

# Foot Tapping Test as Part of Routine Neurologic Examination in Degenerative Compression Myelopathies: A Significant Correlation between 10-sec Foot-tapping Speed and 30-m Walking Speed

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## Abstract:

**Introduction:** Leg spasticity in degenerative compression myelopathy causes impairment of fast and rapid repetitive movements, which tends to appear despite the disproportionate paucity of clinical weakness. As clinically useful measures used to quantify the slowness of voluntary leg movements in this pathological condition, we compared the foot tapping test (FTT) with the simple walking test, which is now considered the gold standard in this field.

**Methods:** We compared the FTT with the simple walking test, the grip-and-release test, and the functional scales of Nurick and the Japanese Orthopedic Association (JOA) in 77 patients with cervical compression myelopathy and 56 age-matched healthy subjects. The FTT was conducted on both sides separately, and the subject, while being seated on a chair, moved his/her toes up and down repeatedly to tap the floor as fast and as vigorously as possible for 10 sec with his/her heels planted on the floor.

**Results:** The number of 10-sec foot tapping in the patient group significantly correlated with the Nurick grades ( $r = -0.566$ ;  $P < 0.0001$ ), the JOA scores ( $r = 0.520$ ;  $P < 0.0001$ ), and the grip-and-release rates ( $r = 0.609$ ;  $P < 0.0001$ ). It also significantly correlated with the 30-m walking time ( $r = -0.507$ ;  $P < 0.0001$ ) and the number of steps taken ( $r = -0.494$ ;  $P < 0.0001$ ). Assessments of wheelchair-dependent patients and side-to-side comparison, in which the simple walking test plays no role, revealed significantly fewer FTT taps in wheelchair-bound patients than in the ambulatory patients and a significant trend for cervical compression myelopathy to dominantly affect the upper and lower limbs on the same side.

**Conclusions:** This study contributes to the reassessment of the currently underutilized FTT as part of a routine neurologic examination of degenerative compression myelopathy.

## Keywords:

Foot tapping test, Leg spasticity, Compression myelopathy, Simple walking test, Grip-and-release test, Laterality

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## Introduction

Cervical compression myelopathy causes spastic lower limb paresis, impairing the ability to walk in many patients. The grading of Nurick<sup>1)</sup> and the scoring system developed by the Japanese Orthopedic Association (JOA)<sup>2)</sup> are examples of the traditional functional scales that have been widely used to assess the severity of this lower limb dysfunction. However, in these ordinal scales each functional category covers a wide range of actual severity, reducing their utility for quantitative assessment. Kinematic walking analy-

ses<sup>3-6)</sup> may be a more sensitive means of quantifying walking difficulty, but such methods require specific equipment and can be time-consuming, limiting their use in clinical practice. Singh and Crockard (1999)<sup>7)</sup> introduced a 30-m simple walking test (SWT) as a more objective, easy-to-use means of quantifying the severity of cervical spondylotic myelopathy, demonstrating that walking time and the number of steps taken over the distance walked significantly correlated with Nurick's functional scores and the myelopathy disability index<sup>8)</sup>. Their work on SWT paved the way for clinical use of performance-based measures for the evaluation of the

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**Table 1.** Neurick's Functional Grading of Severity of Cervical Spondylotic Myelopathy.

Grade	
0	Symptoms of root involvement but without evidence of spinal cord disease
1	Signs of spinal cord disease but no difficulty in walking
2	Slight difficulty in walking which does not prevent full-time employment
3	Difficulty in walking which prevents full-time employment or the ability to do all housework, but not severe enough to require someone else's assistance to walk
4	Able to walk only with someone else's help or the aid of a frame
5	Chairbound or bedridden

**Table 2.** The Japanese Orthopaedic Association Scale for Lower Limb Motor Function.

Points	Motor function of lower limbs
0	Chairbound or bedridden
0.5	Able to stand up but unable to walk
1	Requires walking aids
2	Needs support when going upstairs and downstairs
2.5	Needs support when going downstairs
3	Capable of walking fast but with some difficulty
4	Normal walking ability

speed of voluntary lower limb movements in this pathological condition.

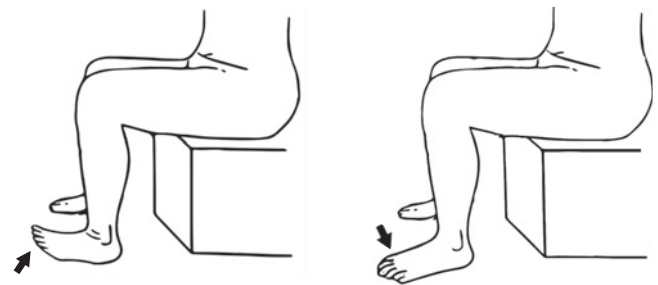
With several subsequent studies, "walking speed" proved to be a useful measure for assessing leg spasticity in cervical compression myelopathy<sup>4-6,9,10</sup> as well as multiple sclerosis<sup>11</sup>. More recently, some authors developed alternative performance-based quantifiable measures, designated as a "Ten second step test"<sup>12,13</sup>, "Triangle step test"<sup>14</sup> and "Foot tapping test" (FTT)<sup>15,16</sup>, all of which, unlike the SWT, can be performed in an examination room. Of these, FTT provides the simplest and easiest-to-use means, and can be performed with the patient seated on a chair as part of the routine neurologic examination, to quantify the slowness of lower limb movements.

To further confirm the FTT's clinical value, the present work studied the correlation between 10-sec foot tapping speed, assessed by the FTT, and 30-m walking speed evaluated by the SWT, now considered the gold standard in this field, in a series of 77 patients with cervical compression myelopathy as compared with 56 healthy volunteers.

## Materials and Methods

### 1. Subjects

We analyzed a total of 77 patients (46 men, 31 women), aged  $68 \pm 13$  years with cervical compression myelopathy. They underwent the FTT as well as a grip-and-release test (GRT)<sup>17</sup>, the upper limb counterpart of the FTT (see Methods 4), either preoperatively (36) or at an average of 34.9 months (range, 1.5-166.6 months) after surgical intervention, when various degrees of residual impairment in their ability to walk (41). Forty-five patients walked unaided, 22 required



**Figure 1.** A foot tapping test. The subject sat on a chair with adjustable height so that the bilateral soles made contact with the floor, and the hip and knee joints flexed at approximately 90°. He/She moved his/her toes up and down repeatedly to tap the floor as fast and as vigorously as possible for 10 sec with the heels planted on the floor. He/She performed the test for both sides separately. The examiner counted the number of taps for each side.

walking aids such as canes/crutches (13) or a walker (9), and 10 were chairbound. Of these, 67 ambulatory patients also underwent SWT.

For comparison, 56 age- and sex-matched healthy volunteers (23 men, 33 women) aged  $69 \pm 7$  years, with no history of peripheral or central nervous system disease or orthopedic disease impairing their ability to walk, underwent the same FTT and SWT studies. All subjects agreed in writing to participate in the study after reading and signing an informed consent form approved by the institutional ethics committee.

### 2. Functional scales

The functional grading of Nurick<sup>1)</sup> is shown in Table 1, and the functional scale of the JOA for lower limb motor function<sup>2)</sup> in Table 2.

### 3. Foot tapping test

The subject sat on a chair with its height adjustable, so that the bilateral soles made contact with the floor, with the hip and knee joints flexed at approximately 90°. We instructed the subjects to move their toes up and down repeatedly, tapping the floor as quickly and vigorously as possible with their heels firmly planted on the floor for 10 sec (Fig. 1). Following a few practice trials, the subjects carried out the subsequent test trials for both sides separately, once on each side. The examiner counted the number of taps, and

each value reported represents a mean for both sides except when making side-to-side comparisons.

#### 4. Simple walking test

Following the method of Singh and Crockard<sup>7)</sup>, the subject walked back and forth barefoot on a 15-m straight line drawn on a smooth, flat surface in a corridor with one turn (30-m walk). The examiner measured the time required using a stopwatch and counted the number of steps taken. We instructed subjects to walk at the maximum comfortable speed with the walking aides they would normally use. They repeated the test twice, and the data reported represent the smaller values in time and number of steps taken.

#### 5. Grip-and-release test

Following the method of Ono, et al.<sup>17)</sup>, the subject sat on an adjustable chair with the shoulder slightly abducted, the elbow flexed at 90° and the forearm pronated. We requested them to open and close their fists as rapidly as possible for 10 sec. They performed the test for both sides separately, once on each side. The examiner counted the number of grip openings, and each value reported represents a mean for both sides except when making side-to-side comparisons.

#### 6. Statistics

Statistical analyses included the Wilcoxon rank sum test for paired data, the Mann-Whitney test for unpaired data, and the Spearman's rank correlation coefficients for interrelation analysis. In addition, we used the McNemar test to analyze consistency of the dominant side of affection between FTT and GRT. Values are given as mean  $\pm$  SD and the significance level was set at  $P < 0.05$ . All statistical analyses were made using SPSS software (Version 21.0; SPSS Inc., Japan).

## Results

### 1. FTT for the patient versus healthy subject groups

The number of taps averaged  $17.9 \pm 5.5$  times in 77 patients and  $23.5 \pm 2.5$  times in 56 healthy subjects, showing a significantly lower value in the patient group than in the healthy subject group ( $P < 0.0001$ ). The side-to-side difference in the number of taps showed a significantly larger difference in the patient group than in the healthy subject group ( $2.9 \pm 3.5$  times vs  $1.4 \pm 1.1$  times;  $P < 0.005$ ).

### 2. FTT versus functional scales

The Nurick functional grades and the JOA scores for lower limb motor function averaged  $2.4 \pm 1.5$  grades and  $1.8 \pm 1.1$  points, respectively, for the total 77 patients. The number of taps in FTT significantly correlated with the Nurick grades ( $r = -0.566$ ;  $P < 0.0001$ ) and the JOA scores ( $r = 0.520$ ;  $P < 0.0001$ ). The number of grip openings in GRT also showed significant correlations with the Nurick grades ( $r = -0.442$ ;  $P < 0.0001$ ) and the JOA scores ( $r =$

$0.473$ ;  $P < 0.0001$ ), but with lower correlation coefficients.

### 3. FTT versus SWT

In 67 ambulatory patients who underwent both FTT and SWT, the walking time in SWT averaged  $44.0 \pm 22.4$  sec and the number of steps,  $69.8 \pm 22.0$  steps. The number of taps in FTT in those patients significantly correlated with the walking time ( $r = -0.507$ ;  $P < 0.0001$ ) (Fig. 2) and the number of steps ( $r = -0.494$ ;  $P < 0.0001$ ) taken in SWT (Fig. 3). Ten wheelchair-dependent patients, who underwent the FTT but not the SWT, showed a significantly smaller ( $P < 0.0005$ ) number of taps in the FTT, averaging  $11.0 \pm 6.0$  times (range, 0-20 times), compared to  $18.9 \pm 4.7$  times in 67 ambulatory patients.

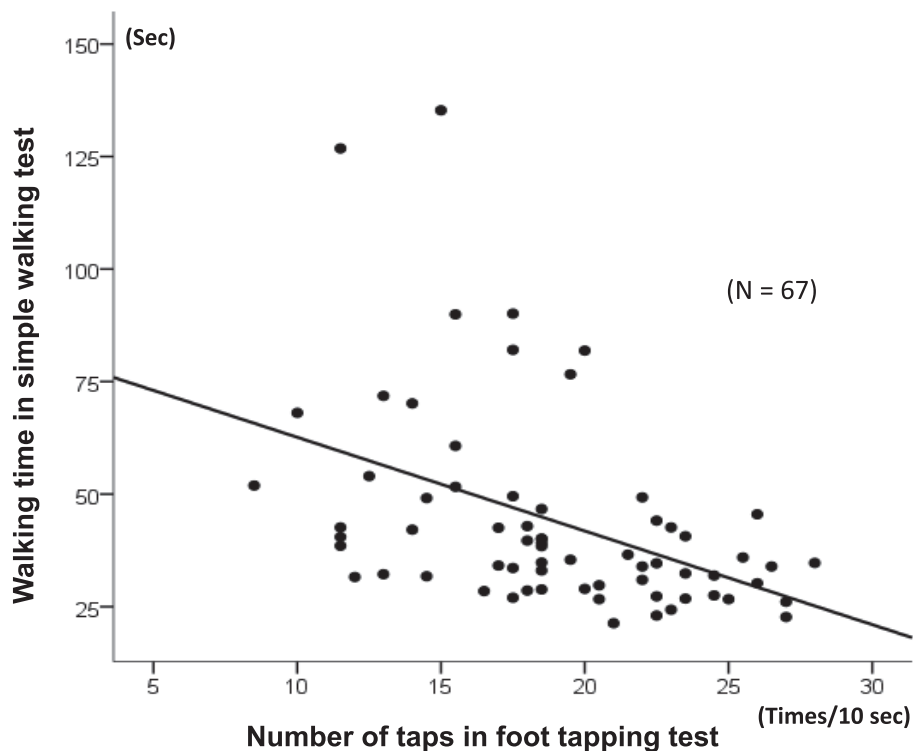
### 4. FTT versus GRT

In 77 patients with cervical myelopathy, the number of taps in the FTT averaged  $17.9 \pm 5.5$  times and the number of grip openings in GRT,  $17.2 \pm 6.1$  times. The results of the two tests showed a significant positive correlation ( $r = 0.609$ ;  $P < 0.0001$ ) with very similar mean values ( $P = 0.266$ ) and side-to-side differences ( $2.4 \pm 2.9$  times/sec for GRT vs  $2.9 \pm 3.6$  times/sec for FTT;  $P = 0.167$ ) (Fig. 4). Side-to-side comparisons of GRT and FTT outcomes serve to assess the dominant side of involvement in the upper and lower limbs, respectively, as summarized in Table 3 (see footnote). According to the McNemar test, the row and column marginal frequencies in Table 3 showed no significant difference ( $P = 0.162$ ), suggesting that the dominantly-affected side of the upper limb identified by GRT tended to coincide with that of the lower limb indicated by FTT.

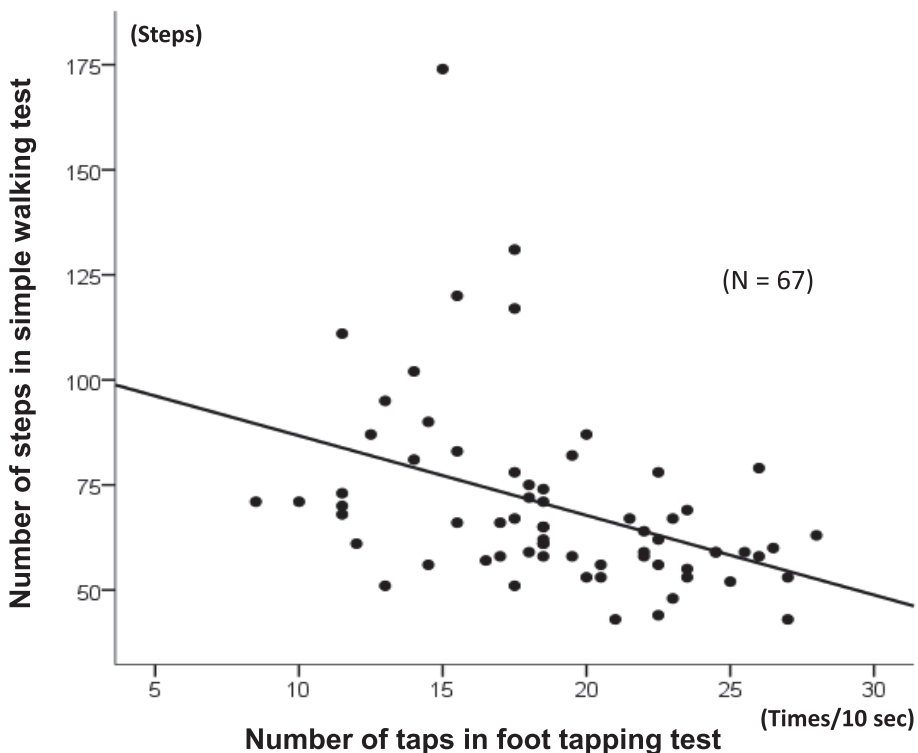
## Discussion

A variable combination of stiff, clumsy, and unsteady walking, which is commonly seen in degenerative compression myelopathies, results from lower limb spasticity. A velocity-dependent increase in tonic stretch reflex ("muscle tone") characterizes limb spasticity as one component of upper motor neuron syndrome<sup>18)</sup>, which functionally impairs fast movements and rapid repetitive limb movements<sup>19)</sup>. Therefore, testing for speed of voluntary limb movements is an important component of routine neurologic examination for degenerative compression myelopathy.

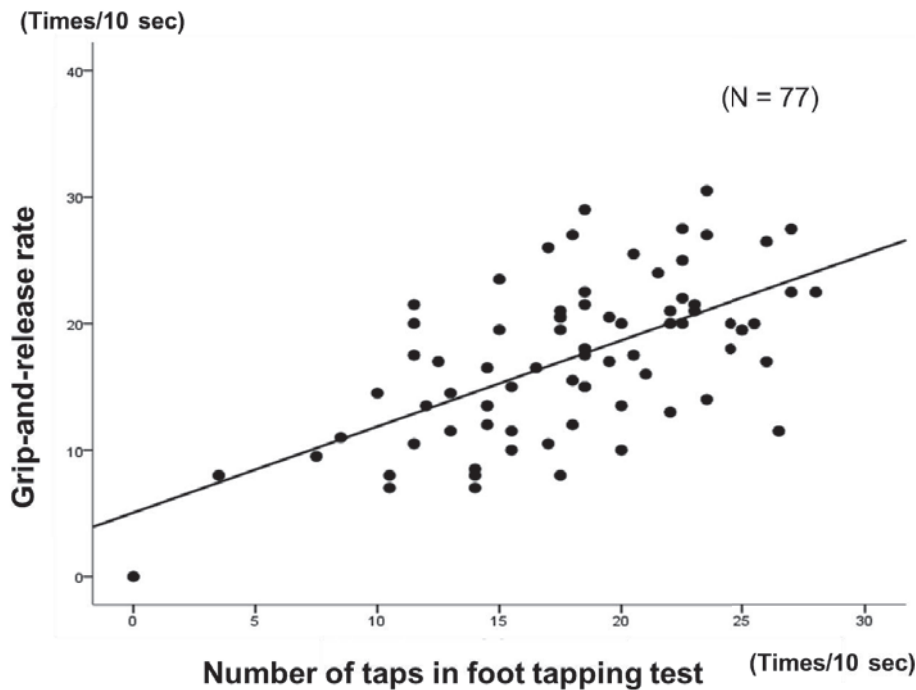
In fact, the GRT, originally described by Ono et al.<sup>17)</sup>, evaluates how rapidly the patient can open and close the fists for 10 sec and, thereby, quantitatively evaluates the loss of finger dexterity resulting from upper limb spasticity. Similarly, Nomura et al.<sup>20,21)</sup> demonstrated that the maximum voluntary ventilation test, in which the patients are requested to breathe as fast and as deeply as possible for 12 sec, serves as a sensitive measure to monitor the ventilatory function in cervical spondylotic myelopathy. Following the same principles, the FTT assesses how rapidly the patient can move the toes up and down repeatedly for 10 sec with the heel firmly planted on the floor, thereby quantifying



**Figure 2.** A comparison between the FTT results (abscissa) and the SWT (ordinate)<sup>7, 10</sup> in 67 ambulatory patients with cervical compression myelopathy. The number of taps in the FTT showed a significant negative correlation with the walking time ( $r=-0.507$ ;  $P<0.0001$ ) taken in the simple walking test.



**Figure 3.** A comparison between the FTT results (abscissa) and the SWT (ordinate)<sup>7, 10</sup> in 67 ambulatory patients with cervical compression myelopathy. The number of taps in the FTT showed a significant negative correlation with the number of steps ( $r=-0.494$ ;  $P<0.0001$ ) taken in the SWT.



**Figure 4.** A comparison between the FTT results (abscissa) and the GRT (ordinate)<sup>16)</sup> in 77 patients with cervical compression myelopathy. The number of taps in the FTT showed a significant positive correlation with the number of grip openings in the GRT ( $r=0.609$ ;  $P<0.0001$ ).

**Table 3.** Dominant Side of Involvement Assessed by Foot Tapping Test Versus Grip-and-release Test.

		Foot tapping test			Row total
		Right†	Left‡	Symmetric§	
Grip-and-release test	Right†	17	1	8	26
	Left‡	2	6	6	14
	Symmetric§	6	10	21	37
	Column total	25	17	35	77

† Right: A lower repetition rate on the right by  $\geq 2$  times/10 sec than on the left side.

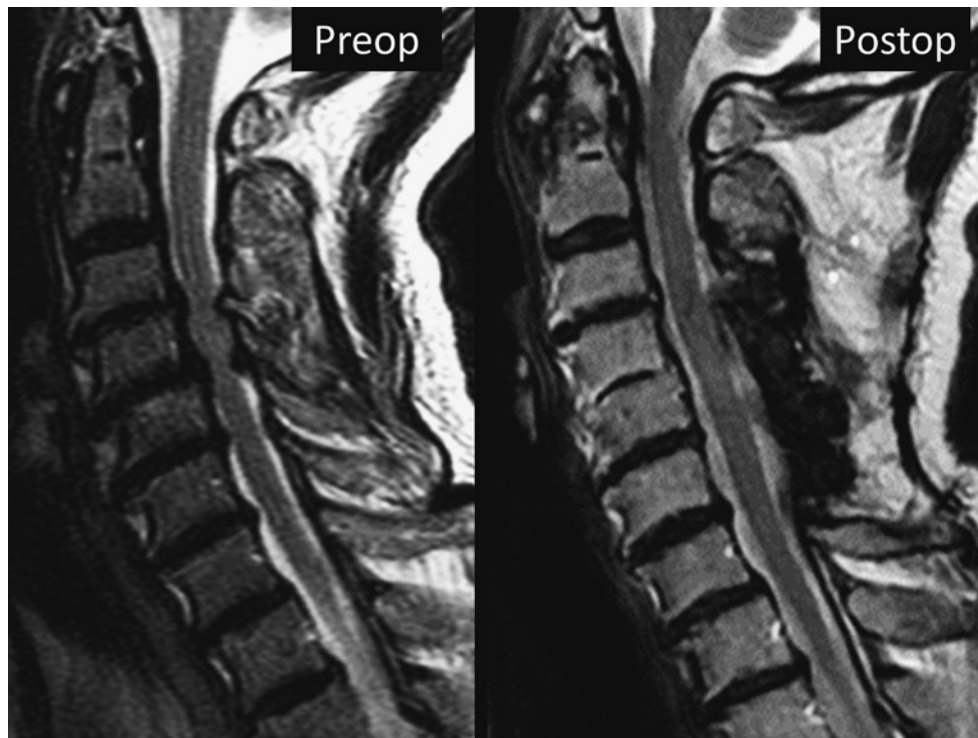
‡ Left: A lower repetition rate on the left by  $\geq 2$  times/10 sec than on the right side.

§ Symmetric: Side-to-side difference in repetition rate by  $< 2$  times/10 sec

Each cell displays the number of patients classified either in the group of bilaterally symmetrical outcomes with a side-to-side difference of  $< 2$  times/10 sec, designated as 'symmetric' or in the groups of asymmetrical outcome with a lower repetition rate by  $\geq 2$  times/10 sec on one side than the other, designated as 'right' or 'left'.

slowness of voluntary leg movements in degenerative compression myelopathy<sup>15,16)</sup>. During the FTT, patients encounter the greatest resistance in response to quick stretch of the ankle plantar flexors (i.e., physiologic extensors) when moving their toes up, whereas during the GRT, they face the highest stiffness of the spastic finger flexors when opening the grip. This is because limb spasticity following the upper motor neuron disorders principally affects the antigravity muscles (i.e., the physiologic extensor muscles in the lower limb and the anatomic flexor muscles in the upper limb in humans)<sup>22-24)</sup>. Therefore, the time required for moving the toes up dictates the speed of foot tapping, while the rate-determining phase of the GRT is when opening the grip.

Several previous studies used “foot tapping speed” to measure movement speeds in patients with brain lesions<sup>25,26)</sup>, multiple sclerosis<sup>27)</sup>, amyotrophic lateral sclerosis<sup>28,29)</sup> and Parkinson disease<sup>30)</sup>. Apart from the upper motor neuron disorders and extrapyramidal disorders, “foot tapping speed” was also assessed as a physical function in older populations to reveal the adverse effects of restricting back pain<sup>31)</sup> or to predict high-risk older drivers<sup>32)</sup>. Applying the FTT to cervical compression myelopathy, Numasawa et al (2012)<sup>16)</sup> conducted a large, multicenter study of 252 patients compared to 792 healthy volunteers. They not only established a normal variability range of FTT results in healthy subjects, but also showed a significant correlation between the FTT data



**Figure 5.** Midsagittal T2-weighted MRIs before (left) and after (right) laminoplasties from C3 to C6 in a 67-year-old woman with cervical spondylotic myelopathy. The JOA motor score for the lower limb improved from 1 point preoperatively to 2.5 points at 46 days postoperatively with the improvement of performance-based measures in the FTT (from 16 to 21 times for the right; from 18 to 24 times for the left) and in the SWT (from 46.7 to 35.4 sec for the walking time; from 70 to 63 steps for the number of steps).

and the JOA scores for lower limb motor function and the grip-and-release rate.

Consistent with the report of Numasawa et al., our data also showed that the number of taps was significantly smaller in the patients than in the age- and sex-matched healthy subjects and significantly correlated with the severity of lower limb paresis assessed by Nurick's functional grade and the JOA score (Fig. 5). One new finding from the present study on 67 ambulatory patients was that it uncovered a significant correlation between the number of taps in the FTT and the walking time as well as the number of steps in the SWT. In the remaining 10 wheelchair-dependent patients, for whom the SWT plays no role, the FTT showed a significantly smaller number of taps than those in the ambulatory patients.

The FTT has another advantage over the SWT when assessing right and left lower limb functions separately. Interestingly, side-to-side differences in the GRT data, compared to those in the FTT results, support the commonly-held view that asymmetric types of tetraparesis tend to dominantly affect the upper and lower limbs on the same side.

Because the FTT is a quick, simple, and cost-effective tool, it is useful for busy spine surgeons as part of the routine neurologic examination or in a primary care setting. However, the FTT has an inherent limitation that the foot tapping speed varies depending on the amplitude of ankle

dorsiflexion. The lack of standardization on how high the subjects need to raise their toes up from the floor during foot tapping may lead to faster taps at the expense of the amplitude, or conversely, slower taps with unnecessarily large amplitude. To avoid such inappropriate performance, we carefully instructed the subjects to tap the floor as fast and as vigorously as possible while keeping both the hip and knee flexed at approximately 90 degrees. Nonetheless, the FTT could be further improved by standardizing the degree of ankle dorsiflexion with some easier method. Another limitation of the current study is insufficient assessment of the FTT's test-retest reproducibility. One previous study<sup>16)</sup>, however, found high immediate test-retest reliability of the FTT in 50 patients with degenerative cervical myelopathy ( $r = 0.899-0.934$ ,  $P < 0.0001$ ).

In conclusion, this study contributes to a reassessment of the FTT, which is currently underused as part of routine neurologic examination of compression myelopathy. One new finding was that the 10-sec foot tapping speed, assessed by the FTT, significantly correlated with the 30-m walking speed evaluated by the SWT, now considered the gold standard of performance-based clinical measures to quantify the spasticity-related slowness of lower limb movements in this pathological condition. The FTT serves as an even better metric than the SWT for testing chairbound patients and assessing right and left lower limb function separately.

**Conflicts of Interest:** The authors declare that there are no relevant conflicts of interest.

**Author Contributions:** Hayato Enoki wrote and prepared the manuscript, and all of the authors participated in the study design. Each author has read, reviewed, and approved the article.

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