

Research Article

Translation and Initial Validation of the Chinese Version of the Action Research Arm Test in People with Stroke

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Purpose. This study aimed to translate the English version of the Action Research Arm Test (ARAT) into Chinese and to evaluate the initial validation of the Chinese version (C-ARAT) in patients with a first stroke. **Methods.** An expert group translated the original ARAT from English into Chinese using a forward-backward procedure. Forty-four patients (36 men and 8 women) aged 22–80 years with a first stroke were enrolled in this study. The participants were evaluated using 3 stroke-specific outcome measures: C-ARAT, the upper extremity section of the Fugl–Meyer assessment (UE-FMA), and the Wolf Motor Function Test (WMFT). Internal consistency was analysed using Cronbach's α coefficients and item-scale correlations. Concurrent validity was determined using Spearman's rank correlation coefficients. Floor and ceiling effects were considered to be present when more than 20% of patients fell outside the preliminarily set lower or upper boundary, respectively. **Results.** The C-ARAT items yielded excellent internal consistency, with a Cronbach's α of 0.98 ($p < 0.001$) and item-total correlations ranging from 0.727 to 0.948 ($p < 0.001$). The C-ARAT exhibited good-to-excellent correlations with the UE-FMA and WMFT functional ability (WMFT-FA) scores, with respective ρ values of 0.824 and 0.852 ($p < 0.001$), and an excellent negative correlation with the WMFT performance time (WMFT-time), with a ρ value of -0.940 ($p < 0.001$). The C-ARAT subscales generally exhibited good-to-excellent correlations with stroke-specific assessments, with ρ values ranging from 0.773 to 0.927 ($p < 0.001$). However, the gross subscale exhibited moderate-to-good correlations with the UE-FMA and WMFT-FA scores, with respective ρ values of 0.665 and 0.720 ($p < 0.001$). No significant floor effect was observed, and a significant ceiling effect was observed only on the WMFT-time. **Conclusions.** The C-ARAT demonstrated excellent internal consistency and good-to-excellent concurrent validity. This test could be used to evaluate upper extremity function in stroke patients without cognitive impairment.

1. Introduction

Stroke, a leading cause of disability in adults worldwide, can result in highly complex clinical situations [1]. Approximately 80% of stroke survivors regain their locomotor function [2]. Among hemiplegic stroke patients, however, approximately 30–66% present with a nonfunctional paretic arm at 6 months after stroke, whereas only 5–20% demonstrate a complete functional recovery [3]. Upper extremity (UE) paralysis often limits patients' daily living activities and may reduce their quality of life [4]. Accordingly, upper limb functional

measurements are essential to improving clinical practice and evaluating the efficacy of rehabilitative interventions [5]. An appropriate outcome measure could improve the diagnostic efficacy and symptom quantification, assist with the planning and follow-up of rehabilitative interventions, and improve communication between clinicians [6]. Furthermore, the precise time course of a recovery of arm paresis depends on the selected outcome measure [7].

Although numerous upper limb measurement tools have been used in stroke rehabilitation studies, only 15 of them have been applied in more than 5% of studies [5]. One

such tool, the Action Research Arm Test (ARAT), primarily concerns the International Classification of Functioning, Disability, and Health activity level and has been applied in approximately 17% of studies [5]. This 19-item observational measure is used to assess UE performance in people with stroke and includes 4 domains: grasping, gripping, pinching, and gross movement. The ARAT involves observations of arm and hand movement during the performance of a range of reaching and grasping tasks. This test is simple and easy to prepare and can be administered to patients at mean time intervals of approximately 8 minutes [8].

Several previous studies have proven the good psychometric properties of the ARAT [8–14]. Hsieh et al. reported strong correlations between the English version of the ARAT and the UE part of the motor assessment scale, arm subscore of the motricity index, and UE part of the modified motor assessment chart (Pearson's $r = 0.96, 0.87,$ and $0.94,$ resp.) in people with stroke [8]. Yozbatiran et al. also demonstrated the excellent construct validity of the ARAT, which correlated strongly with the UE section of the Fugl–Meyer assessment (UE-FMA; $r = 0.94$) in chronic stroke patients with moderate right hemiparesis [14]. Nordin et al. suggested that the ARAT showed satisfied intrarater and interrater reliability for patients after stroke [10]. Lin et al. proved that the ARAT yielded sufficient validity, responsiveness, and reliability in participants with stroke, with satisfactory minimal detectable changes for assessing disability [11]. Accordingly, the ARAT has been widely used in clinical and research studies [15–17].

The original ARAT protocol and manual were translated into Swedish [10]. To the best of our knowledge, only 2 published Chinese studies [18, 19] had estimated the validity and reliability of the original ARAT, and no study had reported on a translation of the English version of the ARAT into Chinese. Accordingly, there was a significant clinical need for a translated Chinese version of the ARAT (C-ARAT). This study aimed to translate the original ARAT into Chinese and explore the internal consistency, concurrent validity, and floor and ceiling effects of this test in people with stroke.

2. Methods

2.1. Translation. The original ARAT was translated from English into Chinese using a forward-backward procedure. The forward procedure was performed by 2 native Chinese speakers who accurately translated the scale from English to Chinese according to the original scale. Next, the 2 translators resolved any discrepancies and synthesised the results based on their translations. The backward procedure was then performed by 2 native English speakers who were blind to the original English version. The 2 translators were neither aware nor informed of the concepts explored to avoid information bias and unexpected meanings in the translated questionnaire. The translated questionnaire was then reviewed by an expert committee comprising the principal investigator, the 4 translators, 2 experienced physiotherapists, 2 occupational therapists, and 2 rehabilitation physicians. The expert committee reviewed all versions of the questionnaire

and developed what would be considered the final version of the questionnaire for field testing [20].

2.2. Subjects. According to a previous study [12], a sample size of 40 subjects with stroke is sufficient to determine the internal consistency and concurrent validity of the C-ARAT. This study included 44 inpatients with stroke in the Department of Rehabilitation Medicine of the First Affiliated Hospital, Sun Yat-sen University, China, between August 2014 and March 2018. The inclusion criteria were as follows: (1) the occurrence of a first stroke with unilateral hemiparetic lesions confirmed by magnetic resonance imaging or computed tomography; (2) an interval of >6 days after stroke; (3) age of 18–80 years; (4) Brunnstrom motor recovery stage II or higher; (5) Modified Ashworth Scale score ≤ 2 ; (6) ability to maintain a sitting position for >30 minutes; (7) no severe deficits in communication, memory, and understanding [Mini Mental State Examination score ≥ 22]; and (8) no additional medical, cardiovascular, or orthopaedic condition or significant UE peripheral neuropathy. The participants' demographic details and major comorbidity data were collected from medical records. The demographic information is shown in Table 1. This study was approved by the Human Subjects Ethics Subcommittee of the First Affiliated Hospital, Sun Yat-sen University, China. Informed written consent was obtained from all of the participants.

2.3. Procedure. Prior to collecting baseline data, an experienced physiotherapist with 9 years of clinical experience in stroke rehabilitation was trained to properly administer the C-ARAT, WMFT, and UE-FMA according to recent guidelines [14, 21]. We used a random drawing to randomise the order of the UE outcome measures, which were administered in a quiet room. The C-ARAT, WMFT, and UE-FMA were applied to patients recruited from the Department of Rehabilitation Medicine of the First Affiliated Hospital, Sun Yat-sen University, China ($n = 44$). A sufficient rest period was provided during the assessment to avoid the influence of fatigue on the results. The entire assessment took approximately 1–2 hours.

2.4. Outcome Measures

2.4.1. ARAT. The ARAT was developed by Lyle [22] in 1981 as a performance test for evaluating UE function and dexterity after stroke. Hsieh reported that the English version of the ARAT was reliable (interrater reliability = 0.98) for the assessment of people with stroke [8]. Yozbatiran et al. [14] presented a standardized approach along with a detailed test manual, which was translated by our expert group into a Chinese version according to a standard forward and backward translation protocol, as described above. The ARAT includes 19 items applied according to a standardized test kit [10]. Each item is graded on a 4-point original scale [0, unable to complete any part of the task within 60 s; 1, partial performance of the task within 60 s; 2, completion of the task but with great difficulty or in an abnormally long time (5–60 s); or 3, normal performance of the task within 5 s]

[14]. The ARAT is categorized into 4 subtests: grasping (6 items; 0–18 points), gripping (4 items; 0–12 points), pinching (6 items; 0–18 points), and gross movement (3 items; 0–9 points). UE function is assessed unilaterally, beginning with the unaffected upper extremity. The scores of each item are summed to calculate a total score for each side within a range of 0–57 points. Each subtest of the ARAT is arranged in a hierarchical order wherein the most difficult item is tested first, the easiest item is tested second, and the difficulty of the items increases gradually thereafter.

2.4.2. Wolf Motor Function Test. The WMFT is a widely used laboratory-based evaluation designed to assess UE function (test-retest reliability = 0.90–0.95) [23] in people with stroke [24–26]. This test comprises 17 items, including 2 strength items and 15 timed task performance items. We used the 15 timed task performance items in this study. This division enables the WMFT to yield 2 scores: a functional ability (FA) score, which quantifies performance quality, and a timed score (TIME), which quantifies the performance speed (in seconds). The FA score rates movement quality on a 6-point ordinal scale ranging from 0 to 5, with higher scores indicating less impairment or activity limitation. A maximum time of 120 seconds was allotted for each task. The final time score is the mean time required to execute all timed tasks. The reliability and validity of the WMFT have been reported in both chronic and subacute populations of stroke patients [27–31]. The WMFT has been translated into Chinese and been proved with good validity and reliability [32].

2.4.3. Upper Extremity Session of Fugl–Meyer Assessment. The UE-FMA, which has been used in 36% of studies, is the most commonly used measure [5] and has excellent interrater reliability and construct validity [33, 34]. The UE-FMA has frequently been used to measure UE motor impairment [1, 35–37] and has been reported to yield good intrarater and interrater reliability and construct validity [34, 38–45]. The UE-FMA comprises 33 items that are scored using a 3-point ordinal scale (0, cannot perform; 1, partially performed; 2, fully performed) to yield a maximum possible total score of 66. The UE-FMA already has Chinese version and widely been used [32].

2.4.4. Modified Ashworth Scale. The muscle tone in the elbow, wrist, and finger flexors was assessed using the Modified Ashworth Scale (range: 0–4) [46]. Here, a score ≥ 1 indicates spasticity.

2.5. Statistical Analysis

2.5.1. Participants. The demographic and clinical characteristics of the participants in this study ($n = 44$) were demonstrated using descriptive statistics.

2.5.2. Internal Consistency. In order to evaluate the quality of the translated ARAT, internal consistency was used to test the

agreement of each item. The internal consistency of the C-ARAT was assessed using Cronbach's α coefficients and item-total correlations. Cronbach's α values with corresponding confidence intervals (CI) were calculated to determine the internal consistency between the items of the C-ARAT. Here, α values of <0.5 , 0.5 to <0.6 , 0.6 to <0.7 , 0.7 to <0.8 , 0.8 to <0.9 , and ≥ 0.9 indicated unacceptable, poor, questionable, acceptable, good, and excellent internal consistency, respectively [47]. The item-total correlations were analysed using Pearson's correlation coefficients.

2.5.3. Validity. The concurrent validity of the C-ARAT was assessed by computing the correlations of the C-ARAT score with the WMFT and UE-FMA scores. As the C-ARAT, WMFT, and UE-FMA are ordinal scales, Spearman's rank correlation coefficient (ρ) was used to evaluate these correlations. Here, ρ values between 0 and 0.25, between 0.25 and 0.50, between 0.50 and 0.75, and >0.75 represented weak, fair, moderate-to-good, and good-to-excellent correlations, respectively [48].

2.5.4. Floor and Ceiling Effects. Floor and ceiling effects were defined as the means percentages of subjects who scored beyond the lower and upper boundaries of the total score, respectively. The cut-off for the floor and ceiling effects was set at 5% of the total score [12]. Therefore, scores <3 , <4 , and <4 points in the C-ARAT, UE-FMA, and WMFT-FA, respectively, and WMFT-time scores ≥ 114 seconds were determined as a floor effect. Scores >54 , >62 , and >71 points on the C-ARAT, UE-FMA, and WMFT-FA, respectively, and WMFT-time scores ≤ 6 seconds were determined as a ceiling effect. Floor or ceiling effect $>20\%$ of the sample size was considered significant [11].

All of the statistical analyses were performed using SPSS version 20.0. All of the applied tests were 2-tailed. The level of significance was set at a p value <0.05 .

3. Results

3.1. Demographics. Forty-four individuals with a first stroke (36 men, 8 women) were enrolled in this study. The median of the participants' age was 57.50 years (range: 22–80 years). The median poststroke duration was 3.00 months (range: 0.5–80.27 months). Thirty-three and 11 patients had ischemic and haemorrhagic stroke, respectively. The right side was affected in 48% of participants. Twenty individuals had hypoesthesia in their affected arms, including 1 case of combined sensory hypoesthesia, 15 cases of superficial sensation hypoesthesia, and 4 cases of combined superficial and deep sensory hypoesthesia. No patient presented with hemineglect. Fifteen individuals had mild speech impediments that did not affect communication. Details of the 44 participants were provided in Table 1.

The C-ARAT, UE-FMA, and WMFT performance scores were summarized in Table 2. The participants had a median total C-ARAT score of 31.50 (range: 3–57), with median grasping, gripping, pinching, and gross motor scores of 12.00, 7.50, 5.50, and 6.00, respectively. The median UE-FMA score

TABLE 1: Characteristics of the study participants (n=44).

Variable	Study sample n=44	
	Values	
Age (years)	57.50 (22-80)	
Onset (months)	3.00 (0.50-80.27)	
Mini mental state examination	27 (22-30)	
Sex		
Male	36 (82)	
Female	8 (18)	
Stroke type		
Ischemic	33 (75)	
Hemorrhagic	11 (25)	
Affected side		
Right	21 (48)	
Left	23 (52)	
Dominance		
Right	44 (100)	
Dominant side affected	21 (48)	
Sensory disorder UE	20 (45.5)	
Mild problem on speech	15 (34.1)	
Brunnstrom stage		
Proximal UE	4 (2-6)	
Distal UE	4 (2-6)	

Note. Values are median (range) or n (%).

TABLE 2: Scores on outcome measures.

Variable	Median (range)
C-ARAT scores	
Total score	31.50 (3-57)
Grasp score	12.00 (0-18)
Grip score	7.50 (0-12)
Pinch score	5.50 (0-18)
Gross motor score	6.00 (3-9)
UE-FMA score	51.00 (19-66)
WMFT scores	
Function score	47.00 (6-74)
Time score (s)	11.49 (1.37-120.00)

C-ARAT, Chinese version of Action Research Arm Test; UE-FMA, Upper-Extremity subscale of the Fugl-Meyer Assessment; WMFT, Wolf Motor Function Test.

was 51.00 (range: 19–66). The median WMFT FA total score was 47.00 (range: 6–74), and the median WMFT time was 11.49 seconds (range: 1.37–120.00 seconds).

3.2. *Internal Consistency.* The data of all 44 subjects were pooled to calculate the internal consistency. The C-ARAT items exhibited excellent internal consistency, with a Cronbach's α value of 0.98. ($p < 0.001$). The Pearson correlation coefficients of the item-total correlations ranged from 0.727 to 0.948. Details were provided in Table 3.

3.3. *Concurrent Validity.* The data on all 44 subjects were pooled to calculate the concurrent validity. The C-ARAT total

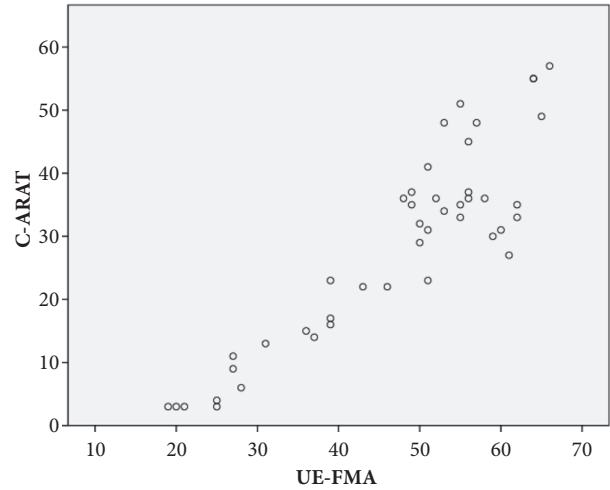


FIGURE 1: The relationship between the performance on the C-ARAT and UE-FMA.

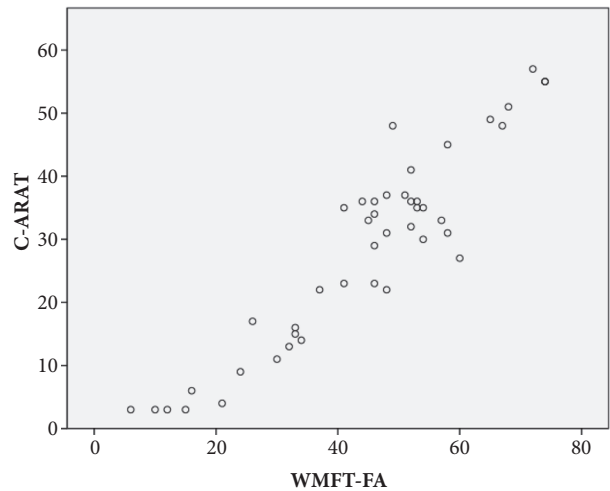


FIGURE 2: The relationship between the performance on the C-ARAT and WMFT-FA.

score and UE-FMA score yielded a correlation of 0.824 ($p < 0.001$), indicating a good-to-excellent correlation. Most C-ARAT subscales also exhibited good-to-excellent correlations with the UE-FMA (grasping, $\rho = 0.857$; gripping, $\rho = 0.844$; pinching, $\rho = 0.773$; $p < 0.001$). However, the gross movement subscale exhibited a moderate-to-good correlation with the UE-FMA ($\rho = 0.665$; $p < 0.001$). Figure 1 presented the relationship between the performance in the C-ARAT and that in the UE-FMA.

The C-ARAT total score and WMFT-FA score yielded a correlation coefficient of 0.852 ($p < 0.001$), which indicated a good-to-excellent correlation. Most of the C-ARAT subscales also exhibited good-to-excellent correlations with the WMFT-FA (grasping, $\rho = 0.873$; gripping, $\rho = 0.917$; pinching, $\rho = 0.780$; $p < 0.001$). The gross movement subscale exhibited a moderate-to-good correlation with the UE-FMA ($\rho = 0.720$; $p < 0.001$). Figure 2 presented the relationship between the performances of the C-ARAT and WMFT-FA.

TABLE 3: Internal consistency of the C-ARAT.

Item	Item-total correlation	Alpha if item deleted
<i>Grasp</i>		
(1) Block 10 cm	0.897	0.978
(2) Block 2.5 cm	0.948	0.978
(3) Block 5 cm	0.929	0.978
(4) Block 7.5 cm	0.899	0.978
(5) Cricket ball	0.879	0.978
(6) Sharpening stone	0.921	0.978
<i>Grip</i>		
(7) Pour water from glass to glass	0.877	0.978
(8) Tube 2.25 cm	0.896	0.978
(9) Tube 1 cm	0.848	0.979
(10) Put washer over a bolt	0.846	0.979
<i>Pinch</i>		
(11) Ball 6 mm 3 rd finger and thumb	0.727	0.98
(12) Marble 1 st finger and thumb	0.924	0.978
(13) Ball 6 mm 2 nd finger and thumb	0.783	0.98
(14) Ball 6 mm 1 st finger and thumb	0.879	0.979
(15) Marble 3 rd finger and thumb	0.874	0.979
(16) Marble 2 nd finger and thumb	0.893	0.978
<i>Gross movements</i>		
(17) Hand behind head	0.790	0.98
(18) Hand on top of head	0.777	0.98
(19) Hand to mouth	0.824	0.979

Note: Cronbach's α coefficient for the entire C-ARAT equals 0.98.

TABLE 4: Spearman's correlation coefficient (ρ) between C-ARAT scores and those of UE-FMA, WMFT-FA, and WMFT-Time.

Variable	UE-FMA	WMFT-FA	WMFT-Time
C-ARAT Total score	0.824 ^a * *	0.852 ^a * *	-0.940 ^a * *
C-ARAT Grasp score	0.857 ^a * *	0.873 ^a * *	-0.894 ^a * *
C-ARAT Grip score	0.844 ^a * *	0.917 ^a * *	-0.927 ^a * *
C-ARAT Pinch score	0.773 ^a * *	0.780 ^a * *	-0.903 ^a * *
C-ARAT Gross score	0.665 ^b * *	0.720 ^b * *	-0.782 ^a * *

Note. ρ values indicate correlation coefficients by Spearman's rank correlation coefficient.

C-ARAT, Chinese version of Action Research Arm Test; UE-FMA, Upper-Extremity subscale of the Fugl-Meyer Assessment; WMFT, Wolf Motor Function Test; WMFT-FA, Wolf Motor Function Test functional ability

^aExcellent correlation.

^bModerate correlation

$p < 0.05$ indicates significant correlations.

** $p < 0.001$.

The C-ARAT scores and WMFT-time score yielded good-to-excellent correlations with ρ values > 0.75 ; the respective ρ values for the total, grasping, gripping, pinching, and gross movement scores were -0.940 ($p < 0.001$), -0.894 ($p < 0.001$), -0.927 ($p < 0.001$), -0.903 ($p < 0.001$), and -0.782 ($p < 0.001$). In other words, the total C-ARAT and all subscales exhibited strong negative correlations with the WMFT-time. Figure 3 presented the relationship between performance in the ARAT and WMFT-time.

Detailed results of the validity analyses were shown in Table 4.

3.4. Floor and Ceiling Effects. Table 5 demonstrated that the WMFT-time had a significant ceiling effect (40.9% of patients) but no floor effect. No significant floor or ceiling effects were observed in C-ARAT, UE-FMA, and WMFT-FA.

4. Discussion

Rapid increases in population aging and medical technique development have led to a growing number of people who suffer from stroke [49]. Furthermore, patients are gaining a greater awareness of the importance of quality of life,

TABLE 5: Floor and ceiling effects of the 3 measures.

	C-ARAT	UE-FMA	WMFT-FA	WMFT-Time
Floor Effect	0 (0)	0 (0)	0 (0)	1 (2.3)
Ceiling Effect	3 (6.8)	4 (9.1)	3 (6.8)	18 (40.9)

Note. Values are n (%).

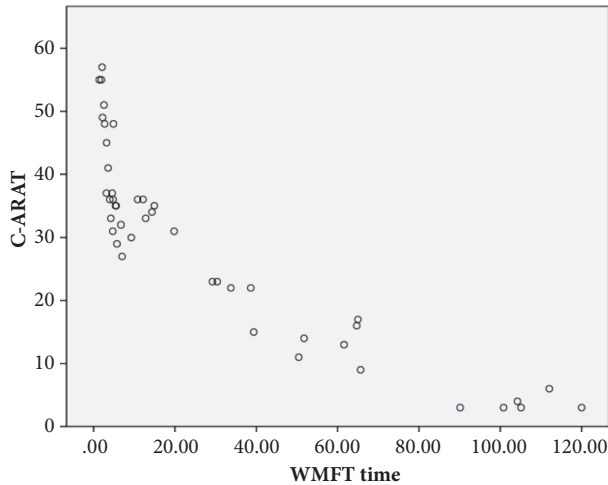


FIGURE 3: The relationship between the performance on the C-ARAT and WMFT time.

self-care, and daily living activities and are increasingly demanding the recovery of arm and hand function. However, approximately 85% of stroke survivors experience some degree of UE paresis [50], and it is difficult to assist these patients with the recovery of upper limb function as improper clinical decision was made. A reliable and valid assessment tool for evaluating UE function could help to improve the clinical decision making. This is the first study to translate the original ARAT protocol and manual into the Chinese language and to explore the concurrent validity, internal consistency, and floor and ceiling effects of this C-ARAT in a Chinese population of patients with first stroke.

In order to estimate how well the items measure the same concept in Chinese version of ARAT, the internal consistency was calculated. Internal consistency is one way to assess the quality of the translation. In this study, internal consistency is defined as agreement among all 19 items measuring the same traits of the construct and the subjects' performance [51]. Our results reported a satisfactory Cronbach's α coefficient of 0.98 for the C-ARAT, indicating excellent internal consistency. This result was consistent with previous studies [12, 52] which measured the internal consistency of original version of ARAT in people with subacute to chronic stroke. Meanwhile, the individual items of the C-ARAT demonstrated satisfactory item-total correlations ($r > 0.727$) [53], and Cronbach's α decreased by a maximum of only 0.002 if any single item was deleted. Therefore, each item of the C-ARAT was worthy of retention. Nijland et al. [12] also observed that the ARAT had excellent internal consistency (Cronbach's $\alpha = 0.98$) in

people with acute stroke. These findings showed that the C-ARAT showed high internal consistency as well as the original version, which may indicate that the Chinese version ARAT was well translated in each item.

Our results demonstrated a good-to-excellent correlation between the total scores of the C-ARAT and UE-FMA (Figure 1), in accordance with previous studies [11, 43, 45]. This indicated that the ARAT score may effectively assess not only function, but also motor impairment in the UE [8]. This study calculated a lower ρ value than those reported by Wei [43], See [45], and Lin [11]. In the study of chronic stroke survivors by Wei, higher ρ values of 0.93 and 0.92 were reported before and after training, respectively [43]. Compared with our study, Wei [43] included younger participants with a longer stroke onset. See evaluated 12 participants during 4 separate visits across the treatment period, for a total of 48 exams focused on validity, and reported a ρ value of 0.93 [45]. However, the sample size and exam procedure in our study differed from those used by See. In the study by Lin [11], participants with stroke were evaluated at 14, 30, 90, and 180 days after stroke, which corresponded to ρ values of 0.90, 0.90, 0.82, and 0.92, respectively. However, the poststroke duration and motor performance and intervention in that study differed considerably from those of our participants. Hsieh et al. [54] observed a moderate correlation ($\rho = 0.71-0.74$) between the UE-FMA and ARAT in chronic stroke survivors who received any 1 of 3 interventions (CIT, BAT, or conventional rehabilitation). The discrepant results between the study by Hsieh et al. and our study may be attributable to differences in severity of the motor impairment. The study by Hsieh et al. [54] included participants with mild functional disability in the proximal and distal UE (Brunnstrom stage 5). In contrast, the participants in our study had more severe disability on the affected side (Brunnstrom stage 3.6, proximal UE, and 4, distal UE).

Our results showed a strong correlation of the C-ARAT total score with the WMFT-FA score (Figure 2), which is consistent with the finding in previous studies [11, 12], especially that of Nijland et al. [12], which indicated that C-ARAT was well translated. A possible explanation was that the translation protocol was well prepared and the translators were professional. As a result, the original ARAT could be translated to Chinese version accurately. However, two studies [28, 54] reported results that differed from ours. The differences may be due to differences in the onset or motor performance before training. Our results also showed a significant negative correlation of the C-ARAT total score with the WMFT time score (Figure 3), in accordance with previous studies [12]. These strong correlations of the C-ARAT with the WMFT-FA and WMFT time suggest that C-ARAT has good concurrent validity with the gold standard

measurement of motor function in stroke patients. These results support the validity of the C-ARAT as an outcome measure of UE function in stroke patients.

In addition, the C-ARAT subscales correlated strongly with stroke-specific assessments ($\rho > 0.75$) except for the gross movement subscale, which showed moderate-to-good correlations with the UE-FMA and WMFT-FA ($\rho = 0.665-0.720$). Nordin et al. [10] and Van der Lee et al. [55] reported that item 19 on the ARAT was problematic because of difficulties in distinguishing between categories 2 and 3. More studies are needed to further standardise the manual for item 19.

In our study, no significant floor and ceiling effect was observed in C-ARAT, UE-FMA, and WMFT-FA according to the criteria of floor and ceiling effect, which was consistent with the findings reported by Nijland [12]. A significant ceiling effect of WMFT-time was observed when compared to C-ARAT, which indicated that C-ARAT may be a more optimal assessment tool to evaluate the people with mild stroke when compared to WMFT-time. In addition, there was an interesting finding in our study. A slight floor effect was found in C-ARAT when compared to UE-FMA and WMFT-FA. This finding may indicate that C-ARAT was more sensitive to detect the clinical improvement in stroke survivors with mild-to-moderate motor impairment. One possible reason was that C-ARAT mainly assessed the motor performance of grip, grasp, pinch, and gross movement. Most of the assessment items correlated with the fine movement, which required the subjects to perform with a higher level of upper limb motor ability. In this way, as more than half of the assessment items in C-ARAT evaluate different aspects of the fine motor function, it showed a better discriminative ability in people with mild stroke. Comparatively, WMFT-time, WMFT-FA, and UE-FMA could be a more sensitive assessment tool in measuring the change of motor function in people with more severe impairment. By measuring the floor and ceiling effect of C-ARAT and some stroke-specific assessment tools, we found that these instruments may be useful in different impairment severity. However, precaution should be taken before making the conclusion. As only 44 subjects were included to analyse the floor and ceiling effect in our study, this finding may not be applied to the general stroke population. With more subjects included, we may draw a more reliable conclusion to determine the optimal assessment window for C-ARAT.

The C-ARAT, which is simple and rapid, assesses not only hand dexterity and strength but also the function of the whole UE. In contrast, the WMFT requires participants to change positions to sit on both sides and in front of the table, as well as a close facing position, and even demands that participants stand and lift a basket during the last task. As this test requires the ability to shift position, it is difficult for some stroke survivors, especially those in the early poststroke phase. In comparison, the ARAT does not require changes in body position and only requires the participant to sit in front of the table. Therefore, the ARAT is a satisfactory instrument for the assessment of UE function in stroke patients. Furthermore, the tools required for the ARAT are inexpensive and the assessment is less time-consuming than for other methods.

Therefore, it is easily obtained and administered in clinical settings.

This study had some limitations. First, the sample size was small. Therefore, we could not conduct analyses according to the severity or type of stroke, type of intervention, or training time. The conclusion may only be applicable to the stroke survivors with the same severity. Second, the enrolled participants had a wide range of stroke onset times; some had been trained in grasping, gripping, or pinching exercises whereas others had no such training. These differences may have led to differences in performance during the C-ARAT. Finally, we only evaluated the concurrent validity, internal consistency, and floor and ceiling effects of the C-ARAT. Further research should explore the comprehensive psychometric characteristics, such as the intra- and interrater reliability, responsiveness, and predictive validity, of the instrument in stroke survivors at different stages.

5. Conclusion

In conclusion, the C-ARAT is an excellent and valid measure of UE function in stroke survivors. Our findings support the generalised clinical or research use of the C-ARAT in Chinese patients with stroke. However, further research is needed to evaluate the comprehensive psychometric characteristics of the C-ARAT.

Data Availability

The ordinal data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors report no conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors' Contributions

Dong-Feng Huang and Yu-Rong Mao designed the experiment; Dong-Feng Huang, Jiang-Li Zhao, Wen-Feng Li, Rui-Hao Bian, Ming-Hui Ding, Qiang Lin, Hai Li, and Zhi-Qin Xu translated the ARAT scale and manual; Jiang-Li Zhao, Yu-Rong Mao, and Wen-Feng Li performed the experiment and analyzed the data; Jiang-Li Zhao, Pei-Ming Chen, Dong-Feng Huang, and Yu-Rong Mao interpreted the results and wrote the manuscript; all authors read and approved the final manuscript.

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References

- [1] J. Jonsdottir, R. Thorsen, I. Aprile et al., "Arm rehabilitation in post stroke subjects: A randomized controlled trial on the efficacy of myoelectrically driven FES applied in a task-oriented approach," *PLoS ONE*, vol. 12, no. 12, Article ID e0188642, 2017.
- [2] B. H. Dobkin, "Rehabilitation after stroke," *The New England Journal of Medicine*, vol. 352, no. 16, pp. 1677–1684, 2005.
- [3] G. Kwakkel, B. J. Kollen, J. Van der Grond, and A. J. H. Prevo, "Probability of regaining dexterity in the flaccid upper limb: impact of severity of paresis and time since onset in acute stroke," *Stroke*, vol. 34, no. 9, pp. 2181–2186, 2003.
- [4] D. S. Nichols-Larsen, P. C. Clark, A. Zeringue, A. Greenspan, and S. Blanton, "Factors influencing stroke survivors' quality of life during subacute recovery," *Stroke*, vol. 36, no. 7, pp. 1480–1484, 2005.
- [5] L. Santisteban, M. Teremetz, J. P. Bleton, J. C. Baron, M. A. Maier et al., "Upper Limb Outcome Measures Used in Stroke Rehabilitation Studies: A Systematic Literature Review," *PLoS One*, vol. 11, no. 5, Article ID e0154792, 2016.
- [6] J. E. Sullivan, B. E. Crouner, P. M. Kluding et al., "Outcome measures for individuals with stroke: Process and recommendations from the American physical therapy association neurology section task force," *Physical Therapy in Sport*, vol. 93, no. 10, pp. 1383–1396, 2013.
- [7] J. C. Cortes, J. Goldsmith, M. D. Harran et al., "A Short and Distinct Time Window for Recovery of Arm Motor Control Early after Stroke Revealed with a Global Measure of Trajectory Kinematics," *Neurorehabilitation and Neural Repair*, vol. 31, no. 6, pp. 552–560, 2017.
- [8] C. L. Hsieh, I.-P. Hsueh, F.-M. Chiang, and P. H. Lin, "Inter-rater reliability and validity of the Action Research arm test in stroke patients," *Age and Ageing*, vol. 27, no. 2, pp. 107–114, 1998.
- [9] I. P. Hsueh and C. L. Hsieh, "Responsiveness of two upper extremity function instruments for stroke inpatients receiving rehabilitation," *Clinical Rehabilitation*, vol. 16, no. 6, pp. 617–624, 2002.
- [10] Å. Nordin, M. A. Murphy, and A. Danielsson, "Intra-rater and inter-rater reliability at the item level of the Action Research arm test for patients with stroke," *Journal of Rehabilitation Medicine*, vol. 46, no. 8, pp. 738–745, 2014.
- [11] J.-H. Lin, M.-J. Hsu, C.-F. Sheu et al., "Psychometric comparisons of 4 measures for assessing upper-extremity function in people with stroke," *Physical Therapy in Sport*, vol. 89, no. 8, pp. 840–850, 2009.
- [12] R. Nijland, E. Van Wegen, J. Verbunt, R. Van Wijk, J. Van Kordelaar, and G. Kwakkel, "A comparison of two validated tests for upper limb function after stroke: The wolf motor function test and the action research arm test," *Journal of Rehabilitation Medicine*, vol. 42, no. 7, pp. 694–696, 2010.
- [13] H.-F. Chen, K.-C. Lin, C.-Y. Wu, and C.-L. Chen, "Rasch validation and predictive validity of the action research arm test in patients receiving stroke rehabilitation," *Archives of Physical Medicine and Rehabilitation*, vol. 93, no. 6, pp. 1039–1045, 2012.
- [14] N. Yozbatiran, L. Der-Yeghiaian, and S. C. Cramer, "A standardized approach to performing the action research arm test," *Neurorehabilitation and Neural Repair*, vol. 22, no. 1, pp. 78–90, 2008.
- [15] S. R. Barreca, P. W. Stratford, C. L. Lambert, L. M. Masters, and D. L. Streiner, "Test-Retest reliability, validity, and sensitivity of the chedoke arm and hand activity inventory: A new measure of upper-limb function for survivors of stroke," *Archives of Physical Medicine and Rehabilitation*, vol. 86, no. 8, pp. 1616–1622, 2005.
- [16] J. M. Blennerhassett, R. M. Avery, and L. M. Carey, "The test-retest reliability and responsiveness to change for the Hand Function Survey during stroke rehabilitation," *Australian Occupational Therapy Journal*, vol. 57, no. 6, pp. 431–438, 2010.
- [17] L.-L. Chuang, C.-Y. Wu, and K.-C. Lin, "Reliability, validity, and responsiveness of myotonometric measurement of muscle tone, elasticity, and stiffness in patients with stroke," *Archives of Physical Medicine and Rehabilitation*, vol. 93, no. 3, pp. 532–540, 2012.
- [18] C. Wen, J. Wang, X. Pan, G. Wang, Z. Yu et al., "Validity of Action Research Arm Test in Stroke Patients," *China Journal Rehabilitation Theory Practice*, vol. 14, no. 01, pp. 53–54, 2008.
- [19] C. Wen, J. Wang, G. Wang, Z. Yu, T. Sun et al., "Reliability of the Action Research Arm Test in Stroke Patients," *China Journal Rehabilitation Theory Practice*, vol. 13, no. 09, pp. 868–869, 2007.
- [20] D. E. Beaton, C. Bombardier, F. Guillemin, and M. B. Ferraz, "Guidelines for the process of cross-cultural adaptation of self-report measures," *The Spine Journal*, vol. 25, no. 24, pp. 3186–3191, 2000.
- [21] K. J. Sullivan, J. K. Tilson, S. Y. Cen et al., "Fugl-meyer assessment of sensorimotor function after stroke: standardized training procedure for clinical practice and clinical trials," *Stroke*, vol. 42, no. 2, pp. 427–432, 2011.
- [22] R. C. Lyle, "A performance test for assessment of upper limb function in physical rehabilitation treatment and research," *International Journal of Rehabilitation Research*, vol. 4, no. 4, pp. 483–492, 1981.
- [23] D. M. Morris, G. Uswatte, J. E. Crago, E. W. Cook III, and E. Taub, "The reliability of the wolf motor function test for assessing upper extremity function after stroke," *Archives of Physical Medicine and Rehabilitation*, vol. 82, no. 6, pp. 750–755, 2001.
- [24] O. Einav, D. Geva, D. Yoeli, M. Kerzhner, and K.-H. Mauritz, "Development and validation of the first robotic scale for the clinical assessment of upper extremity motor impairments in stroke patients," *Topics in Stroke Rehabilitation*, vol. 18, no. 1, pp. 587–598, 2011.
- [25] M. W. O'Dell, G. Kim, L. Rivera et al., "A psychometric evaluation of the arm motor ability test," *Journal of Rehabilitation Medicine*, vol. 45, no. 6, pp. 519–527, 2013.
- [26] C. Rodriguez-De-Pablo, S. Balasubramanian, A. Savic, T. D. Tomic, L. Konstantinovic, and T. Keller, "Validating ArmAssist Assessment as outcome measure in upper-limb post-stroke telerehabilitation," in *Proceedings of the 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC '15)*, pp. 4623–4626, IEEE, Milano, Italy, August 2015.
- [27] S. L. Wolf, P. A. Catlin, M. Ellis, A. L. Archer, B. Morgan, and A. Piacentino, "Assessing Wolf motor function test as outcome measure for research in patients after stroke," *Stroke*, vol. 32, no. 7, pp. 1635–1639, 2001.
- [28] D. F. Edwards, C. E. Lang, J. M. Wagner, R. Birkenmeier, and A. W. Dromerick, "An evaluation of the wolf motor function test in motor trials early after stroke," *Archives of Physical Medicine and Rehabilitation*, vol. 93, no. 4, pp. 660–668, 2012.
- [29] T. M. Hodics, K. Nakatsuka, B. Upreti, A. Alex, P. S. Smith, and J. C. Pezzullo, "Wolf motor function test for characterizing moderate to severe hemiparesis in stroke patients," *Archives of Physical Medicine and Rehabilitation*, vol. 93, no. 11, pp. 1963–1967, 2012.

- [30] C.-Y. Wu, T. Fu, K.-C. Lin et al., "Assessing the streamlined wolf motor function test as an outcome measure for stroke rehabilitation," *Neurorehabilitation and Neural Repair*, vol. 25, no. 2, pp. 194–199, 2011.
- [31] N. D. Pereira, S. M. Michaelsen, I. S. Menezes, A. C. Ovando, R. C. Lima, and L. F. Teixeira-Salmela, "Confiabilidade da versão brasileira do Wolf Motor Function Test em adultos com hemiparesia," *Brazilian Journal of Physical Therapy*, vol. 15, no. 3, pp. 257–265, 2011.
- [32] Y. Wu, Y. Min, and T. Yan, "Validity and reliability of Wolf motor function test on assessing the upper extremities motor function of Chinese stroke patients in acute stage," *Chinese Journal of Rehabilitation Medicine*, vol. 24, no. 11, pp. 992–998, 2009.
- [33] M. H. Rabadi and F. M. Rabadi, "Comparison of the Action Research Arm Test and the Fugl-Meyer Assessment as Measures of Upper-Extremity Motor Weakness After Stroke," *Archives of Physical Medicine and Rehabilitation*, vol. 87, no. 7, pp. 962–966, 2006.
- [34] P. W. Duncan, M. Propst, and S. G. Nelson, "Reliability of the Fugl-Meyer assessment of sensorimotor recovery following cerebrovascular accident," *Physical Therapy in Sport*, vol. 63, no. 10, pp. 1606–1610, 1983.
- [35] M. N. McDonnell, S. L. Hillier, M. C. Ridding, and T. S. Miles, "Impairments in precision grip correlate with functional measures in adult hemiplegia," *Clinical Neurophysiology*, vol. 117, no. 7, pp. 1474–1480, 2006.
- [36] A. Prochazka and J. Kowalczewski, "A fully automated, quantitative test of upper limb function," *Journal of Motor Behavior*, vol. 47, no. 1, pp. 19–28, 2015.
- [37] Q. Qian, X. Hu, Q. Lai, S. C. Ng, Y. Zheng, and W. Poon, "Early Stroke Rehabilitation of the Upper Limb Assisted with an Electromyography-Driven Neuromuscular Electrical Stimulation-Robotic Arm," *Frontiers in Neurology*, vol. 8, p. 447, 2017.
- [38] A. R. Fugl-Meyer, L. Jääskö, I. Leyman, S. Olsson, and S. Steglind, "The post-stroke hemiplegic patient. 1. A method for evaluation of physical performance," *Scandinavian Journal of Rehabilitation Medicine*, vol. 7, no. 1, pp. 13–31, 1975.
- [39] K. Berglund and A. R. Fugl-Meyer, "Upper extremity function in hemiplegia. A cross-validation study of two assessment methods," *Scandinavian Journal of Rehabilitation Medicine*, vol. 18, no. 4, pp. 155–157, 1986.
- [40] T. Platz, C. Pinkowski, F. van Wijck, I.-H. Kim, P. di Bella, and G. Johnson, "Reliability and validity of arm function assessment with standardized guidelines for the Fugl-Meyer test, action research arm test and box and block test: a multicentre study," *Clinical Rehabilitation*, vol. 19, no. 4, pp. 404–411, 2005.
- [41] B. Hemmen and H. A. Seelen, "Effects of movement imagery and electromyography-triggered feedback on arm-hand function in stroke patients in the subacute phase," *Clinical Rehabilitation*, vol. 21, no. 7, pp. 587–594, 2007.
- [42] S. L. Wood-Dauphinee, J. I. Williams, and S. H. Shapiro, "Examining outcome measures in a clinical study of stroke," *Stroke*, vol. 21, no. 5, pp. 731–739, 1990.
- [43] X.-J. Wei, K.-Y. Tong, and X.-L. Hu, "The responsiveness and correlation between Fugl-Meyer Assessment, Motor Status Scale, and the Action Research Arm Test in chronic stroke with upper-extremity rehabilitation robotic training," *International Journal of Rehabilitation Research*, vol. 34, no. 4, pp. 349–356, 2011.
- [44] S. J. Page, P. Levine, and E. Hade, "Psychometric properties and administration of the wrist/hand subscales of the Fugl-Meyer assessment in minimally impaired upper extremity hemiparesis in stroke," *Archives of Physical Medicine and Rehabilitation*, vol. 93, no. 12, p. 2373-6.e5, 2012.
- [45] J. See, L. Dodakian, C. Chou et al., "A standardized approach to the Fugl-Meyer assessment and its implications for clinical trials," *Neurorehabilitation and Neural Repair*, vol. 27, no. 8, pp. 732–741, 2013.
- [46] R. W. Bohannon and M. B. Smith, "Interrater reliability of a modified Ashworth scale of muscle spasticity," *Physical Therapy in Sport*, vol. 67, no. 2, pp. 206–207, 1987.
- [47] D. George and P. Mallery, *PSS for Windows step by step: A simple guide and reference*, Allyn & Bacon, Boston, Mass, USA, 4th edition, 2003.
- [48] W. M. Portney LG, *Foundations of Clinical Research: Applications to Practice*, Pearson/Prentice Hall, Upper Saddle River, NJ, USA, 3rd edition, 2009.
- [49] E. J. Benjamin, M. J. Blaha, S. E. Chiuve et al., "Heart Disease and Stroke Statistics-2017 Update: A Report From the American Heart Association," *Circulation*, vol. 135, no. 10, pp. e146–e603, 2017.
- [50] H. S. Jorgensen, H. Nakayama, H. O. Raaschou, and T. S. Olsen, "Stroke: Neurologic and functional recovery the Copenhagen Stroke Study," *Physical Medicine and Rehabilitation Clinics of North America*, vol. 10, no. 4, pp. 887–906, 1999.
- [51] T.-W. Liu, S. S. M. Ng, and G. Y. F. Ng, "Translation and Initial Validation of the Chinese (Cantonese) Version of Community Integration Measure for Use in Patients with Chronic Stroke," *BioMed Research International*, vol. 2014, Article ID 623836, 7 pages, 2014.
- [52] J. H. van der Lee, L. D. Roorda, H. Beckerman, G. J. Lankhorst, and L. M. Bouter, "Improving the action research arm test: A unidimensional hierarchical scale," *Clinical Rehabilitation*, vol. 16, no. 6, pp. 646–653, 2002.
- [53] A. Field, *Discovering Statistics Using SPSS*, Sage, Thousand Oaks, Calif, USA, 3rd edition, 2009.
- [54] Y.-W. Hsieh, C.-Y. Wu, K.-C. Lin, Y.-F. Chang, C.-L. Chen, and J.-S. Liu, "Responsiveness and validity of three outcome measures of motor function after stroke rehabilitation," *Stroke*, vol. 40, no. 4, pp. 1386–1391, 2009.
- [55] J. H. Van der Lee, V. De Groot, H. Beckerman, R. C. Wagenaar, G. J. Lankhorst, and L. M. Bouter, "The intra- and interrater reliability of the action research arm test: a practical test of upper extremity function in patients with stroke," *Archives of Physical Medicine and Rehabilitation*, vol. 82, no. 1, pp. 14–19, 2001.