

Long-Term Retention of Teamwork Skills After Simulation-Based Training in Acute Care

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Abstract

Simulation-based education is central to medical training, particularly in acute and cardiological care where teamwork is critical. This longitudinal study assessed long-term retention of non-technical skills using the Team Emergency Assessment Measure (TEAM).

688 clinicians (cardiologists, general practitioners, and nurses) were included. Mean TEAM scores rose significantly from 4.47 at baseline to 8.69 immediately post-course ($p < 0.001$) and remained at 6.98 after one year ($p < 0.001$). Although scores declined slightly from the immediate post-course level, they stayed substantially above baseline. Recent high-fidelity simulation and advanced life support training were independent predictors of better performance.

Conclusion: Simulation training yields substantial and durable improvements in teamwork, with partial retention at one year. Regular high-quality refresher programs are recommended.

INTRODUCTION

Medical education has progressively shifted from traditional, transmission-based models toward learner-centred, experiential approaches grounded in active learning and rigorous competency development [1]. In parallel, patient safety has emerged as a central priority across healthcare systems, driven by the need to reduce preventable adverse events and strengthen team-based performance in complex clinical environments [2]. Within this dual transition, simulation has become a foundational methodology for developing both technical and non-technical skills, providing a controlled yet realistic setting in which clinicians can practise decision-making, communication, leadership and coordinated action under conditions that mirror real-world pressure and uncertainty [1].

Cardiology and acute-care specialties exemplify this need particularly well. Increasing procedural complexity, rapid technological advances and the inherently interdisciplinary nature of cardiovascular care require healthcare teams to function with high levels of coordination and shared situational awareness. Simulation-based training offers an effective and safe means of preparing clinicians for these demands, allowing them to rehearse critical scenarios, manage infrequent but high-risk complications, and strengthen teamwork behaviours that directly influence clinical performance and patient outcomes [2, 3]. Effective communication—both among healthcare professionals and with patients—is fundamental to ensuring shared understanding and safe clinical decision-making, and simulation-based training plays a key role in strengthening these communication skills within realistic, high-stakes scenarios. [4]

Despite its widespread adoption, simulation remains resource-intensive and operationally demanding, underscoring the importance of evaluating its effectiveness through robust, longitudinal outcome measures[5]. While immediate improvements in teamwork and clinical performance are well documented, far fewer studies have examined how these gains are retained over time, and the evidence beyond six months is particularly limited [2]. Existing reports, such as the study by Wayne et al. on

advanced cardiac life support skills, suggest that important competencies may decay yet remain partially preserved months after training [6]. However, the determinants of such retention, across different professional roles, levels of experience, and training contexts, remain insufficiently understood. Standardised tools like the TEAM tool provide a reliable means of assessing teamwork performance, but their application in long-term follow-up studies remains scarce [7].

Evaluating simulation within a comprehensive educational framework also requires attention to higher-level outcomes. According to the Kirkpatrick model, enduring behavioural change and organisational impact represent the most meaningful indicators of training effectiveness, yet they are the least frequently studied due to their methodological complexity and the influence of concurrent contextual variables [8]. Identifying which learner characteristics and prior experiences contribute to greater benefit, such as exposure to high-fidelity simulation or advanced life support training, may help optimise programme design, allocate resources more efficiently and determine appropriate retraining intervals.

The primary objective of this study was to evaluate the impact of simulation-based training on teamwork performance using the TEAM instrument at three time points: before the course, immediately after, and one year later. Secondary objectives were: (1) to describe the demographic and professional profile of participants; (2) to develop a predictive model identifying factors associated with higher TEAM scores immediately post-intervention and at one-year follow-up; (3) to assess participant satisfaction and its predictors; and (4) to analyse trends in simulation activity over the six-year study period.

METHODOLOGY

This study was designed as a longitudinal observational analysis based on a prospective institutional registry of simulation-based training programmes delivered between 2018 and 2024. The programmes targeted clinicians working in cardiology, general practitioner and nurses, and included both simulation centre-based and in situ simulation activities. Only courses in which teamwork performance constituted an explicit learning objective and was formally assessed using the validated Spanish version of the TEAM instrument were eligible for inclusion [7]. Activities lacking structured teamwork evaluation or delivered outside the institutional simulation framework were excluded.

Participant eligibility was determined through the institutional registry. Eligible clinicians were those who attended a simulation education programme during the study period, completed the first simulation course of their initial training, allowing for collection of the baseline TEAM score, and were prospectively tracked for potential participation in subsequent courses. Exclusion criteria included incomplete baseline TEAM data, participation in training not aligned with the study's assessment requirements, or withdrawal of consent. A total of 817 participants were evaluated of whom 688 met enough collected data criteria (84% retention rate). Baseline characteristics of retained and non-retained participants did not differ significantly in age, sex, professional role or baseline TEAM score (Supplementary material, Fig. 1).

All training activities adhered to the INACSL Healthcare Simulation Standards of Best Practice, ensuring consistency in scenario design, facilitation and debriefing. Scenarios focused on acute cardiological emergencies requiring coordinated team responses and placed explicit emphasis on non-technical skills, including leadership, communication, situational awareness, task delegation and collaborative decision-making. Training sessions were conducted either in a high-fidelity simulation centre equipped with advanced manikins or in situ within clinical areas of two tertiary hospitals and a primary care centre. Each session lasted between four and eight hours and was facilitated by two experienced instructors with formal training in simulation pedagogy and debriefing, maintaining an instructor-to-learner ratio not exceeding 1:8. Professional actors trained for this purpose participated as simulated patients, ensuring consistency of role portrayal and emotional fidelity across scenarios.

TEAM assessments were conducted by a single independent evaluator who was not involved in facilitation, instruction or scenario management. This approach minimised the risk of halo effects and enhanced the objectivity of ratings. Data collection followed a standardised timeline: baseline TEAM assessment was recorded immediately after the first scenario of the participant's initial course and before any debriefing occurred; the post-course assessment was obtained after the final scenario of the same course; and the one-year follow-up assessment was conducted after unique evaluative scenario performed attended approximately twelve months later. Additional variables included age, sex, professional role (attending physician, resident or nurse), workplace (primary care vs hospital care), prior exposure to high-fidelity simulation or advanced life support (ALS) training within the preceding two years, and any additional relevant training completed between assessments focused on soft skills.

All data were anonymised, coded and stored in secure password-protected databases. Descriptive statistics were used to characterise the sample and explore distributions of baseline variables. Longitudinal changes in TEAM scores and predictors of performance were examined using linear mixed-effects models with a random intercept for each participant to account for within-individual correlation across repeated measures. Fixed effects included demographic characteristics, professional role, training setting, prior exposure to simulation or ALS, and satisfaction scores. Model selection was guided by the Akaike and Bayesian Information Criteria, and statistical significance was set at $p < 0.05$. Assumptions of model linearity, homoscedasticity and normality of residuals were assessed graphically and analytically. All analyses were performed using STATA 19th version.

Missing data were handled according to STROBE recommendations. Missing outcome data occurred exclusively at follow-up due to participants not returning for subsequent training. Given the robustness of mixed-effects models in managing unbalanced longitudinal datasets under a missing-at-random assumption, no imputation was performed. Sensitivity analyses comparing retained and non-retained participants suggested no systematic differences in key baseline variables.

RESULTS

A total of 43 simulation courses were delivered between 2018 and 2024 across hospital-based and primary care settings. During this period, 688 clinicians participated in at least one eligible activity. The mean age of participants was 36.5 years (SD 8.74), and the majority were women (n = 481; 69.9%). The professional distribution included 438 attending physicians (63.6%), 87 medical residents (12.6%) and 163 nurses (23.7%). Most clinicians had not completed a high-fidelity simulation course in the preceding two years (77.5%) nor an ALS course during the same period (53.8%). Detailed baseline characteristics are presented in Table 1.

Table 1

Table 1 Basal characteristics of the study population.	
Variable	Value
Age (mean ± SD)	36.48 (8.74)
Sex	
Male	481 (69.91%)
Female	207 (30.09%)
Professional type:	
Consultant	438 (63.66%)
Nurse	163 (23.69%)
Resident	87 (12.65%)
Previous courses	
High-fidelity simulation < 2 years (HFSim): Yes	155 (22.53%)
ALS course < 2 years: Yes	318 (46.22%)
Surveys	
Training satisfaction (scale 0–10)	9.76 (0.46)
TEAM1 SCORE previous (Survey 1 - S1)	4.47 (1.23)
TEAM1 SCORE Post (Survey 2 - S2)	8.68 (0.64)
TEAM1 SCORE 1 Year (Survey 3 - S3)	6.98 (1.01)

Participant engagement in simulation-based training increased progressively throughout the study period. The number of attendees per year almost doubled in 2024 compared with 2019, reflecting the expansion of institutional simulation capacity and demand This upward trend was observed across all professional categories and training settings, suggesting a sustained institutional commitment to simulation as a core educational strategy (Fig. 1).

Longitudinal TEAM assessments demonstrated significant improvements in teamwork performance across time. Mean TEAM scores increased from 4.47 (SD 1.23) at baseline to 8.69 (SD 0.64) immediately after training and remained substantially above baseline at the one-year follow-up, with a mean score of 6.98 (SD 0.46) (Fig. 2). All comparisons were statistically significant: baseline versus post-course ($p < 0.001$), baseline versus one-year follow-up ($p < 0.001$) and post-course versus one-year follow-up ($p = 0.01$). These findings indicate strong short-term learning gains and partial retention of competencies at one year.

Satisfaction with the training was uniformly high. All participants completed the satisfaction questionnaire, with a mean score of 9.76 (SD 0.2) on a 1–10 scale. Satisfaction was not associated with demographic characteristics, professional role, workplace setting or prior exposure to simulation or ALS training.

Mixed-effects regression modelling revealed a strong independent effect of the simulation intervention on TEAM performance. Immediately after training, the intervention effect was large ($\beta = 4.208$; 95% CI 4.125–4.291; $p < 0.001$). At one year, performance remained significantly elevated compared with baseline ($\beta = 2.512$; 95% CI 2.429–2.595; $p < 0.001$). The random-intercept structure indicated moderate between-participant variability (variance ≈ 0.36), which decreased substantially (variance ≈ 0.18) after including variables representing recent exposure to high-fidelity simulation or ALS training. This reduction suggests that a considerable portion of individual differences in teamwork performance is explained by access to advanced simulation or resuscitation training within the preceding two years.

Recent participation in high-fidelity simulation was independently associated with higher TEAM scores ($\beta = 0.69$; 95% CI 0.58–0.81; $p < 0.001$), as was recent ALS training ($\beta = 0.57$; 95% CI 0.48–0.66; $p < 0.001$). These associations remained stable across all model specifications, indicating that both modalities exert complementary effects on teamwork performance, potentially through different cognitive and behavioural mechanisms.

Age showed a small negative association with TEAM scores in univariable analysis ($\beta \approx -0.011$; $p = 0.001$), but this effect was attenuated and lost statistical significance in multivariable models after accounting for recent training exposure. No meaningful associations were identified for sex, professional role, workplace profile, training setting (in situ versus simulation centre) or participation in additional courses during the follow-up period. Complete model outputs, including coefficients, standard errors and confidence intervals, are summarised in Table 2 and visually represented in Fig. 3.

Table 2

Model outputs including all characteristics and its relationship with skills retention according to multivariate models and its statistical significance.

Variable	Coefficient (β)	Standard error	z	p-value	Confidence interval 95% β
Survey 2 (post) score	4.208	0.042	99.44	< 0.001	[4.125, 4.291]
Survey 3 (1 year) score	2.512	0.042	59.35	< 0.001	[2.429, 2.595]
Gender (male)	-0.006	0.063	-0.09	0.927	[-0.128, 0.117]
Age (years)	-0.104	0.003	-1.52	0.01	[-0.150, -0.05]
Consultant professional	0.036	0.522	0.31	0.73	[-0.046, 0.262]
Nursing professional	0.046	0.069	0.67	0.502	[-0.089, 0.181]
Resident professional	-0.014	0.088	-0.16	0.871	[-0.187, 0.159]
Hospital-based work	0.062	0.058	1.06	0.287	[-0.052, 0.176]
On-site course	0.056	0.058	0.96	0.339	[-0.059, 0.170]
New course in between (yes)	0.054	0.167	0.33	0.745	[-0.272, 0.381]
ALS course last 2 years (yes)	0.569	0.048	11.91	< 0.001	[0.475, 0.663]
Simulation course last 2 years (yes)	0.688	0.058	11.95	< 0.001	[0.575, 0.801]
Satisfaction scale score	0.062	0.062	1.00	0.319	[-0.060, 0.184]

DISCUSSION

This longitudinal study provides robust evidence of the effectiveness of simulation-based training in strengthening teamwork competencies among healthcare professionals. The substantial improvement in TEAM scores immediately after the intervention, coupled with their sustained elevation at one year, indicates that simulation can produce both immediate and durable gains. These findings are consistent with prior systematic reviews showing that simulation enhances both technical and non-technical skills across diverse clinical settings [9]. They also align with broader analyses of team-training interventions, which report significant improvements in teamwork processes and performance outcomes [10].

The observed decline between immediate post-course performance and one-year follow-up mirrors patterns described in the literature. Research in advanced cardiac life support (ACLS) demonstrates that competencies deteriorate over time without deliberate reinforcement, although performance typically remains above baseline several months after training [11]. Our findings parallel this trajectory: although

performance declined from its post-course peak, participants maintained a meaningful advantage at one year, suggesting partial retention consistent with established models of learning consolidation and decay.

A major contribution of this study is the identification of strong predictors of higher TEAM performance. Recent participation in high-fidelity simulation and ALS training emerged as independent and complementary factors associated with better outcomes. These results resonate with the broader evidence base demonstrating that frequent, context-relevant exposure to structured team-training programmes yields superior outcomes compared with isolated or low-frequency interventions. For example, interprofessional simulation combined with principles of crisis resource management (CRM) or TeamSTEPPS has been shown to enhance leadership, communication and shared situational awareness in a sustained manner [12, 13]. Our findings reinforce the idea that not only the presence but also the recency and quality of training influence team performance.

The attenuation of the age effect in multivariable models further highlights an equity issue in access to advanced training. Rather than age per se being associated with lower performance, our results suggest that older clinicians may have received fewer recent opportunities for high-fidelity or ALS training. Similar observations have been described in the literature, where variability in access and programme design contributes to differential outcomes across clinical teams [10]. This underscores the importance of institution-level strategies to ensure equitable continuing education regardless of seniority.

Notably, we found no significant differences between in situ and centre-based simulation. This aligns with research suggesting that fidelity of equipment or environment is less critical than the rigour of instructional design, psychological safety, appropriate challenge and high-quality debriefing [14]. Likewise, the absence of role-based differences among attending physicians, residents and nurses is consistent with interprofessional literature demonstrating that teamwork skills are transversal and benefit equally from shared, scenario-based learning.

These results carry several practical implications. First, given the pattern of retention observed in this study and in prior ACLS research, annual refresher training may represent an evidence-based interval for maintaining non-technical skills. Second, the identification of recent simulation or ALS exposure as predictors opens the possibility of targeted interventions for individuals or groups with limited recent training. Third, the finding that simulation setting does not significantly influence outcomes supports the scalability of simulation programmes, particularly in resource-limited environments where in situ training may be more feasible.

This study has some limitations. TEAM scores reflect performance in simulated environments and do not directly capture workplace behaviour; therefore, transfer to clinical practice cannot be assumed. Attrition at the one-year follow-up introduces the possibility of selection bias, although no baseline differences were observed between participants retained and those lost to follow-up. The association between recent exposure to high-fidelity or ALS training and improved performance may be influenced by self-selection, as more motivated or higher-performing clinicians may be more likely to seek such

training. Finally, the observational design precludes causal inference, and residual confounding cannot be fully excluded.

CONCLUSIONS

This longitudinal study demonstrates that simulation-based training produces substantial and enduring improvements in teamwork performance among clinicians from diverse professional backgrounds. Although a partial decline in performance was observed one year after training, participants retained significant gains relative to baseline, supporting the long-term educational value of well-designed simulation programmes. Recent exposure to high-fidelity simulation and ALS training emerged as strong and consistent predictors of superior TEAM performance, underscoring the importance of regular, high-quality training opportunities for maintaining non-technical skills.

The absence of differences between simulation centre and in situ training reinforces the feasibility and scalability of simulation-based education across resource-variable environments, provided that instructional design and debriefing quality are preserved. Together, these findings offer empirically grounded guidance for the design, timing and targeting of simulation curricula and suggest that annual refresher training may represent an appropriate interval for sustaining teamwork competence in acute-care settings.

Declarations

Ethics approval and consent to participate: Ethical approval was obtained from the appropriate institutional review board, and informed consent was obtained from all participants.

Consent for publication: All authors reviewed and approved the final manuscript for publication.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: Conceptualization and methodology: A.D. Data collection: E. L, R.M, L.P and J.L.F . Data analysis: V.M and A.V . First manuscript draft: A.V, A.D and V.M

Figures and tables V.B and L.V . Supervision: R.M, F.A and R.S . Manuscript revision and correction: All authors.

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Figures

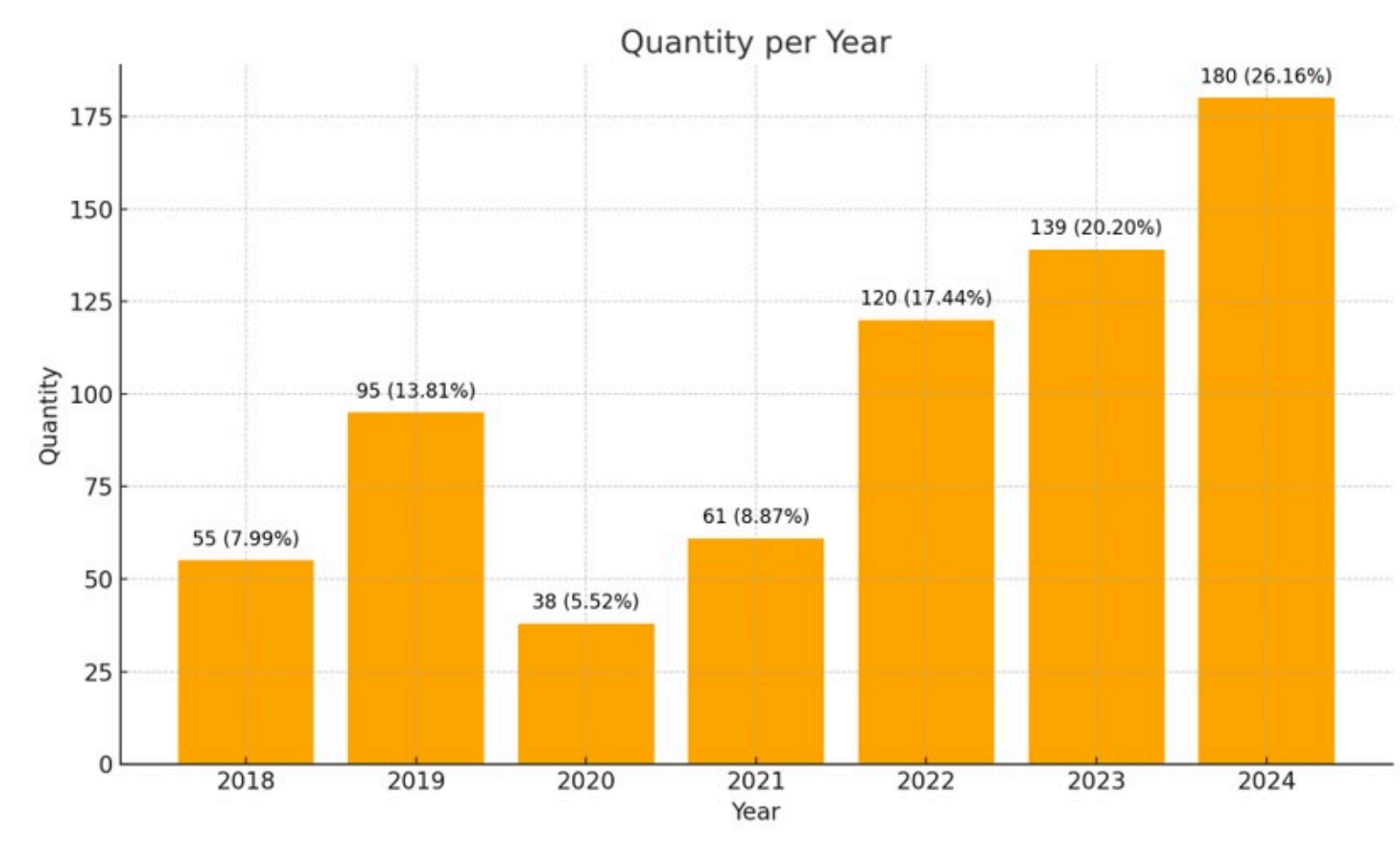


Figure 1

Temporal trends evolution according to attendees per year

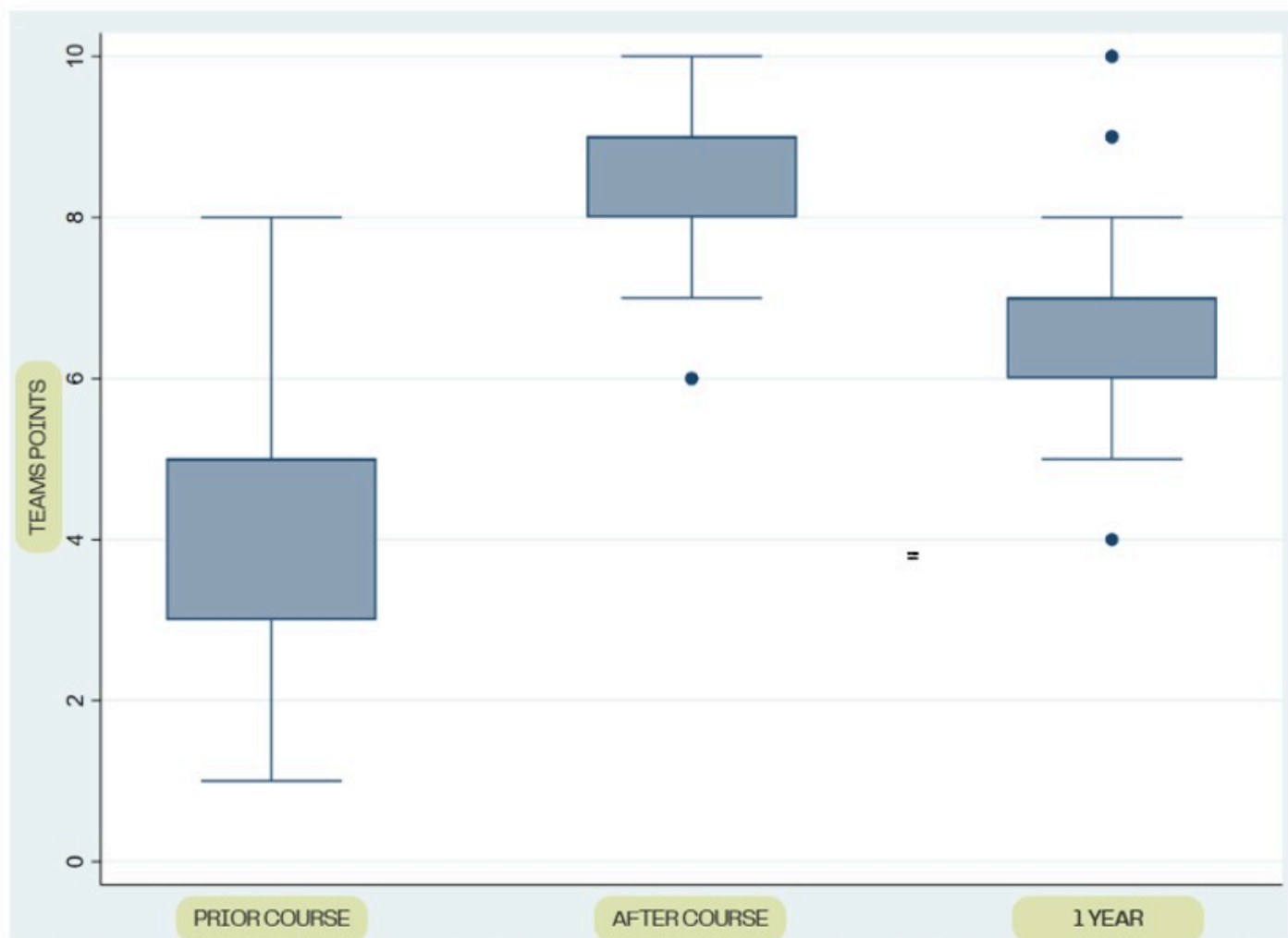


Figure 2

TEAMS points according to the assessed moment: Before and right after the simulation course and one year after.

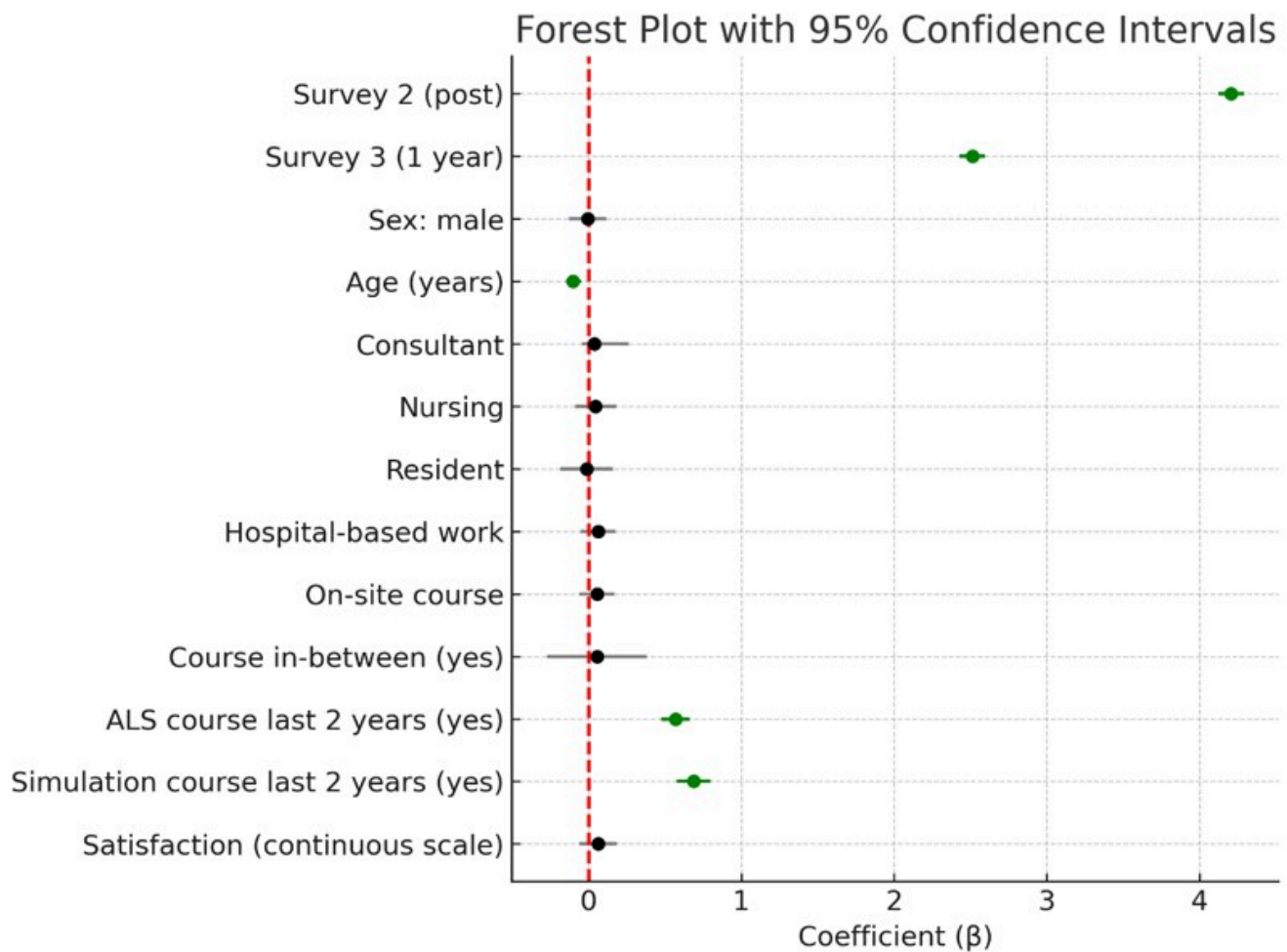


Figure 3

Forrest plot analysis showing Beta coefficient and its relationship with TEAMS scores

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