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Reliability and accuracy of the brachial plexus neurodynamic test

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ABSTRACT

Study Design: Observational study.
Introduction: The brachial plexus neurodynamic test (BPNT), based on previous neurodynamic tests, is considered a clinically meaningful tool to objectively assess brachial plexus extensibility. This novel test's psychometric properties have yet to be determined.
Purpose of the Study: The primary study aim was to assess the inter- and intrarater reliability and accuracy of the BPNT, which biases the median nerve and brachial plexus, among clinicians of various professional experience levels and geographic US regions. The secondary study aim was to determine if professional experience or geographic region affects the accuracy levels of this test.
Methods: In phase 1, inter-rater reliability and accuracy was determined. About 307 participants attending neural mobilization conferences and courses were instructed in the BPNT and asked to score 7 different videos of 14 possible test levels. In phase 2, intrarater reliability was determined via scoring the same test videos twice.
Results: High inter-rater intraclass correlation coefficient (range, 0.98-0.99) and accuracy (range, 0.88-0.94) levels were determined for all clinical experience levels and geographic regions. Intrarater intraclass correlation coefficient values were high (range, 0.96-1.0) among all participants. One-way analysis of variance indicated no significant differences on test accuracy based on professional clinical experience ($F = 0.104$; $P = .958$) and geographic region ($F = 0.416$; $P = .416$) among all 307 participants.
Discussion: Excellent inter- and intrarater reliability and accuracy levels may allow clinicians to correctly identify BPNT positions regardless of their professional experience or geographic location.
Conclusion: The BPNT can reliably and accurately quantify outcomes in neural mobility scoring.
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Introduction

Neurodynamic testing to assess movement loss of the upper extremity due to injured, sensitized, or entrapped neural tissue is widely accepted.[1-14] Upper limb neurodynamic tests (ULNTs) assess for mechanosensitivity, with moderate degrees of reliability and validity.[3,7,9] Clinical practice guidelines have been developed to use evidence-based practice for musculoskeletal impairments. Based on these guideline recommendations, clinicians should use ULNTs when examining patients with neck or upper quarter symptoms.[15]

Although references to stressing upper limb neural tissue can be traced back to the early- to mid-1900s,[16,17] it was Elvey[18,19] who initially proposed the brachial plexus tension test (BPTT), which led to therapeutic interest in neural tissue as a potential pathoanatomic source of pain and movement dysfunction in patients with cervicobrachial disorders. Biasing neural tissue through a series of sequential movements was expanded on and documented by David Butler[1,20] as upper limb tension test 1 or upper limb neurodynamic test 1 (ULNT 1), which have demonstrated poor to excellent intrarater (intraclass correlation coefficient [ICC], 0.69-0.98) and poor to good inter-rater (ICC, 0.41-0.82) reliability levels.[21,22] All the variations of this test as described by Robert Elvey and David Butler are compared for their respective movement sequence differences in Table 1. One of the differences was that shoulder depression wording was removed from ULNT 1 in the second book of D. Butler.[1] Butler describes maintaining the shoulder girdle in neutral elevation in both publications.[1,20] All these variations have shown to effectively impart strain in the median nerve, brachial plexus, and cervical nerve roots in cadaver studies.[23-25]

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Table 1
Comparison of upper limb neural mobility testing movement sequence

BPTT[19]	ULTT 1[20]	ULNT 1[1]
1. Shoulder girdle depression	1. Constant depression force applied to the shoulder girdle	1. Shoulder girdle elevation blocked in neutral position
2. Shoulder abduction (behind coronal plane)	2. Shoulder abduction to 110°	2. Shoulder abduction (in coronal plane) to 110°
3. Shoulder external rotation	3. Forearm supinated, wrist extended, and thumb in radial extension	3. Wrist and finger extension, thumb in radial extension
4. Forearm supination	4. Shoulder external rotation	4. Forearm supination
5. Elbow extension	5. Elbow extension	5. Shoulder external rotation
6. Wrist and finger extension	6. Lateral cervical flexion away	6. Elbow extension
		7. Lateral cervical flexion away

BPTT = brachial plexus tension test; ULTT = upper limb tension test; ULNT = upper limb neurodynamic test.

The clinical utilization of these tests (ie, ULNT 1) require clinicians to record test results via elbow range of motion (ROM) goniometric measurements achieved at the onset or threshold point of the patient's familiar symptoms or upper extremity discomfort.[4,5,11,12,24-27] As such, clinical documentation encompasses the following challenges: (1) highly involved patients may demonstrate positive test results early in the test sequence (before completing shoulder abduction), precluding the use of elbow ROM for documentation; (2) taking goniometric measurements during testing at patients' symptom tolerance point can be cumbersome; and (3) difficulty in determining the amount of change that occurred in test, treat, retest examination (ie, test responsiveness) for identifying an effective treatment response. Although these tests are commonly used in the clinic, they are conducted without using a standardized grading scale, which could overcome their clinical disadvantages. Lack of standardized outcome measures to assess efficacy of neurodynamic treatments has been identified as a concern in recent meta-analyses of systemic reviews.[28,29]

To address these concerns, a novel grading scale, the brachial plexus neurodynamic test (BPNT) (Fig. 1), was developed and piloted by M. W. Butler[30] while working with patients suspected of brachial plexus injury. The BPNT is a 0-5/5 grading scale, which was created to effectively address the concerns stated previously: (1) it provides a continuum of data collection points throughout the ROM of the tested upper extremity; (2) there is no need for using a goniometer during testing as the grading scale levels correlate with easily recognizable arm positions; and (3) it provides a more reproducible scale for reliably assessing a patient's functional improvement before, during, and after neural mobilization treatments. The BPNT reflects a modified version of the previously published ULNT 1[1] and BPTT.[19]

	**0/5**: Patient laying supine, shoulders level with their arm across their abdomen; their shoulder in IR and adduction, their elbow positioned at 90°, wrist and fingers in neutral
	**1/5**: Externally rotate the shoulder to neutral; keeping the elbow at 90°, the wrist and fingers in neutral
	**2/5**: With the elbow, wrist, and fingers as above and the thumb held in radial abduction, abduct the shoulder to 110° in the frontal plane, while firmly blocking scapular elevation and maintaining the forearm in neutral position
	**3/5**: Externally rotate the shoulder to 90° while keeping the elbow at 90°, then supinate the forearm, while keeping the wrist and fingers in neutral position and thumb in radial abduction
	**4/5**: With the shoulder, wrist, fingers and thumb as above, slowly extend the elbow to 0°
	**5/5**: Finish the test by extending the wrist and fingers
+ and – scores can apply incrementally between the shown 6 arm positions.	

Fig. 1. The BPNT and its grading scale. BPNT = brachial plexus neurodynamic test.

The BPNT is slightly different than the previously reported ULNT 1 by D. Butler[5] and BPTT by Elvey.[19] Although sequenced differently, test components of the BPNT remain consistent with both ULNT 1 and BPTT. Various measurement methods using cadaver tissue demonstrated that these tests have produced comparable tension, strain, and displacement of neural tissue along the median nerve bed from the carpal tunnel, proximal arm, through the brachial plexus, to the nerve roots that supply the brachial plexus.[23-25,31-33] Thus, if the components of the test remain constant, the order of movement does not appear to affect strain or relative position of the neural tissue at the end of the test.[34]

The inter- and intrarater reliability and accuracy levels of BPNT have not been established to date. It is imperative for an instrument to demonstrate adequate inter- and intrarater reliability and accuracy levels for clinicians to have confidence in clinical utilization of that instrument. Reliability refers to an instrument's ability to produce consistent findings within or between different testers over time. Accuracy reflects to the precision or proximity of a test measurement to a preset true value.[35] Thus, determining the psychometric properties of BPNT will allow clinicians to measure meaningful motion changes in the upper extremity among patients with restricted neurodynamics before and after interventions, essentially advancing clinical practice.

Purpose

The primary aim of the study was to determine the reliability (ie, inter- and intrarater) and accuracy of the BPNT based on the neurodynamic tests that bias the median nerve and brachial plexus among clinicians of various professional experience levels and different geographic US regions. The secondary aim of the study was to determine whether professional experience and geographic region influence the accuracy levels of the BPNT. The main hypothesis in this study was that the BPNT would demonstrate high reliability and accuracy irrespective of professional experience level and geographic US region.

Methods

This is an observational reliability study. Its data collection consisted of 2 phases. Phase 1 was conducted to determine the inter-rater reliability and accuracy of BPNT. Phase 2 was conducted to determine the intrarater reliability of BPNT. Two convenience samples of 307 and 9 testers were recruited to complete phase 1 and 2, respectively, with participation being voluntary. The study inclusion criterion for recruitment was to be a clinician or a student attending conferences, courses, or lectures on neural mobilization by the lead author. The only exclusion criterion was vision impairment, as testing was completed via video observation.

Data collection occurred during the course of 1 year across the United States. All participants signed a university-approved informed consent form before data collection. This study was approved by the Stockton University Institutional Review Board for Human Subjects.

Instrumentation

Participants were instructed in the BPNT shown in Figure 1. The BPNT consists of 14 distinct grades based on the shown 6 specific arm positions and the associated (+) and (−) scores that can apply incrementally between arm positions. A (+) sign is used when a patient's score is beyond a grade level but less than half way to the next level. A (−) sign is used if a score falls more than half way but before the next level.

All participants had approximately 1 hour of instruction in the BPNT by the lead author. Group teaching methods included a power point presentation of all the test positions followed by 30 minutes of laboratory demonstration and practice. Further practice of the BPNT occurred just before data collection by the instructor calling out various grades in random order and the participants assuming the corresponding test positions. This final review lasted approximately 5 minutes consistently across all participants.

Phase 1 assessment process

At least 1 hour but no more than 1 day after instruction in use of the grading scale, as a group, participants were shown 7 videos projected on a large screen of a subject being tested via the BPNT. All videos consisted of the same female subject dressed in the same clothing with the same camera location used for each scoring position to ensure consistency of observation. The subject being tested was a healthy physical therapist with knowledge of the grading scale to insure test accuracy. Videos represented only 7 of all 14 possible test positions. All participants watched the same videos in random order and scored the test positions on a data collection sheet and were encouraged to keep their responses private while sitting next to each other. Thirty seconds was allotted between each video shown to allow appropriate time for scoring. Five of the 7 tested positions were exact grades from 1/5 to 5/5, with 2 tested positions incorporating (+) and (−) grade levels. All 307 separate participant grades on all 7 videos were used toward determining the inter-rater reliability levels of the BPNT. The total number of correct responses provided by each participant on all 7 videos was used toward determining the BPNT accuracy levels.

Phase 2 assessment process

At least 1 month after phase 1, a smaller convenience sample consisting of 9 of the initial 307 clinicians agreed to participate in phase 2 assessment process. Demographic data on these participants' clinical experience, geographic location, and clinical specialty are shown in Table 2. These participants were asked to view and regrade the same 7 videos from phase 1 in random order using a separate data collection sheet. Phase 1 and 2 grades on all 7 videos were used toward determining the intrarater reliability levels of the BPNT across all 9 participants.

Power analysis

To determine if the study's sample size was adequate, a power analysis for correlations was conducted. This type of power analysis was selected since ICC is a correlation-based statistical index. Based on a correlation coefficient power table for 1-tailed test, an estimated sample size of 6 is required for a 0.90 power level with a 0.05 alpha level and correlation coefficient or ICC levels of at least 0.90.[35] In this study, both the intrarater and inter-rater ICC levels were found to be >0.90 with a sample size of 7 (ie, 7 rated videos), indicating that the study has adequate power and sample size.

Table 2
Descriptive data and intrarater reliability levels among participants based on geographic region, clinical experience level, and professional specialty

Tester number	Geographic region	Clinical experience (y)	Clinical specialty	Intrarater ICC
1	NE	6-15	PT	1.0
2	NE	6-15	PT	0.96
3	NE	1-5	PT	1.0
4	NE	6-15	PT	1.0
5	NE	0	SPT	1.0
6	NE	6-15	PT	1.0
7	NE	0	SPT	1.0
8	NE	>15	OT/CHT	1.0
9	NE	1-5	PT	1.0

ICC = intraclass correlation coefficient; NE = Northeast (PA, NJ); PT = physical therapist; SPT = student physical therapist; OT = occupational therapist; CHT = certified hand therapist.

Statistical analysis

Data were analyzed via descriptive and inferential statistics. The primary aim of the study was analyzed via ICC statistics to determine the grading scale inter- and intrarater reliabilities. Intrarater reliability analysis was based on the comparison between all 307 individual participant grades on all 7 different videos. Intrarater reliability analysis was based on the comparison of phase 1 and 2 grades within each participant. During data analysis, all documented test grades were expressed by their exact numerical value (1-5). Grade levels with (+) or (−) values were assigned a 0.33 or 0.66 numerical value, respectively, added to the last full-grade value (ie, 3+/5 = 3.33; 4−/5 = 3.66). ICC values were interpreted as follows: <0.75 poor to moderate, 0.76-0.90 good, and >0.90 excellent.[35] The accuracy of the BPNT was assessed via statistical frequencies that determined the total number of correct responses provided by each participant after assessment of all 7 videos. Each participant's total correct response rate (ie, percent value of total correct response divided by 7) was used toward the final data analysis. The secondary aim of the study was analyzed via 2 separate 1-way analysis of variance to test the main effects of clinical experience (ie, years in practice) and geographic location on the accuracy of BPNT. Statistical significance was set at $P \leq .05$ for the aim of the secondary study. The Statistical Package for the Social Sciences, version 23.0 (SPSS, Inc, Chicago, IL) was used to complete all data analysis.

Results

Descriptive statistics for all participants' clinical experience, geographic region, and clinical specialty frequencies are presented in Table 3. The inter-rater ICC (2, 1) and accuracy level values for the BPNT among all participants of various clinical experience levels and different US geographic regions are shown in Table 4. Inter-rater ICC values were determined to be excellent (range, 0.98-0.99) among all participants of all clinical experience levels and geographic regions. Similarly, the accuracy levels of BPNT were found to be high (range, 0.88-0.94) among all participants' clinical experience levels and geographic regions. The intrarater ICC (2, 1) values for the BPNT were determined to be excellent (range, 0.96-1.0) among all selected 9 participants. Table 2 displays all the descriptive statistics and intrarater reliability values for these participants. Regarding the secondary aim of the study, 1-way analysis of variance indicated no significant differences on the BPNT accuracy based on professional clinical experience ($F = 0.104$; $P = .958$)

Table 3
Descriptive data for all study participants

Clinical experience (y)	Frequency	Geographic region	Frequency	Clinical specialty	Frequency
>15	116	NE	134	PT	118
6-15	92	SE	27	OT	49
1–5	73	MW	146	CHT	92
0	26			Other	22
				SPT	26
Total	307		307		307

NE = Northeast (PA, NJ); PT = physical therapist; SE = Southeast (GA, FL); OT = occupational therapist; MW = Midwest (TX, IL, MO); CHT = certified hand therapist (PT and OT); Other = physical therapist assistant, occupational therapist assistant, certified athletic trainer, and physician assistant; SPT = student physical therapist (no clinical experience).

and geographic region ($F = 0.416$; $P = .416$) among all 307 participants used in the study.

Discussion

This is the first study to determine the psychometric properties of this novel BPNT grading scale, which can be reliably used for assessing patients with restricted neural dynamics involving the median nerve, brachial plexus, and associated nerve roots. The BPNT was found to have excellent inter- and intrarater reliability (range, 0.98-0.99 and 0.96-1.00, respectively) and high accuracy (range, 0.88-0.94) regardless of clinical experience and geographic location. These results are in partial agreement with previous studies[21,22] that have demonstrated a wide range of poor to excellent (ICC, 0.69-0.98) intrarater and poor to good (ICC, 0.41-0.82) inter-rater reliability levels for the previously established ULNTs among healthy participants.

The highly variable ULNTs reliability results could be partially attributed to their selected test termination point. Lower reliability levels are associated with UNLTs using a termination point of tissue resistance recorded by the tester rather than pain onset reported by the patient. Highly variable reliability levels of the previously reported UNLTs could also be accredited to their associated standard error of measurements of the electrogoniometers used during testing. In this study, the BPNT was found to have excellent inter- and intrarater reliability levels consistently across all testers and conditions (ie, clinical experience level and geographic location).

High reliability levels of the BPNT contribute to the methodological strengths of this newly developed grading scale, which offers greater neurodynamic assessment objectivity throughout the spectrum of upper extremity ROM. The BPNT bypasses the disadvantage of relying on cumbersome electrogoniometric measurements that do not represent common clinical practice. No previous study has attempted to determine whether a confounding effect exists between the ULNT 1 psychometric properties and clinical experience or geographic location. The purpose of developing and determining the psychometric properties of the BPNT was to effectively resolve concerns regarding the reproducibility and clinically complex documenting process of the previously used ULNTs.

Table 4
Inter-rater and accuracy levels for the BPNT among all participants of various clinical experience levels and different geographic US regions

Clinical experience (y)	Inter-rater ICC	Mean accuracy rate (SD)	Geographic region	Inter-rater ICC	Mean accuracy rate (SD)
>15	0.98	0.91 (0.58)	NE	0.98	0.88 (0.14)
6-15	0.98	0.91 (0.13)	SE	0.99	0.92 (0.92)
1-5	0.99	0.94 (0.10)	MW	0.98	0.94 (0.52)
0	0.98	0.92 (0.11)	All regions	0.98	0.92 (0.37)
All testers	0.98	0.92 (0.37)			

BPNT = brachial plexus neurodynamic test; ICC = intraclass correlation coefficient; SD = standard deviation; NE = Northeast (PA, NJ); SE = Southeast (GA, FL); MW = Midwest (TX, IL, MO).

This study is unique in using videos during the assessment process as no known previous studies have used this method to determine the psychometric properties of a previously established ULNT assessment instrument. The videos for each grade level were created in a standardized way for assessment consistency and to enhance the internal validity of the study. Each video projected the same subject, dressed in the same clothes, in the same examining room, laying on the same plinth, and examined by the same clinician at her dominant upper extremity. The methodological reasoning for videotaping a healthy subject was to allow for demonstrating test levels from the start to the end of the BPNT.

Another unique methodological approach in this study was to recruit participants with different clinical experiences, including student physical therapists (SPTs) who had already completed all or most of their musculoskeletal course work and had complete understanding of the anatomic and physiological function of the region (ie, upper extremity, cervical spine, brachial plexus, and upper quadrant peripheral nerve distribution). The advantage of recruiting SPTs in this study was to ensure the reproducibility and accuracy of the BPNT for all possible testers in a clinical environment. The assumption is that SPTs should be capable of reliably performing this test with confidence during their clinical rotations and have comparable findings with their clinical instructors. Besides the 9% of the participant population being SPTs, this study recruited a variety of clinicians that could use this test to assess individuals with potential neurodynamic restrictions. This included physical therapists (38%), occupational therapists (16%), certified hand therapists (30%), and other (ie, physical therapy assistants, occupational therapy assistants, athletic trainers, certified clinicians [7%]). The wide range of professionally credentialed clinicians with various levels of clinical experience (ie, range, 0-15+ years of practice) strengthened this study's external validity and therefore its extrapolation power. This claim was reassured by the study's results, which determined no significant differences in reliability and accuracy levels of this grading scale among all clinical experience strata.

The decision to recruit participants from multiple geographic regions was based on the same methodological rationalization. The recruited participants represented 3 distinct US regions (ie, Northeast [NE], Southeast, and Midwest). Participants from the NE region, which included the states of PA and NJ, accounted for 44% of the total sample. Participants from the Southeast region, which included the states of GA and FL, comprised 9% of the total sample. Finally, participants from the Midwest region, which included the states of TX, IL, and MO, represented 47% of the total sample. The advantage of using a multiregion participant sample was to strengthen this study's external validity and therefore its extrapolation power in clinical practice across different US geographic areas. The final study results of no significant difference in grading scale reliability and accuracy among geographic regions essentially confirmed this claim.

The strengths of this study articulate the process to standardization for the BPNT as a clinical tool. The lack of standardization in previously applied neurodynamic tests has been identified as a weakness in demonstrating the effectiveness of treatment designed to mobilize neural tissue.[28,29] The advantage of the BPNT is that it clearly quantifies and classifies the various positions of the ULNT 1 and BPTT from a proximal to distal tensioning strategy along the nerve bed in an easily reproducible and effective manner, thereby aiding the clinician in gathering useful clinical data during neurodynamic testing. Thus, results of this study contribute to the emerging evidence toward establishing critical psychometric properties of the BPNT as a useful tool for improving clinical practice.

Despite several strengths, results of this study should be interpreted with caution due to some methodological weaknesses. One weakness was the lack of assessment of all 14 possible positions of the BPNT during data collection. The reasoning to select only half of the possible test positions was based on the intent to maintain timeliness of the testing process and survey administration for course attendees. However, the 7 selected tested positions were chosen to assess participants' ability to effectively identify the 5 basic test positions of the grading scale and 2 positions that fell between grades to assess their ability to determine a (+) or (−) grade. Further testing is needed for all positions of the BPNT.

The use of 9 participants for the intrarater portion of the study could be considered a weakness. However, only 9 testers from the original 307 tester pool were able to return for participation in phase 2. Although these participants were in 1 geographical region (ie, NE), they represented various clinical experience and professional specialization levels (Table 2). Despite the low tester retention during phase 2, the final intrarater reliability levels were found to be consistently very high across all 9 testers, compellingly reinforcing the validity of this study's conclusions. Phase 2 lower rater participation did not affect the power of the study. Power analysis indicated that the included sample size of 7 videos was adequate for both the inter- and intrarater statistical analysis in this study.

Finally, establishing the reliability and accuracy of this grading scale based on video assessment compared with a direct clinician-to-patient assessment may have limited this study's clinical meaningfulness. However, the primary scope of this study was to determine the degree of a clinician's ability to reliably and accurately apply or interpret a newly developed grading scale of the BPNT. By establishing a high degree of reliability and accuracy in this manner, this study provides an important foundation for future research using the BPNT in clinical studies.

Conclusion

This study demonstrated high inter- and intrarater reliability and accuracy of the BPNT across a range of clinicians' experience levels, geographic US regions, and clinical specialties. Therefore, the BPNT may constitute a reliable quantitative measure in neural mobility testing, regardless of a clinician's clinical experience and geographic location. Further testing is warranted to ascertain the reliability and responsiveness of this new neural tissue mobility grading scale when used among patients with various upper extremity disorders, including brachial plexopathy.

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Quiz: # 641

Record your answers on the Return Answer Form found on the tear-out coupon at the back of this issue or to complete online and use a credit card, go to *JHTReadforCredit.com*. There is only one best answer for each question.

1. The BPNT is designed to test the ______________ of the brachial plexus
   a. flexibility
   b. extensibility
   c. irritability
   d. integrity

2. The primary purpose of the investigation was to determine the ____________ of the BPNT
   a. difficulty of administering
   b. clinical value
   c. concurrent validity
   d. accuracy and reliability

3. Attendees were asked to score
   a. patient outcomes
   b. an expert trained and experienced in the BPNT technique
   c. a series of videos
   d. a series of live practitioners

4. Reliability was determined using
   a. a 3 way ANOVA
   b. an ICC
   c. Pearson's Correlation Coefficient
   d. Student's T Test

5. The authors use the term *neural mobility* in describing scoring when deploying the BPNT
   a. true
   b. false

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