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Effectiveness of a new basic course incorporating medical trainer simulator for HEMS education in Japan: a pre-post intervention study

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Abstract

Background Japan's HEMS (Helicopter Emergency Medical Services) has recently shifted from quantitative expansion to qualitative improvement, highlighting the need for standardizing training and enhancing safety. This study aimed to evaluate a newly developed basic training course that integrates a Medical Trainer (MeTra) simulator, addressing the need for standardized education and improved safety in HEMS operations.

Methods In total, 208 HEMS professionals (83 doctors, 49 nurses, and 76 operational staff) participated in the revamped course, which combines e-learning, practical discussions, and MeTra simulation. Self-reported questionnaires assessing non-technical (4 items) and technical skills (6 items) using a 5-point Likert scale were administered pre- and post-course. Wilcoxon signed-rank tests evaluated changes in perceived competence. We also measured the MeTra simulator's fidelity and overall course satisfaction.

Results All non-technical and technical skills items improved significantly ($p < 0.05$), with notable gains in patient management during aircraft malfunction (average increase of 1.49 points) and fire extinguisher use (average increase of 1.11 points). Participants rated the MeTra simulator highly, especially for its enclosed environment, with 91% rating it four or higher, and for its communication system fidelity, with 96% rating it four or higher. Overall course satisfaction was high, with 96% rating it four or higher. Nonetheless, in line with Cook's caution on Kirkpatrick Level 2 data, these findings primarily reflect participants' perceptions rather than objective performance, and no control group was included.

Conclusions The new basic course incorporating the MeTra simulator may enhance self-reported competencies for diverse HEMS professionals. This standardized education program marks a significant step towards aligning Japan's HEMS training with international standards.

Keywords Air ambulances, Simulation Training, Emergency Medical Services, Crew Resource Management, Healthcare

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Introduction

Simulation and training for HEMS crews

Helicopter Emergency Medical Services (HEMS) demand specialized training to safeguard patients and crews when operating in time-critical, high-risk environments [1]. This initiative stems from worldwide and domestic evidence concerning HEMS safety and practical training. Prior studies indicate that many HEMS personnel believe better training and accident reporting can enhance safety [2], stressing the need for inter-agency collaboration and recurrent scenario-based training [3]. In parallel, simulation-based medical education has substantially improved team coordination, clinical expertise, and patient outcomes [4], with documented gains in structured decision-making and safety-related self-evaluations in HEMS [5]. Grounded in the "Standards for Safe Operation of Doctor Helicopters," formulated through Health and Labour Sciences Research [6], the new course's main objective is to bolster safety awareness and further stress that medical professionals are essential to flight operations. A Norwegian study by Abrahamsen et al. [7] discovered that HEMS doctors generally receive less simulation-based training and evaluation of non-technical skills than pilots or other crew, underscoring the significance of including such competencies in Japan's doctor helicopter system.

HEMS training formats vary widely, from traditional didactic lectures and tabletop exercises to immersive, high-fidelity simulation [8–10]. While low- or medium-fidelity models may offer cost-effectiveness and basic skills practice, high-fidelity simulators (including full-size helicopter mock-ups and realistic environmental cues) have been associated with more significant improvements in team coordination, situational awareness, and technical skill retention [11]. However, some studies suggest that more straightforward approaches may suffice for introductory skills or when resources are limited. Training outcomes can differ based on fidelity level, learner experience, and instructional design.

Previously, the Doctor Helicopter course primarily relied on classroom instruction. The revised program, however, shifts toward practical, simulation-based training. An earlier report demonstrates that simulation-based programs can be more effective than alternate learning strategies [12]. This transition resonates with the "joining a conversation" concept in medical education, where newcomers must rapidly assimilate specialized knowledge and collaborative methods within an already-established system [13].

HEMS in Japan and rationale for a new basic course

Japan's HEMS, known as the "Doctor Helicopter," began operations in April 2001 and by April 2022 had extended coverage to all 47 prefectures [14]. This expansion has enabled earlier pre-hospital medical intervention and improved access to emergency care in rural and remote areas, an impressive quantitative achievement. Nonetheless, the nation faces a pressing need to enhance the qualitative aspects of HEMS, such as standardized safety protocols, comprehensive crew training, and interprofessional communication [15].

Since 2001, the Japanese Society for Aeromedical Services (JSAS) has offered the "Doctor Helicopter Course," attended by multidisciplinary personnel: doctors, nurses, pilots, mechanics, and operation managers. Although this course has been held 54 times as of July 2024, its original format relied heavily on classroom instruction. Following Japan's first and only Kanagawa Doctor Helicopter crash in 2015, national oversight committees recognized the need to strengthen safety measures and expand practical, simulation-based training components [6]. In parallel with international trends in aeromedicine and increasingly stringent mandates, the JSAS Doctor Helicopter Training Committee redesigned its curriculum, ultimately introducing a new basic course in November 2022.

This revised program was developed to meet emerging demands outlined in the "Standards for Safe Operation of Doctor Helicopters" [6], emphasizing that medical professionals are integral to flight operations.

The new basic course incorporates e-learning, scenario-driven discussions, and hands-on sessions using a high-fidelity simulator known as the MeTra (Medical Trainer). Previous research supports the effectiveness of advanced simulation in air medical training [11], which aligns with our rationale for integrating MeTra into the new curriculum. The course aims to bolster HEMS crews' safety awareness and technical proficiency by shifting from lecture-based methods to immersive simulation.

Given these considerations—global evidence on the benefits of simulation, Japan's unique HEMS expansion, and the urgent need for standardized, hands-on training—this study evaluates the content and impact of the newly launched basic course. We focus on technical and non-technical skill development in a sample of multidisciplinary HEMS professionals, assessing whether the integration of simulation-based methods can advance the qualitative goals of Japan's Doctor Helicopter program.

Method

Structure of the new basic course

Since its launch in October 2022, the new basic courses have been conducted eight times, with each refining the learning experience based on participant feedback and evolving educational needs. Substantially modified from the previous two-day classroom-based program, this course integrates (1) pre-course e-learning, (2) extended group discussions on practical topics, and (3) hands-on training using the MeTra simulator.

First, participants use a pre-course e-learning module covering foundational helicopter knowledge and critical safety management principles. This online component typically includes concise video tutorials, interactive quizzes, and scenario previews to ensure participants have a shared baseline of theoretical concepts before attending the in-person sessions. This preparatory step gives learners a foundational grasp of basic aircraft operations and potential risk factors inherent to HEMS missions.

Building on this theoretical groundwork, participants join extended group discussions to delve deeper into real-world applications. Facilitated by experienced instructors, these scenario-driven dialogues focus on challenges such as emergency landings, in-flight fires, and crew resource management strategies. Small, multidisciplinary groups—often doctors, nurses, pilots, mechanics, and operation managers—dissect each scenario collaboratively to explore communication tactics, teamwork dynamics, and prompt decision-making under high-pressure conditions. These reflective discussions also emphasize interprofessional awareness, helping each participant understand how different roles intersect and collectively uphold safety standards during helicopter operations.

Finally, the hands-on training portion employs the MeTra simulator, a high-fidelity system replicating core cockpit layouts, realistic cabin noise levels, vibrations, and other environmental factors. During simulator sessions, participants rotate through carefully scripted emergency scenarios, applying the theoretical insights from e-learning and the teamwork strategies honed in group discussions. Under guided observation, trainees practice critical communications, and rapid problem-solving—each exercise followed by targeted debriefs to reinforce best practices and pinpoint areas needing further improvement. By aligning online learning, scenario-based discussion, and immersive simulation into a cohesive learning cycle, this new basic course aims to elevate participants' technical proficiencies and their confidence and readiness for actual HEMS missions.

Introduction and functionality of MeTra (medical trainer) (Fig. 1)

Developed by Central Helicopter Service, Ltd. (Aichi, Japan), the MeTra simulator fully reproduces a helicopter interior. Although concern exists that high physical fidelity may overwhelm less-experienced learners [16], this simulator was designed to balance realism with educational benefit. Key features facilitate immersive training, including cabin noise reproduction, synchronized seat vibration, visual/video feeds, and in-flight communication systems. While it closely mimics the helicopter environment, MeTra does not include a dedicated patient manikin.

It includes the following features, each aligned with the recommended practice for immersive training:

- Reproduction of in-cabin noise, including engine start-up.
- Seat vibration synchronized with cabin noise.
- Display for projecting in-flight camera footage.
- Speaker output for in-flight communications.
- Recording capability for training sessions, allowing immediate post-training review.
- Real-time video monitoring from a separate room.
- Immediate post-training review and multi-disciplinary feedback sharing.
- Front window display showing external video from takeoff to landing.
- Training scenarios for handling external obstacles during various flight phases.
- Simulations of emergencies such as in-flight fires and water landings.

Overall program and evaluation approach

In designing and evaluating this new basic course, we recognized the importance of applying a rigorous, theory-informed framework, as Cheng et al. [17] recommended in their simulation-based research reporting guidelines. Accordingly, we adopted Kirkpatrick's four-level model [18], which encompasses reaction (Level 1), learning (Level 2), behavior change (Level 3), and results (Level 4). For this initial study, we particularly emphasized Levels 1 (participant reactions) and 2 (learning). Equally, we sought beyond merely asking "if it works" by examining how the course may foster skill acquisition—an approach aligned with Parker et al.'s call for capturing emergent outcomes and clarifying program mechanisms [19]. Thus, although we report pre-post questionnaire findings, we acknowledge that exploring the underlying processes is also crucial for meaningful program evaluation.

Research subject selection criteria

1. Research Subjects: Multidisciplinary personnel involved in doctor helicopter operations attending the new basic course organized by the Japan Society for Aeromedical Sciences between November 6, 2022, and June 9, 2024. This includes doctors, nurses, pilots, mechanics, and operations managers.
2. Inclusion Criteria:
    - Scheduled attendance at the New Basic Course.
3. Exclusion Criteria:
    - Inability to complete the questionnaire.

(a)

(b)

Fig. 1 (**a**) MeTra (Medical Trainer) Helicopter Simulator. MeTra, an advanced full-scale helicopter simulator, replicates a realistic medical transport environment. (**b**) MeTra in-flight. MeTra features authentic cabin noise, vibration, video displays, and communication systems to provide immersive training experiences for medical professionals in air ambulance scenarios

4. Discontinuation Criteria:
   - Voluntary withdrawal from the study.
   - Discontinuation of the course.

Participant characteristics

In total, 303 participants attended the new basic course. Of these, 216 completed pre-course questionnaires, and 299 completed post-course questionnaires. Ultimately, 208 participants had both pre-and post-course data and were included in the primary analysis. Among them, 114 reported prior experience; 94 reported no HEMS experience. None had previously attended the conventional course.

Course evaluation methodology

Because this was a single-group, pre–post design with no control group, our measures primarily capture participants' reactions and perceived learning (Kirkpatrick Level 2). Participants completed pre- and post-course questionnaires to gauge changes in their self-reported knowledge and skills after taking the new basic course. Although such self-reports can be valuable, they do not equate to objectively measured skill gains.

Questionnaire content and rationale

We aligned questionnaire items to the curriculum aims, in line with Cheng et al.'s recommendations for rigorous simulation-based research [17]. However, we did not use a validated non-technical skills tool, interpreting our results as preliminary. This is consistent with Parker et al.'s argument for exploring "how" an intervention shapes professional behaviors rather than merely reporting numeric changes [19].

Although "patient management during aircraft malfunctions" may blend technical and non-technical competencies, we categorized it under non-technical skills to match the course's design, which separately highlights procedural tasks versus CRM-based competencies.

Questionnaire structure and items

All participants completed a self-administered questionnaire before (pre-course) and after (post-course) the new basic training. The questionnaire consisted of five sections—(a) participant demographics, (b) non-technical skills, (c) technical skills, (d) MeTra simulator evaluation, and (e) overall assessment—each rated on a 5-point Likert scale. Specific response anchors varied by item type, as described below.

a. Participant Demographics.
   - Occupation (doctor, nurse, pilot, mechanic, operation manager, etc.)
   - HEMS experience (e.g., prior doctor-helicopter missions or flights).

b. Non-technical Skills.
   Four questions assessed participants' understanding of key non-technical domains (1 = "Don't understand at all," 5 = "Fully understand"):

   (1) Do you understand the cooperation system between flight crew and medical crew (CRM)?
   (2) Do you understand the response to emergency landings?
   (3) Do you understand the response to in-flight fires?
   (4) Do you understand how to respond to patients during aircraft malfunctions?

c. Technical Skills.
   Six questions evaluated participants' ability to perform specific technical tasks (1 = "Cannot do at all," 5 = "Can definitely do"):

   (1) Can you evacuate from the aircraft during an emergency landing?
   (2) Can you use a fire extinguisher in case of an in-flight fire?
   (3) Can you fasten your seatbelt?
   (4) Can you assume an impact-protection position during an emergency landing?
   (5) Can you use the radio in the helicopter?
   (6) Can you use a life jacket during a water landing?

d. MeTra Simulator Evaluation.
   Participants with prior HEMS experience compared the simulator environment to an actual helicopter using the following five items (1 = "Different," 5 = "Same"):

   - Vibration fidelity.
   - Noise reproduction accuracy.
   - Visual stimuli realism.
   - Enclosed environment authenticity.
   - Communication system (e.g., radio) similarity.

e. Overall Assessment.
   Four questions evaluated participants' perceptions of the simulator and the overall course. Each question was rated on a 5-point scale, as shown in parentheses:

   (1) How was the simulation using the training simulator (Metra?).
   (1 = Dissatisfied, 2 = Somewhat dissatisfied, 3 = Neutral, 4 = Somewhat satisfied, 5 = Satisfied)

(2) Do you think this training will be useful for your future activities?
(1 = Not useful, 2 = Not very useful, 3 = Neither agree nor disagree, 4 = Somewhat useful, 5 = Useful)
(3) Would you like to use this simulation again in the future?
(1 = Do not want to use, 2 = Might not want to use, 3 = Neither agree nor disagree, 4 = Might want to use, 5 = Want to use)
(4) Overall, how would you evaluate this course?
(1 = Dissatisfied, 2 = Somewhat dissatisfied, 3 = Neutral, 4 = Somewhat satisfied, 5 = Satisfied)

Analysis of questionnaire results

We compared participants' pre- and post-course evaluations to gauge any perceived skill enhancement attributable to the new basic course. We also assessed the MeTra simulator's fidelity to actual helicopter operations. Additionally, subgroup analyses examined possible differences based on participants' prior helicopter boarding experience (inexperienced vs. experienced) and on their professional roles (doctors, nurses, or operational staff).

Statistical analysis

We used descriptive statistics to summarize participant demographics (age, gender, occupation, helicopter boarding experience) as mean ± standard deviation or median [interquartile range] for continuous variables and frequency and percentage for categorical variables. The Wilcoxon signed-rank test assessed changes in non-technical and technical skills pre- and post-course.

For subgroup comparisons, we used the Mann-Whitney U test to examine differences between participants with versus without prior helicopter boarding experience. For occupation-based comparisons (doctors, nurses, and operational staff), we employed the Kruskal-Wallis test. When a test result reached statistical significance, we conducted post hoc pairwise comparisons with a Bonferroni adjustment to limit type I error inflation across multiple comparisons. However, because these subgroup analyses are exploratory, we acknowledge that this correction may be conservative and increase the possibility of type II errors, especially given our sample size. The purpose of these additional analyses is primarily hypothesis-generating rather than conclusive.

All statistical analyses were conducted using SPSS version 27.0 (IBM Corp., Armonk, NY, USA), with a significance level of 5% (two-sided).

Ethical considerations

This study was approved by our institutional review board (approval number: E24-0233) and conducted by the standards of good clinical practice and the Declaration of Helsinki. Participants were provided with the opportunity to opt, and no identifiable personal information was used.

Results

A total of 208 individuals participated in this study, including 83 doctors (39.9%), 49 nurses (23.6%), and 76 operational staff (36.5%). The mean number of HEMS missions was 24.93 ± 3.59, with 94 participants (45.2%) reporting no prior experience.

Non-technical skills

Table 1 summarizes the pre- and post-course comparisons, and Fig. 2 illustrates the distribution of responses across the 5-point Likert scale.

Before the course, mean comprehension scores in non-technical skills were CRM 3.66 ± 1.04 (69.71% ≥ 4),

Table 1 Pre- and Post-Curse comparison of HEMS technical and Non-Technical skill scores ($N = 208$)

Skill Category	Pre-Course Mean ± SD	Post-Course Mean ± SD	Mean Difference	*p*-value †
Non-Technical Skills				
CRM Understanding	3.66 ± 1.04	4.64 ± 0.55	+ 0.98	< 0.05
Emergency Landing Response	3.51 ± 1.09	4.70 ± 0.50	+ 1.19	< 0.05
In-flight Fire Response	3.41 ± 1.16	4.71 ± 0.51	+ 1.30	< 0.05
Patient Management during Aircraft Malfunction	3.04 ± 1.12	4.53 ± 0.63	+ 1.49	< 0.05
Technical Skills				
Emergency Aircraft Evacuation	3.51 ± 1.19	4.44 ± 0.69	+ 0.93	< 0.05
Fire Extinguisher Use	3.50 ± 1.20	4.61 ± 0.59	+ 1.11	< 0.05
Seatbelt Operation	4.50 ± 0.90	4.91 ± 0.36	+ 0.41	< 0.05
Impact-Protection Positioning	4.00 ± 1.11	4.81 ± 0.52	+ 0.81	< 0.05
Radio Operation	4.00 ± 1.25	4.73 ± 0.57	+ 0.73	< 0.05
Life Jacket Use	3.69 ± 1.20	4.71 ± 0.53	+ 1.02	< 0.05

†: Wilcoxon signed-rank test

Each item was scored on a 5-point Likert scale, where 1 = "Not at all" and 5 = "Very much."

The mean difference is calculated as (Post-Course– Pre-Course)

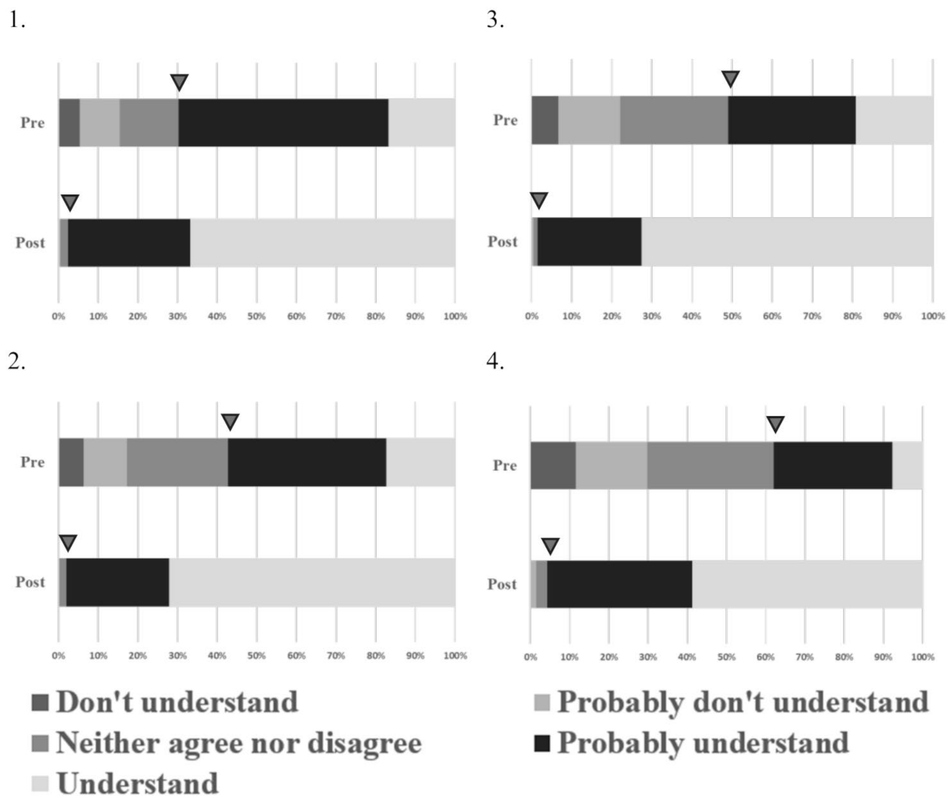

Fig. 2 Non-technical Skills (Items 1–4) After MeTra Training. This figure illustrates participants' self-rated comprehension (on a 5-point scale) for four non-technical skills: (**1**) Cooperation between flight and medical crew (CRM). (**2**) Response to emergency landings. (**3**) Response to in-flight fires. (**4**) Patient management during aircraft malfunctions. Pre-course (Pre) and post-course (Post) responses are shown as stacked bars, indicating the percentage distribution across five Likert categories. Triangles (▼) mark the cutoff for ratings of 4 or higher

emergency landing response 3.51 ± 1.09 (57.21% ≥ 4), in-flight fire response 3.41 ± 1.16 (50.0% ≥ 4), and patient management during aircraft malfunction 3.04 ± 1.12 (37.98% ≥ 4). After the course, these scores improved significantly: CRM 4.64 ± 0.55 (97.6% ≥ 4), emergency landing response 4.70 ± 0.50 (97.6% ≥ 4), in-flight fire response 4.71 ± 0.51 (98.56% ≥ 4), and patient management during aircraft malfunction 4.53 ± 0.63 (95.67% ≥ 4). Over 95% of participants rated themselves four or higher post-course in each category. The most significant mean increase was in patient management during aircraft malfunction (+ 1.49 points).

Technical skills

Table 1 also summarizes the pre- and post-course comparisons for technical competencies, while Fig. 3 illustrates the distribution of responses on the same 5-point scale.

Before the course, mean comprehension scores in technical skills were emergency aircraft evacuation 3.51 ± 1.19 (58.17% ≥ 4), fire extinguisher uses 3.50 ± 1.20 (54.81% ≥ 4), seatbelt operation 4.50 ± 0.90 (87.5% ≥ 4), impact-protection positioning 4.00 ± 1.11 (75% ≥ 4), radio operation 4.00 ± 1.25 (72.6% ≥ 4), and life jacket use 3.69 ± 1.20 (63.94% ≥ 4). After the course, these scores improved significantly: emergency aircraft evacuation 4.44 ± 0.69 (92.31% ≥ 4), fire extinguisher use 4.61 ± 0.59 (95.67% ≥ 4), seatbelt operation 4.91 ± 0.36 (98.56% ≥ 4), impact-protection positioning 4.81 ± 0.52 (97.12% ≥ 4), radio operation 4.73 ± 0.57 (95.67% ≥ 4), and life jacket use 4.71 ± 0.53 (97.12% ≥ 4). Over 90% of participants rated themselves four or higher post-course in each category. The most significant mean increase was fire extinguisher use (+ 1.11 points).

MeTra simulator comparison with actual Doctor helicopter (Fig. 4)

Of the 208 participants, 114 had prior HEMS experience and evaluated the MeTra simulator to actual doctor helicopter operations. Their mean post-course mean scores were vibration 3.45 ± 1.07 (57.90% ≥ 4), noise 3.75 ± 1.03 (71.93% ≥ 4), visual stimuli 3.82 ± 0.98 (65.79% ≥ 4), enclosed environment 4.38 ± 0.74 (91.23% ≥ 4), and communication environment 4.55 ± 0.61 (95.62% ≥ 4). Over 90% of experienced participants scored the enclosed and communication environments ≥ 4, indicating substantial similarity to real-world helicopter conditions.

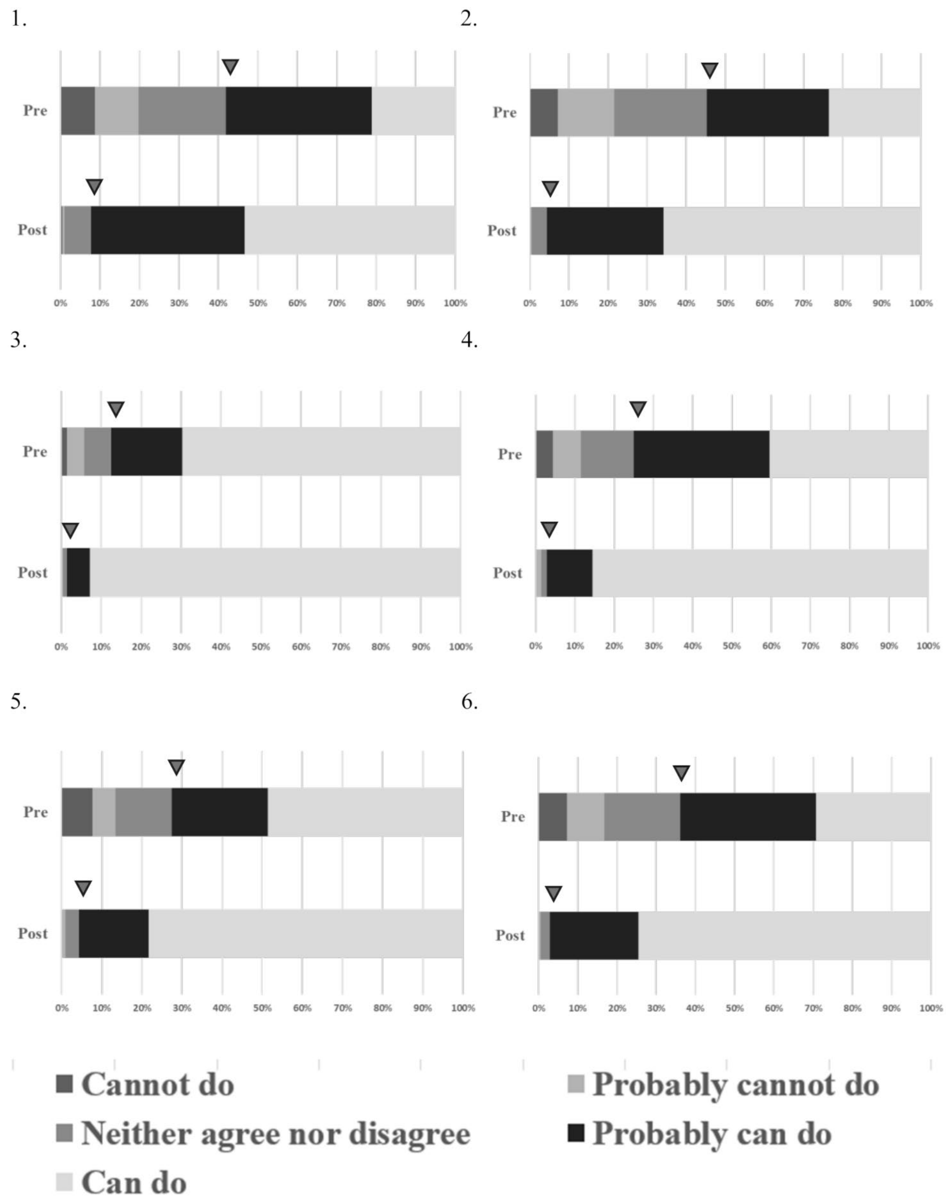

Fig. 3 Technical Skills (Items 1–6) After MeTra Training. This figure shows participants' self-rated proficiency (on a 5-point scale) in six technical skills: (**1**) Aircraft evacuation during an emergency landing. (**2**) Fire extinguisher operation in case of an in-flight fire. (**3**) Fastening seatbelts. (**4**) Assuming an impact-protection position. (**5**) Operating the helicopter radio. (**6**) Using a life jacket during a water landing. Pre-course (Pre) and post-course (Post) responses are presented as stacked bars, indicating the percentage distribution across the Likert categories. Triangles (▼) mark the cutoff for ratings of 4 or higher

Overall evaluation of MeTra simulator and course (Fig. 5)

For overall appraisal, mean scores were MeTra simulator effectiveness 4.71 ± 0.61 ($93.75\% \geq 4$), usefulness for future activities 4.78 ± 0.57 ($96.15\% \geq 4$), desire for future use 4.70 ± 0.63 ($92.18\% \geq 4$), and overall course satisfaction 4.74 ± 0.55 ($95.68\% \geq 4$). Most participants (96.15%) rated each aspect at four or higher, underscoring a high perceived utility and satisfaction with the new basic course and MeTra simulator.

Subgroup analyses

Analysis-based onboarding experience

Significant differences were observed in non-technical and technical skill items pre- versus post-course for all participants, regardless of whether they had prior helicopter boarding experience. At baseline, participants without previous experience scored lower in CRM understanding (inexperienced 3.47 ± 1.19 vs. experienced 3.82 ± 1.04, $p = 0.03$), patient management during aircraft malfunction (2.86 ± 1.20 vs. 3.19 ± 1.04, $p = 0.05$), seatbelt operation (4.15 ± 1.12 vs. 4.79 ± 0.54, $p < 0.01$),

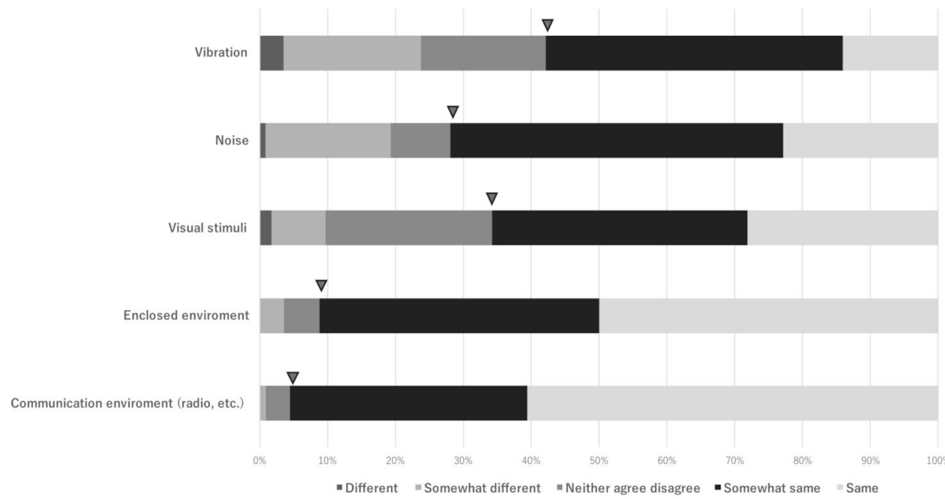

Fig. 4 MeTra Simulator Fidelity Compared to Actual Doctor Helicopter. This bar graph shows how participants with prior HEMS experience rated the simulator's vibration, noise, enclosed environment, visual realism, and communication system on a 5-point scale (1 = "Different," 5 = "Same"). Triangles (▼) mark the cutoff for ratings of 4 or higher

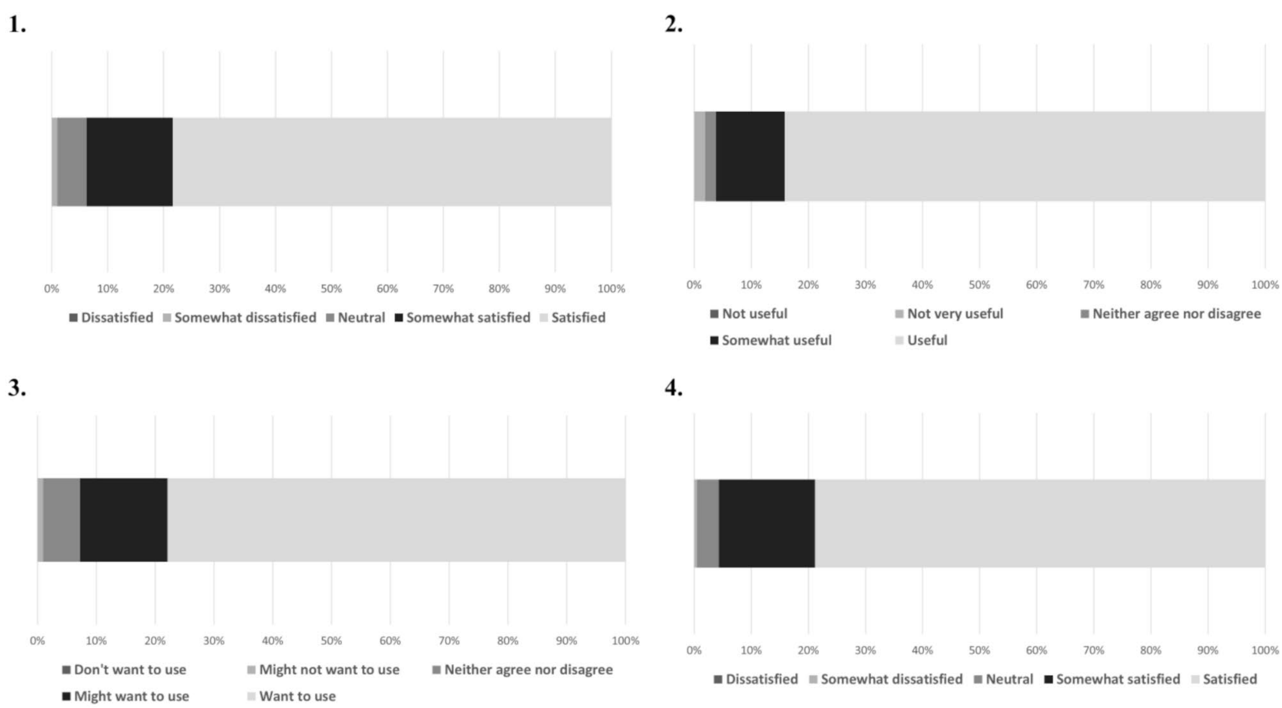

Fig. 5 Overall Evaluation of MeTra Simulator and Training Course. This bar graph illustrates the percentage distribution of participants' ratings (on a 5-point scale) for four overall assessment items: (**1**) MeTra simulator effectiveness, (**2**) course utility for future operations, (**3**) interest in future simulator use, and (**4**) overall course satisfaction

impact-protection positioning (3.73 ± 1.26 vs. 4.21 ± 0.91, $p < 0.01$), and radio operation (3.66 ± 1.40 vs. 4.28 ± 1.03, $p < 0.01$). After completing the course, only impact-protection positioning remained significantly different between the groups (4.70 ± 0.69 vs. 4.90 ± 0.30, $p = 0.03$) (Supplemental Fig. 1a). No significant differences were noted in the overall evaluation of the MeTra simulator or the course, regardless of onboarding experience (Supplemental Fig. 1b).

Analysis by occupation

Significant pre-course differences emerged among doctors, nurses, and operational staff for several items. For instance, in emergency landing response, doctors had lower baseline scores than operational staff (3.22 ± 1.00

vs. 3.86 ± 1.09, $p < 0.01$). Likewise, in-flight fire response showed lower pre-course scores for both doctors (3.00 ± 0.98) and nurses (3.27 ± 1.11) compared with operational staff (3.93 ± 1.17, $p < 0.01$).

Emergency aircraft evacuation ability exhibited significant differences between doctors and operational staff and between nurses and operational staff, both pre- and post-course. Fire extinguisher useability similarly showed pre-course differences (doctors vs. operational staff, nurses vs. operational staff) and remained significant after training for nurses and operational staff. Pre-course seatbelt operation scores were lower among nurses than operational staff, while impact-protection positioning ability was significantly lower for doctors and nurses than operational staff. Furthermore, radio operation ability and life jacket usability differed across these occupational categories (Supplemental Fig. 2a).

When comparing the MeTra simulator environment to actual helicopter operations, only the "enclosed environment" item differed significantly between nurses (3.90 ± 0.89) and operational staff (4.37 ± 0.95, $p < 0.01$). No significant occupational differences were found in the overall evaluation of the MeTra simulator or the new basic course (Fig. 2b).

Discussion

This study evaluated the effectiveness of the new basic course and MeTra simulator in Japanese doctor helicopter operations. The findings are timely, given Japan's shift from "quantitative expansion" to "qualitative improvement" in its nationwide doctor helicopter system. The significance of this new course is underscored by the heightened safety concerns following Japan's first doctor helicopter crash in 2015.

Key findings and immediate implications

Our results demonstrate self-reported improvements in participants' non-technical and technical skills. As Ziv et al. [20] posit, simulation-based medical education can enhance patient safety by improving healthcare professionals' performance and error management capabilities. Notably, post-course increases in emergency response skills, such as patient management during aircraft malfunctions and fire extinguisher use, are particularly salient from a practical standpoint. However, because our evaluation depended on self-reported questionnaires, these improvements—although encouraging—should be interpreted with caution. Cook (2011) noted that when an educational intervention is compared with no intervention, effects are often magnified, and such results, while positive, are less surprising [21]. Because this study lacked a comparison group that received a different, established educational method, our conclusions regarding skill gains are necessarily more cautious. Although these findings are encouraging for new and experienced participants, further objective evaluations or comparisons to alternate training approaches would provide a more robust basis for confirming actual skill acquisition.

Sarfati et al.'s [22] systematic review highlights the increasing implementation of simulation-based learning programs in healthcare systems to assess non-technical skills and prevent human factor-related medical errors. Our findings align with this trend, demonstrating the perceived efficacy of simulation-based learning in enhancing various competencies crucial for doctor helicopter operations.

Simulator fidelity and educational theory

Hytten's [23] research reported higher survival rates in actual accidents for crew members who underwent helicopter accident simulation training. Furthermore, Taber [24] suggests incorporating higher physical and cognitive fidelity in helicopter underwater escape training may improve survivability. These insights indicate that our MeTra simulator-based training could potentially contribute to improved survival rates in real emergencies, but further research is needed to verify these benefits objectively.

The high evaluation of the MeTra simulator, particularly its reproduction of enclosed and communication environments, indicates its potential to overcome the limitations of conventional indoor training methods. Rauter et al.'s [25] study demonstrates that high-fidelity simulator training can improve skills comparable to real-environment training and facilitate skill transfer. However, some research suggests that high physical fidelity may impose excessive cognitive load for novices, potentially detracting from learning [16]. Moreover, as Hamstra et al. [26] point out, higher perceived fidelity does not necessarily lead to improved educational outcomes if it does not align with learners' needs and objectives. Instead, functional fidelity—or alignment of key tasks—may be more critical for promoting the effective transfer of skills. With this in mind, elements like vibration and noise were included to mirror essential facets of HEMS operations. Although we aimed to strike a balance between authenticity and educational benefit, further analysis is needed to identify whether novices risk being overwhelmed or whether the advantages of realism outweigh such drawbacks.

Sociocultural factors in debriefing and training

Further complicating these questions are cultural norms and organizational dynamics. Hierarchical barriers, reluctance to challenge authority, and the concept of "losing face" can powerfully shape debriefing interactions [27]. Recent work by Rana et al. (2023) highlights how national culture, power distance, and professional hierarchies may limit open dialogue during debriefings, even when simulation is designed to be interactive [28]. In Japan's HEMS environment, such cultural factors could hinder critical feedback or mask skill gaps—especially among junior staff reluctant to speak up. Although we aimed to foster a psychologically safe environment, future studies should explore tailored debriefing models that address these sociocultural influences directly.

Need for standardization and ongoing dialogue

Identifying items with low pre-course understanding highlights potential inadequacies in facility-based education following the "Standards for Safe Operation and Flight of Doctor Helicopters" [6]. This issue is particularly relevant in the Japanese context, where pre-flight education for flight staff is currently entrusted to individual helicopter bases. Participants in the basic course for staff with limited doctor helicopter experience demonstrated insufficient pre-course understanding. This situation underscores the importance of standardized educational programs across the Japanese Society for Aeromedical Services. Révai [29] suggests that such programs serve as tools to promote dialogue among relevant parties and continuous improvement.

Imoehl et al.'s [30] standardized curriculum model offers valuable insights for designing Japan's doctor helicopter education system. It emphasizes practical training, theoretical learning, multifaceted content, continuous evaluation, and program flexibility and should be adapted to Japan's healthcare system and cultural context.

Révai [29] emphasizes that standardized programs should be regularly reviewed through continuous dialogue and reflection. Thus, Japan's doctor helicopter education system should introduce standardized programs and use them as a foundation for ongoing dialogue among relevant parties and system evolution.

The resolution of understanding differences based on onboarding experience and occupation post-course demonstrates the program's perceived effectiveness across diverse backgrounds. This, along with the course's value for experienced participants, underscores the necessity of continuous education, a point supported by multiple studies [31–33]. Nabecker et al.'s [31] proposal of quarterly basic and advanced skill sessions could particularly apply to Japan's program.

The occupation-specific analysis revealed skill differences (e.g., in emergency evacuation and fire extinguisher use), providing direction for future course improvements. Paige et al.'s [34] study suggests that high-fidelity simulation-based multi-professional team training can immediately impact team attitudes and behaviors. Incorporating targeted scenarios and immediate feedback for these skills could enhance training effectiveness.

In addition, we observed differences in certain skill items by boarding experience and occupation. While these subgroup analyses yielded interesting insights—such as lower pre-course technical skill scores among inexperienced personnel and varying pre-course evacuation competencies across professional roles—these findings should be interpreted cautiously. We did not plan a priori hypothesis for these specific stratifications, so these post-hoc comparisons serve primarily exploratory and descriptive purposes. Future work with larger cohorts and clearly defined hypotheses must confirm whether these differences remain robust and carry practical implications for training design.

Strengths, limitations, and future directions

One notable strength of this study is its real-world urgency: The course was developed in direct response to the 2015 crash, ensuring that intervention goals are aligned with immediate safety needs rather than purely theoretical objectives. Participants spanned multiple professional categories, capturing a broad cross-section of HEMS operations. Additionally, the program's innovative use of high-fidelity simulation was a first for many attendees, who reported high satisfaction and perceived utility. These factors underscore the course's practical relevance and potential influence on standardizing doctor helicopter education across Japan.

Nevertheless, several limitations of this study warrant consideration. First, because we relied on self-reported measures rather than direct observation or objective testing, any conclusions about actual skill improvement must be interpreted cautiously, and previous research by Morgan et al. has shown that perceived confidence does not necessarily correlate with objective clinical competence [35]. Consequently, our design's focus on self-reported outcomes primarily reflects participants' perceptions (Kirkpatrick Level 1 and 2) [21], which—consistent with Cook's caution regarding "education versus no education"—should be interpreted carefully. Moreover, we did not employ a control group or theory-based objective measures to confirm the effectiveness of this intervention, further limiting our ability to draw causal inferences about participants' actual learning gains. Additionally, we did not use validated non-technical skills assessment tools (e.g., NOTTS, ANTS, NOTECHS), which may have restricted the specificity of our non-technical skills evaluation. We recommend incorporating objective or performance-based outcome measures (Kirkpatrick Level 3 or 4) in future studies to provide more robust evidence of real-world performance improvements and patient outcome benefits.

The validity of our evaluation items requires ongoing assessment. Also, due to the lack of evaluation data on the conventional course, a direct comparison with the new curriculum was not feasible, precluding a precise determination of this course's relative benefits. As such, the current findings primarily reflect participants' perceptions of their proficiency rather than confirmed skill acquisition.

Future studies comparing objective outcomes or performance-based assessments between cohorts of the conventional and new courses would provide more robust evidence. Additionally, larger sample sizes and broader participant demographics could enhance the generalizability of results.

Despite these limitations, our findings suggest the perceived effectiveness of the new basic course and MeTra simulator. High overall satisfaction and strong participant agreement on its potential utility indicate a promising direction for Japan's doctor helicopter education. Maxson et al.'s [36] study corroborates that simulation training can improve interprofessional collaboration and patient care decision-making, though further objective evaluations remain essential.

In an international context, this new course and simulator represent a significant step towards aligning Japan's doctor helicopter education with global standards. As Masterson et al. [37] note, establishing international standards for HEMS crew competencies remains a challenge. Nonetheless, the comprehensive approach to standardizing safety and operational skills is a worthwhile model for future Japanese HEMS training and, potentially, for other countries facing similar aeromedical service challenges.

Conclusions

This study demonstrates that the new basic course and MeTra simulator are associated with notable self-reported improvements in technical and non-technical skills for Japanese doctor helicopter operations. While demonstrating cross-occupational effectiveness, our findings also highlight differences by professional role, underscoring the importance of standardized training tailored to diverse professionals. By establishing a robust educational framework, this program represents an important step in aligning Japan's HEMS education with international standards. However, because the present evaluation relied on self-reported data, future research should incorporate objective performance measures and longer follow-ups to confirm factual skill enhancement and sustained safety benefits. These findings may ultimately inform and advance aeromedical services in Japan and globally.

Abbreviations

HEMS Helicopter Emergency Medical Service
JSAS Japanese Society for Aeromedical Services
MeTra Medical Trainer
CRM Crew Resource Management

Supplementary Information

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Supplementary Material 1: Questionnaire

Supplementary Figure 1: Pre- and Post-Course Skill Comparison by Experience Level. (**a**) Pre- and post-course competencies by boarding experience. Bars represent mean scores on a 5-point scale. Legend: Inexp = Inexperienced, Exp = Experienced, Pre = Pre-course, Post = Post-course. (**b**) Overall Evaluation of MeTra Simulator and Course by Experience Level. Evaluation of MeTra simulator and course by boarding experience. Bars represent mean scores on a 5-point scale

Supplementary Figure 2: Analysis by occupation. (**a**) Skill Comparison by Occupation. Pre- and post-course competencies by occupation on a 5-point scale. Bars represent mean scores; error bars indicate standard deviations. Legend: Dr = Doctor, Ns = Nurse, Op = Operational staff, Pre = Pre-course, Post = Post-course. (**b**) MeTra Simulator Fidelity and Overall Evaluation by Occupation. MeTra evaluation by occupation. Bars represent mean scores on a 5-point scale; error bars indicate standard deviations

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Author contributions

K.O.,T.H., J.T., M.T., and R.O. conceived the study and designed the questionnaire. K.O., N.W., K.Y., S.I., K.S., H.I., and S.M. contributed to data collection. All authors read and approved the final manuscript.

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Data availability

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee, Faculty of Medicine, Juntendo University (approval number: E24-0233) and conducted in accordance with the standards of good clinical practice and the Declaration of Helsinki. According to the Ethical Guidelines for Medical and Biological Research Involving Human Subjects by the Ministry of Education, Culture, Sports, Science and Technology, and the Ministry of Health, Labour and Welfare, Japan, the requirement for written informed consent was waived due to the retrospective nature of this study. Participants were provided with the opportunity to opt out through information disclosure on the Japanese Society for Aeromedical Services website. No identifiable personal information was used in this research. Clinical trial number: not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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