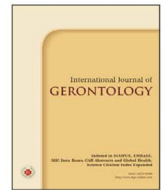




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Original Article

The Taiwanese Revised Tilburg Frailty Indicator for Patients with Chronic Kidney Disease: Psychometric Properties

Fang-Ru Yueh^a, Huan-Fang Lee^a, Chen-Hui Huang^b, Le Trinh Lam^c, Susan Fetzner^d, Miaofen Yen^{a*}

^a Department of Nursing, College of Medicine, National Cheng Kung University, Tainan, Taiwan, ^b Department of Nursing, National Chi Nan University, Nantou, Taiwan, ^c University of Medicine and Pharmacy at Ho Chi Minh City, Ho Chi Minh City, Vietnam, ^d Department of Nursing, College of Health and Human Services, University of New Hampshire, New Hampshire, United States

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SUMMARY

Background: Patients with chronic kidney disease (CKD) are at high risk of frailty, leading to adverse outcomes. The Taiwanese version of the Tilburg Frailty Indicator (TFI-T) has been validated in community-dwelling older adults, but its psychometric properties have not been assessed in CKD patients. This study evaluates the reliability and validity of the Taiwan revised version of the Tilburg Frailty Indicator (TFI-TR) for this population.

Methods: The cross-sectional design was conducted for outpatients with nephrology in Taiwan. Five steps were taken to test the TFI-TR. First, the modified Delphi method was performed to revise the item content of TFI-T. Second, item analysis was used to examine item determination. Third, construct validity was examined using confirmatory factor analysis (CFA), Fried frailty phenotype (FP), and Kihon Checklist (KCL) for criterion validity. Fourth, the reliability was explored using the KR-20 reliability coefficient. Finally, the ROC curve was used to determine the cut points of TFI-TR.

Results: A 15-item CKD-specific version of the TFI-T (TFI-TR) with three domains was developed. Item analysis showed good discrimination. CFA demonstrated good construct validity (TLI = 0.88; CFI = 0.90; RMSEA = 0.043), and criterion validity was supported by moderate correlations with FP and KCL ($r = 0.45, 0.62$). The KR-20 reliability coefficient was 0.70. A cut-off score of 4.5 yielded good sensitivity and specificity (AUC = 0.86, 95% CI = 0.78–0.94).

Conclusions: The TFI-TR demonstrates acceptable validity and reliability for screening frailty among CKD outpatients. A cut-off of 4.5 provides good diagnostic performance.

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1. Background

Frailty has been identified as cumulative declines in multiple physiological systems. Patients with frailty could be vulnerable to developing adverse health outcomes, such as falls, disability, hospitalization, and mortality.^{1–3} Previous studies have demonstrated that frailty was correlated with adverse health outcomes when patients with chronic kidney disease (CKD) have a higher risk of suffering frailty.^{4,5} The prevalence of frailty is high in the late stage of CKD.^{6,7} However, the estimated prevalence of frailty might differ according to various measures and definitions, ranging from 7% to 73%.^{5,8} The inconsistency in the definition of frailty can be attributed to the controversy that arises from its conceptualization and operationalization.⁹ Recent studies have also emphasized that frailty is a multidimensional concept. Therefore, a comprehensive evaluation is necessary to evaluate multiple physical, psychological, and social domains.¹⁰ Until now, there are thirty-eight instruments to assess multidomain frailty.¹¹ The Fried frailty phenotype (FP) is the first to be developed and is commonly used to assess frailty, but it only evaluates the physical domain and is not comprehensive.¹ Addi-

tionally, the Kihon Checklist (KCL) generally evaluates multidomain frailty but has too many items.¹² Recently, COnsensus-based Standards for the selection of health measurement instruments (COSMIN) showed that the Tilburg Frailty Indicator (TFI) is considered highly reliable and valid.¹¹ The review of Gobbens¹³ also mentioned that the psychometric properties of TFI are being qualified as good. TFI is based on an integral model to develop the relationship between frailty, life course, disease, and relative adverse outcomes.^{14,15} TFI was developed in the Netherlands and exhibited good psychometric performance among community-dwelling individuals.¹⁴ Lin et al.¹⁶ translated TFI into Mandarin (TFI-T) for Taiwanese and tested it on community-dwelling older people in Taiwan. However, TFI has not been applied to frailty among patients with CKD. As explained earlier, CKD patients are a particular population highly associated with frailty, but the reliability and validity are still unclear. This study aims to validate the Taiwan revised version of the Tilburg Frailty Indicator (TFI-TR) among patients with CKD.

2. Methods

The development of the TFI-TR followed Devellis' guidelines for scale development, and psychometric testing was conducted after the scale was developed.¹⁷ A cross-sectional study was used to test

* Corresponding author. Department of Nursing, College of Medicine, National Cheng Kung University, No. 1, University Road, Tainan City, Taiwan.
E-mail address: miaofen@mail.ncku.edu.tw (M.f. Yen)

the TFI-T on a sample of patients with CKD.

2.1. Study design and sample

A cross-sectional study determined the reliability and validity of the TFI-TR. Participants were patients with CKD who were followed in an outpatient nephrology clinic in southern Taiwan. The inclusion criteria were: (1) the participant was over 20 years old; (2) the participant communicated in Mandarin or Taiwanese. Exclusion criteria were: (1) the participant had a history of psychiatric problems; (2) the participant received renal replacement therapy. The sample sizes of scale developing estimation were suggested by Clark and Watson;¹⁸ above 250 was the minimum requirement.

2.2. Instruments of frailty measurements

2.2.1. The Taiwanese version of the TFI

The TFI-T¹⁶ includes two parts. Part A contains the determinants of frailty and multimorbidity. Part B consists of the three domains of frailty. Only Part B was used in the current study and includes three domains: physical domain (8 items), psychological domain (4 items), and social domain (3 items). Items are scored as yes (0) or no (1) (11 items), while four items are scored as yes (1), no (0), or sometimes (0). Item 9 is scored as 1 (yes) or 0 (no/sometimes). A total score of 15 indicates the highest level of frailty. Lin et al.¹⁶ recommended a cut score of 5.5 to achieve a sensitivity of 74.6% and a specificity of 83% in identifying frailty. Construct validity indicated three items with low factor loadings ($< .03$). No items were deleted by Lin et al.¹⁶ Cronbach's alpha of the TFI-T was 0.78 for the total scale and ranges from 0.79 to 0.81 for the domains.¹⁶

2.2.2. Fried frailty phenotype

The frailty phenotype (FP) is a gold standard for assessing physical frailty.¹ Previous systematic review indicated that the FP has been the most commonly used tool to assess frailty in patients with CKD.^{5,19} Although previous studies indicated that the TFI and physical indicators showed a low correlation, the determination of frail and non-frail between FP and TFI showed good prediction (AUC = 0.82).²⁰ Therefore, the FP was used to validate the physical domain of the Tilburg Frailty Indicator (TFI) criteria.

Frailty is classified by five self-report questions, including weight loss, self-described exhaustion, weakness, slowness, and low physical activity. Each question is assigned a 1 (yes) or 0 (no) score. Total scores range from 0 (no frailty) to 5 (frailty). Total scores are ranked 0 as robust, 1 to 2 as pre-frail, and greater than two as frailty. Chen²¹ translated the FP into Mandarin with the low physical activity item in the Taiwan version replaced with the low physical activity of the Taiwan International Physical Activity Questionnaire Short Form (IPAQ-SF). The content validity of IPAQ-SF was found to be 0.99, and the intraclass correlation coefficient was measured at 0.70.²¹ The low internal consistency was reported by the Kuder-Richardson 20 (KR-20) reliability coefficient of 0.32 for elders living in the Taiwan community.²²

2.2.3. Kihon checklist

The KCL was developed in Japan.²³ Research points out that KCL is already used to assess frailty among CKD patients and indicates that frailty is associated with kidney function decline.²⁴ Moreover, to our knowledge, the KCL is first based on the development of Asian groups and provides acceptable reliability and validity.²⁵ On the other hand, since 2017, Taiwan's Ministry of Health and Welfare has used KCL to assess frailty before and after preventing and delaying

disability care programs.²⁶ The KCL comprises 25 items divided into seven domains of frailty, and domains include instrumental activities of daily living (5 items), physical (5 items), nutrition (2 items), eating (3 items), socialization (2 items), memory (3 items) and mood (5 items).²³ Each item is scored as 1 (yes) or 0 (no), with a total score ranging from 0 to 25, with 0–3 as robust, 4–7 as pre-frail, and > 7 as frailty. Hsieh²⁶ translated the KCL into Mandarin, achieving a Cronbach's alpha of 0.70, a sensitivity of 70%, and a specificity of 83% among elders living in the community.

2.3. Procedure

After providing informed consent, patients completed a demographic questionnaire and the research instruments (TFI-TR, the FP, and the KCL). A small gift (value of \$ 6.00) was awarded for completion.

2.4. Steps of the psychometric properties

Data analyzed through this study were using SPSS version 22.0 and Mplus 8.3. The demographic characteristics of the participants were analyzed with descriptive statistics, which included frequency, percentage, mean, and standard deviation. A p -value less than 0.05 was determined as statistically significant.²⁷ The following are the details of the psychometric testing methods.

2.5. Data analysis

The three low-scoring items reported by Lin et al.¹⁶ were reviewed. The Chinese translations were revised based on Gobben's original English statements. Five experts reviewed the revisions, and consensus was reached.

2.5.1. Item content of TFI-TR

After receiving the informed consent forms from the original development author and the author of TFI-T, the research team rechecked the meaning of items for consistency between English and Taiwanese Chinese and revised the wording and sentences of TFI-T. To determine equivalence and ensure that items in the two languages have equivalent meanings, we conducted a panel meeting with five experts whose professions were nephrology and nursing, and we discussed and revised the content. Finally, a 15-item TFI-TR was used to examine the validity and reliability of the current study.

2.5.2. Item discrimination

Item discrimination was examined using item analysis. The total scores were ranked in the upper 27% and the lower 27%. A t -test was used to establish low and high critical ratio (CR) values ($p < .01$). The CR and item-subdomain correlations (ISC) were calculated to measure the discriminating effectiveness of an item. The greater the correlation, the more effective the item reflects frailty.²⁸ The item was acceptable when the $CR \geq 2.54$ and the $ISC > 0.3$.²⁹

2.5.3. Validity

Construct validity was assessed using confirmatory factor analysis (CFA) with the weighted least squares (WLS) method, employing a weighted matrix of asymptotic covariance for estimation. This study's probability results with values below 0.05 indicated a satisfactory factor analysis. Factor loadings equal to or exceeding 0.30 indicated significant relationships between items and factors.²⁹ The criteria for assessing fit and validity in this study included the following: $\chi^2/\text{degree of freedom (df)}$, Root Mean Square Error of Ap-

proximation (RMSEA) $\leq .05$, as well as the Comparative Fit Index (CFI) $\geq .90$ and Tucker-Lewis Index (TLI) $\geq .90$, with p -values $\leq .05$ being considered statistically significant.²⁷ Concurrent validity was established by calculating the Pearson correlation coefficient between TFI-TR, FP, and KCL.

2.5.4. Reliability

The reliability was evaluated by internal consistency and calculated using Kuder-Richardson Formula 20 (KR-20), a typical estimator for the reliability of dichotomous data.³¹

2.5.5. Cut-points estimation

The receiver operating characteristic (ROC) curve was used to evaluate the frailty and instrument accuracy cut point. The best cut point was determined by the diagnostic value using the Youden index (Youden index = sensitivity + specificity – 1).³²

2.6. Ethical consideration

This study was conducted with approval from the Institutional Review Board of National Cheng Kung University Hospital (B-ER-109-494). All participants provided oral and written informed consent.

3. Results

Data were obtained from 300 adults with CKD. The mean age of the participants was 65.3 ± 13.4 . Most participants were male (61.7%, $n = 185$). Over half of the participants were diagnosed with CKD Stage 3 ($n = 173$, 57.7%). The prevalence of frailty in the sample varied with the measurement used: 4.7% (FP), 26.7% (KCL) and 29.3% (TFI-TR) (Table 1).

3.1. Content of the TFI-TR

The final version of TFI-T was modified as TFI-TR based on the panel meeting results. In particular, alternative wording was deliberated for items 2, 14, and 15, and a conclusion was reached.

3.2. Item discrimination

The distribution of the TFI-TR scores for each item was examined. There were no missing values for the 15 items. Mean item scores ranged from 0.05 to 0.45 (Table 2). All CR exceeded 2.5 and were significant ($p < .01$) item ISC were significant, ranging from .34 to .76 between each item and its domain.

3.3. Validity

3.3.1. Construct validity

The construct validity of TFI-TR was assessed by examining a three-factor model, which displayed acceptable model fit indices, including $\chi^2 = 134.79$; $df = 87$; $\chi^2/df = 1.55$; TLI = .88; CFI = .90; RMSEA = .04 (.03–.06). These indices align with the recommended values for questionnaire validation, where the normed chi-square (χ^2/df) should be lower than 5 and the value of the RMSEA index should be lower than .08.²⁸ The data support the validity of the model. Standardized item loading values ranged from .22 to .76 (Figure 1). It is suggested that factor loadings of all subscales should be higher than 0.30.³³

3.3.2. Concurrent validity

We evaluated the concurrent validity of TFI-TR by using Pear-

son's correlation coefficient among the FP and KCL. Pearson's correlation coefficient indicated a significant correlation between the physical domain of TFI-TR score and the FP score ($r = 0.45$, $p < .01$). Furthermore, a strong and significant correlation was also found between TFI-TR and the KCL ($r = 0.62$, $p < .01$).

Table 1

Demographic characteristics of participants (N = 300).

Variable	n (%)	Mean $\pm$ SD
Gender (male)	185 (61.7%)	
Age (years)		65.3 $\pm$ 13.4
CKD stage		
Stage 1 (eGFR ≥ 90)	29 (9.7%)	
Stage 2 (eGFR 60–89)	71 (23.7%)	
Stage 3 (eGFR 30–59)	173 (57.7%)	
Stage 4 (eGFR 15–29)	20 (6.7%)	
Stage 5 (eGFR < 15)	7 (2.3%)	
FP index (range 0–5)		
Non-frail (0)	118 (39.3%)	
Pre-frail (1–2)	168 (56%)	
Frail (3–5)	14 (4.7%)	
KCL (range 0–25)		
Non-frail (0–3)	79 (26.3%)	
Pre-frail (4–7)	141 (47%)	
Frail (8–25)	80 (26.7%)	
KCL sub-domains		
IADL (0–5), Frailty ≥ 3	77 (25.7%)	
Physical (0–5), Frailty ≥ 2	97 (32.3%)	
Nutrition (0–2), Frailty ≥ 2	4 (1.3%)	
Eating (0–3), Frailty ≥ 2	56 (18.7%)	
Socialization (0–2), Frailty include item 16	17 (5.7%)	
Memory (0–3), Frailty ≥ 2	154 (51.3%)	
Mood (0–5), Frailty ≥ 2	79 (26.3%)	
TFI-TR (range 0–15)		3.3 $\pm$ 2.48
Non-frail (0–4)	212 (70.7%)	
Frail (5–15)	88 (29.3%)	
Physical (0–8)		1.8 $\pm$ 1.71
Psychological (0–4)		0.7 $\pm$ 0.93
Social (0–3)		0.8 $\pm$ 0.74

CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; FP, Fried phenotype; IADL, instrumental activities of daily living; KCL, Kihon Checklist; SD, standard deviation; TFI-TR, Tilburg Frailty Indicator Taiwan Revised version.

Table 2

TFI-TR domain item discriminant, correlations and summary statistics (n = 300).

Domain/Item number	Mean $\pm$ SD	Variance	Skewness	CR	ISC
Physical domain					
1	0.36 $\pm$ 0.48	0.23	0.59	12.93	0.50
2	0.09 $\pm$ 0.29	0.09	2.81	4.34	0.26
3	0.14 $\pm$ 0.35	0.12	2.09	7.01	0.42
4	0.14 $\pm$ 0.35	0.12	2.05	7.40	0.47
5	0.13 $\pm$ 0.34	0.11	2.21	4.50	0.32
6	0.24 $\pm$ 0.43	0.18	1.25	5.73	0.36
7	0.36 $\pm$ 0.48	0.23	0.59	11.74	0.56
8	0.36 $\pm$ 0.48	0.23	0.59	14.22	0.56
Psychological domain					
9	0.14 $\pm$ 0.35	0.12	2.09	6.35	0.40
10	0.23 $\pm$ 0.42	0.19	1.29	7.01	0.56
11	0.30 $\pm$ 0.46	0.21	0.90	10.46	0.62
12	0.05 $\pm$ 0.23	0.05	4.00	3.07	0.32
Social domain					
13	0.13 $\pm$ 0.34	0.12	2.17	3.77	0.26
14	0.45 $\pm$ 0.50	0.25	0.20	4.66	0.48
15	0.18 $\pm$ 0.38	0.15	1.70	4.48	0.38

CR, critical ratio; ISC, item-subdomain correlation; SD, standard deviation.

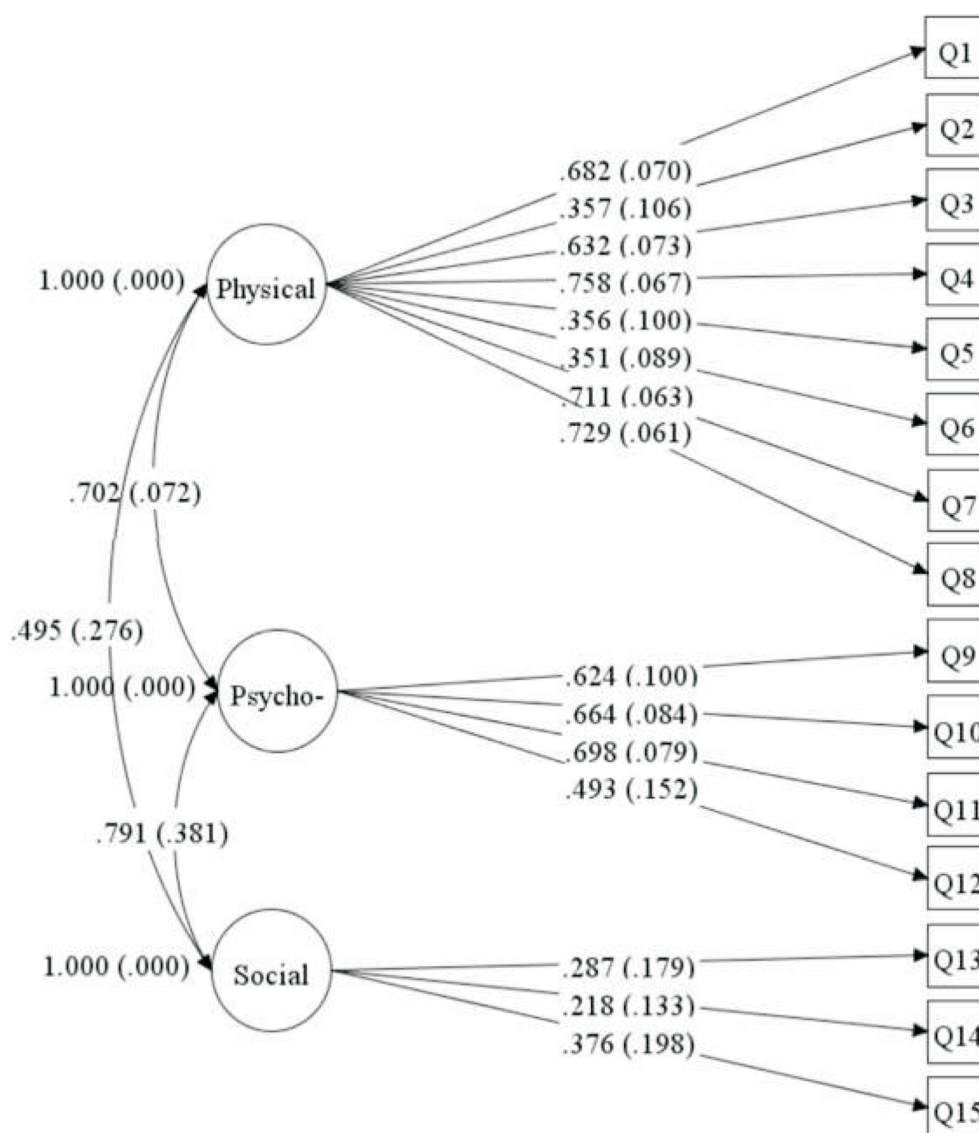


Figure 1. Final CFA model of the TFI-TR.

3.4. Reliability

The KR-20 reliability coefficient for the TFI-TR total score was 0.70. The subdomain scores were 0.63 (physical), 0.48 (psychological), and 0.11 (social).

3.5. Estimating appropriate cut-off values

The FP has three categories (robust, prefrailty, and frailty), but the TFI-TR has two categories (frailty and non-frailty). Consequently, we compared the differences in FP scores using the area under the ROC curve for the TFI-TR instrument and chose the FP at the cut-off point of 3, which showed the ROC curve was 0.875 ($p < .05$ and $SE = .041$). According to Youden's index, the best cut point for TFI-TR was 4.5. The accuracy of the TFI-TR at a cut point of 4.5 showed that the instrument had 85.7% sensitivity and 73.4% specificity.

4. Discussion

Our results indicated sufficient validity (construct validity, concurrent validity, and criterion validity), satisfactory reliability (internal consistency), and good accuracy, as well as adequate responsiveness for TFI-TR. Analysis of the 15 items revealed that items with do-

main correlations between 0.32 and 0.62 were closely related to the subdomains, except for Item 2 ('Unexplained weight loss' in the physical domain) and Item 13 ('Living alone' in the social domain). The findings are consistent with data of Mulasso³⁴ using an Italian patient sample. In addition, the results of Santiago³⁵ were similar to those of our studies. The low correlation of Item 2 may be that the term "unexplained weight loss" is not clearly defined, as the TFI-TR is a self-report questionnaire.³⁴ "Living alone" in Item 13 represents social frailty and may not be appropriate for patients with CKD who require self-care assistance. In the Chinese culture, which emphasizes the importance of family care with the proverb "fostering children to defend aged", expresses that social expectations require children to take care of their aging parents.³⁶

CFA model fit indices were acceptable supporting structural validity of the 15 items across three factors. Nevertheless, two items (13, 14) in the TFI-TR exhibited low factor loadings, the results are similar to those of previous studies.^{16,37} To address this concern, the TFI-TR combined the psychological and social domains; however, the results of the CFA showed that combining the social and psychological domains did not improve the factor loading of the social domain.

There were significant moderate correlations between the TFI-TR and the FP and KCL. As expected, the TFI-TR correlation with KCL was stronger as the KCL is a multidomain measure while the FP only

evaluates the physical domain. Similar results were reported in a sample ($n = 210$) of Taiwanese, showing a stronger correlation between TFI-T and KCL among community-dwelling older adults.¹⁶ However, the result was inconsistent with the Spanish version, which resulted in a lower correlation between TFI and KCL ($r = 0.54$).³⁸ Possible reasons are that KCL is originally from Asia, has better cultural adaptation, and is widely applied in Taiwan based on the government.²⁶ This also indicates the necessity of developing a native scale.

For context, the KCL was initially developed for community-dwelling older adults; however, evidence suggests that it may also apply to patients with CKD.³⁸ Additionally, a study by Kojima et al.³⁹ demonstrated a high prevalence of frailty among individuals under 65 with chronic diseases, as assessed using the KCL. Our finding showed the appropriate correlation between KCL and TFI-TR, the results consistent with Lin.¹⁶ However, our findings are inconsistent with Mazya⁴⁰ that showed a higher correlation between the TFI and FP compared to other multidomain frailty assessment tools, such as the Clinical Frailty Scale. One possible explanation is that the population in the previous study had a poorer health status and was older than the participants in the current study.⁴¹

The KR-20 reliability coefficient was 0.70 for all items of the TFI-TR. This result is consistent with findings from previous international studies of the TFI in Italian ($r = 0.66$),³⁴ German ($r = 0.67$),⁴² and Spanish ($r = 0.69$).³⁸ Although internal consistency was robust for the total score and the physical domain subscale, internal consistency was lower for the psychological and social domains. The results are consistent with the original TFI and other versions.^{14,22,35} However, the reliability of the social domain of the TFI-TR was found to be lower than previous studies. The predictive value of social frailty measure has been shown to be more limited than the other domains.¹⁵ This finding may be due to three items, living alone, lack of social relations, and social support, not fully capturing the complexity of social frailty. Bunt et al.⁴³ indicated that social frailty was a multidimensional concept, which included the absence of social and general resources, absence of certain activities or social behaviors. The low social support domain may also reflect the study population. Patients with CKD are younger compared to previous studies and rarely live alone, especially in the Taiwan culture where adherence to filial piety results in elders living and receiving social support from family members. Approximately half of the patients with CKD responded that they received enough support from other people. This finding may have contributed to under-reporting frailty or social frailty among patients with CKD.

The optimal cut point of 4.5 was established.¹⁶ Lin et al.¹⁶ indicated the TFI's cut-off points of 5.5 in older community in Taiwan. Likewise, in Germany, Freitag et al.⁴² determined the TFI's cut point of 5 as the same original version.¹⁴ The lower cut-points obtained for the TFI-TR may reflect the specific characteristics of CKD patients.

4.1. Limitations

This study has certain limitations. First, the TFI-TR has a low factor loading in the social domain. For a comprehensive assessment of the concept of frailty, future studies need to include social frailty assessment. This low consistency may be due to the small number of items in each domain, which inherently restricts the reliability estimates. However, these items were kept in this study because they are theoretically important concepts of multidimensional frailty. Future research should focus on revising or expanding the item pool, particularly in the social domain, to enhance internal consistency while preserving the overall conceptual framework of the instrument. Second, this study was a cross-sectional design, which re-

stricts the ability to establish causal relationships between frailty and its associated factors. Moreover, the predictive validity (such as disability, hospitalization, or mortality) of the TFI-TR could not be evaluated in the current study. To address this limitation, the longitudinal designs should be implemented in future research and catch frailty trajectory over time. This evidence is necessary for developing early intervention strategies. Third, the generalizability of the findings within the current study was limited. The different stages were not limited and were analyzed in advance. In the current study, the majority of the population was in stage 3. This resulted in the limited generalizability of stages 4 and 5. Therefore, future studies should validate the TFI-TR in cohorts with more advanced CKD and dialysis-dependent patients to confirm its utility across the full spectrum of CKD severity. Finally, the enrollment of patients with CKD was limited to a single city, which may restrict the finding as generalizability to other regions. In the future, studies should consider expanding the location of data collection to enhance the external validity of the results.

5. Conclusions

The reliability and validity of the 15-item TFI-TR were examined, and the results showed that the TFI-TR is suitable for measuring CKD patients with frailty. A 15-item TFI-TR can provide suitable frailty measurements for CKD patients in community dwellings. Healthcare professionals can adopt the scale to measure the frailty level of CKD patients and provide strategies to prevent or delay the progression of frailty.

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Declaration of any potential financial and non-financial conflicts of interest

The authors declare no competing interests.

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