Variability and Reliability of the Pendulum Test for Spasticity Using a Cybex® II Isokinetic Dynamometer

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I undertook this study to determine the test-retest variability and reliability of the pendulum test for muscle spasticity performed with the Cybex® II isokinetic dynamometer. Thirty patients, with intracranial lesions and hemiplegia of 15 days' to 3 years' duration, were tested four times, consecutively. With the patients lying supine, the angle of flexion, at which the knee first reversed direction after the leg was dropped, was measured on each goniogram from the dynamometer chart recorder. The mean differences between the angles of reversal and the angles of maximum possible knee flexion (the relative angle of reversal) for the first through the fourth trials were 27.2, 27.0, 26.3, and 25.6 degrees, respectively. The relative angle of reversal did not differ significantly between trials. The mean difference between the largest and smallest relative angle of reversal for each of the subject's trials was 6.1 degrees. The intraclass correlation coefficient between the relative angle of reversal for the four trials was .96. Because the test variability was not significant and because the correlation between trials was high, the test may merit broader application to patients with intracranial lesions. Further investigation of variability across days and after treatments is advised.

Key Words: *Muscle spasticity, Physical therapy.*

Vodovnik and others have described a method for documenting quadriceps femoris muscle spasticity using electrogoniometric records of the swinging leg.[1-5] Their testing procedure, sometimes referred to as the pendulum test, requires that an examiner first extend a patient's knee and then drop the patient's leg. The electrogoniometric record, obtained during the testing procedure, reflects the oscillations of knee flexion and extension accompanying the drop. According to Bajd and Bowman, after the leg is dropped, "spasticity, in general, stops the swinging of the lower leg and pushes it back to the starting position."[1] Bajd and Vodovnik have described the procedure as practical, sensitive, and not further improved by incorporation of electromyography.[3] Rather than using only an electrogoniometer to document spasticity, Bohannon and Larkin[6] and Knutsson[7] have used an electrogoniometer in conjunction with an isokinetic dynamometer. Because isokinetic dynamometers can be used to control the speed of the knee's movements and because spasticity is a velocity-dependent response to passive stretch, isokinetic dynamometers may be valuable particularly in the testing of quadriceps femoris muscle spasticity.

Investigators have commented on the variability of goniograms obtained during a series of consecutive pendulum tests. Bajd and Bowman, for example, reported that in patients with spinal cord injuries, fast repetitions (every 30 seconds) of the pendulum test influence subsequent tests so that spasticity is decreased.[1] In collaboration with Vodovnik, these same two authors reported that the goniograms from pendulum tests were much more consistent in patients with hemiparesis than in patients with spinal cord injuries.[2] These statements notwithstanding, the variability and reliability of pendulum test goniograms have not been described statistically, except by Bohannon and associates,[8] whose description was brief and involved only a minimum number of patients and trials. If clinicians are to use the pendulum test in patient assessment, they need information relative to the variability and reliability of the test as applied to specific patient types and using specific instrumentation. Without this information, the clinician has no means of knowing how to interpret test results. The purpose of this study was to determine the between-trial variability and reliability of the pendulum test performed with the Cybex®II isokinetic dynamometer.* My expectations were that, for patients with intracranial lesions, the variance between trials would not be significant and that the reliability would be high.

METHOD

Subjects

The first 30 patients admitted who had intracranial lesions and who met the entry criteria of the study participated in the study after their provision of informed consent. The entry criteria were that the patients could follow instructions and that they demonstrated either manually discernible resistance to passive knee flexion (as graded on the Ashworth scale[9]) or a stiff-legged gait.[10] Seventeen of the patients were men, and 13 were women. Their average age was 50.9 ± 15.9 years, with a range of 22 to 79 years. Twenty-two patients had a diagnosis of cerebrovascular accident. The remaining eight patients had head injuries. The patients were 15 days to 3 years beyond the onset of their hemiparesis. The more paretic side of each patient was tested.

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Procedure

My testing procedure, which was similar to that reported previously by Bohannon and Larkin,[6] involved the following steps:

1. Positioning the patient supine on the Cybex® exertest table.
2. Strapping the patient to the table at the thigh, pelvis, and trunk.
3. Positioning the dynamometer input shaft laterally over the tested knee's axis of rotation and strapping the shin pad of the dynamometer lever arm just proximal to the malleoli.
4. Adjusting the speed of the isokinetic dynamometer to 300°/sec.
5. Instructing the patient to relax completely.
6. Adjusting the position angle (electrogoniometer) channel to ensure that the angular recordings of knee positioning would fall within the range of the scale.
7. Flexing the patient's knee and pushing back the lower leg until the heel contacted the padded table leg clamp.
8. Running a short strip of chart paper at 5 mm/sec.
9. Allowing the patient's leg to hang free while running another short strip of chart paper at 5 mm/sec.
10. Raising the patient's leg until the knee was fully extended.
11. Running a short strip of chart paper at 5 mm/sec.
12. Reminding the patient to relax and dropping the patient's leg while running the chart recorder at 5 mm/sec.
13. Allowing the chart recorder paper to run until the dropped leg ceased to oscillate.
14. Repeating Steps 7 through 13, three times, allowing rest intervals of about 15 seconds between each series of steps.

The measurement I used to indicate spasticity was the angular difference between maximum possible knee flexion (the angle at which the heel contacts the padded leg table clamp) and the angle of flexion at which the knee first reversed direction toward extension when dropped. This angular difference is represented by angle d minus angle a in the Figure and will be referred to, hereafter, as the relative angle of reversal (RAR). This measurement has been described previously by Bohannon and co-workers.[6,8] Tests of the uninvolved side of patients with hemiplegia have revealed that the RAR is always zero degrees on that side (unpublished data, 1985).

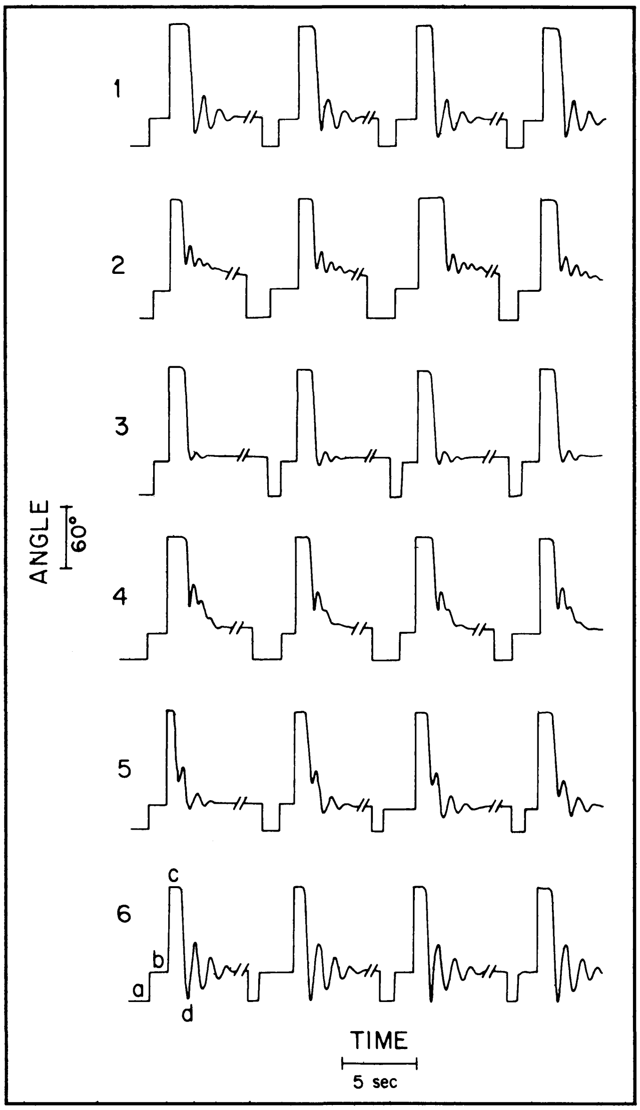

Figure. Goniometric tracings from four consecutive pendulum tests of six patients with intracranial lesions. Patient 6 demonstrates normal pendulum test results (a = angle of maximum possible knee flexion, b = angle of the knee with the leg hanging freely, c = knee fully extended, d = angle of flexion at which the knee first reverses direction after the leg is dropped [d minus a = relative angle of reversal]).

Data Analysis

The measurements for the 30 patients, obtained during four successful leg drops, were described statistically and compared between trials using a one-way analysis of variance (ANOVA) for repeated measures. An intraclass correlation coefficient (ICC [2,1]) was used to determine the reliability of repeated pendulum tests.[11] Calculating the ICC required that the patients be treated as a factor and that trials be substituted for the "judges" of Bartko's formula.[11]

RESULTS

The Figure illustrates the goniograms of four leg drops from six of the patients who participated in this study. The goniograms obviously are unique to each patient. Table 1 reports the descriptive statistics for four successive leg drops. As is apparent, the mean values for the RAR decreased slightly with repeated trials. The ANOVA, however, demonstrated no significant differences in the RAR between the four trials ($F = 1.44$, $df = 3$, $p = .23$) (Tab. 2). The mean difference between the largest and smallest (not necessarily the first and fourth) RAR for each patient was 6.1 ± 4.7 degrees, with a range of 0 to 18 degrees. The ICC demonstrated the reliability between trials to be high ($r = .96$).

DISCUSSION

As expected, the variance between the RAR of test repetition was not significant. Moreover, the range of the RAR was small for most of the patients. The ICC of .96 is consistent with the Pearson product-moment correlation (.99) reported previously by Bohannon and co-workers.[8] Thus, the procedure, as performed, is probably of adequate reliability for the clinical testing of spasticity in patients with hemiplegia. Because the decrease in the RAR was not significant between trials, the latencies between the times that were discussed by

TABLE 1
Angle[a] from Maximum Possible Flexion at Which Reversal of Direction Occurred During Four Sequential Pendulum Test Trials of Spasticity on 30 Patients with Hemiplegia

Trial	$\bar{X}$	*s*	Range
1	27.2	18.1	0–56
2	27.0	17.2	0–55
3	26.3	17.2	0–57
4	25.6	17.5	0–60

[a] In degrees.

TABLE 2
One-Way Analysis of Variance for Repeated Measures for Four Sequential Pendulum Test Trials of Spasticity on 30 Patients with Hemiplegia

Source	*df*	SS	MS	*F*	*p*
Subjects	29	34403.97	1186.34		
Trial	3	48.17	16.06	1.44	NS
Error	87	967.83	11.12		
TOTAL	119	35419.97	297.65		

Bajd and Bowman,[2] may not apply to patients with hemiplegia. Nonetheless, the measurement of spasticity, after several preliminary leg drops[2] and with longer latencies between leg drops, still may result in more consistent results. These possibilities merit further investigation.

My results cannot be generalized to pendulum tests performed across days or weeks, or to tests performed on patients with other types of central nervous system lesions. Further testing of the use of the Cybex®II isokinetic dynamometer is required before the procedure described herein can be used confidently to document the consequences of clinical interventions. Given the simplicity of the pendulum test, other researchers may wish to evaluate the appropriateness of the test for their patients.

CONCLUSIONS

Four consecutive trials of the pendulum test performed with the Cybex®II isokinetic dynamometer on patients with intracranial lesions did not differ significantly from one another. The reliability of the test (.96) is sufficiently high to merit broader application. Questions relative to variability between different days or weeks of testing, however, merit investigation before the test can be used to monitor the effects of clinical interventions.

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