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Cross-cultural adaptation and psychometric validation of the Nursing Activities in the Care of Extracorporeal Membrane Oxygenation-Supported Patients scale among Korean nurses: a methodological study

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Abstract

Background The progressive integration of extracorporeal membrane oxygenation (ECMO) into critical care practice has substantially intensified the scope and complexity of nursing responsibilities within the intensive care unit (ICU). Valid and reliable tools are needed to objectively assess ICU nurses' activities regarding care of ECMO-supported patients (ECMO-SP). This study sought to produce a culturally adapted Korean translation of the Nursing Activities in the Care of ECMO-SP scale and to examine its psychometric assessment, including validity and reliability.

Methods This methodological study was conducted from January to April 2024 among ICU nurses recruited from hospitals with more than 500 beds in the Seoul metropolitan area. To assess construct validity, a total of 100 nurses completed self-administered questionnaires for exploratory factor analysis, while 209 nurses were given the same ones for confirmatory factor analysis. The present study examined convergent, discriminant and criterion-related validity. Furthermore, internal consistency and test-retest reliability of the scale were evaluated.

Results The 19-item Korean version of the Nursing Activities in the Care of ECMO-SP scale yielded four factors—1) Nursing care of ECMO-SP not related to the ECMO device, 2) Activities on ECMO device during emergencies, 3) ECMO device calibrating and monitoring, and 4) Medication and blood administration through ECMO device. Standardized factor loadings showed that most items had loadings ≥ 0.60 . AVE values ranged from 0.52 to 0.56 (all > 0.50), and CR values ranged from 0.78 to 0.88 (all ≥ 0.70), indicating adequate convergent validity and construct reliability. The scale also demonstrated good discriminant validity and positive correlations with patient safety nursing competency. The overall reliability of the scale was 0.92.

Conclusions Implementing the Nursing Activities in the Care of ECMO-SP scale may enhance the practice quality of novice nurses in Korean healthcare settings. Moreover, its application can support the development of ICU nurses' competencies in ECMO care. Future research involving psychometric validation across diverse hospital environments

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and multilingual adaptations is needed. This could improve the tool's generalizability and contribute to the standardization of ECMO nursing care.

Keywords Extracorporeal membrane oxygenation, Nursing care, Psychometrics, Surveys and questionnaires, Intensive care units

Background

Extracorporeal membrane oxygenation (ECMO) has improved survival rates for patients experiencing severe cardiopulmonary failure or cardiogenic shock [1]. ECMO use has expanded dramatically worldwide in recent years with newly emerging infectious diseases and growing numbers of critically ill patients [2, 3]. Its utilization is also rapidly increasing in South Korea. Nurses who care for patients with ECMO should evaluate and manage various risks, including blood clot formation, bleeding, and air bubble entry [4]. Related nursing activities include continuous monitoring of the ECMO circuit, blood flow, pump speed, and the fraction of inspired oxygen, infection control, fluid balance management, and medication adjustments [5, 6]. Additionally, nursing responsibilities include preventing pressure injuries, providing nutritional support, and adjusting mechanical ventilation, which support functional recovery and enhance ECMO survival outcomes [7].

Given the highly complex and specialized nature of ECMO therapy, it is essential that bedside nurses deliver care consistent with the most current global evidence-based standards to achieve optimal patient outcomes [8]. Recent literature has highlighted the diverse responsibilities of ECMO nurses—such as active participation in multidisciplinary teams, anticoagulation management, and the assessment of patient vulnerability [8, 9]—and emerging guidelines have outlined refined learning objectives required for ECMO-specific competencies [10]. However, no rigorously validated and reliable instrument is available to determine whether nursing activities in this context meet established standards [11]. Thus, developing a reliable and valid measurement tool would enable systematic appraisal of nursing performance, inform targeted educational strategies, and foster continuous quality improvement in ECMO patient care.

The Nursing Activities in the Care of ECMO-supported patients (ECMO-SP) scale was created by Melnikov et al. (2024) [4] to address this specific need. This scale was specifically designed for intensive care unit (ICU) nurses, measuring key nursing activities and work engagement related to ECMO care. It assesses routine nursing duties and nurses' responses to emergencies. Cultural and organizational factors may influence the implementation and perceived importance of nursing activities related to ECMO, including ICU nursing activities in South Korea. However, the scale has yet to be fully validated across different cultures and healthcare environments. Therefore,

this study aimed to culturally adapt the Nursing Activities in the Care of ECMO-SP scale for use in South Korea and to evaluate its validity and reliability among ICU nurses.

Methods

Study design

This methodological study employed a cross-sectional study design to evaluate the validity and reliability of the Nursing Activities in the Care of ECMO-SP scale among Korean ICU nurses, after completing translation and cultural adaptation.

Participants and data collection

A total of 350 nurses were recruited from hospitals with more than 500 beds in the Seoul metropolitan area from January to April 2024. Recruitment took place through a Korean online community for nurses. Eligible participants were bedside ICU nurses with at least 12 months of clinical experience who provided direct care to ECMO patients. Nurse managers, administrative nurses, and nurses without direct patient care responsibilities were not eligible to participate.

Sample size

A minimum of 100 participants was considered acceptable for exploratory factor analysis (EFA) [12]. Confirmatory factor analysis (CFA) required a sample of at least 200 participants [13]. As EFA and CFA have different analytical purposes, it is appropriate to use separate samples for these analyses [14]. 309 valid questionnaires were included in the final analysis after excluding 41 incomplete responses. The final dataset ($n = 309$) was randomly divided into two independent and non-overlapping samples: 100 participants were allocated to the EFA and 209 to the CFA, ensuring that no participant was included in both analyses.

Measures

The data included the participants' general (e.g., sex, age, education) and work-related characteristics (e.g., ICU type, total clinical experience), the Nursing Activities in the Care of ECMO-SP scale, and Critical Care Nursing Competency Questionnaire for Patient Safety (C3Q-safety).

The nursing activities in the care of ECMO-SP

The original tool comprises 20 items grouped into four dimensions—1) nursing activities not related to the ECMO device, 2) activities related to the ECMO device during emergencies, 3) calibrating and monitoring the ECMO device, and 4) medication and blood administration through the ECMO device [4]. This instrument evaluates the frequency of nursing activities involved in the care of ECMO-SP, with responses recorded on a 5-point Likert scale (1 = *never* to 5 = *always*). A higher total score indicates greater involvement in nursing activities related to ECMO-SP and ECMO devices. The Cronbach's α of the original study was xx [4]. In this study, the overall Cronbach's α was 0.84, and Cronbach's α for the four dimensions ranged from 0.72 to 0.92.

Critical care nursing competency questionnaire for patient safety (C3Q-safety)

The C3Q-safety developed by Okumura et al. (2019) [15] comprises 22 items grouped into four domains: (1) decision-making, (2) collaboration, (3) nursing interventions, and (4) principles of nursing care. Each item is rated on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) [15]. Higher total scores indicate better patient safety nursing competency. In the original study [15], cronbach's α values for the overall C3Q-safety and its four domains ranged between 0.73 and 0.83. The present study yielded an overall coefficient of 0.81.

Cross-cultural adaptation process and psychometric assessment

These procedures correspond to the key stages recommended in the World Health Organization (WHO) Guidelines on Translation and Adaptation of Instruments [16], including forward translation, expert panel review, back-translation, pre-testing, and development of the final version (Fig. 1).

Translation

Forward translation was conducted by three bilingual ICU nurses, followed by two expert review to ensure conceptual equivalence. The original English tool was independently translated into Korean by three native Korean speakers with international patient care experience and a master's or higher degree in nursing. The first translation was reviewed and revised by a professor of nursing who was fluent in English and Korean, who then finalized the second translation. This second translation was back translated by an English-speaking critical care physician fluent in Korean. This step ensured that the translation was consistent with the original tool. Preliminary Tool 1 was produced at the end of this translation process. A back-translation was performed by a bilingual critical care physician, and discrepancies were resolved through

consensus. Particular attention was paid to terminology with potential ethical or clinical ambiguity, and clarification was obtained through consultation with the original scale developer.

Terminology standardization

Terminology standardization was conducted as part of the structured translation and cultural adaptation process in accordance with the WHO guidelines [16]. During content validation, expert feedback was systematically reviewed by bilingual ICU nurses who are native Korean speakers with experience in international patient care, along with other expert reviewers, to identify ambiguous or potentially misleading clinical terminology. When discrepancies arose (e.g., terms related to respiratory support, medication administration, or ECMO device function), alternative expressions were evaluated based on clarity of clinical meaning, consistency with routine ICU practice, and alignment with the original construct. Terminology revisions were finalized through expert consensus, and clarification was obtained through consultation with the original scale developer when needed. This process ensured standardized, clinically appropriate, and culturally relevant terminology across the adapted instrument.

Linguistic and conceptual adaptation

Terminology was reviewed to identify misleading wording in the Korean translation. In this process, the concept of "weaning" required clarification. Weaning was defined as the gradual reduction of ECMO support with native organ recovery. In Korean nursing practice, the term is used in the same recovery-based manner and is not associated with withdrawal of life-sustaining treatment. We eliminated ambiguities and adopted widely accepted terminology to better reflect the original intent. Additionally, we enhanced consistency and understanding by pairing the Korean translations with English expressions that are frequently used in clinical practice. These adjustments were made after expert review and evaluation, and the tool was adapted to be more linguistically and conceptually appropriate for the Korean context (Preliminary Tool 3). The fully adapted Korean version of the 19-item ECMO nursing activity scale, incorporating all linguistic and conceptual revisions, is provided in Supplementary Table S2.

Content validation

Content validation was performed by an expert group consisting of a professor of nursing, a doctoral student of nursing, six clinical nurses with ≥ 10 years of ICU experience and direct experience in caring for ECMO-SP, a cardiovascular and thoracic surgery nurse with ICU experience, and a perfusionist nurse with ICU

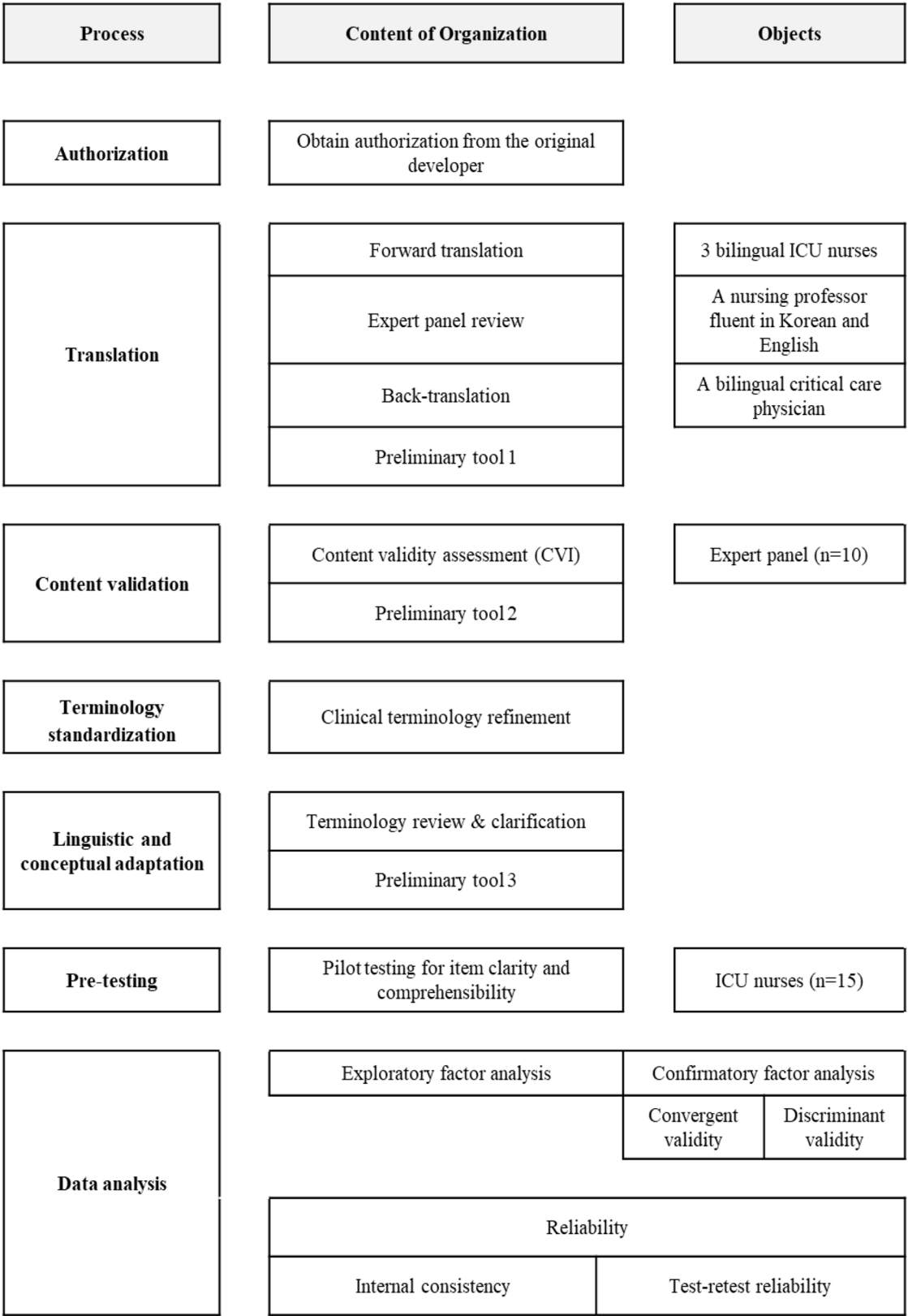


Fig. 1 Cross-cultural adaptation process and psychometric assessment

experience. Experts were selected based on predefined criteria, including relevant clinical experience and direct involvement in ECMO patient care. For each item, responses were recorded on a 4-point Likert scale, where 1 indicated “*not relevant at all*,” 2 “*somewhat irrelevant*,” 3 “*relevant*,” and 4 “*highly relevant*.” The average scale Content Validity Index (S-CVI/Ave) was 0.97. Ten experts also evaluated and calculated the Content Validity Index for Individual Items (I-CVI). In accordance with Lynn’s recommended criterion [17], items with an I-CVI ≥ 0.78 were considered acceptable for retention. The tool was revised and supplemented based on the evaluation outcomes (Preliminary Tool 2).

Expert feedback led to several substantive modifications to improve clarity. For example, the phrase “Withdrawal from the respirator” was revised to prevent misinterpretation as withdrawal of life-sustaining treatment. In addition to this example, further wording modifications were made to enhance semantic clarity and clinical interpretability. Technical terminology was refined to align with commonly accepted clinical usage, with “vasopressants” revised to “vasopressors,” and the ambiguous expression “blood clot formation” clarified as “thrombus formation within the oxygenator” to specify the anatomical location of thrombus development. Furthermore, items related to medication administration were revised to clearly distinguish between continuous and bolus administration through the ECMO circuit. These modifications were guided by predefined principles, including clarity of clinical intent, consistency with routine ICU practice, and preservation of the original construct meaning, and were finalized through expert consensus.

Pilot study

To support the tool’s linguistic and conceptual adaptation, a pilot study (pre-testing) was conducted with a convenience sample of 15 Korean ICU nurses to gather feedback on item difficulty and wording clarity. Participants reported that the items were clear and easy to understand, and no further revisions to wording or structure were suggested.

Data analysis

Data analysis was carried out using IBM SPSS Statistics version 29.0 and IBM® SPSS Amos version 30.0. For EFA, the maximum likelihood extraction method with varimax rotation was applied, and the model’s adequacy was assessed through the Kaiser–Meyer–Olkin (KMO) and the Bartlett’s test of sphericity. CFA was conducted to evaluate the model fit, drawing on multiple goodness-of-fit statistics. The absolute fit measures comprised the chi-square statistic (χ^2), the ratio of the chi-square statistic to its degrees of freedom (χ^2/df), the root mean

square error of approximation (RMSEA), and the standardized root mean square residual (SRMR). The incremental fit measures included the comparative fit index (CFI), the Tucker–Lewis index (TLI), and the normed fit index (NFI). A good model fit was defined as $\chi^2/df \leq 3$, $SRMR \leq 0.08$, $RMSEA \leq 0.08$, and CFI and $TLI \geq 0.9$ [18].

Standardized factor loadings, average variance extracted (AVE), and composite reliability (CR) were used to evaluate convergent validity [14]. Discriminant validity was assessed using the Fornell–Larcker criterion, which requires the square root of the average variance extracted (AVE) for each factor to exceed the corresponding inter-factor correlations [19]. Criterion validity was assessed using Pearson’s correlation coefficient. A priori, we expected positive and moderate correlations between the ECMO nursing activity scale and the C3Q-Safety scale, as the two instruments assess related but conceptually distinct constructs.

Internal consistency was examined through Cronbach’s α and item–total correlation analyses. To examine temporal stability, the same instrument was administered twice using an online survey platform. In accordance with recommended procedures, the retest was conducted three weeks after the baseline survey. Of the original sample, 62 participants (20%) were invited and 41 completed the retest (response rate: 66.1%). Test–retest reliability was assessed using the ICC (2,1) model (two-way random effects, absolute agreement, single measure), and 95% confidence intervals were calculated.

Results

Cross-cultural and linguistic adaptation

After a panel review by 10 experts, the phrase “withdrawal from the respirator” (item 7) was found to be potentially misleading. In clinical practice, this term often implies withdrawal of life-sustaining medical care. For clarity, it was revised to “weaning from respiratory support as a result of patient improvement” (e.g., extubation and discontinuation of oxygen therapy).

Furthermore, the expert review highlighted the need for clearer terminology regarding medication categories. Accordingly, items 1, 2, and 3 were revised to include the English terms (“sedatives,” “vasopressors,” and “analgesics”) alongside the Korean terms to facilitate understanding. Some items also required more specific wording. For example, “Blood clot formation” in item 9 was revised to “thrombus formation within the oxygenator” to clarify the location of the clot formation. In addition, “Membrane obstruction” in item 10 was revised to “oxygenator failure due to obstruction” to more accurately describe impaired device function resulting from obstruction of the oxygenator membrane.

Furthermore, we amended “changing blood flow values” in item 13 to “adjustment of revolutions per minute”

to use more precise terminology when describing how the ECMO pump speed is adjusted. Similarly, we changed “adjusting blood flow pressure” in item 15 to “adjustment of blood flow” to better reflect a more general concept. Lastly, we revised items 17 and 18 to improve the clarity of the language describing the medication and fluid administration through the ECMO intravenous lines.

Demographic characteristics

This study included Sample 1 ($n=100$) for EFA and Sample 2 ($n=209$) for CFA (Table 1). No statistically significant differences were observed in participant characteristics between the EFA and CFA groups.

Psychometric assessment

Item analysis and exploratory factor analysis

The item analysis and EFA for the Korean version of the Nursing Activities in the Care of ECMO-SP scale are presented in Table 2. A mean score of 3.83 was given for all items, ranging from 3.33 to 4.35. The item-total correlation coefficient (r) ranged from 0.36 to 0.80.

In the initial analysis of 20 items, item 3 had a factor loading below the recommended threshold (<0.40) and did not load meaningfully on any factor. This pattern reduced the interpretability and coherence of the factor structure; therefore, based on psychometric criteria and consultation with the original developer, item 3 was

removed, and the analysis was repeated. In the subsequent analysis of 19 items, an adequate KMO value of 0.867 was identified and the Bartlett's test of sphericity was significant at the $p<0.001$ level. The total explained variance was 59.9%, with factor loadings greater than 0.6 for most items. A scree plot was also examined (Fig. 2), which showed a clear inflection at the fourth factor, supporting the retention of a four-factor solution.

In the present study, item 7 from Factor 1 of the original instrument was reassigned to Factor 2. Based on the factor analysis results, five items (1, 2, 4, 5, and 6) were assigned to Factor 1 (Nursing care of ECMO-SP not related to the ECMO device), six (7, 8, 9, 10, 11, and 12) to Factor 2 (Activities on the ECMO device during emergencies), and four items (13, 14, 15, and 16) to Factor 3 (ECMO device calibrating and monitoring) and four items (17, 18, 19, and 20) to Factor 4 (Medication and blood administration through ECMO device).

Although item 5 had a factor loading of 0.32, it was retained based on its psychometric and expert evaluation. The item demonstrated an acceptable item–total correlation ($r=0.468\geq 0.30$), indicating a meaningful contribution to internal consistency. Deleting the item resulted in only a negligible change in Cronbach's α ($0.920 \rightarrow 0.921$). Furthermore, the expert panel rated this item as essential ($I-CVI=1.00$), indicating strong content relevance to ECMO nursing activities. While Factor 1 exhibited a

Table 1 Participant characteristics for the total, EFA, and CFA samples

Characteristics	Category	Total ($n=309$) n (%) or Mean $\pm$ SD	EFA ($n=100$) n (%) or Mean $\pm$ SD	CFA ($n=209$) n (%) or Mean $\pm$ SD	t or χ^2	p
Sex	Male	17 (5.5)	6 (6.0)	11 (5.3)	0.071	0.790
	Female	292 (94.5)	94 (94.0)	198 (94.7)		
Age(year)		29.7 $\pm$ 3.26	29.8 $\pm$ 3.33	29.7 $\pm$ 3.23	0.202	0.840
Education	College	19 (6.1)	7 (7.0)	12 (5.7)	0.835	0.659
	Bachelor	281 (90.9)	89 (89.0)	192 (91.9)		
	Master	9 (2.9)	4 (4.0)	5 (2.4)		
Position	Staff nurse	289 (93.5)	95 (95.0)	194 (92.8)	0.530	0.467
	Charge nurse	20 (6.5)	5 (5.0)	15 (7.2)		
ICU type	Medical	202 (65.4)	69 (69.0)	133 (63.6)	3.125	0.793
	Surgical	97 (31.4)	28 (28.0)	69 (33.0)		
	Mixed	10 (3.2)	3 (3.0)	7 (3.4)		
Total clinical experience (years)	1–3	69 (22.4)	20 (20.0)	49 (23.4)	0.947	0.814
	4–5	119 (38.5)	38 (38.0)	81 (38.8)		
	6–10	107 (34.6)	38 (38.0)	69 (33.0)		
	≥ 11	14 (4.5)	4 (4.0)	10 (4.8)		
Current clinical career (years)	1–2	15 (4.9)	7 (7.0)	8 (3.8)	1.882	0.597
	2–3	143 (46.3)	44 (44.0)	99 (47.4)		
	4–5	116 (37.5)	39 (39.0)	77 (36.8)		
	≥ 6	35 (11.3)	10 (10.0)	25 (12.0)		
Experience of caring for ECMO patients(years)		2.71 $\pm$ 2.45	2.56 $\pm$ 2.05	2.78 $\pm$ 2.63	-0.752	0.453
Participation in ECMO education program	Yes	292 (94.5)	97 (97.0)	195 (93.3)	1.780	0.182
	No	17 (5.5)	3 (3.0)	14 (6.7)		

Note. Exploratory factor analysis (EFA) was conducted using a subsample of 100 participants, and confirmatory factor analysis (CFA) was conducted using a separate subsample of 209 participants

ICU = Intensive Care Unit

Table 2 Item analysis and exploratory factor analysis using maximum likelihood extraction with Varimax rotation ($n = 100$)

Item	Factor loading				Mean	SD	<i>r</i>	Skewness	Kurtosis
	Factor 1	Factor 2	Factor 3	Factor 4					
1. Titration of sedatives	0.61	-0.01	0.05	0.16	4.29	0.72	0.36	0.45	0.36
2. Titration of vasopressors	0.51	0.12	0.05	0.09	4.28	0.78	0.39	0.37	0.39
4. 'Position changes'	0.54	-0.04	-0.04	-0.09	4.35	0.67	0.17	-0.72	0.17
5. Adjusting the rate of enteral nutrition	0.32	0.25	0.12	0.25	4.05	0.91	0.52	0.55	0.52
6. Adjusting the respiratory support device to the patient's condition	0.68	0.13	0.13	0.16	4.28	0.81	0.42	0.41	0.42
7. Weaning from respiratory support as a result of patient improvement (e.g., extubation, discontinuation of oxygen therapy)	0.30	0.47	0.07	0.24	3.80	1.10	0.66	-0.11	0.66
8. Air bubble entry	0.03	0.78	0.28	0.29	3.56	1.27	0.77	-0.68	0.77
9. Thrombus formation within the oxygenator	0.14	0.73	0.10	0.29	3.68	1.10	0.68	-0.62	0.68
10. Oxygenator failure due to obstruction	-0.02	0.87	0.22	0.25	3.46	1.31	0.78	-0.89	0.78
11. Stopping the ECMO device	-0.08	0.87	0.08	0.18	3.44	1.34	0.73	-1.04	0.73
12. Bleeding in the lines	0.33	0.65	-0.08	0.10	3.70	1.11	0.66	-0.68	0.66
13. Adjustment of revolution per minute (RPM)	0.46	0.08	0.34	0.44	3.93	0.99	0.66	0.70	0.66
14. Adjustment of sweep gas flow and fraction of inspired oxygen (FiO ₂)	0.62	0.13	0.28	0.37	3.95	1.02	0.61	-0.03	0.61
15. Adjustment of blood flow	0.26	0.25	0.57	0.48	3.88	1.09	0.68	0.13	0.68
16. Calibrating gas flow and fraction of inspired oxygen	0.20	0.27	0.67	0.46	3.74	1.15	0.71	0.05	0.71
17. Administration of fluid through the ECMO venous cannula	0.08	0.31	0.20	0.79	3.58	1.35	0.77	-0.65	0.77
18. Medication administration through the ECMO venous cannula	0.10	0.52	0.15	0.68	3.33	1.46	0.80	-1.13	0.80
19. Blood products administrations through the venous side of ECMO, besides platelets	0.02	0.56	0.16	0.69	3.38	1.40	0.80	-1.00	0.80
20. Taking blood for tests from ECMO device including gases in the arterial and venous pipes and ACT test	0.23	0.27	0.18	0.76	3.71	1.32	0.70	-0.39	0.70
Eigenvalue	7.59	2.02	1.35	0.42					
Explained variance (%)	39.93	10.61	7.12	2.23					
Cumulative total variance (%)	39.93	50.54	57.66	59.90					

Note. Exploratory factor analysis was conducted using the EFA subsample ($n = 100$)

The extraction method was maximum likelihood, and Varimax rotation was applied

Italicized factor loadings indicate cross-loadings (≥ 0.30) on more than one factor

Item 5 (factor loading = 0.32) was retained based on content validity and its minimal impact on Cronbach's α

Kaiser-Meyer-Olkin = 0.87, Bartlett's test of sphericity = 1237.27 ($p < 0.001$)

relatively modest internal consistency ($\alpha = 0.69$), removing the lowest-performing item increased reliability only minimally ($\alpha = 0.72$). Based on these psychometric and conceptual considerations, item 5 was retained to preserve the content coverage and conceptual integrity of the ECMO nursing activity construct. Moreover, item 14 had an acceptable factor loading and was retained without modification.

In the EFA conducted in Sample 1, item 14 loaded more strongly on Factor 1 (0.62) than on Factor 3 (0.28). However, in the CFA performed in Sample 2, item 14 demonstrated a high standardized factor loading on Factor 3 (0.75) and was therefore retained in Factor 3 in the final model.

Confirmatory factor analysis

The tool's four factors were specified as latent variables in the CFA (Fig. 3). The absolute fit indices were as follows: $\chi^2 = 322.561$ ($p < 0.001$), $\chi^2/df = 2.23$, RMSEA = 0.077, and SRMR = 0.075; the incremental fit indices were CFI = 0.93, TLI = 0.91, and NFI = 0.87.

Overall, these findings support the adequacy of the four-factor structure of the 19-item Korean version of the Nursing Activities in the Care of ECMO-SP scale was confirmed. Additionally, the goodness-of-fit index (GFI = 0.93) and the adjusted goodness-of-fit index (AGFI = 0.94) exceeded the recommended criterion of 0.90, further reinforcing the appropriateness of the proposed four-factor model.

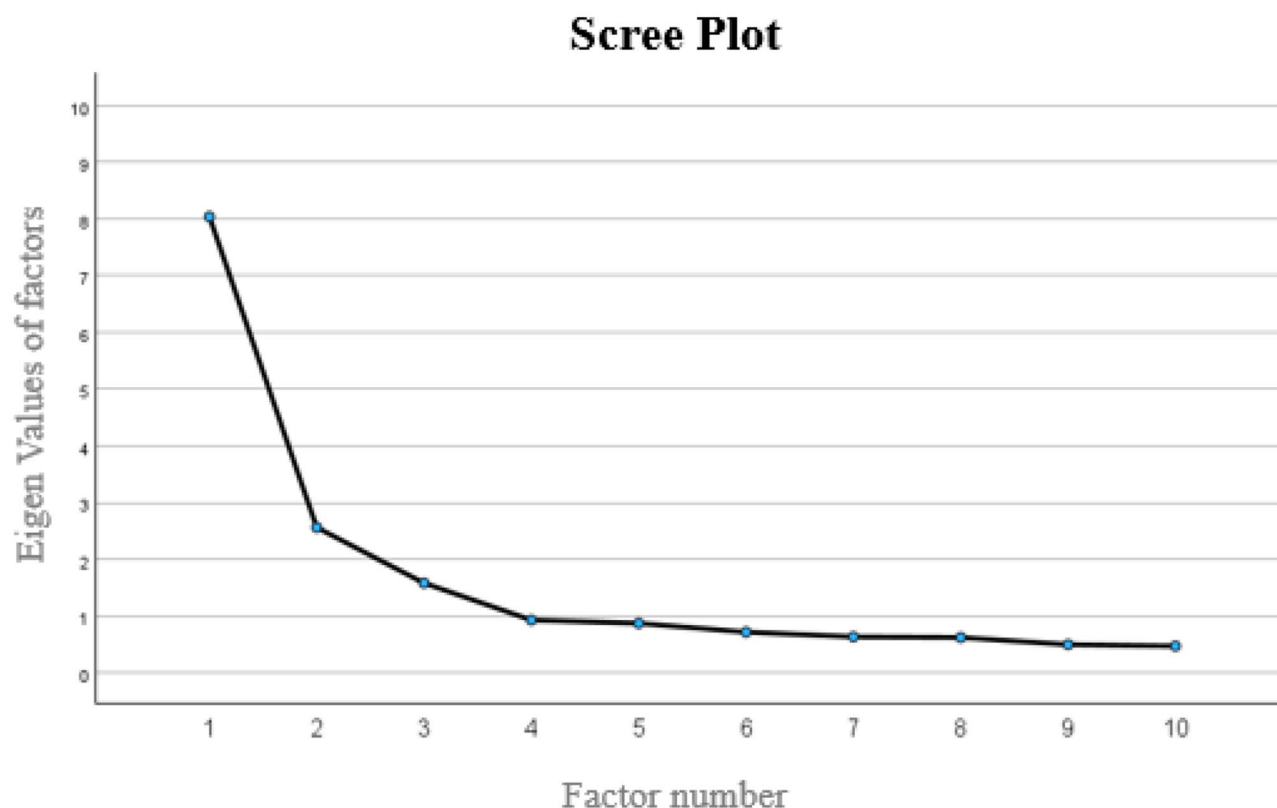


Fig. 2 Scree plot of eigenvalues for the Korean version of the Nursing Activities in the Care of Extracorporeal Membrane Oxygenation–Supported Patients scale

Convergent and discriminant validity

As shown in Supplementary Table S1, the assessment of convergent and discriminant validity revealed that all the standardized factor loadings had critical ratios exceeding 1.96 and reached statistical significance at $p < 0.05$. Most items had factor loadings of 0.60 or higher. This verified the scale's convergent validity. Confidence intervals did not include 1, indicating that the tool had discriminant validity.

Criterion validity

We found a statistically significant positive correlation between the Korean version of the Nursing Activities in the Care of ECMO-SP scale and C3Q-safety ($r = 0.46$, $p < 0.001$). In addition, all four factors of the Korean version of the Nursing Activities in the Care of ECMO-SP scale had significant positive correlations with the C3Q-safety ($r = 0.29$ to $r = 0.59$).

Reliability

Table 3 shows an overall reliability of 0.92 for the Korean version of the Nursing Activities in the Care of ECMO-SP scale. Cronbach's coefficients were 0.69 for Factor 1, 0.89 for Factor 2, 0.86 for Factor 3, and 0.91 for Factor 4. Test–retest reliability demonstrated acceptable

temporal stability, with an overall ICC(2,1) of 0.711 (95% CI: 0.528–0.841).

Discussion

The Korean version of the ECMO-SP scale demonstrates acceptable validity and reliability, indicating that it is an appropriate instrument for evaluating ECMO-related nursing activities in Korean clinical settings. Through multiple rounds of expert review and revision, this study enhanced the cultural validity and contextual appropriateness of the Korean version of the ECMO-SP scale. Beyond confirming psychometric adequacy, the present study provides important conceptual and contextual insights into how ECMO nursing activities are structured and operationalized within a distinct healthcare environment. The four-factor structure identified in this study broadly aligns with that of the original instrument developed by Melnikov et al. [4], suggesting that the core domains of ECMO nursing activities are conceptually comparable across cultures. This consistency supports the theoretical assumption that ECMO nursing practice comprises both patient-centered and technology-centered dimensions that coexist in highly complex critical care settings.

The observed differences in item interpretation can be partly explained by linguistic nuances that carry distinct

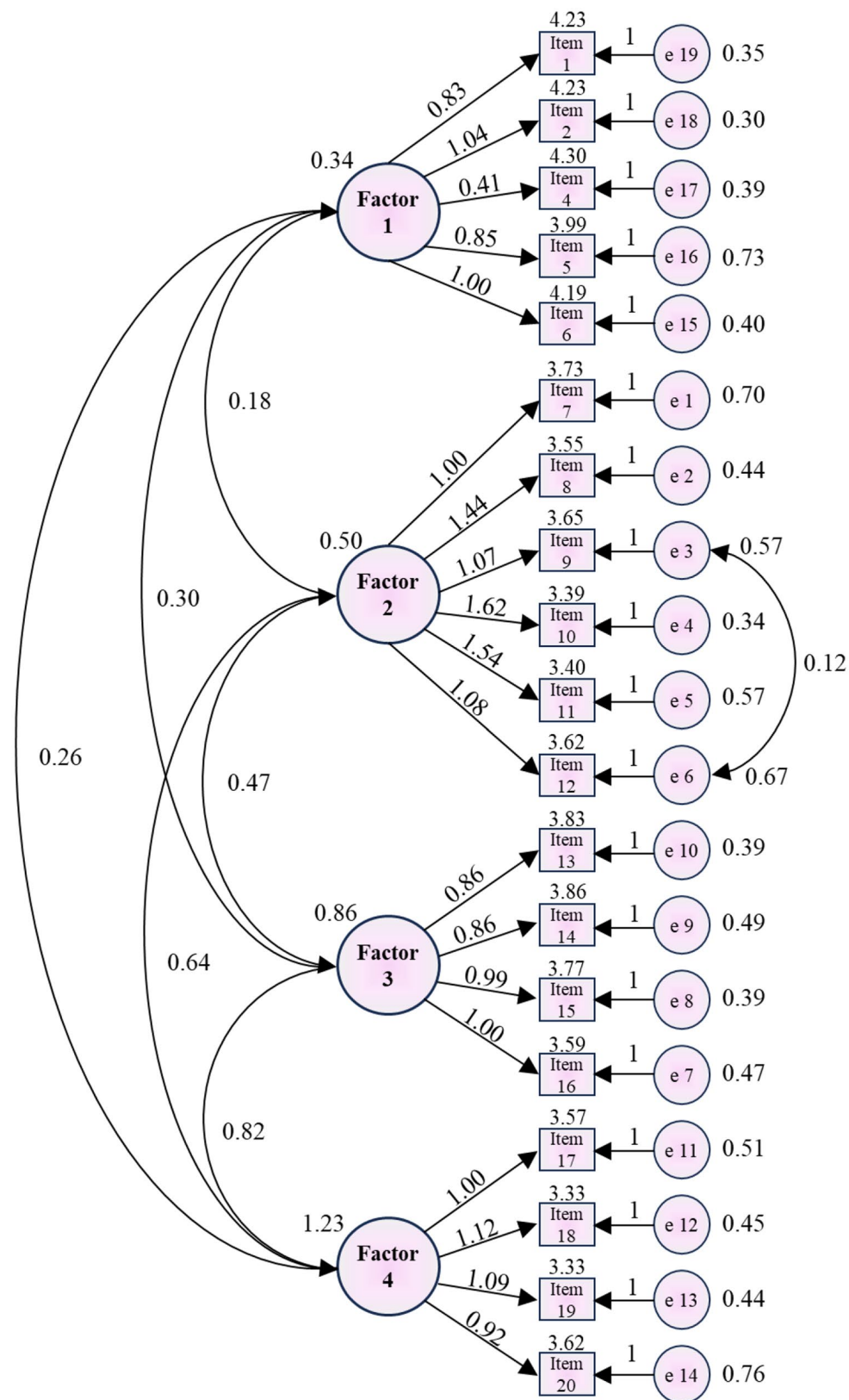


Fig. 3 CFA model of the Korean version of the Nursing Activities in the Care of Extracorporeal Membrane Oxygenation-Supported Patients scale. CFA = Confirmatory Factor Analysis. ECMO = Extracorporeal Membrane Oxygenation. Factor 1 = Nursing Care of ECMO-SP not related to the ECMO device. Factor 2 = Activities on ECMO device during emergencies. Factor 3 = ECMO device calibrating and monitoring. Factor 4 = Medication and blood administration through ECMO device

Table 3 Internal consistency reliability of the four-factor structure (Cronbach's α using total sample; McDonald's ω using CFA sample)

Factors	Item	α if Item is deleted (N = 309)	Cronbach's α (N = 309)	McDonald's ω (n = 209)
Factor 1: Nursing care of ECMO-SP not related to the ECMO device	1	0.92	0.69	0.73
	2	0.92		
	4	0.93		
	5	0.92		
	6	0.92		
	7	0.92		
Factor 2: Activities on ECMO device during emergencies	8	0.92	0.89	0.90
	9	0.92		
	10	0.92		
	11	0.97		
	12	0.92		
	13	0.92		
Factor 3: ECMO device calibrating and monitoring	14	0.92	0.86	0.87
	15	0.92		
	16	0.92		
	17	0.92		
Factor 4: Medication and blood administration through ECMO device	18	0.91	0.91	0.91
	19	0.91		
	20	0.91		
Total Cronbach's α			0.92	0.96

Note. Cronbach's α values were calculated using the full combined sample (N = 309)

McDonald's ω values were estimated using the CFA subsample (n = 209) based on standardized factor loadings and error variances

Item composition per factor was as follows = Factor 1 (Items 1, 2, 4, 5, 6); Factor 2 (Items 7–12); Factor 3 (Items 13–16); Factor 4 (Items 17–20)

ECMO = Extracorporeal Membrane Oxygenation

ECMO-SP = ECMO-Supported Patients

ethical, legal, and clinical implications across cultures. Such nuances may influence how specific nursing activities are understood and operationalized within different healthcare systems. Item 7 required particular attention because the term “withdrawal” in Korean clinical practice is commonly associated with withdrawal of life-sustaining treatment. After consultation with the original developer, the item was clarified to reflect weaning from respiratory support due to clinical improvement, consistent with ELSO guidelines [20], and was translated accordingly.

This translation decision further highlighted important cultural and institutional differences between the context in which the original instrument was developed and the Korean healthcare system. Although withdrawal of life-sustaining treatment is institutionally recognized in the original cultural context, religious and ethical considerations contribute to complex social consensus regarding end-of-life decision-making [21]. In contrast, in South Korea, the enactment of the Life-Sustaining Treatment Decision Act has led to increasing research and gradual clinical integration of end-of-life decision-making processes, with terminology related to treatment withdrawal being perceived as particularly sensitive within legal and ethical frameworks [22]. These findings underscore that cross-cultural adaptation of measurement instruments

requires more than literal translation and must encompass clinical, legal, and cultural contexts.

Notably, several culturally meaningful differences were observed in the allocation and interpretation of specific items. For example, item 7, originally classified under Factor 1 (Nursing care of ECMO-supported patients not related to the ECMO device), was reassigned to Factor 2 (Activities on the ECMO device during emergencies) in the Korean version, reflecting contextual differences in how Korean ICU nurses perceive urgency, risk, and professional responsibility in ECMO care. These findings underscore that factor structures may reflect how nursing roles are enacted within specific organizational and cultural contexts. In addition, the retention of Factor 3 (ECMO device calibrating and monitoring) as a distinct factor reinforces the notion that technical proficiency with ECMO equipment constitutes a core domain of nursing expertise rather than a subsidiary task. This interpretation is consistent with prior literature describing ECMO nursing as encompassing both patient-centered clinical care and competencies related to ECMO device management within complex critical care environments [8, 23, 24].

An important methodological decision in this study was the retention of item 5 despite its relatively low factor loading (0.32). Rather than relying solely on statistical

thresholds, this decision was informed by expert consensus and conceptual relevance, reflecting a trade-off between statistical rigor and content validity. Nevertheless, this decision should be interpreted with caution, as the relatively low factor loading may indicate a limited statistical contribution within the present sample. The relevance and interpretation of item 5 may also vary across cultural and clinical contexts due to differences in nursing roles, scope of practice, and organizational structures. Accordingly, future cross-cultural validation studies are warranted to further examine the performance of item 5 across diverse settings, including potential item refinement, rewording, or culture-specific adaptation to enhance measurement precision while preserving its conceptual meaning.

Although some items demonstrated moderate cross-loadings across factors, final factor assignment was guided not only by statistical loading values but also by conceptual coherence and theoretical relevance. A notable example is item 14, which showed higher loading on Factor 1 in the EFA but demonstrated strong loading on Factor 3 in the CFA. This discrepancy may reflect sample variability, differences in clinical contexts between subsamples, or instability in item interpretation. Despite the lower EFA loading on its assigned factor, item 14 was retained in Factor 3 based on its strong conceptual fit with ECMO device calibration and monitoring functions, which was subsequently supported by robust CFA performance. Items assigned to Factor 3 were retained based on their primary focus on ECMO device calibration and monitoring functions, even when these activities were closely integrated with broader patient care. This approach reflects the inherently complex and overlapping nature of ECMO nursing practice, in which technical monitoring tasks are embedded within holistic care rather than functioning as isolated procedures. Accordingly, regular education and training programs should be provided to ICU nurses to support effective ECMO monitoring and utilization. However, this inconsistency warrants acknowledgment as a limitation and suggests the need for further validation to confirm stable factor associations across diverse samples.

The observed moderate positive correlations with the C3Q-Safety scale are consistent with the prespecified hypothesis and support criterion validity. These findings indicate that the ECMO-SP scale is meaningfully associated with patient safety competence while capturing a related but distinct construct, which is consistent with the absence of excessively strong correlations [15]. Most fit indices indicated acceptable model fit; however, the slightly lower NFI value underscores the importance of interpreting model fit using multiple indices rather than relying on a single indicator. In this regard, similar context-related variability has been reported in nursing

activity and workload instruments, such as the Nursing Activities Score (NAS), whose performance and interpretation have been shown to vary across clinical settings due to differences in care delivery models, nurse roles, and institutional practices [25]. This supports the importance of contextual adaptation rather than strict replication of the original instrument.

Implications and recommendations for practice

Based on the present findings and their cultural and contextual interpretation, the Korean version of the ECMO-SP scale provides a practical and standardized tool for assessing ECMO nursing activities across diverse clinical settings. By providing a structured framework that captures both patient-centered and technology-intensive aspects of ECMO care, the scale can support competency-based education, performance evaluation, and workforce planning for ECMO nurses.

In particular, the scale may be useful for identifying educational needs among novice and experienced nurses and for evaluating the effectiveness of targeted training programs, including simulation-based ECMO education. The explicit inclusion of ECMO-specific activities may also contribute to the standardization of ECMO nursing practices within and across institutions. Furthermore, given that linguistic and cultural considerations were shown to be critical in the adaptation process. Future studies are recommended to conduct additional validation across various clinical contexts and to pursue multilingual adaptations of the scale. Such efforts would enhance the generalizability of the instrument and facilitate international comparisons of ECMO nursing practice.

Limitations

The limitations of this present study are delineated as follows. First, the study population was limited to ICU nurses in the Seoul metropolitan area. Because this area includes the capital city of South Korea, the applicability of these findings to the wider national population may be limited. Future research should incorporate hospitals from diverse geographic areas. Second, because this study relied on self-reported survey data and separate EFA and CFA samples, the results may be subject to response bias and limited generalizability. Additional validation studies across diverse clinical environments are warranted to further strengthen the scale's applicability.

Conclusion

Our findings demonstrate that the Korean adaptation of the Nursing Activities in the Care of ECMO-SP scale is a valid and reliable instrument for the precise and systematic evaluation of ECMO nursing activities. By enabling the objective assessment of nursing roles in this highly

specialized field, the tool holds significant potential for guiding educational strategies and clinical performance evaluation in the care of patients on ECMO. Its application can strengthen continuing professional education, thereby supporting the growth of a competent, and globally adaptable nursing workforce. Furthermore, these results provide a strong foundation for advancing the standardization of ECMO nursing practice, informing workforce planning, and ultimately improving the quality and safety of patient care worldwide.

Abbreviations

ECMO	Extracorporeal Membrane Oxygenation
ECMO-SP	ECMO-Supported Patients
ICU	Intensive Care Unit
WHO	World Health Organization
CVI	Content Validity Index
I-CVI	Content Validity Index for Individual Items
S-CVI/Ave	Scale-Level Content Validity Index, Average method
C3Q-safety	Critical Care Nursing Competency Questionnaire for Patient Safety
EFA	Exploratory Factor Analysis
CFA	Confirmatory Factor Analysis
KMO	Kaiser-Meyer-Olkin
CFI	Comparative Fit Index
TLI	Tucker-Lewis Index
NFI	Normed Fit Index
GFI	Goodness-of-Fit Index
AGFI	Adjusted Goodness-of-Fit Index
RMSEA	Root Mean Square Error of Approximation
SRMR	Standardized Root Mean Square Residual
AVE	Average Variance Extracted
CR	Composite Reliability
ICC	Intraclass Correlation Coefficient
IRB	Institutional Review Board

Supplementary Information

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Supplementary Material 1

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Author contributions

HJK: The conception and design of the study, acquisition of data, formal analysis, interpretation of data, Writing – original draft, Writing – review & editing. SHP: Writing – original draft, Writing – review & editing. YJS: The conception and design of the study, data analysis, interpretation of data, funding acquisition, supervision Writing – original draft, Writing – review & editing.

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Data availability

The datasets used and/or 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 Institutional Review Board (IRB) of Seoul National University Hospital (IRB No. H-2312-179-1499) for the ethical protection of human subjects. The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants. Participants voluntarily consented to take part after fully understanding the study's purpose and procedures.

Consent for publication

Informed consent for the publication of participant's personal or clinical details was obtained from all individuals included in this study.

Competing interests

The authors declare no competing interests.

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