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# Psychometric Evaluation of the Chinese Version of the Integrated Measure for Training Transfer in Nursing Practice

**Jifang Cheng**
The Second Affiliated Hospital Zhejiang University School of Medicine
**Baohua Li**
The Second Affiliated Hospital Zhejiang University School of Medicine
**Shengbo Jiang**
The Second Affiliated Hospital Zhejiang University School of Medicine
**Meng Wang**
The Second Affiliated Hospital Zhejiang University School of Medicine
**Chunjie Wen**
The Second Affiliated Hospital Zhejiang University School of Medicine
**Xia Zhu**
The Second Affiliated Hospital Zhejiang University School of Medicine
**Bin Yu**
The Second Affiliated Hospital Zhejiang University School of Medicine
**Xiaoxiao Yin**
yinxiaoxiao@zju.edu.cn

The Second Affiliated Hospital Zhejiang University School of Medicine

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## Abstract

**Background**

Training transfer refers to the application of knowledge and skills acquired through training in clinical practice. However, validated instruments that provide a differentiated assessment of factors influencing training transfer among specialist nurses in China remain scarce. This study aimed to translate and culturally adapt the Integrated Measure for Training Transfer in Nursing Practice (IMTT-NP) into Chinese and evaluate its psychometric properties among specialist nurses.

**Methods**

A cross-sectional psychometric validation study was conducted among 951 specialist nurses from tertiary hospitals across six provinces in China. The IMTT-NP was translated and culturally adapted through forward and backward translation. Content validity was assessed through expert review. Construct validity was examined using exploratory factor analysis (n = 475) and confirmatory factor analysis (n = 476). Convergent and discriminant validity, internal consistency, two-week test–retest reliability, and concurrent validity with the Factors Influencing Training Transfer questionnaire were also evaluated.

**Results**

The Chinese IMTT-NP demonstrated strong content validity, with item-level content validity indices ranging from 0.83 to 1.00 and an average scale-level content validity index of 0.94. Exploratory factor analysis supported a 12-factor structure that explained 58.1% of the total variance. Confirmatory factor analysis showed satisfactory model fit ($\chi^2/df = 1.507$, CFI = 0.948, TLI = 0.943, RMSEA = 0.033, and SRMR = 0.034). All dimensions satisfied the Fornell–Larcker criterion. Cronbach's α and McDonald's ω for the total scale were 0.924 and 0.971, respectively. Test–retest reliability among 37 participants yielded an intraclass correlation coefficient of 0.946. Concurrent validity was supported by a moderate correlation with the Factors Influencing Training Transfer questionnaire ($r = 0.463$, $p < 0.001$).

**Conclusions**

The Chinese IMTT-NP demonstrated satisfactory psychometric properties among specialist nurses working in tertiary hospitals in China. It may be used to assess perceived factors influencing training transfer and inform subsequent training and workplace-support strategies. Further validation is needed in other nursing populations and healthcare settings.

Clinical trial number: Not applicable.


## 1.Background

As nursing practice continues to evolve toward specialization and competency-based care, the development of specialist nurses has become an important strategy for strengthening the nursing workforce and improving the quality of healthcare services. Specialist nurses receive advanced training in specific clinical fields and are expected to integrate specialized knowledge, clinical skills, evidence-based practice, and decision-making abilities into patient care, clinical management, and interdisciplinary collaboration[1–3]. However, the effectiveness of specialist nurse training depends not only on the acquisition of knowledge and skills during training but also on whether these competencies can be successfully transferred and sustained in clinical practice[4]. Training transfer refers to the effective and continuous application of knowledge, skills, and competencies acquired through training in the workplace setting[5, 6].Despite increasing investment in specialist nurse education, a gap between training outcomes and clinical application remains a challenge internationally and may be particularly relevant in China, where specialist nurse development systems are still evolving[7, 8].

Specialist nurse training requires substantial investment of educational resources, including theoretical instruction, clinical skills training, mentorship, and competency-based assessment[9, 10]. Nevertheless, the acquisition of competencies during training does not necessarily guarantee their application in clinical practice, and the effectiveness of transfer may decline over time without appropriate support[11, 12]. Ineffective training transfer may limit the contribution of specialist nurses to clinical practice and reduce the effectiveness of nursing workforce development programs. Therefore, identifying the factors that facilitate or hinder training transfer is essential for optimizing specialist nurse training systems and promoting the translation of educational outcomes into clinical improvements[13].

Training transfer is a complex and dynamic process influenced by multiple interacting factors, including individual characteristics, workplace environment, and training-related factors. The Dynamic Transfer Model conceptualizes transfer as an evolving process shaped by trainee characteristics, motivation, training design, and organizational context[14]. In addition, Self-Determination Theory highlights that autonomy, competence, and relatedness are essential motivational factors that influence individuals' engagement in applying newly acquired knowledge

and skills[15]. Previous studies have demonstrated that workplace support, opportunities to apply learning, constructive feedback, supervisory support, and recognition of professional competence may promote successful training transfer[9, 11, 16]. Therefore, comprehensive assessment of training transfer requires consideration of individual, interpersonal, organizational, and training-related determinants.

The Factors Influencing Training Transfer (FITT) questionnaire is an important nursing-specific instrument developed in China[17]. The FITT questionnaire provides an important framework for understanding transfer-related factors; however, some dimensions contain multiple conceptually distinct constructs, which may limit the identification of specific facilitators and barriers affecting training transfer. For example, managerial support includes supervisory behaviors, organizational resources, performance-related rewards, and peer support, while organizational and personal facilitators combine organizational climate, collegial support, and individual self-efficacy. Such broad categorization may reduce the ability to precisely evaluate specific determinants of training transfer[17]. Therefore, further refinement of measurement tools is needed to provide a more theoretically grounded and multidimensional assessment.

The Integrated Measure for Training Transfer in Nursing Practice (IMTT-NP) was developed by integrating the Learning Transfer System Inventory and the Learning Climate Questionnaire within the Dynamic Transfer Model[18]. Unlike instruments focusing on general training outcomes, the IMTT-NP provides a comprehensive framework for assessing determinants of training transfer across individual, work-environment, and training domains. The instrument consists of 12 dimensions, including motivation, transfer-effort performance expectations, personal capacity to transfer, outcome expectations, use of learning and self-efficacy, performance-related rewards, peer support, coaching by colleagues, resistance to change, negative responses from colleagues and employers, supervisor sanctions, supervisor and employer support, training, and trainer factors[18]. Furthermore, the trainer dimension incorporates principles from Self-Determination Theory by assessing support for autonomy, competence, and relatedness within the learning environment[13, 18]. By distinguishing these determinants across 12 dimensions, the IMTT-NP provides a theoretically grounded and differentiated assessment of factors that may facilitate or hinder training transfer. However, it assesses nurses' perceptions of these determinants rather than directly measuring transfer behavior or clinical outcomes.

Cultural adaptation is particularly relevant because training transfer occurs within specific organizational and professional contexts. In China, specialist nurse development is largely embedded within hospital-based training, nursing management, and performance-evaluation systems. National nursing policy emphasizes competency-oriented training, position-based management, performance appraisal, and organizational incentives[19]. A qualitative study conducted in Chinese tertiary hospitals identified peer, supervisor, and organizational support, coworker opposition, and organizational cultures characterized by change, knowledge sharing, and learning as important influences on nurses' training transfer[6]. These contextual characteristics may affect how nurses interpret dimensions concerning rewards, sanctions, supervisory support, peer coaching, resistance to change, and opportunities to apply learning. Because the IMTT-NP was originally developed and validated among nurses in Dutch tertiary teaching hospitals, rigorous translation, cultural adaptation, and psychometric evaluation were required before its use among specialist nurses in China could be supported[18].

This study aimed to translate and culturally adapt the IMTT-NP into Chinese and evaluate its psychometric properties among specialist nurses working in national-level specialty nursing training bases within tertiary hospitals in China.

## 2. Methods

## 2.1. Study design

A cross-sectional methodological study was conducted to evaluate the psychometric properties of the Chinese version of the IMTT-NP.

## 2.2. Setting and participants

This multicenter study was conducted in 10 tertiary hospitals across six provinces in eastern, central, and western China. All participating hospitals were designated as national-level specialty nursing training bases with established specialist nurse training programs. Participants were recruited using a convenience sampling method via hospital announcements and departmental recommendations. Eligible participants were specialist nurses currently engaged in frontline clinical practice who had at least one year of clinical experience after obtaining the national specialist nurse certificate. Nurses who declined to provide informed consent were excluded.

The required sample size was estimated according to the commonly cited recommendation of at least 10 participants per scale item. For the 58-item IMTT-NP, a minimum sample of 580 participants was therefore required. In addition, sample sizes of at least 500 are generally considered adequate for construct validity assessment, whereas a minimum of 300 participants is recommended for reliability analysis. A total of 1,158 questionnaires were submitted. After data-quality screening, 951 valid questionnaires were retained, yielding a valid questionnaire rate of 82.12%. The final sample therefore exceeded the recommended minimum for the subsequent psychometric analyses.

## 2.3. Instrument

Data were collected using a personal information form, the IMTT-NP, and the FITT questionnaire for specialist nurses.

### 2.3.1 Demographic questions

The general population knowledge questionnaire includes gender, age, marital status, professional title, position, work experience, employment status, specialty area.

### 2.3.2. The IMTT-NP

The IMTT-NP, developed by Hakvoort[18], is a self-report instrument that assesses training transfer in nursing practice. The instrument was developed based on the Learning Transfer System Inventory and the Learning Climate Questionnaire, integrating individual, work-environment, and training-related factors. The IMTT-NP consists of 58 items organized into 12 dimensions: supervisor and employer support, supervisor sanctions, colleagues and employer reprimands, coaching colleagues, resistance to change, motivation/transfer effort-performance expectations, performance/reward, personal capacity to transfer, outcome expectations, use of learning and self-efficacy, training, and trainer. Items are rated on a 7-point Likert scale ranging from − 3 (strongly disagree) to + 3 (strongly agree). After reverse scoring negatively worded items, higher scores indicate more favorable conditions for training transfer.

### 2.3.3. The FITT questionnaire

The FITT questionnaire, developed by Bai et al.[17], was used as an external criterion to evaluate concurrent validity of the Chinese version of the IMTT-NP. The FITT is a nursing-specific instrument designed to assess perceived factors influencing the transfer of training into clinical practice. It consists of 53 items across five subscales: managerial support, hindrances in the organization, validity of the training program, organizational and personal facilitators, and personal attitudes toward training transfer. Each item is rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree), with higher scores indicating more favorable conditions for training transfer. The original instrument demonstrated excellent internal consistency, with an overall Cronbach's α of 0.965[17].

## 2.4. The process of translating the IMTT-NP

The original IMTT-NP was translated into Chinese through a systematic process including forward translation, back-translation, and cultural adaptation[20]. Initially, two bilingual nursing researchers independently translated the scale into Chinese. A nursing scholar then reviewed and consolidated these translations to produce the final Chinese version. Subsequently, two Chinese master's students in English, who had not previously encountered the scale, back-translated this version into English. Finally, a doctoral nursing student verified the conceptual equivalence of the back-translation against the original scale. Any discrepancies were resolved through discussion, and both versions were carefully assessed for conceptual and cultural equivalence.

## 2.5. Expert Evaluation of Validity

### 2.5.1. Content validity

The content validity of the Chinese version of the IMTT-NP was evaluated by a panel of six experts with diverse nursing backgrounds, including one scale-development specialist, one nursing education expert, two clinical specialist nurses, and two nursing management experts[21]. Each expert independently rated the relevance of the 58 items using a four-point scale (1 = not relevant, 2 = requires revision, 3 = relevant with minor modifications, and 4 = highly relevant). The item-level content validity index (I-CVI) was calculated by dividing the number of experts assigning a rating of 3 or 4 by the total number of experts. Overall scale-level content validity was evaluated using the average scale-level content validity index (S-CVI/Ave)[22]. To account for chance agreement, the modified kappa statistic (κ*) was calculated for each item. Values of 0.40–0.59 indicated moderate agreement, 0.60–0.74 indicated good agreement, and values above 0.75 indicated excellent agreement[23].

### 2.5.2. Face validity and pilot testing

A pilot test was conducted with 20 specialist nurses to evaluate the comprehensibility of the translated items. Participants were asked to identify unclear or ambiguous wording and provide suggestions for improvement. All items were considered comprehensible, and no further modifications were required.

## 2.6. Data collection

Data were collected from October to November 2024. Training coordinators at the participating national-level specialty nursing training bases invited potentially eligible nurses from different hospitals and specialties to an online meeting via Tencent Meeting. During the meeting, the

researcher explained the study purpose and procedures, answered questions, and confirmed eligibility. Nurses who met the inclusion criteria and provided informed consent were invited to complete the questionnaire via Wenjuanxing, an online survey platform. Completion took approximately 15–20 minutes. Participation was voluntary, and electronic informed consent was obtained before access to the questionnaire was granted. All items were mandatory, and the survey settings restricted each WeChat account to one submission. To ensure data quality, questionnaires showing invariant or systematic response patterns were excluded.

## 2.7. Data analysis

### 2.7.1. Data Management Procedures

Several measures were implemented to ensure data accuracy and integrity. The survey settings restricted each WeChat account to one submission, and all items were mandatory to minimize missing data. Completion time was monitored, and questionnaires completed in less than three minutes were considered invalid. In addition, six attention-check items were randomly embedded in the questionnaire to assess whether participants had read the items carefully; questionnaires containing incorrect responses to the attention-check items were excluded. Nine negatively worded items (items 4.1, 4.2, 4.3, 6.1, 6.2, 6.3, 9.1, 9.2, and 9.3) were reverse-scored before analysis to ensure that higher scores consistently represented higher levels of the corresponding constructs.

### 2.7.2. Statistical analysis

Statistical analyses were conducted using R version 4.4.2. The psych package (version 2.6.5) was used to assess factorability, conduct parallel analysis and exploratory factor analysis, and calculate Cronbach's α and McDonald's ω. The lavaan package (version 0.7.2) was used for the first- and second-order confirmatory factor analyses and to obtain standardized parameter estimates and latent-factor correlations. The semTools package (version 0.5.9) was used to calculate average variance extracted, and the irr package (version 0.84.1) was used to calculate intraclass correlation coefficients. Model paths were visualized using the DiagrammeR package (version 1.0.12). Descriptive statistics, group comparisons, and Pearson's correlation analyses were performed using functions from the base R stats package.

Participant characteristics were summarized using frequencies and percentages for categorical variables. Normally distributed continuous variables were described using means and standard deviations, whereas non-normally distributed continuous variables were summarized using medians and interquartile ranges. The sociodemographic and professional characteristics of the EFA and CFA subsamples were compared using an independent-samples t test, Pearson's chi-square test, or Fisher's exact test with Monte Carlo simulation, as appropriate.

Internal consistency reliability was evaluated using Cronbach's α and McDonald's ω, with values ≥ 0.70 considered acceptable[24]. Test–retest reliability was assessed in a subsample of 37 participants over a two-week interval using a two-way, absolute-agreement, average-measures intraclass correlation coefficient (ICC), with values of 0.50–0.75, 0.75–0.90, and > 0.90 interpreted as moderate, good, and excellent reliability, respectively[25].

The total sample (N = 951) was randomly divided using a fixed random seed of 123 into an EFA subsample (n = 475) and a CFA subsample (n = 476). Sampling adequacy for EFA was assessed using the Kaiser–Meyer–Olkin measure and Bartlett's test of sphericity[26]. EFA was conducted using maximum likelihood extraction with Promax rotation[27]. The number of factors retained was determined using parallel analysis, eigenvalues greater than 1.0, inspection of the scree plot, theoretical interpretability, and consistency with the structure of the original instrument. Items with factor loadings ≥ 0.40 and without substantial cross-loadings were retained[28]. CFA was performed using maximum likelihood estimation, with correlations permitted among the 12 first-order factors[29]. A theoretically specified second-order CFA model was also examined and compared with the correlated first-order model using model fit indices and information criteria. Model fit was evaluated using the comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). CFI and TLI values ≥ 0.90 and RMSEA and SRMR values ≤ 0.06 were considered indicative of satisfactory model fit[30]. The CFA path diagram was generated using DiagrammeR, with standardized factor loadings displayed; error terms were omitted and only inter-factor correlations with absolute values ≥ 0.40 were shown to improve readability[31].

Convergent validity was evaluated using standardized factor loadings, average variance extracted (AVE), and composite reliability (CR). CR was calculated from the standardized CFA loadings. Discriminant validity was assessed using the Fornell–Larcker criterion by comparing the square root of the AVE for each dimension with the absolute values of its correlations with the other latent dimensions. Concurrent validity was examined using Pearson's correlation coefficient between the Chinese IMTT-NP and FITT questionnaire scores[32].

## 2.8. Ethical principles

This study was approved by the Ethics Committee of the Second Affiliated Hospital of Zhejiang University School of Medicine (SAHZU; approval number: 2024 – 0556). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and its later amendments. All participants were fully informed of the purpose, significance, and procedures of the study, and were made aware that their

responses to the scale would be used solely for scientific research purposes. Participation was voluntary and anonymous, and electronic informed consent was obtained from all participants before they accessed the questionnaire.

## 3. Results

## 3.1. Expert-based validation

### 3.1.1. Face validity

Six experts provided feedback aimed at improving clarity through minor wording modifications and grammatical corrections. No items were removed from the instrument following this process.

### 3.1.2. Content validity

The item-level content validity indices (I-CVIs) ranged from 0.833 to 1.0 (Table S1). The modified kappa values were 0.816 or higher for most items. The overall scale content validity (S-CVI/Ave) was 0.940.

## 3.2. Psychometric testing

### 3.2.1. Sample characteristics

A total of 951 specialist nurses were included in the psychometric analysis. The total sample was randomly divided into an EFA subsample (n = 475) and a CFA subsample (n = 476). The sociodemographic and professional characteristics of the total sample are presented in Table 1. No statistically significant differences were observed between the EFA and CFA subsamples in any of the examined characteristics ($p > 0.05$), supporting the comparability of the two subsamples.

Table 1
Characteristics of EFA and CFA subsamples

| Characteristic | Total sample (N = 951) | EFA subsample (n = 475) | CFA subsample (n = 476) | p value |
|---|---|---|---|---|
| Gender | | | | 0.44 |
| Male | 121 (12.72) | 56 (11.79) | 65 (13.66) | |
| Female | 830(87.28) | 419 (88.21) | 411 (86.35) | |
| Age | 35.32 (5.41) | 35.31 (5.39) | 35.33 (5.43) | 0.97 |
| Marital status | | | | 0.88 |
| Married | 811(85.28) | 405 (85.26) | 406 (85.29) | |
| Single | 122(12.83) | 60 (12.63) | 62 (13.03) | |
| Divorced | 18(1.89) | 10 (2.11) | 8 (1.68) | |
| Education level | | | | 0.82 |
| Diploma or below | 23(2.42) | 10 (2.11) | 13 (2.73) | |
| Bachelor's degree | 884(92.96) | 443 (93.26) | 441 (92.65) | |
| Master's degree or above | 44(4.63) | 22 (4.63) | 22 (4.62) | |
| Professional title | | | | 0.69 |
| Nurse | 8(0.84) | 4 (0.84) | 4 (0.84) | |
| Senior nurse | 213(22.40) | 101 (21.26) | 112 (23.53) | |
| Nurse supervisor | 641(67.40) | 326 (68.63) | 315 (66.18) | |
| Associate chief nurse | 82(8.62) | 39 (8.21) | 43 (9.03) | |
| Chief nurse | 7(0.74) | 5 (1.05) | 2 (0.42) | |
| Position | | | | 0.85 |
| Staff nurse | 453(47.63) | 235 (49.47) | 218 (45.80) | |
| Ward preceptor | 185(19.45) | 90 (18.95) | 95 (19.96) | |
| Team leader | 172(18.09) | 83 (17.47) | 89 (18.70) | |
| Ward nurse manager | 130(13.67) | 62 (13.05) | 68 (14.29) | |
| Director of nursing | 11(1.16) | 5 (1.05) | 6 (1.26) | |
| Work experience | | | | 0.09 |
| ≤ 5 years | 55(5.78) | 24 (5.05) | 31 (6.51) | |
| > 5–10 years | 283(29.76) | 156 (32.84) | 127 (26.68) | |
| > 10 years | 613(64.46) | 295 (62.11) | 318 (66.81) | |
| Employment status | | | | 0.95 |
| Labor dispatch | 41(4.31) | 21 (4.42) | 20 (4.20) | |
| Hospital contract | 527(55.42) | 265 (55.79) | 262 (55.04) | |
| Permanent staff | 383(40.27) | 189 (39.79) | 194 (40.76) | |
| Specialty area | | | | 0.62 |
| Cardiovascular | 342(35.96) | 166 (34.95) | 176 (36.98) | |

Note. Data are presented as mean (standard deviation) or n (%). Percentages were calculated within each subsample. Age was compared using an independent-samples t test. Categorical variables were compared using Pearson's chi-square test or Fisher's exact test with Monte Carlo simulation, as appropriate. EFA = exploratory factor analysis; CFA = confirmatory factor analysis.

| Characteristic | Total sample (N = 951) | EFA subsample (n = 475) | CFA subsample (n = 476) | p value |
|---|---|---|---|---|
| Interventional | 219(23.03) | 106 (22.32) | 113 (23.74) | |
| Operating Room | 31(3.26) | 15 (3.16) | 16 (3.36) | |
| Orthopedics | 71(7.47) | 44 (9.26) | 27 (5.67) | |
| Traditional Chinese Medicine | 21(2.21) | 12 (2.53) | 9 (1.89) | |
| Critical & Emergency Care | 126(13.25) | 64 (13.47) | 62 (13.03) | |
| Anesthesia & Pain | 26(2.73) | 13 (2.74) | 13 (2.73) | |
| Oncology | 115(12.09) | 55 (11.58) | 60 (12.61) | |

Note. Data are presented as mean (standard deviation) or n (%). Percentages were calculated within each subsample. Age was compared using an independent-samples t test. Categorical variables were compared using Pearson's chi-square test or Fisher's exact test with Monte Carlo simulation, as appropriate. EFA = exploratory factor analysis; CFA = confirmatory factor analysis.

## 3.2.2. Exploratory factor analysis

EFA was conducted to examine the factor structure of the Chinese version of the IMTT-NP. The data were suitable for factor analysis, as indicated by a Kaiser-Meyer-Olkin value of 0.93 and a significant Bartlett's test of sphericity, $\chi^2$ (1653) = 29631.21, $p < 0.001$. A 12-factor solution was retained based on parallel analysis, eigenvalues, the scree plot, theoretical interpretability, and consistency with the structure of the original instrument. All 58 items were retained, with factor loadings ranging from 0.532 to 0.998 and no substantial cross-loadings. The 12-factor solution explained 58.1% of the total variance. Item-level primary EFA loadings and communalities are presented in Supplementary Table S2.

## 3.2.3. Confirmatory factor analysis

CFA was conducted to examine the 12-factor structure identified in the EFA (Fig. 1). The model fit indices were as follows: $\chi^2(1529) = 2303.914$, $p < 0.001$, $\chi^2/df = 1.507$, CFI = 0.948, TLI = 0.943, RMSEA = 0.033, 90% CI [0.030, 0.035], and SRMR = 0.034. Standardized factor loadings ranged from 0.596 to 0.946. Item-level standardized CFA loadings are presented in Supplementary Table S2.

**Note**

Standardized factor loadings are shown. Correlations below 0.40 are not displayed.

A second-order CFA model based on the structure of the original instrument was also examined. The second-order model showed the following fit indices: $\chi^2(1579) = 2658.492$, $p < 0.001$, $\chi^2/df = 1.684$, CFI = 0.927, TLI = 0.924, RMSEA = 0.038, 90% CI [0.035, 0.040], and SRMR = 0.056. As shown in Table 2, compared with the first-order 12-factor model, the second-order model showed lower CFI and TLI and higher RMSEA, SRMR, AIC, and BIC. Therefore, the first-order 12-factor model was retained as the final model.

Table 2
Comparison of first-order and second-order CFA models

| Model | $\chi^2$ | df | $\chi^2/df$ | CFI | TLI | RMSEA | 90% CI | SRMR | AIC | BIC |
|---|---|---|---|---|---|---|---|---|---|---|
| First-order 12-factor model | 2303.914 | 1529 | 1.507 | 0.948 | 0.943 | 0.033 | 0.030–0.035 | 0.034 | 70325.152 | 71083.258 |
| Second-order model | 2658.492 | 1579 | 1.684 | 0.927 | 0.924 | 0.038 | 0.035–0.040 | 0.056 | 70579.729 | 71129.564 |

Note. $\chi^2/df$ = chi-square divided by degrees of freedom; CFI = comparative fit index; TLI = Tucker–Lewis index; RMSEA = root mean square error of approximation; CI = confidence interval; SRMR = standardized root mean square residual; AIC = Akaike information criterion; BIC = Bayesian information criterion.

## 3.2.4. Convergent and discriminant validity

The standardized factor loadings ranged from 0.596 to 0.946. The AVE values for the 12 dimensions ranged from 0.500 to 0.669, and the CR values ranged from 0.768 to 0.942. All AVE values were at or above 0.50, and all CR values exceeded 0.70, supporting the convergent validity of the Chinese version of the IMTT-NP. Inter-factor correlations ranged from − 0.463 to 0.707. The square root of the AVE for each dimension exceeded the absolute values of its correlations with all other latent dimensions, satisfying the Fornell–Larcker criterion and supporting the discriminant validity of the 12-factor model (Table 3).

Table 3
Convergent and discriminant validity of the Chinese version of the IMTT-NP

| Factor | AVE | CR | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 | F11 | F12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | 0.568 | 0.833 | 0.754 | | | | | | | | | | | |
| F2 | 0.628 | 0.853 | 0.350 | 0.792 | | | | | | | | | | |
| F3 | 0.613 | 0.825 | 0.383 | 0.439 | 0.783 | | | | | | | | | |
| F4 | 0.669 | 0.859 | 0.186 | 0.272 | 0.257 | 0.818 | | | | | | | | |
| F5 | 0.627 | 0.836 | 0.355 | 0.542 | 0.426 | 0.367 | 0.792 | | | | | | | |
| F6 | 0.623 | 0.831 | 0.156 | 0.190 | 0.234 | 0.536 | 0.385 | 0.789 | | | | | | |
| F7 | 0.641 | 0.843 | 0.245 | 0.375 | 0.286 | 0.265 | 0.493 | 0.337 | 0.800 | | | | | |
| F8 | 0.667 | 0.857 | -0.129 | -0.209 | -0.097 | -0.446 | -0.167 | -0.361 | -0.084 | 0.817 | | | | |
| F9 | 0.529 | 0.768 | 0.162 | 0.236 | 0.246 | 0.579 | 0.317 | 0.637 | 0.302 | -0.463 | 0.727 | | | |
| F10 | 0.540 | 0.824 | 0.391 | 0.466 | 0.473 | 0.374 | 0.538 | 0.434 | 0.579 | -0.137 | 0.472 | 0.735 | | |
| F11 | 0.552 | 0.916 | 0.499 | 0.542 | 0.428 | 0.323 | 0.550 | 0.264 | 0.585 | -0.136 | 0.274 | 0.707 | 0.743 | |
| F12 | 0.500 | 0.942 | 0.379 | 0.402 | 0.354 | 0.294 | 0.481 | 0.192 | 0.354 | -0.124 | 0.256 | 0.506 | 0.556 | 0.707 |

Note. AVE = average variance extracted; CR = composite reliability. Bold diagonal values represent the square root of the AVE; off-diagonal values represent correlations between latent dimensions.

## 3.3. Reliability analysis

Internal consistency was assessed using Cronbach's α and McDonald's ω. Test-retest reliability was used to evaluate the temporal stability of the Chinese version of the IMTT-NP.

## 3.3.1. Internal consistency reliability

The Chinese version of the IMTT-NP showed satisfactory internal consistency. Cronbach's α and McDonald's ω were 0.924 and 0.971, respectively, for the total scale. Across the 12 dimensions, Cronbach's α ranged from 0.770 to 0.944, and McDonald's ω ranged from 0.771 to 0.944 (Table 4). Item-level results are presented in Supplementary Table S3.

Table 4
Internal consistency reliability of the Chinese version of the IMTT-NP

| Factor | Cronbach's α | McDonald's ω |
|---|---|---|
| Total scale | 0.924 | 0.971 |
| F1 | 0.830 | 0.831 |
| F2 | 0.811 | 0.840 |
| F3 | 0.814 | 0.817 |
| F4 | 0.854 | 0.854 |
| F5 | 0.830 | 0.833 |
| F6 | 0.838 | 0.838 |
| F7 | 0.842 | 0.843 |
| F8 | 0.854 | 0.855 |
| F9 | 0.770 | 0.771 |
| F10 | 0.810 | 0.813 |
| F11 | 0.913 | 0.914 |
| F12 | 0.944 | 0.944 |
| Note: Values of Cronbach's α and McDonald's ω ≥ 0.70 were considered indicative of acceptable internal consistency. | | |

### 3.3.2. Test-retest reliability

The test-retest reliability of the Chinese version of the IMTT-NP was assessed among 37 specialist nurses. The ICC was 0.946 for the total scale and ranged from 0.707 to 0.913 across the 12 dimensions (Table S4).

## 3.4. Concurrent validity

The concurrent validity of the IMTT-NP was supported by a moderate and statistically significant correlation with FITT ($r = 0.463$, $p < 0.001$, 95% CI 0.412–0.512).

## 4. Discussion

## 4.1. Validity of the Chinese IMTT-NP

### 4.1.1. Content validity and cultural adaptation

Face validity was confirmed through expert review, with six experts suggesting only minor wording and grammatical adjustments, indicating that the items were clear and appropriate for the intended construct[33]. Content validity of the IMTT-NP was rigorously evaluated following standard procedures, including development of a content validity table, expert panel review, selection of appropriate assessment methods, and systematic evaluation of each item and dimension for relevance[34]. The scale demonstrated robust content validity, with I-CVIs ranging from 0.833 to 1.0, most modified kappa values ≥ 0.816, and an S-CVI/Ave of 0.940, indicating that the items effectively captured the intended construct[34]. These results were supported by a meticulous translation and cultural adaptation process, which preserved both semantic and cultural equivalence, with minor wording adjustments that adapted terms such as "supervisor," "leaders," "workgroup," and "organization" to denote direct nursing supervisors, trainers, clinical departments, and healthcare institutions, thereby enhancing the scale's cultural relevance in the Chinese nursing context.

### 4.1.2. Structural validity of the 12-factor model

The EFA identified a 12-factor structure consistent with that of the original IMTT-NP[18]. The 12 factors explained 58.1% of the total variance. Although the explained variance was moderate, retention of all 58 items was supported by their satisfactory factor loadings (0.532–0.998), absence of substantial cross-loadings, and the need to preserve the theoretical framework and comprehensive content coverage of the original instrument. The CFA further supported the 12-factor structure, with satisfactory model fit ($\chi^2/df = 1.507$, CFI = 0.948, TLI = 0.943, RMSEA = 0.033, and SRMR = 0.034) and standardized factor loadings ranging from 0.596 to 0.946[35].

Although both first-order and second-order models showed acceptable fit, the correlated first-order 12-factor model demonstrated superior performance, with higher CFI and TLI values and lower RMSEA, SRMR, AIC, and BIC values. The significant chi-square difference test further supported the first-order model ($\Delta\chi^2 = 354.578$, $\Delta df = 50$, $p < 0.001$)[36]. These findings indicate that the 12 dimensions are interrelated but represent distinct aspects of training transfer, supporting the interpretation of the IMTT-NP as a multidimensional rather than unidimensional construct. Furthermore, all dimensions satisfied the Fornell–Larcker criterion, providing additional evidence of discriminant validity[37].

Taken together, these findings support the structural validity of the Chinese IMTT-NP and its consistency with the theoretical structure of the original instrument. Nevertheless, the relatively complex 58-item structure may increase respondent burden in clinical settings, and future studies should explore whether a shortened version can achieve comparable psychometric performance while maintaining adequate content coverage.

### 4.1.3. Concurrent validity

Concurrent validity was supported by the moderate positive correlation between the Chinese IMTT-NP and FITT questionnaire ($r = 0.463$, $p < 0.001$, 95% CI 0.412–0.512). The correlation indicates that the two instruments assess related aspects of training transfer while maintaining distinct measurement characteristics.

The moderate association may be explained by differences in conceptual scope and dimensional structures. The FITT evaluates training transfer factors through five broader domains, whereas the IMTT-NP differentiates 12 dimensions covering more specific motivational, interpersonal, organizational, training-related, and trainer-related factors[17, 18]. For example, the IMTT-NP separately evaluates resistance to change, workplace responses, supervisory sanctions, peer coaching, and trainer support, which may capture aspects not fully represented in FITT. Therefore, the current findings support the complementary validity of the Chinese IMTT-NP. Future research should further examine criterion-related validity using objective indicators, such as observed practice changes or supervisor evaluations.

## 4.2. Reliability of the Chinese IMTT-NP

The Chinese version of the IMTT-NP demonstrated satisfactory reliability. Internal consistency was supported by Cronbach's α and McDonald's ω values[38]. The total scale showed high internal consistency (Cronbach's $\alpha = 0.924$; $\omega = 0.971$), and all dimensions showed Cronbach's α and McDonald's ω values above 0.70. Composite reliability values also supported the consistency of the latent constructs. In addition, test–retest reliability demonstrated good temporal stability, with an ICC of 0.946 for the total scale and 0.707–0.913 across dimensions[39]. Together, these findings indicate that the Chinese IMTT-NP provides a reliable assessment of perceived factors influencing training transfer among specialist nurses. The combination of multiple reliability indicators strengthens confidence in the stability and consistency of the instrument.

## 4.3. Potential applications in nursing education and management

Effective training transfer is critical in nursing practice, particularly in the context of global and national nursing workforce shortages[40]. Given the substantial resources invested in professional training, understanding the factors that facilitate or hinder the application of acquired knowledge and skills may help healthcare institutions refine their training and workplace-support strategies[41]. International health authorities and China's National Nursing Development Plan have also emphasized the importance of translating professional learning into practice[42, 43]. In this context, the Chinese version of the IMTT-NP provides a culturally adapted instrument for assessing perceived factors influencing training transfer among specialist nurses.

The instrument may have several potential applications. First, it can provide a structured profile of nurses' perceptions of the conditions influencing training transfer. Second, its dimensions may help identify perceived barriers and facilitators that warrant further investigation or targeted support. These dimensions include motivation, personal capacity, peer support, supervisory responses, organizational support, training characteristics, and trainer support. Third, the instrument may complement evaluations of training programs by assessing transfer-related factors at planned follow-up points. However, as a retrospective self-report instrument, it does not directly assess the effects of educational interventions, actual transfer behavior, clinical competence, nursing quality, or patient outcomes. It should therefore be used alongside objective indicators, such as clinical audits, observed changes in practice, training performance records, or supervisor evaluations, when evaluating training outcomes.

## 4.4. Strengths

This study has several methodological strengths. The relatively large sample of 951 specialist nurses recruited from tertiary hospitals across six provinces provided an adequate sample size for psychometric evaluation and included participants from different regional healthcare settings. Randomly dividing the sample into separate EFA and CFA subsamples reduced the risk of model overfitting, although this procedure represented internal split-sample validation rather than independent external validation. Internal consistency was evaluated using Cronbach's α, McDonald's ω, and composite reliability. The inclusion of McDonald's ω provided additional evidence of reliability without relying solely on

the tau-equivalence assumption underlying Cronbach's α. Furthermore, the systematic forward-backward translation, expert review, pilot testing, and content validity assessment supported the semantic and cultural appropriateness of the Chinese version of the IMTT-NP.

## 4.5. Limitations

This study has several limitations. Its cross-sectional design precluded assessment of changes in training transfer over time. Convenience sampling may have introduced selection bias, as nurses who were more motivated or interested in training transfer may have been overrepresented. In addition, concurrent validity was assessed using another self-reported instrument, which may have increased common method variance. The absence of objective criteria, such as clinical audits, observed changes in practice, or supervisor evaluations, limits conclusions regarding actual transfer behavior. Future studies should evaluate criterion-related validity using independent behavioral or organizational indicators, including supervisor evaluations, peer assessments, and clinical performance audits. The participants were exclusively specialist nurses working in tertiary hospitals across six provinces, whose organizational climates, resources, and training systems may differ from those in primary care institutions, rural healthcare facilities, and non-tertiary hospitals. Therefore, the findings should not be generalized beyond the sampled population without further validation. Finally, the EFA and CFA subsamples were derived from the same cohort and represented internal split-sample validation rather than independent external validation. Replication using independent and more diverse samples is warranted.

## 5. Conclusion

This study translated and culturally adapted the IMTT-NP into Chinese and evaluated its psychometric properties among specialist nurses working in tertiary hospitals in China. The Chinese version demonstrated satisfactory validity and reliability in this population. Its 12-dimensional structure provides a differentiated assessment of perceived personal, interpersonal, organizational, training-related, and trainer-related factors that may facilitate or impede training transfer. The instrument may assist nursing educators and administrators in identifying transfer-related barriers and facilitators and may inform the development and evaluation of subsequent training and workplace-support strategies. However, it does not directly measure actual transfer behavior, clinical competence, or nursing quality. Its validity among general nurses and nurses working in primary care institutions, non-tertiary hospitals, or rural settings remains unknown and should be examined in future independent studies.

## Declarations

# Ethics approval and consent to participate

Each participant signed an informed consent form before the study and remained anonymous on all questionnaires. All procedures were carried out in accordance with the 1964 Declaration of Helsinki and its subsequent amendments. In addition, this study was approved by the Ethics Committee of the Second Affiliated Hospital of Zhejiang University School of Medicine.

# Consent for publication

N/A.

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# Author Contribution

JC and BY contributed to the conceptualization and formal analysis of the study and acquired funding. JC also contributed to drafting the manuscript. XY contributed to the conceptualization and formal analysis, drafted and critically revised the manuscript, supervised the study, and was responsible for project administration. BL, SJ, MW, and CW contributed to the methodology and investigation. BL, SJ, MW, CW, and XZ contributed to data curation. All authors read and approved the final manuscript.

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# Data Availability

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

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