STUDY PROTOCOL

International Journal of Clinical and Biomedical Research

Vol. 11, No. 2 (2026)
pISSN: 2521-0394 · eISSN: 2395-0471

Convergent and Discriminant Validity of the Bimanual Assessment Measure in Patients with Stroke: A Study Protocol

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ABSTRACT

Effective assessment of upper limb coordination is pivotal for guiding post-stroke rehabilitation. The Bimanual Assessment Measure (BAM) is a recently developed, psychometrically promising instrument designed to evaluate bimanual hand function and inter-limb coordination in stroke survivors. Although the BAM has demonstrated strong reliability since its inception, its convergent and discriminant validity have not yet been formally investigated. Establishing these validity properties is essential to confirm its construct validity, support its integration into clinical and research practice. This study aims to determine the convergent and discriminant validity of BAM in individuals with chronic stroke by comparison with established upper limb assessment instruments. This prospective observational study include stroke survivors (aged 18–65 years, stroke onset ≥6 months prior) from a tertiary care neurorehabilitation centre, selected according to pre-specified inclusion and exclusion criteria. Three standardized instruments will be administered in a single session: the BAM, the Adult Assisting Hand Assessment–Stroke (Ad-AHA Stroke), and the Jebsen-Taylor Hand Function Test (JTHFT). Convergent validity will be assessed by correlating BAM scores with Ad-AHA Stroke scores using Spearman's rank correlation coefficient. Discriminant validity will be examined by comparing BAM (bimanual) scores with JTHFT (unimanual) scores using the Spearman correlation/Mann-Whitney U test, to confirm that the two instruments measure distinct constructs. The findings of this investigation will provide robust evidence regarding the convergent and discriminant validity of the BAM in the stroke population, thereby strengthening its psychometric foundation and supporting its clinical applicability as a comprehensive bimanual outcome measure in stroke rehabilitation.

Keywords: Stroke rehabilitation; Bimanual Assessment Measure; Bimanual coordination; convergent validity; Discriminant validity; Upper limb outcome measures; Adult Assisting Hand Assessment; Jebsen-Taylor Hand Function Test.

INTRODUCTION

Stroke is defined by the World Health Organization (WHO) as the rapid onset of clinical signs of focal or global disturbance of cerebral function, persisting for more than 24 hours or resulting in death, attributable to a vascular cause [1]. It represents the second leading cause of mortality worldwide and ranks third in terms of combined mortality and disability as quantified by disability-adjusted life years (DALYs) [2].

The epidemiological burden of stroke is substantial and escalating. The Global Stroke Fact Sheet 2022, published by the World Stroke Organization, reports more than 12.2 million new stroke cases annually, a global stroke prevalence exceeding 101 million, and over 6.55 million stroke-related deaths per year [2]. In Asia, approximately 9.5–10.6 million strokes occur annually, as estimated by a 2023 review in Cerebrovascular Diseases Extra [3]. Within India specifically, the total number of stroke cases increased by 47% between 1990 and 2021, rising from 4.4 million to 9.4 million, while the annual incidence of new cases increased by 51%, from approximately 650,000 to over 1.25 million over the same period [4].

Stroke produces deficits across multiple functional domains, including motor impairments (hemiparesis, spasticity), cognitive dysfunction (memory impairment, executive dysfunction), communication disturbances (aphasia, dysarthria), and swallowing difficulties (dysphagia, aspiration risk) [5]. Among these sequelae, upper extremity dysfunction is one of

the most prevalent and functionally debilitating. Despite active participation in structured rehabilitation programmes, the majority of stroke survivors experience incomplete recovery of upper extremity motor function. The predominant abnormalities in the hemiparetic upper limb include contractures, spasticity, muscle weakness, and impaired independent joint control, collectively compromising the ability to perform activities of daily living (ADLs) [6].

Upper limb impairment following stroke frequently disrupts bimanual function—the coordinated use of both hands for functional tasks. Research indicates that nearly 50% of stroke survivors experience persistent upper limb impairments beyond three months post-stroke, directly limiting their capacity to perform bimanual ADLs [7]. Lai et al. (2019) demonstrated quantifiable deficits in bimanual force coordination in stroke patients with upper extremity paresis, linking these impairments to reduced motor and functional performance [8]. A systematic review further confirmed that stroke survivors exhibit significant impairments in both kinematic and kinetic control during bimanual coordination tasks compared with age-matched healthy controls, with deficits evident across diverse classes of bimanual actions [9].

Accurate assessment of bimanual hand function post-stroke is essential for characterizing coordination deficits, predicting functional outcomes, and directing rehabilitation interventions. Several validated instruments are currently available for this purpose. The Adult Assisting Hand Assessment–Stroke (Ad-AHA Stroke) evaluates the spontaneous coordination of the impaired hand with the unaffected hand during semi-structured bimanual tasks [10]. The Bimanual Assessment Measure (BAM) assesses hand coordination in both preferred and pre-stroke roles, with emphasis on the stabilizer and manipulator functions of each hand [11]. The Bimanual Observation of The Hands (BOTH) is an observational instrument that evaluates bimanual coordination during functional tasks [12]. The ABILHAND Questionnaire is a patient-reported measure of perceived difficulty with bimanual ADLs [13].

The Bimanual Assessment Measure (BAM)

The BAM was developed by Johnson et al. in 2022 as a task-based, performance-rated instrument designed to identify bimanual coordination deficiencies beyond those attributable to unimanual impairment alone, and to assess the potential for recovery of pre-stroke hand roles (manipulator or stabilizer) in individuals with chronic stroke [11]. The instrument comprises 11 functionally relevant bimanual tasks, each scored on the basis of three components: the spontaneous role of the affected hand (manipulator, stabilizer, or non-use), task completion time, and quality of movement. The total performance score is expressed as a percentage.

Psychometric evaluation demonstrated excellent internal consistency (Cronbach's $\alpha = 0.97$), with inter-task correlations ranging from 0.54 to 0.89. Intra-rater reliability was excellent (ICC = 0.78–1.00), and inter-rater reliability was high (ICC = 0.95 on the first assessment occasion and 0.99 on the second). Test–retest reliability was also excellent ($r = 0.94$, $p < 0.0001$). In terms of validity, BAM scores of stroke patients (mean = 61.63%, SD = 31.42%) were significantly lower than those of age-matched healthy controls (mean = 95.30%, SD = 3.69%) ($t(45) = -5.21$, $p < 0.0001$), confirming known-groups validity. Face validity was supported by input from occupational therapists and stroke survivors [11, 12]. Notably, convergent and discriminant validity have not been examined in any prior study, constituting the primary rationale for the present investigation.

The Adult Assisting Hand Assessment–Stroke (Ad-AHA Stroke)

The Ad-AHA Stroke, developed by Van Gils et al. (2018) [14], is an observation-based instrument comprising 19 items across five domains: arm use, coordination, grasp and release, fine motor adjustments, and general use. Each item is rated on a four-point scale, and a logit-based unit score (0–100) is derived using Rasch analysis. Psychometric properties are well established: intra-rater and inter-rater reliability are excellent (ICC = 0.99), the standard error of measurement (SEM) is low (2.15 and 1.64 out of 100, respectively), and weighted kappa for individual item scores exceeded 0.79. Convergent validity was supported by strong correlations with established upper limb assessments ($r > 0.9$). Discriminant validity was demonstrated by significantly lower Ad-AHA Stroke scores in patients with visuospatial neglect compared with those without neglect [14]. On account of these robust psychometric properties, the Ad-AHA Stroke will serve as the reference standard for evaluating the convergent validity of the BAM in the present study.

The Jebsen-Taylor Hand Function Test (JTHFT)

The JTHFT is a standardized, objective assessment of fine and gross unimanual hand function, comprising seven timed subtests that simulate functional ADLs: writing, simulated page turning, lifting small objects, simulated feeding, stacking, and lifting large light and heavy objects. It has been extensively validated in stroke populations and demonstrates moderate-to-excellent test–retest reliability (ICC = 0.60–0.99 for both hands; ICC = 0.77 for the dominant hand lifting a large light object subtest) [15]. Given that the JTHFT specifically measures unimanual capacity, it will be employed in the present study as the comparator instrument for assessing the discriminant validity of the BAM—confirming that the BAM and JTHFT measure conceptually distinct constructs.

Study Rationale

Psychometric validation is an indispensable component of outcome measure development, as it ensures that instruments provide accurate, reliable, and clinically meaningful data for both research and practice. While the BAM has demonstrated strong reliability and face and known-groups validity, its convergent validity (alignment with a gold-standard bimanual measure) and discriminant validity (independence from a unimanual measure) remain unestablished. Addressing this gap is critical before the BAM can be recommended with full confidence as a comprehensive bimanual outcome measure in stroke rehabilitation settings. The present study is designed to provide this evidence.

Objectives

Primary Objective

To determine the convergent validity of the BAM by examining the correlation between BAM scores and Ad-AHA Stroke scores in patients with chronic stroke.

To determine the discriminant validity of the BAM by comparing BAM (bimanual) scores with JTHFT (unimanual) scores, confirming that the two instruments assess distinct functional constructs.

Secondary Objective

To characterize the relationship between bimanual hand function (assessed via the BAM) and unimanual capacity (assessed via the JTHFT) in stroke survivors, thereby contributing to the understanding of the interdependence and independence of these two aspects of upper limb performance.

METHODS AND DESIGN

Study Design: This is a prospective, cross-sectional observational study designed to evaluate the convergent and discriminant validity of the BAM in a sample of community-dwelling and hospitalized stroke survivors attending a tertiary care neurorehabilitation centre.

Setting and Duration: The study will be conducted over a period of 18 months at a tertiary care hospital with a dedicated neurorehabilitation unit providing both inpatient and outpatient stroke rehabilitation services. All assessments will be carried out in the neurophysiotherapy laboratory, which is equipped with standardized assessment tools and provides a quiet, distraction-free environment appropriate for performance-based evaluations.

Ethical Considerations: The study will be conducted in strict accordance with the ethical principles of the Declaration of Helsinki. All potential participants will receive a comprehensive explanation of the study purpose, procedures, risks, and benefits in the language of their preference, and written informed consent will be obtained from each participant prior to enrolment. Participation is voluntary and participants may withdraw at any time without consequence. Patient data will be anonymized and stored securely; confidentiality will be maintained throughout all phases of the study.

Eligibility Criteria

Inclusion Criteria

1. Confirmed first-ever stroke diagnosis per WHO criteria, with stroke onset ≥6 months prior to study participation.
2. Age 18–65 years at the time of enrolment.
3. Presence of at least 10° of active finger abduction and 10–15° of voluntary finger flexion/extension in the affected hand.
4. Ability to maintain an independent or supported seated position for a minimum of 30 minutes (corresponding to the expected assessment duration), with a Trunk Impairment Scale (TIS) score greater than 8 (indicating mild-to-moderate or no trunk impairment).

Exclusion Criteria

1. Presence of other neurological conditions causing permanent neurological damage or significant cognitive impairment sufficient to preclude reliable test participation (operationally defined as inability to follow two-step commands).
2. History of recent musculoskeletal injury or trauma to the upper extremity that may interfere with upper limb function assessment.

Sample Size Estimation

Convergent Validity: Sample size was calculated for Spearman's rank correlation assuming a two-tailed significance level of $\alpha = 0.05$ ($Z\alpha/2 = 1.96$), statistical power of 80% ($Z\beta = 0.84$), and an expected correlation coefficient of $r \approx 0.80$ based on analogous prior studies [16, 17].

Discriminant Validity: Sample size was determined for the Spearman correlation/ Mann-Whitney U test assuming a standard deviation of $\sigma = 12$ (as reported by Johnson et al., 2022 [11]) and a moderate effect size (Cohen's $d \approx 0.5$), with 80% power at $\alpha = 0.05$ [18, 19]. All participants from the convergent validity subgroup will be incorporated within this larger sample, ensuring analytical consistency and enabling within-sample comparisons across both validity analyses.

Participant Recruitment and Data Collection

Participants fulfilling the eligibility criteria will be recruited consecutively from the outpatient and inpatient neurorehabilitation services. Following enrolment and written informed consent, the following demographic and clinical data will be collected and recorded in a standardized data collection form: age, sex, occupational background, hand dominance, place of residence, stroke-affected side, stroke type (ischaemic/haemorrhagic), duration since stroke onset, and presence or absence of unilateral visuospatial neglect (assessed using the Star Cancellation Test).

Assessment Instruments

Assessment Procedure

Participants will undergo assessment using the three instruments in a standardized sequence to minimize fatigue and order effects.

- **BAM:** Performance-based evaluation of 11 bimanual tasks; scored as percentage performance
- **Ad-AHA Stroke:** Video-recorded semi-structured task; scored using Rasch-based analysis
- **JTHFT:** Timed unimanual functional tasks administered to the affected hand

Standardized instructions and scoring protocols will be followed for all instruments.

Table 1. Summary of assessment instruments

Instrument	Construct Assessed	Administration	Psychometric Properties	Role in This Study
BAM	Bimanual coordination (affected hand role, timing, movement quality)	11 functional tasks; scored as % performance; ~15 min	α = 0.97; ICC = 0.95–0.99; r = 0.94	Primary measure; both validity analyses Index test
Ad-AHA Stroke	Bimanual spontaneous hand use (stabilizer role of impaired hand)	Semi-structured task (gift-wrapping); 19 items; Rasch-based scoring (0–100); video-rated	ICC = 0.99; SEM = 1.64–2.15; convergent r > 0.9	Reference standard for convergent validity analysis Convergent validity comparator
JTHFT	Unimanual hand function (fine and gross motor)	7 timed ADL subtests; affected hand only; ~10–15 min	ICC = 0.60–0.99; established predictive validity	Comparator for discriminant validity comparator

BAM = Bimanual Assessment Measure; Ad-AHA Stroke = Adult Assisting Hand Assessment–Stroke; JTHFT = Jebsen-Taylor Hand Function Test; ICC = intraclass correlation coefficient; SEM = standard error of measurement; ADL = activity of daily living.

Validity Analyses

Convergent Validity: Convergent validity will be evaluated by examining the association between BAM scores and Ad-AHA Stroke scores.

- Statistical test: Spearman's rank correlation coefficient (ρ)
- Interpretation thresholds:
  - ≥0.70 → strong correlation
  - 0.50–0.69 → moderate correlation
  - <0.50 → weak correlation

A strong positive correlation (ρ ≥ 0.70) will be interpreted as evidence supporting convergent validity, consistent with COSMIN recommendations.

Discriminant Validity: Discriminant validity will be assessed by examining the relationship between BAM scores and JTHFT scores.

- Statistical test: Spearman's rank correlation coefficient (ρ)

It is hypothesized that:

- BAM (bimanual construct) and JTHFT (unimanual construct) will demonstrate a low-to-moderate correlation (ρ < 0.50)

Evidence of discriminant validity will be established if:

1. The correlation between BAM and JTHFT is significantly lower than the correlation between BAM and Ad-AHA Stroke
2. The magnitude of correlation aligns with theoretical expectations of construct independence

Secondary Analysis: To further explore the relationship between bimanual and unimanual function:

- **Partial correlation analysis** (adjusting for age, stroke duration, and severity) will be performed
- **Optional**: Linear regression may be used to evaluate predictors of BAM scores

ICF Code Analysis: International Classification of Functioning, Disability and Health (ICF) codes pertaining to hand function (d440, d4400, d4401, d4402, d4403) will be mapped to BAM task items and analyzed to facilitate standardized interpretation of hand function across the bimanual assessment framework.

Statistical analyses:

It will be conducted using appropriate software (e.g., SPSS v26.0 or R v4.3). The significance threshold will be set at $p < 0.05$ for all analyses.

Participant characteristics and outcome scores will be summarized using:

- Mean ± standard deviation (SD) for normally distributed data
- Median and interquartile range (IQR) for non-normally distributed data
- Frequencies and percentages for categorical variables
- As per obtained result the statistical test may be changed to find best results

DISCUSSION

The present study protocol describes a prospective investigation of the convergent and discriminant validity of the BAM—a gap explicitly identified by its developers [11]. Addressing this gap is clinically and scientifically significant, as validity evidence is a prerequisite for confident clinical adoption of any outcome measure. The BAM's focus on bimanual task performance, spontaneous hand role adoption, and movement quality represents a meaningful advance over unimanual assessments that have historically dominated upper limb rehabilitation research and practice.

Bimanual hand function is fundamental to independent performance of ADLs. The majority of daily functional tasks—including household activities (folding laundry, washing dishes, opening containers), food preparation (cutting, spreading, pouring), dressing and grooming (buttoning, zipping, tying), and personal hygiene (brushing teeth, combing hair, bathing)—demand coordinated and complementary use of both hands [20-25]. After a unilateral stroke, the paretic upper extremity experiences motor and sensory impairments that fundamentally disrupt bimanual coordination [26]. Conventional upper limb rehabilitation has predominantly focused on improving performance of the affected limb through unilateral exercises, predicated on the assumption that enhanced unimanual function will generalize to improved bimanual coordination. However, current evidence indicates that unimanual impairments do not reliably predict bimanual coordination deficits, and that the latter are governed by a more complex interaction of factors, including task demands, lesion location, residual cerebral connectivity, and the functional capacity of both limbs [26].

Rehabilitation approaches that explicitly target bimanual function have demonstrated promise. Modified constraint-induced movement therapy (mCIMT) has produced significant improvements in movement kinematics and functional outcomes in stroke survivors, and may indirectly enhance bimanual performance by promoting use of the affected limb during bilateral tasks [27]. Combining mCIMT with bimanual training (mCIMT-BiT) has demonstrated significant gains in arm motor function in a randomized controlled trial [28]. Comprehensive bimanual assessment tools such as the BAM are therefore essential to quantify treatment effects in these intervention paradigms and to monitor functional recovery over the rehabilitation continuum.

The selection of the Ad-AHA Stroke as the reference standard for convergent validity is methodologically justified on the basis of its robust psychometric properties, its conceptual alignment with the BAM in measuring bimanual performance, and its established status as a validated bimanual outcome measure for chronic stroke [14]. The selection of the JTHFT as the discriminator for testing discriminant validity is equally justified: as a measure of unimanual function, it should, theoretically, not correlate strongly with a measure of bimanual coordination if the latter possesses adequate discriminant validity [15].

The anticipated findings of this study will have direct implications for clinical practice. Confirmed convergent validity will allow clinicians to use the BAM with confidence as an alternative or complementary bimanual outcome measure alongside the Ad-AHA Stroke. Established discriminant validity will confirm that the BAM captures aspects of hand function not assessed by unimanual tools such as the JTHFT, supporting its use as a distinct and non-redundant component of a comprehensive upper limb assessment battery.

Limitations: Several limitations of the present study warrant acknowledgement. The single-centre design may limit the generalizability of findings across different clinical settings and patient populations. The cross-sectional administration of assessments precludes evaluation of responsiveness or longitudinal validity. The restriction of the Ad-AHA Stroke to the gift-wrapping task—rather than the full assessment—may introduce some constraint on the breadth of the convergent validity evidence and major limitation explicitly Future multicentre studies with larger and more diverse samples, incorporating longitudinal follow-up, are recommended to extend and consolidate the validity evidence generated by the present investigation.

CONCLUSION

The Bimanual Assessment Measure (BAM) represents a clinically meaningful and psychometrically promising instrument for the comprehensive evaluation of bimanual hand coordination in stroke survivors, addressing a functional domain inadequately captured by conventional unimanual assessments. The present study protocol provides a rigorous methodological framework for establishing the convergent and discriminant validity of the BAM in a well-characterized chronic stroke population. Confirmation of these validity properties will substantially advance the psychometric evidence base for the BAM and support its integration as a reliable, clinically applicable bimanual outcome measure in stroke rehabilitation. The results will also provide insight into the distinct but interrelated contributions of unimanual and bimanual function to upper limb recovery, with implications for the design of targeted, evidence-based rehabilitation programmes.

Declarations

Consent for Publication: Not applicable (no individual patient data are reported in this protocol).

Competing Interests: The authors declare no competing interests.

Funding: Nil

Authors' Contributions: All authors contributed to the conception and design of the study protocol. The manuscript was drafted by the lead author and critically revised by all co-authors. All authors approved the final version for submission.

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