Age and Ageing 1998; 27: 107–113

Inter-rater reliability and validity of the Action Research arm test in stroke patients

CHING-LIN HSIEH, I-PING HSUEH, FU-MEI CHIANG[1], PO-HSIN LIN

School of Occupational Therapy, College of Medicine, National Taiwan University, 7 Chun-Shan S. Road, Taipei, Taiwan, Republic of China
[1]Department of Physical Medicine and Rehabilitation, National Taiwan University Hospital, Taipei, Taiwan, Republic of China

Address correspondence to Ching-Lin Hsieh. Fax: (+886) 2 391 0614; E-mail: mike26@ha.mc.ntu.edu.tw

Abstract

Background and purpose: the Action Research arm test (ARAT) was constructed for assessing recovery of upper extremity function after cortical injury. The objective of the study was to verify the inter-rater reliability and validity of the ARAT in stroke patients.
Methods: 50 stroke patients participated in the study. For the purpose of inter-rater study, the ARAT was administered by three experienced raters on each patient within a 3-day period. Validity was assessed by comparing the patients' scores on the ARAT with those obtained for the other well-validated measurements evaluating upper extremity motor impairment and disability.
Results: intra-class correlation coefficient (ICC) for the total score was 0.98 indicating very high inter-rater reliability. ICCs were also very high in each of the subscales. The score of the ARAT was closely correlated with that of the upper extremity part of the motor assessment scale, the arm sub-score of the motricity index and the upper extremity movements of the modified motor assessment chart (Pearson $r = 0.96$, 0.87 and 0.94, respectively).
Conclusion: the preliminary results of this study support the value of the ARAT for measuring recovery of arm-hand function in stroke patients.

Keywords: *arm function, cerebrovascular disorders, disability evaluation, motor skills*

Introduction

The most elegant design of a clinical study will not overcome the damage caused by unreliable or imprecise measurement [1]. The evidence of reliability and validity is frequently confined to specific diagnoses, service settings and administration [2]. Evidence on a specific measure may be extremely variable. Johnston *et al.* [3] have acknowledged that more formal studies of the reliability and validity of the measure and assessment procedures are desirable.

The Action Research arm test (ARAT) developed by Lyle [4] was based on the upper extremity function test of Carroll [5, 6]. The ARAT was constructed for assessing recovery of upper extremity function (focal disability) following cortical injury. The ARAT is designed for evaluation of both sides of patients, in order to obtain a more total description of the upper extremity function. The ARAT contains four subscales—'grasp', 'grip', 'pinch' and 'gross movement'—comprising 19 items in total. Each subscale fulfilled the statistical criteria for Guttman scales and so is constructed of items arranged in hierarchical order of difficulty. Items within each subscale are ordered in such a way that if a patient accomplishes the most difficult item, this predicts success with all less difficult subscale items. Thus, the patient is credited with succeeding with all items of the subtest for that limb. On the other hand, failure with the easiest item predicts failure with all items of greater difficulty on that subscale. Thus, the ARAT has been specially constructed to save testing time. It takes no more than 10 min to examine a stroke patient on the ARAT [7].

The psychometric characteristics of the ARAT have been rarely explored. Lyle [4] has identified four subscales, each fulfilling the necessary statistical criteria for reproducibility and scalability. Lyle [4] ascertained inter-rater and test-retest reliablities to be

as high as $r = 0.99$ and 0.98 respectively, calculated by Pearson product-moment correlation. However, generalization of the results requires caution. First, the subjects of Lyle's study were chronic hemiplegic patients (mean duration 4 years) but not patients at the acute or subacute stage commonly seen at clinics or in research. Second, the hemiplegia was secondary to stroke, traffic or industrial accident or assault. The broad scope of the subject's condition may obscure some specific characteristics of a particular disease. Third, the statistical method used to examine reliability may be inappropriate. Correlation coefficient, a measure of association not of agreement [8, 9], often overestimates the degree of true agreement and may yield misleading information about reliability [10].

DeWeerdt and Harrison [7] compared the motor recovery of upper extremity, by the administration of the Fugl-Meyer assessment and the ARAT to 53 stroke patients at 2 and 8 weeks after onset. They found that both tests appear to monitor the upper limb function equally well. They preferred the ARAT because it is probably more meaningful to the patient and takes less time to administer.

The psychometric details of the ARAT have not been well established. The primary purpose of this study was to determine the extent to which different examiners agreed on the performance of stroke patients using the ARAT. The relationships between the scores on the ARAT and some other well-validated measurements evaluating upper extremity motor impairment and disability were also investigated.

Methods

Subjects

Of the 108 consecutive stroke patients admitted to the Physical Medicine and Rehabilitation department at National Taiwan University Hospital in Taipei between April and August 1996, 50 met the following criteria: (i) diagnosis according to International Classification of Diseases, Ninth Revision Clinical Modification (ICD-9-CM) codes for subarachnoid haemorrhage (430), cerebral haemorrhage (431 and 432), cerebral infarction (433 and 434) or other (436 and 437) and (ii) ability to follow verbal commands.

The clinical diagnosis of stroke was confirmed by physicians using neuro-imaging examination (computed tomography or magnetic resonance imaging). Patients who were diagnosed with transient ischaemic attack (ICD-9-CM code 435) or with late effects of cerebrovascular disease (ICD-9-CM code 438) were excluded. Most of the patients excluded were those who could not follow commands (e.g. patients with global aphasia). Before the study, all subjects gave their informed consent to be included in the study.

Table 1. Characteristics of the study patients ($n = 50$)

Characteristic	Value
Gender	
Male	30
Female	20
Mean age, years (SD)	65 (13.0)
Median days after onset (range)	55 (8-535)
Frequency of diagnoses	
Subarachnoid haemorrhage	7
Cerebral haemorrhage	13
Cerebral infarction	21
Other	9
Frequency of paresis	
Right	22
Left	23
Bilateral	5
Mean test score (SD)	
ARAT[a]	83.7 (24.6)
UEMAS	7.7 (6.9)
AMI	46.2 (31.9)
UEMMAC	83.9 (21.6)

[a]The average score of the three raters on the ARAT.
ARAT, Action Research arm test; AMI, arm score of the motricity index; UEMAS, upper extremity part of the motor assessment scale; UEMMAC, upper extremity part of the modified motor assessment chart.

Further information on the study sample is presented in Table 1.

Procedure

The study was divided into two parts. For the first part, an inter-rater study, the ARAT was administered by three different occupational therapists on the same patient within 3 days. The 3-day period was established to minimize the effect of a possible spontaneous recovery, a confounding variable that could affect the result. All of the three occupational therapists voluntarily participated in the study. They were blind to results of one another's assessments during the study period.

Before the beginning of the study the raters were familiarized with the ARAT. All raters reviewed the original literature which described the test and received a 30 min in-service training session on the administration of the evaluation. To improve their efficiency, all raters employed this instrument in their clinical practice for at least 1 week before participating in the study. The allocation of the raters to a given evaluation session (1, 2 or 3) for a given patient was done in accordance with a counterbalanced design.

The ARAT must be administered in a formal set-up. The following equipment is required: a chair and a specially constructed table, woodblocks, a cricket ball, a sharpening stone, two different sizes of alloy tubes, a

washer and bolt, two glasses, a marble and a 6-mm ballbearing. Some of the details of the test are given in the Appendix [4]. For further details of the test's standardization and administration the reader should refer to Lyle's original report [4].

The second part was a validity study. Assessment of validity requires standard measures with which the scale is to be compared [10]. The criteria evaluating upper extremity motor impairment and disability were administered during the same period as the reliability study by another occupational therapist (L.P.-H.), who was blind to the result of the ARAT. Concurrent validity of the ARAT was assessed by comparing the results of the ARAT with that of the motor assessment scale. The motor assessment scale includes eight hierarchical measures largely focused on disability [11]. The validity and reliability were well studied and results were supportive [11, 12]. Three subscales—upper-arm function, hand movements and advanced hand activities measuring upper extremity disability (upper extremity motor assessment scale; UEMAS)—were employed in this study. The total score of the three subscales was used for analysis.

The association between the results of the ARAT and upper extremity motor impairment was also examined. The modified motor assessment chart and the motricity index were employed as criteria. The MMAC based on the sensorimotor assessment according to Fugl-Meyer *et al.* [13] was constructed for assessing motor capacity after acute stroke. The modified motor assessment chart gives somewhat more information on the patient's motor performance than the Fugl-Meyer scale. This is because the modified motor assessment chart, like the ARAT, evaluates both the paretic and non-paretic sides of stroke patients and each item is evaluated on a 4-point scale. The bilateral evaluation gives important information about the healthy side of the patient. The modified motor assessment chart is a reliable and valid tool for survival and outcome of the motor function [14, 15]. The components relating to upper extremity movements (upper extremity modified motor assessment chart; UEMMAC) including bilateral arm, wrist and hand function were employed for this study.

The motricity index, including three subscales (arm, leg and trunk control), is a measure of motor loss primarily developed for use after stroke. Validity and reliability have been proven and it has been found to be sensitive to change in recovery after stroke [16–19]. The arm subscale (arm motricity index; AMI) was used for analysis.

Statistical analysis

As the ARAT is designed for evaluation of both sides of patients, the total score of both sides on the ARAT was used for analysis. The intra-class correlation coefficient (ICC) was employed to examine the degree of agreement between repeated measurements taken by the three raters on the same patient. The ICC expresses measurement error and agreement as the relation between true variance and observed variance. The ICC can provide estimates of both association and agreement and can also be used with more than two sets of data (e.g. raters) [9]. The coefficients are obtained from an analysis of variance (ANOVA) model. ICC $\geq$ 0.80 indicates high reliability [20]. The 95% confidence interval was calculated for each ICC to take sampling variation into account. ANOVA for repeated measure on the mean difference between scores obtained on the three measurements was used to determine the presence of a systematic bias. When a systematic bias existed, Duncan's multiple-range test was performed to establish where inter-rater means differed. The standard Pearson product-moment correlation was employed to examine the relationship between scores of the ARAT and the upper extremity part of the motor assessment scale, the arm sub-score of the motricity index and the upper extremity movements of the modified motor assessment chart. The average score of the three raters was used.

Results

The mean time needed to administer the ARAT on the patients was about 8 min. The coefficient of inter-rater reliability for the less severely affected arm was 1. Separate analyses of reliability and validity both for the less severely affected arm and for the more severely affected arm were not performed because the results would not have been altered.

For the inter-rater study, homogeneity of variance ($P > 0.05$) was disclosed between the sets of scores using Hartley's test [21]. A two-way ANOVA was employed to compute the variances needed to estimate the inter-rater reliability ICC values. The fixed effect of ICC model 3 [22] was used to compute the ICC value for inter-rater reliability.

ICC for the total score was 0.98 (95% confidence interval: 0.97–0.99, $F = 178.3$, $P < 0.0001$) indicating very high inter-rater reliability. ICCs were also very high in each of the subscales (Table 2).

ANOVA for repeated measure of the mean difference between the scores on the three measurements indicated the presence of a systematic bias on three subscales (grasp, grip and pinch) and hence on the total score. Duncan's multiple-range test revealed that one rater scored systematically higher than either or both of the other raters ($P \leq 0.01$). Figure 1 shows the relationship between the patients' scores on the ARAT as rated by two of the three raters. The mean difference for the total score was the largest value (2.1) between each of the three raters.

The Pearson product-moment correlation was used to examine the association between the ARAT and the

Table 2. Inter-rater reliability analysis of the Action Research arm test

	Mean score (SD), by rater			Difference	
	A	B	C	*F* value (*P*)[a]	ICC (95% CI)
Grasp	26.4 (8.2)	26.9 (8.6)	26.7 (8.3)	3.55 (0.036)	0.98 (0.97-0.99)
Grip	16.9 (5.2)	18.0 (5.8)	17.5 (5.4)	8.46 (0.001)	0.96 (0.93-0.97)
Pinch	25.5 (7.8)	25.6 (8.0)	24.7 (7.4)	7.68 (0.001)	0.96 (0.94-0.98)
Gross movement	14.0 (3.6)	14.3 (3.9)	14.3 (3.9)	1.26 (0.291)	0.95 (0.92-0.97)
Total score	84.9 (25.6)	83.6 (24.2)	83.0 (24.0)	3.56 (0.036)	0.98 (0.97-0.99)

[a]Calculated by analysis of variance for repeated measure.
ICC, intra-class correlation coefficient; CI, confidence interval.

other well-validated measurements (i.e. UEMAS, AMI and UEMMAC). The purpose was to determine whether ARAT examined the same attribute as the other outcome measures. The degree of validity was assessed by estimating correlation coefficient and its statistical significance. The results showed that the ARAT measurements result was closely associated with the UEMAS disability measurement ($r = 0.96$ explained 92% of the variance). Figure 2 shows that the scores of the ARAT were highly associated with those of the AMI and the UEMMAC impairment measurements which were $r = 0.87$ and 0.94, respectively.

Discussion

Any measurement tool requires extensive examination to understand its particular strengths and limitations [23]. In addition, without such examination, individuals cannot be confident that it performs in the ways that its developers and users intended.

The psychometric characteristics of the ARAT have been examined rarely. Our primary objective was to investigate the inter-rater agreement of the ARAT. Inter-rater agreement is an important issue for rating scales. If trained personnel cannot agree, the objectivity and usefulness of assessment will be doubtful [3]. We also investigated the relation between performance on the ARAT and the other well-validated measurements evaluating disability and impairment.

The results of this study indicate the ARAT is extremely reliable for each of the subscales as well as the total scale when performed by different raters. Different users of the ARAT achieved consistent results.

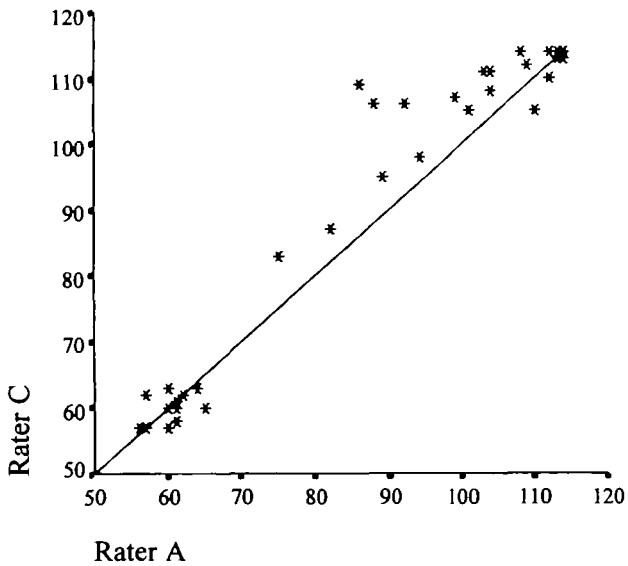

Figure 1. The relationship between the patients' scores on the Action Research arm test as rated by two of the three raters.

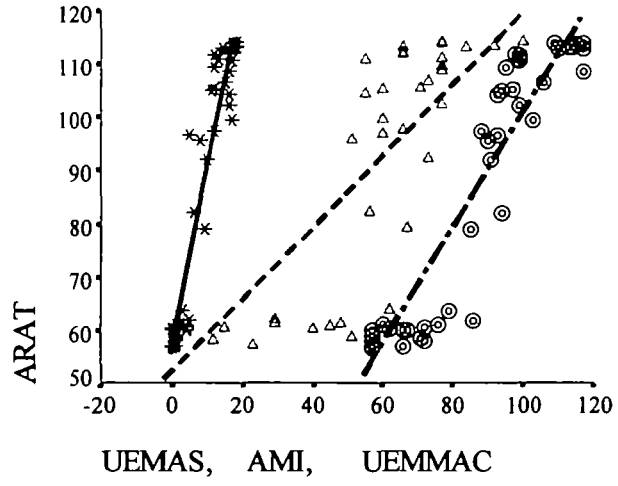

Figure 2. The relationship between the performance on the Action Research arm test (ARAT) and the upper extremity part of the motor assessment scale (UEMAS; *), the arm sub-score of the motricity index (AMI; Δ) and the upper extremity movements of the modified motor assessment chart (UEMMAC; ◎). ARAT/UEMMAC $R^2 = 0.8860$; ARAT/AMI $R^2 = 0.7618$; ARAT/UEMAS $R^2 = 0.9182$.

However, it is possible that high inter-rater reliability in the present study might have been achieved because we included only a small number of well-trained and experienced (>5 years) therapists. Untrained raters and raters with less experience, either with stroke patients or with the ARAT, may not achieve a similar degree of consistency.

A systematic bias was found for three subscales (grasp, grip and pinch) and for the total score (Table 2). However, the magnitude of the mean difference in scores between any two of the raters was small (no more than 2.1 out of 114 for the total score). Therefore, this statistically significant difference may not be clinically significant. Increasing sample size for reliability studies yields more precise estimation of ICCs but increases the likelihood of disclosing systematic biases that are not of clinical significance [24]. The estimation of ICCs takes into account the systematic bias and the random error [25]. Our results showed that ICCs were very high in spite of the presence of systematic bias between the raters.

The results showed a strong relation between performance on the ARAT and the UEMAS ($r = 0.96$). The extreme association between the ARAT and the UEMAS implies a similarity in the construct (i.e. arm disability) being evaluated. The results support the validity of the ARAT as a measure of upper extremity function in patients who have a stroke. The high r-value does not indicate agreement. Exact agreement between scores on the ARAT and the UEMAS would not be expected because of the different methods employed in scoring the two assessments.

The results also showed that the scores of the ARAT were highly associated with those of the AMI and the UEMMAC (impairment measurements). This finding of the present study is similar to that of DeWeerdt and Harrison's study [7], in that the scores of the ARAT were closely correlated with those of the Fugl-Meyer assessment (a test of impairment) in stroke patients. The results indicate that the scores of the ARAT may reflect not only arm function but also upper extremity motor impairment that represents the exteriorization of neurophysiological states due to cerebrovascular diseases. Thus, the scores of the ARAT may also represent the degree of upper extremity motor impairment.

The ARAT is designed for evaluation of both sides of patients with cortical injuries, helping to obtain a more total description of the upper extremity function than investigation of only the hemiplegic side. From the point of view of dependency it is necessary to know whether the patient has unlimited function on the non-affected side. In particular, some patients (e.g. individuals with brain stem lesions) have both sides affected, although generally one side to a lesser extent than the other. Furthermore, a number of studies have reported that the ipsilateral non-affected side of patients with a single focal hemispheric infarct showed slowed sensory-motor responses [26–28].

The evaluation of the non-paretic side is not time-consuming because of the hierarchical design of the ARAT. In fact, the evaluation of the non-affected side can also serve as a kind of demonstration in which the rater will determine whether the patient understands his/her commands. The evaluation will be hence performed more smoothly.

Other commonly used instruments for assessing arm–hand function in stroke patients which might be used instead of the ARAT include: the grip strength test [29], the nine-hole peg test [30] and the Frenchay arm test [31]. Although grip strength is probably a sensitive measure of recovery from stroke [17], the test measures distal strength rather than proximal strength and dexterity as in the ARAT. The nine-hole peg test mainly focuses on finger dexterity, but it cannot detect deficits of proximal strength and is not useful when impairment is severe, especially when the patient's upper extremity motor function is limited [30]. The Frenchay arm test assesses proximal control and dexterity. It contains only five subtests and is simple and quick to administer. Patients tend to either pass or fail all subtests [30], which suggests this test might not be sensitive enough to distinguish patients with minor difference in motor control and dexterity. The ARAT assesses not only proximal and distal strength but also dexterity. It is easy and quick to use. Therefore, the ARAT may be preferable among the instruments which are used to evaluate arm–hand function in stroke patients. Although it requires construction of a special table, the materials needed for the ARAT are not expensive or difficult to obtain.

Future research should compare the performance of raters from different disciplines with varying levels of experiences. Studies to examine the predictive validity and sensitivity to change of the ARAT are also needed. Studies with other patient groups and age ranges are also necessary to establish the clinical utility of the ARAT.

In brief, the preliminary evidence presented in this study indicates that consistent and valid information can be obtained from the ARAT. This result supports the value of the ARAT for measuring recovery of arm–hand function in stroke patients.

Key points

- Precise, valid and reliable measures are important in rehabilitation.
- The Action Research arm test assesses arm function after cortical injury and is useful in monitoring motor recovery after stroke.
- This study shows that the test has very high inter-observer reliability.
- Action Research arm test scores correlate well with other measurements of arm movement and function.

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Received 26 February 1997

Appendix. The Action Research arm test [4]

Guidelines to rater: items within each subscale are ordered in such a way that if a patient accomplishes the most difficult item (the first item of each subscale), then this predicts success with all less difficult subscale items. Thus, the patient is credited with succeeding with all items of the subscale for that limb. On the other hand, failure with the easiest item (the second item of the first three subscales and the first item of the fourth subscale) predicts failure with all items of greater difficulty on that subscale. The scores on the different items are added up for both sides, to a maximum of 114.

	Score, by side[a]							
	Left				Right			
Item	0	1	2	3	0	1	2	3

Grasp subscale

Grasp and lift blocks, a cricket ball and a sharpening stone from one shelf of a table to another (lift over 37 cm)

1. Block, 10 cm *(if score = 3, total = 18 and → grip subscale)*
2. Block, 2.5 cm *(if score = 0, total = 0 and → grip subscale)*
3. Block, 5 cm
4. Block, 7.5 cm
5. Cricket ball
6. Sharpening stone

Grip subscale

7. Pour water from one glass to another *(if score = 3, total = 12 and → pinch subscale)*
8. Displace an alloy tube (diameter 2.25 cm) from one side of the table to the other *(if score = 0, total = 0 and → pinch subscale)*
9. Displace an alloy tube (diameter 1 cm) from one side of the table to the other
10. Put washer over a bolt

Pinch subscale

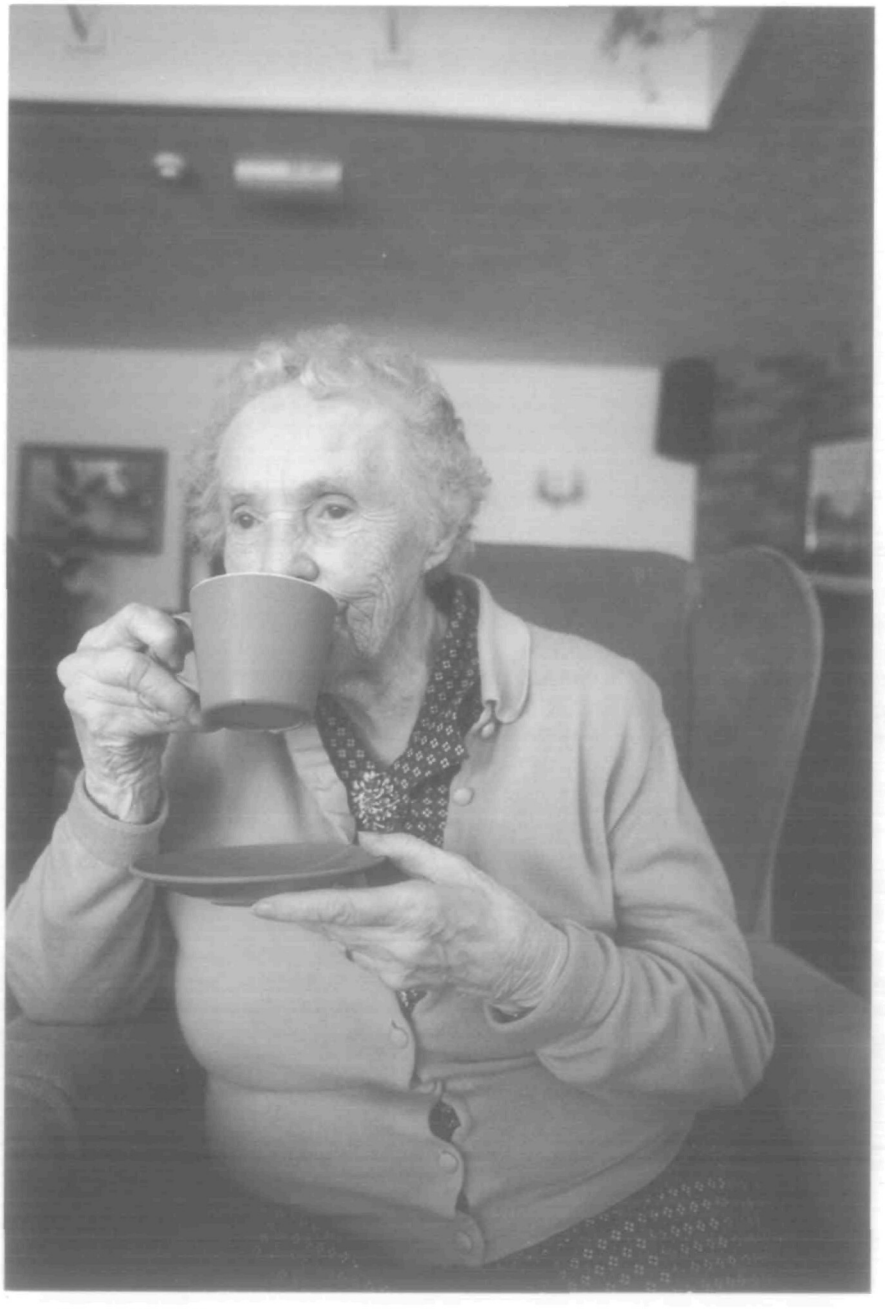
Pinch and lift the ball bearing marble from one shelf of a table to another (lift over 37 cm)

11. Ball bearing of 6 mm, 3rd finger and thumb *(if score = 3, total = 18 and → gross movement subscale)*
12. Marble, 1st finger and thumb *(if score = 0, total = 0 and → gross movement subscale)*
13. Ball bearing of 6 mm, 2nd finger and thumb
14. Ball bearing of 6 mm, 1st finger and thumb
15. Marble, 3rd finger and thumb
16. Marble, 2nd finger and thumb

Gross movement subscale

17. Hand behind head *(if score = 3, total = 9 or if score = 0, total = 0)*
18. Hand on top of head
19. Hand to month

[a]3, performs the test normally; 2, completes the test but takes abnormally long or has great difficulty; 1, performs the test partially; 0, cannot perform any part of the test.



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