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Original Article

Introduction of the Purdue Pegboard Test for fine assessment of severity of cervical myelopathy before and after surgery

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Abstract. [Purpose] To evaluate the severity of symptoms before and after cervical myelopathy surgery using the Simple Test for Evaluating hand Function. Because a test ceiling effect was observed in patients with less severe forms of myelopathy, we investigated the correlation between and accuracy of several different tests in order to clarify the usefulness of the Purdue Pegboard Test for evaluation of one or both hands. [Participants and Methods] Thirty-four patients (6 females and 28 males; mean age, 64.5 years) were examined, and scores were determined for each of the following tests: Purdue Pegboard Test; Simple Test for Evaluating hand Function; Japanese Orthopedic Association assessment; and Disabilities of the Arm, Shoulder, and Hand assessment. Correlations between scores of different tests were then determined. The cut-off values used for the Purdue Pegboard Test and the Simple Test for Evaluating hand Function were determined using the area under the receiver operating characteristic curve to assess the use of chopsticks. [Results] The Purdue Pegboard Test assembly task correlated moderately with the Japanese Orthopedic Association and Disabilities of the Arm, Shoulder, and Hand scores. In the receiver operating characteristic curve analyses, the Purdue Pegboard Test cut-off value was 11 and the Simple Test for Evaluating hand Function cut-off value was 90. [Conclusion] The Purdue Pegboard Test is useful for evaluating manual dexterity and coordination in both hands in patients with cervical myelopathy.

Key words: Spinal cord diseases, Evaluation, Dexterity

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INTRODUCTION

Cervical myelopathy is often caused by cervical spondylotic myelopathy (CSM), cervical disc herniation (CDH), or ossification of the posterior longitudinal ligament (OPLL). This is a condition that can be caused by compression of the cervical spinal cord and is characterized by unskilled movements of both hands and fingers, slow grasp and release, and sensory dysfunction[1–3)]. Laminoplasty, anterior fixation, and posterior fixation are well known surgical procedures for cervical myelopathy. The Japanese Orthopedic Association (JOA) scoring system is an excellent method to evaluate the extent of myelopathy; the JOA score is related to the severity of cervical myelopathy and the degree to which it limits activities of daily living (ADL)[4)]. The JOA scoring system was subsequently modified and is now widely used internationally[5)]. The JOA score is classified into 5 levels according to upper limb ADLs and can be evaluated relatively easily. However, it has been

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reported that some items in the JOA score may be associated with low inter-rater reliability due to subjective evaluation[4]. Furthermore, the JOA scoring system is limited by the fact that it uses categorical scaling, thus making it difficult to capture slight symptomatic changes or functional recovery. Therefore, the JOA scoring system is often used in combination with the Simple Test for Evaluating Hand Function (STEF), which is an upper-limb function test that has been verified objectively and for which the reliability and validity have been confirmed. The STEF is a quick and objective method for assessing hand and upper arm capability, especially with respect to the speed of movement[6]. The STEF has been used to evaluate many diseases showing upper limb dysfunction, including hemiplegia, cervical spinal cord injury, rheumatoid arthritis, and peripheral neuropathy[7]. The STEF correlates with various functional tests, such as the JOA score and the hand grip test, and is a useful diagnostic tool for cervical myelopathy[8, 9]. Among the 10 tests that make up the STEF, skill elements that test the coordination of motion (including number 8 [gold disc], 9 [small ball] and 10 [pin]) have been reported to be useful for preoperative evaluation and follow-up[10]. While STEF has been reported to be useful for patients with severe forms of myelopathy, it has a ceiling effect for patients with less severe forms of myelopathy. To solve this problem, we focused on the Purdue Pegboard Test (PPT). The PPT is a reliable and valid diagnostic method that is used internationally to evaluate the skill elements that make up the STEF[11]. Previous studies have shown that the PPT is just as useful as the STEF for the functional assessment of the hand[12, 13]. Furthermore, PPT consists of a task that includes setting a pin in a hole determined with one hand, a task of setting a pin in a hole determined with both hands, and an assembly operation in which a washer and a nut are sequentially inserted into the pin with both hands. However, none of the existing studies specifically investigated the use of PPT to evaluate the movement of both hands in patients with cervical myelopathy. Therefore, we investigated the correlation with other tests and the accuracy of tests in order to clarify the usefulness of Purdue Pegboard Test (PPT) that can be evaluated with one or both hands. In this study, we compared the utility of the STEF and PPT as performance tests for the upper limbs after surgery in patients with cervical myelopathy. We hypothesized that the PPT would strongly correlate with scores from the JOA assessment and the disability of the arm, shoulder, and hand (DASH) test compared to the STEF. We also hypothesized that the PPT would be more responsive than the STEF to JOA upper limb score changes after surgery.

PARTICIPANTS AND METHODS

To measure the effectiveness of the STEF method in patients with cervical myelopathy, we collected data from a prospective cohort of patients who were diagnosed with CSM, OPLL, or CDH, and for whom it was believed that surgical treatment was necessary for progressive or severe cervical myelopathy. Patients were recruited between January 2016 and March 2018. Upper extremity function was determined and scored using the JOA (JOA UEF; four-point system), DASH, PPT, and STEF methods. Scores were recorded preoperatively and one month postoperatively. Patients were classified into two groups, a "possible group" and an "impossible group" based on their ability or inability to eat with chopsticks.

The JOA score is a 17-point evaluation method that rates the use of chopsticks, unbuttoning clothes, and other tasks using a scale from poor to excellent. The JOA score has been updated to become the modified JOA score; the JOA (1975) is the most suitable and most frequently used tool for the evaluation of cervical spondylosis in Japanese patients[13] (Table 1).

The PPT measures coordinated motion or skill movements of the hands, fingers, and arms. This test consists of four segments: segments 1 and 2 test the insertion of pins using each hand individually; segment 3 tests the insertion of pins with both

Table 1. The Japanese Orthopedic Association scoring system for cervical myelopathy

I	Motor function of the upper limbs
	4 - Normal
	3 - Able to eat using chopsticks with slight difficulty
	2 - Able to eat using chopsticks with difficulty
	1 - Able to eat using a spoon only
	0 - Unable to eat unaided
II	Motor function of the lower limbs
	4 - Normal
	3 - Able to walk without support with slight difficulty
	2 - Able to walk up and down stairs only with support
	1 - Require support to walk even on level ground
	0 - Unable to walk
III	Sensory function (same in upper and lower limbs and trunk)
	2 - Normal
	1 - Slight sensory disturbance or numbness
	0 - Distinct sensory disturbance
IV	Bladder function
	3 - Normal
	2 - Slight urination difficulty (frequency, retardation)
	1 - Serious urination difficulty (residual urine, dysuria)
	0 - Urine retention

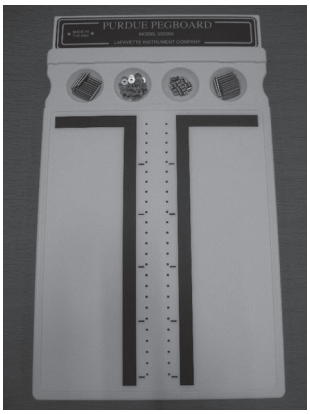

Fig. 1. The Purdue Pegboard Test.
This is an assessment involving the insertion of a pin (25 mm in length and 3 mm in diameter) into a board on which 25 holes are arranged vertically. The test is carried out for a predetermined length of time.

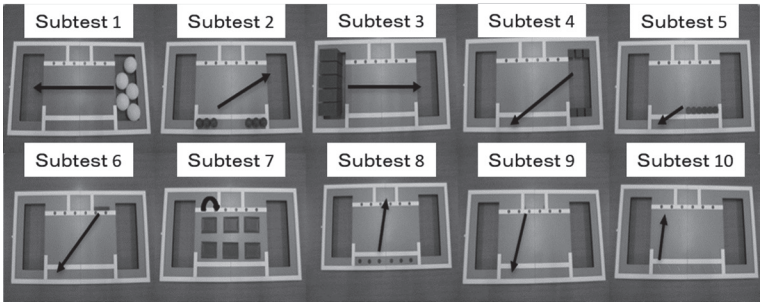

Fig. 2. The Simple Test for Evaluating Hand Function (STEF).
The shapes of the objects used in the STEF are as follows: subtest 1 (large ball), subtest 2 (middle sphere), subtest 3 (large rectangle), subtest 4 (neutral direction), subtest 5 (wooden disc), subtest 6 (small cube), subtest 7 (cloth), subtest 8 (gold disc), subtest 9 (small ball) and subtest 10 (pin).

hands simultaneously and is assessed over 30-second time periods; segment 4 tests a patient's ability to build small assemblies involving pins, collars, and washers with both hands simultaneously and is assessed over a 1-minute time period (Fig. 1). The PPT has been validated for wrist and hand disorders and distinguishes between patients with and without hand injuries[14, 15].

The STEF evaluates the accuracy, smoothness, speed, and dexterity of voluntary movements in the upper extremities. This test is composed of 10 different subtests in which patients carry different objects as fast as possible from right to left or from left to right. Each subtest is assessed on a 1 to 10-point scoring system, with a total of 100 points available (Fig. 2). The subtests are classified into three categories: grip motion, pinch motion, and coordinated motion[7].

The DASH is a 30-item patient-rated questionnaire that assesses disability and symptoms of the upper extremities. Each question has five response choices that range from "no difficulty or no symptom" to "unable to perform activity or very severe symptoms". This test measures the degree of difficulty when performing various physical activities such as social activities, work, and sleep. It also measures the severity of several types of pain, including activity-related pain, tingling, weakness, and stiffness. The DASH questionnaire also features the psychological effect of the disability on self-image[16].

This study was approved by the Kanazawa Medical University Hospital Expert Committee on University Research Ethical Evaluation (approval number: H109). Verbal and written information was given to all patients and all patients provided written consent before assessment. All experimental procedures were conducted in accordance with the Declaration of Helsinki.

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 25 (SPSS, Inc., Chicago, IL, USA), and the significance level was set to 5%. The correlation of each test was tested with Spearman's rank correlation coefficient based on preoperative data.

Analyses of receiver operating characteristic (ROC) curves were performed to compare the ability of the PPT and STEF to discriminate among patients who could use chopsticks, categorized as being possible or impossible, as assessed by the JOA UEF. ROC curves were generated by varying the test cut-off point at which an outcome becomes positive or negative. The "sensitivity" and "1-pecificity" were plotted based on the predicted outcome for a given cut-off point compared with a reference standard. ROC curves showed a corresponding area under the curve (AUC) that represented the probability that the PPT and STEF would rank a randomly chosen positive JOA UEF instance higher than a randomly chosen negative JOA UEF instance. The higher the AUC, the more efficient the test was at predicting positive and negative outcomes as defined by the reference standard. In general, tests with an AUC of 0.75 or greater are considered to have useful discriminative ability[17].

RESULTS

Thirty-four patients with cervical myelopathy were examined in this study, including 29 patients with CSM, 2 patients with CDH, and 3 patients with OPLL. Data relating to patient demographics are shown in Table 2.

The results of the correlation analysis for each test item are shown in Table 3. The PPT showed low correlation with the JOA score for right-hand tasks (r=0.37) and those involving both hands (r=0.40). Similarly, the STEF showed low correlation with the JOA score for right-hand (r=0.43) and left-hand (r=0.50) tasks. The DASH showed low correlation with PPT for both-hand tasks (r=−0.36). The STEF showed weak correlation with the DASH score for right-hand (r=−0.38) tasks. However, regarding assembly, the PPT showed moderate correlation (r=0.53) with the JOA score and DASH (r=−0.62).

Table 2. Patient demographics

Parameters	Patients (n=34)
Age (years)	64.5 ± 11.4
Gender (male:female)	28:6
Disease	CSM: 29, CDH: 2, OPLL: 3
Pre-operative JOA score (17-point system)	13.0 ± 2.2
Pre-operative JOA score UEF (4-point system)	2.8 ± 0.6
Pre-operative PPT score	Dominant hand: 9.7 ± 3.9 Non-dominant hand: 9.2 ± 3.5
Pre-operative STEF score	Dominant hand: 88.8 ± 8.9 Non-dominant hand: 91.9 ± 4.9
Pre-operative DASH score	36.3 ± 27.0
Operation	Laminoplasty: 30 Laminoplasty + posterior fusion: 1 Posterior fusion: 2 Anterior fusion: 1

Mean ± SD (range).
CSM: cervical spondylotic myelopathy; CDH: cervical disc herniation; OPLL: cervical ossification of posterior longitudinal ligament; JOA score: The Japanese Orthopedic Association scoring system for cervical myelopathy; UEF: Upper extremity function (Motor function of the upper limbs of the JOA score); PPT: Purdue Pegboard Test; STEF: Simple Test for Evaluating Hand Function; DASH: Disability of the Arm, Shoulder, and hand Questionnaire.

Table 3. Correlation analyses for all of the indices tested

	PPT				STEF	
	R	L	B	A	R	L
JOA	0.37*	0.34	0.40*	0.53**	0.43*	0.50**
DASH	−0.20	−0.09	−0.36*	−0.62**	−0.38*	−0.30

Pre-operative data were used for this analysis. The table shows the correlation coefficient for each test. R: Right hand; L: Left hand; B: Both hands; A: Assembly task, JOA: The Japanese Orthopedic Association scoring system for cervical myelopathy; DASH: Disabilities of the Arm, Shoulder and Hand Questionnaire, PPT: Purdue Pegboard Test, STEF: Simple Test for Evaluating Hand Function. *p<0.05, **p<0.01.

ROC curve analysis was used to predict the use of chopsticks in the upper extremity of the JOA score. This analysis showed that the cut-off value for the PPT was 11 (sensitivity: 0.588; 1-specificity: 0.294; AUC: 0.656) while that for the STEF was 90 (sensitivity: 0.824; 1-specificity: 0.294; AUC: 0.798).

DISCUSSION

The aim of this study was to determine the usefulness of the PPT as an evaluation method before and after surgery for cervical myelopathy. We found that the PPT assembly task correlated with the JOA and DASH scores. This correlation was stronger than that between the PTT assembly task and STEF. Using ROC curves that predicted the use of chopsticks in the upper extremity of JOA scores, we found that the cut-off value for the PPT was 11 while that for the STEF was 90. Contrary to our hypothesis, STEF was more sensitive to postoperative JOA upper limb score changes than that for PPT.

Our analysis found that the PPT and STEF showed a weak-to-moderate correlation with the JOA score. The correlation between the STEF and JOA scores was the same as that reported in a previous study[18]. While the correlation between the DASH and the STEF was weak, the PPT showed a moderate correlation with the assembly tasks. The DASH is a patient-based assessment of daily activities and is an evidence-based evaluation method that is also used internationally. In addition, a number of recent reports have highlighted the usefulness of the DASH for the evaluation of patients with diseases of the cervical spine[19]. Based on this, we decided to incorporate the DASH into our present study. Dysfunction in the upper extremity in cases of cervical myelopathy has been reported to occur bilaterally, as represented by the concept of "myelopathy hand"[1]. Therefore, it is generally believed that the PPT, which can evaluate bilateral hand tasks (e.g., both-hand and assembly tasks), might be more appropriate for reflecting the failure of ADLs associated with cervical myelopathy than the STEF, which is a unilateral hand test. The results of our present study suggest that the PPT not only considers coordination when evaluating upper extremity dysfunction in patients with cervical myelopathy but may also be useful as a means of evaluating bilateral-hand movement.

The sensitivity analysis results regarding changes in the JOA upper limb score were contrary to our expectation. Usually,

the use of chopsticks involves the ability to coordinate a wide range of structures from the thumb to the little finger. Our ROC analyses results showed that it was possible to predict the ability to eat completely independently using chopsticks after surgery and further indicated that the STEF was more sensitive than the PPT when evaluating the function of the upper extremities. This may be due to the fact that the PPT uses a task that predominantly requires the thumb to the middle finger. Conversely, the STEF involves a range of examination tasks that require the use of all fingers, from the thumb to the little finger. Nevertheless, the sensitivity and specificity of the STEF remain insufficient, as indicated by numerous previous studies. For example, STEF scores tend to be high for mild failure cases, and the ceiling effect is believed to be a factor in some studies[10].

Based on the results of the present study, we believe that the STEF is a comprehensive test that evaluates upper extremity function but cannot evaluate bilateral hand use. The PPT evaluation method, however, is specialized for dexterity and bilateral hand use. For patients with cervical myelopathy, the PPT can provide detailed data relating to upper limb function by incorporating both-hand and assembly tasks, and therefore provide useful data that cannot be acquired by the STEF. Furthermore, by combining the STEF and the PPT it may be possible to compensate for the ceiling effect of the STEF in patients with mild disability.

There are several limitations in this study that should be considered. First, this was a single-center study and may, therefore, be subject to selection bias. Second, follow-up was performed for only 1 month after surgery. Although hand dexterity has been reported to improve after the early postoperative period, functional recovery occurs after approximately 6 months. For these reasons, we adhered to strict inclusion and exclusion criteria in this study. Multi-center studies are now required to validate our findings. In conclusion, the PPT is useful for evaluating the function of both hands in patients with cervical myelopathy. Furthermore, the PPT can be used in addition to the STEF to provide a comprehensive evaluation of unilateral function in the upper extremities.

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Conflict of interest

The authors declare that there is no conflict of interest.

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