This multidimensional approach is preferable to relying exclusively on self-confidence or knowledge tests when the educational outcome is a practical skill. At the same time, future studies should move beyond internal consistency toward inter-rater reliability, criterion validity, and blinded assessment. Furthermore, establishing a rigorous evaluation framework—incorporating standardized rubrics and expert-led debriefing—is critical for transforming simulated performance into reliable indicators of clinical readiness (Offiah et al., 2019, p. 268). Finally, integrating these rigorous assessment frameworks into broader health education curricula will foster a more consistent standard for training, ultimately facilitating a smoother transition from academic preparation to independent practice (Ajemba et al., 2024, p. 1840; Stedje & Herzog, 2021, p. 12).

For educational practice, the findings support using structured SBL as a complement to conventional demonstration and supervised practice in sport massage courses. An effective model could include standardized scenarios, clear performance criteria, repeated practice, immediate feedback, reflective debriefing, and gradually increasing learner independence. Simulation should complement, rather than replace, authentic practice with real recipients.

For curriculum development, simulation experiences could be mapped to specific competency domains and progressively increased in complexity. However, broader adoption should consider comparative evidence, resource requirements, educator training, and transfer to authentic practice. The present findings do not establish that SBL can replace conventional instruction or clinical experience.

Strengths and Limitations

Several strengths should be considered. The study assessed actual performance across four dimensions of sport massage competence rather than relying solely on self-reported outcomes.

It also reported confidence intervals, effect sizes, component-level analyses, and individual N-Gain distributions. The instrument was validated through expert judgment and demonstrated good internal consistency (Cronbach's $\alpha = .87$). However, the one-group pretest–posttest design limits causal inference. Without a control group, the observed improvements cannot be attributed exclusively to the SBL intervention, as maturation, concurrent learning activities, or other extrinsic factors may have contributed to the outcomes (Fitzgerald et al., 2019, p. 44).

Several limitations constrain causal and generalizable interpretation. First, the one-group pretest–posttest design without a control group prevents attributing improvements exclusively to SBL, as maturation, routine instruction, repeated assessment, lecturer influence, and concurrent learning activities may have contributed to the observed changes. Second, the purposive sample of 30 fourth-semester students from a single Indonesian university limits statistical precision and generalizability across institutions, educational levels, and cultural contexts. Third, although the performance rubric demonstrated expert-based content validation and good internal consistency (Cronbach's $\alpha = .87$), blinded scoring and inter-rater reliability were not reported, leaving potential assessor bias. Future studies should employ blinded assessors and report inter-rater reliability where feasible. Fourth, the absence of longitudinal follow-up limits conclusions regarding skill retention and transfer to authentic sport massage practice. Fifth, four component-level paired comparisons were conducted without multiplicity adjustment. Although the effects were consistent across domains, future confirmatory studies should prespecify primary and secondary outcomes and apply appropriate multiplicity control. Finally, participant flow, missing-data procedures, cost-effectiveness, safety outcomes, transfer to real athletes, and alignment with professional competency standards were not evaluated. These limitations restrict conclusions regarding long-term effectiveness, implementation value, and professional readiness.

Future Research

Future research should prioritize adequately powered randomized controlled and longitudinal studies comparing structured simulation-based learning (SBL) with conventional or alternative active-learning approaches. Multi-site studies are needed to assess generalizability, while dose-response studies should determine whether different simulation frequencies and durations enhance learning. Longitudinal research should also examine skill retention and transfer to authentic sport massage practice.

Further studies should investigate mediators and moderators such as practice time, feedback quality, self-efficacy, prior experience, and instructor expertise. Measurement should incorporate validated assessments, blinded scoring, inter-rater reliability, and objective performance indicators where feasible. Implementation and economic evaluations should additionally examine resource requirements, instructor training, and cost-effectiveness. Overall, future research should emphasize controlled comparisons, rigorous measurement, retention and transfer, dose-response effects, and multi-site replication to establish the educational and practical value of SBL in Physical Education.

CONCLUSION

This study found that structured simulation-based learning was associated with substantial short-term improvement in sport massage competence among undergraduate Physical Education students. Following four simulation sessions, students demonstrated higher performance across the overall competence measure and all four assessed domains: massage technique, procedure sequence, pressure and rhythm control, and therapeutic communication. These findings support the study hypotheses and indicate that structured simulation can provide a practical learning environment for developing multidimensional sport massage skills through repeated performance, feedback, and application of procedures.

The main contribution of this study is the extension of simulation-based learning evidence from predominantly health-

professions education to sport massage instruction within Physical Education, using a multidimensional performance-based assessment. The findings provide internationally relevant evidence that simulation can be incorporated into Physical Education curricula to support practical skill development. However, because the study used a one-group pretest–posttest design with a purposively selected sample from a single Indonesian institution and assessed short-term outcomes without a control group or long-term follow-up, the findings should not be generalized as evidence of causal superiority over other instructional approaches. Further multi-site, controlled, and longitudinal research is needed to establish the durability, transferability, and comparative effectiveness of simulation-based sport massage education.

DECLARATIONS

Ethical Approval

Ethical approval for this study was obtained from the Ethics Committee of Universitas Pembangunan Masyarakat Indonesia (Approval Number: UPMI/Research-LPPM-7798) prior to data collection. All study procedures involving human participants were conducted in accordance with applicable ethical principles.

Consent to Participate

All participants were informed about the purpose and procedures of the study before participation. Participation was voluntary, and participants provided informed consent to participate in the research.

Consent for Publication

Not applicable. This study does not report identifiable individual information, images, or other personal data that would require consent for publication.

Author Contributions (CRediT)

Nasution, A. F.: Conceptualization; Methodology; Investigation; Data Curation; Formal Analysis; Writing – Original Draft; Writing – Review & Editing.

Foret, R.: Conceptualization; Methodology; Validation; Supervision; Writing – Review & Editing; Project Administration.

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Conflict of Interest

The authors declare that they have no competing interests or conflicts of interest that could have influenced the design, conduct, analysis, interpretation, or reporting of this study.

Data Availability

The data supporting the findings of this study are not publicly available because they consist of participant-level educational assessment data. Data may be made available from the corresponding author upon reasonable request, subject to applicable ethical, privacy, and institutional restrictions.

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Generative AI tools were used solely to assist with language editing and clarity of presentation. The authors reviewed and verified all AI-assisted content and remain fully responsible for the accuracy, originality, and integrity of the final manuscript. Generative AI was not used to generate or manipulate research data, statistical analyses, or research findings.

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