

Prospective comparison of age- and sex-related differences in quantifiable 10-s grip and release and 10-s step test results for diagnosis of cervical spondylotic myelopathy in 454 patients with cervical spondylotic myelopathy and 818 asymptomatic subjects

Masaaki Machino, MD¹); Shiro Imagama, MD, PhD¹); Kei Ando, MD, PhD¹); Kazuyoshi Kobayashi, MD, PhD¹); Tetsuro Hida, MD¹); Kenyu Ito, MD¹); Mikito Tsushima, MD¹); Akiyuki Matsumoto, MD¹); Satoshi Tanaka, MD¹); Masayoshi Morozumi, MD¹); Keigo Ito, MD, PhD²); Fumihiko Kato, MD, PhD²); Yoshihiro Nishida, MD, PhD¹); Naoki Ishiguro, MD, PhD¹)

- 1) Department of Orthopedic Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan
- 2) Department of Orthopedic Surgery, Chubu Rosai Hospital, Japan Labor Health and Welfare Organization, Nagoya, Japan

Address for correspondence and reprints:

Shiro Imagama, MD, PhD (corresponding author)

Department of Orthopaedic Surgery, Nagoya University Graduate School of Medicine

65, Tsurumai, Showa-ku, Nagoya, Aichi, 466-8550, Japan

Phone: +81-51-741-2111

Fax: +81-52-744-2260

E-mail: imagama@med.nagoya-u.ac.jp

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ABSTRACT

Study Design. A prospective comparison

Objective. The purpose of this prospective study was to verify the clinical effectiveness of the 10-s grip and release (G&R) and 10-s step quantitative tests for assessing the severity of cervical spondylotic myelopathy (CSM) and to compare age- and sex-related differences in the results between large cohorts of CSM patients and asymptomatic subjects.

Summary of Background Data. To determine the severity of CSM, objective and reproducible means of measuring patient disability are essential. No studies have evaluated differences in quantitative test results between a large series of CSM patients and healthy subjects.

Methods. Four hundred fifty-four CSM patients and 818 asymptomatic subjects were included. The Japanese subjects were in their 40s to 70s and were divided according to their age by decade. The 10-s G&R and 10-s step tests were used to quantitatively assess performance. The severity of myelopathy before surgery was evaluated according to a scoring system proposed by the Japanese Orthopaedic Association for cervical myelopathy (JOA score) in the CSM patients.

Results. In the CSM patients, the 10-s G&R and step test results significantly correlated with the JOA score ($P < 0.0001$). The number of the 10-s G&R and step tests significantly decreased with age in both groups. There was a difference in the 10-s G&R and step test results between males and females. In the asymptomatic subjects, the number of the 10-s G&R and step tests in the females was less than that in the males. The numbers in the 10-s G&R and step tests were significantly lower in CSM patients than those in asymptomatic subjects in each decade ($P < 0.01$).

Conclusions. The 10-s G&R and 10-s step tests were useful for quantitatively assessing CSM severity, and age and sex differences in results should be considered in screening.

Level of Evidence: Level II

KEY POINTS

- The clinical effectiveness of the 10-s grip and release (G&R) and 10-s step tests for determining cervical spondylotic myelopathy (CSM) severity was prospectively verified.
- The age- and sex-related differences in results between a large cohort of CSM patients and asymptomatic subjects were compared.
- The G&R and step test results significantly correlated with the JOA score and significantly decreased with age in both groups. A sex-related difference in the results of both tests was observed.
- The numbers in the G&R and step tests were significantly lower in CSM patients than those in asymptomatic subjects in each decade.
- The 10-s G&R and 10-s step tests are easily performed quantifiable tasks that are useful in detecting CSM assessing its severity.

1 **INTRODUCTION**

2 Cervical compressive myelopathy (CCM) is one of the most common neurological
3 disorders. It has been shown that in ageing populations, the number of patients affected by CCM
4 is increasing.^{1,2} Symptoms include sensory disturbances of the extremities, clumsiness of hands,
5 gait disturbance and urinary dysfunction.^{3,4} In cases of severe compression or a progressive
6 course, the accepted treatment for CCM is usually surgical decompression.^{5,6} However, in
7 determining the severity of any disease process, it is essential to have objective and reproducible
8 means of measuring patient disability before treatment.⁷

9 Various clinical grading systems have been used to assess the severity of CCM. There
10 are a few quantifiable and screening tests to assess neurological conditions in CCM, including
11 the 10-s grip and release (G&R) test and 10-s step test.^{8,9} The 10-s G&R test was introduced to
12 evaluate myelopathy of the hand. This test is generally believed to correlate well with the degree
13 of disability of the upper extremities.⁸ The 10-s step test has been shown to be useful for
14 assessing the severity of CCM.⁹ The G&R and step tests have also been demonstrated to be
15 highly reproducible. Particularly, the G&R and step tests are access friendly and easy to use in
16 clinical practice.

17 However, the clinical usefulness of these tests has not been fully evaluated in cervical
18 spondylotic myelopathy (CSM) patients only because previous studies have included ossification
19 of the posterior longitudinal ligament (OPLL), and the sample sizes were relatively small.
20 Clinical symptoms have been reported to be different between patients with CSM and those with
21 OPLL; it is likely that those studies contained some bias.^{6,10} No studies have evaluated
22 differences in the results of these quantifiable performance evaluations between a large series of
23 CSM patients and healthy subjects.

24 We hypothesised that these quantitative performance test numbers should be lower in
25 CSM patients than in healthy subjects. The purpose of this prospective study was to verify the
26 clinical effectiveness of the 10-s G&R and 10-s step quantitative tests for assessing the severity
27 of CSM and to compare age- and sex-related differences in the results between large cohorts of
28 CSM patients and asymptomatic subjects.

29

30 **MATERIALS AND METHODS**

31 **Study Population**

32 *CSM patients*

33 Between January 2007 and March 2011, 701 consecutive Japanese patients with
34 CCM were collected in Chubu Rosai Hospital and prospectively enrolled in this study. The
35 following exclusion criteria were used: (1) OPLL; (2) history of rheumatoid arthritis, cerebral
36 palsy, Parkinson's disease, stroke or tumours; (3) spinal injuries; (4) destructive spondyloarthritis
37 caused by haemodialysis; (5) previous cervical surgery; (6) severe kyphotic deformity, spinal
38 fusion with instrumentation; (7) thoracic spondylotic myelopathy and (8) lumbar spinal canal
39 stenosis. Of the 701 patients, 528 patients with CSM who were concurrently suffering from other
40 locomotor disorders, such as hip or knee osteoarthritis, were eligible for participation. Moreover,
41 of the 528 patients, 454 patients, excluding those in the third, fourth and ninth decades of life,
42 were finally included as CSM patients. The CSM patients ranging in age from their 40s to their
43 70s (289 males and 165 females, mean age: 64.8 years) were classified according to their age by
44 decade (Table 1).

45 All patients presented with symptoms of myelopathy. Magnetic resonance imaging and
46 myelographic findings were consistent with myelopathy secondary to multisegmental cervical

47 spondylotic stenosis. Each patient had myelopathy confirmed with a physical examination, and
48 cord compression was present only between the C2/C3 and C7/T1 disc levels.

49

50 *Asymptomatic subjects (Controls)*

51 Between February 2006 and February 2008, 1,230 healthy Japanese volunteers were collected in
52 Chubu Rosai Hospital and prospectively enrolled as asymptomatic subjects in this study.

53 Subjects with a history of brain or spinal surgery; comorbid neurological diseases, such as
54 cerebral infarction or neuropathy; symptoms related to sensory or motor disorders (e.g.
55 numbness, clumsiness, motor weakness and gait disturbances) or the presence of severe neck
56 pain were excluded. Pregnant women and individuals who received worker's compensation or
57 presented with symptoms after a motor vehicle accident were also excluded. Finally, 818 healthy
58 volunteers (408 males and 410 females), excluding those in the third and fourth decade of life,
59 were included as asymptomatic subjects. There were at least 100 males and 100 females in each
60 decade from their 40s to 70s. Table 1 shows the age and sex of the subjects. The Institutional
61 Review Board approved this project, and we obtained written informed consent from the CSM
62 patients and asymptomatic subjects before the examination (Table 1).

63

64 **Clinical Outcomes**

65 The severity of myelopathy before surgery was evaluated according to a scoring system
66 proposed by the Japanese Orthopaedic Association for cervical myelopathy (JOA score) in the
67 CSM patients.^{10,11} The JOA score quantifies neurological impairment by evaluating motor
68 function in the upper and lower extremities (4 points each), sensory function in the upper and
69 lower extremities as well as in the trunk sensibility (2 points each, total 6 points) and urinary

70 bladder function (3 points). Therefore, a perfect JOA score for cervical myelopathy is 17 points
71 (Table 2).¹²

72 The 10-s G&R and 10-s step tests were used to quantitatively assess performance.^{8,9} The
73 patients and healthy volunteers were provided with information regarding these two tests before
74 the examination. In the 10-s G&R test, data were collected from the left or right side, depending
75 on which side was weaker.

76

77 *Ten-second G&R test (10-s G&R test)*

78 The patients and healthy volunteers were asked to grip and release with their fingers as
79 rapidly as possible with the forearm kept in pronation and the wrist in mild extension. The
80 number of completed cycles of movement within 10 s was separately counted on each side.⁸
81 Patients who were not able to perform complete grip and/or extension of fingers were asked to
82 just do their movement as much as possible.

83

84 *Ten-second step test (10-s step test)*

85 The patients and healthy volunteers were asked to take high steps by bending their knees
86 to 90° such that their thighs were parallel to the floor. They were asked to take as many of these
87 steps as they could in place without holding onto anything for balance for 10 s. If the patient
88 seemed at risk of falling, the test was performed in proximity to a hand bar.^{9,13}

89

90 **Statistical Analysis**

91 Data were analysed using SPSS statistical software (version 18.0; SPSS, Inc., Chicago,
92 IL, USA). All values were expressed as the mean \pm standard deviation. Nonparametric analysis

93 using the Mann–Whitney U-test was used for analysing the differences between the two groups.
94 Finally, the Kruskal–Wallis test followed by the Mann–Whitney U-test were used for
95 analysing the differences among more than three groups. Spearman’s rank correlation
96 coefficient was used to determine correlations. $P < 0.05$ was considered to indicate statistical
97 significance.

98

99 **RESULTS**

100 In the CSM patients, the number of cycles completed in the G&R test significantly
101 correlated with the total JOA score ($r = 0.5064$, $P < 0.0001$) (Figure 1). The results from the
102 G&R test in the CSM patients for the assessment of the motor function of the upper extremities
103 are shown in Figure 2. The number of completed cycles in the G&R test significantly correlated
104 with the motor function grading of the upper extremities assessed based on the JOA score ($r =$
105 0.4810 , $P < 0.0001$). The number of completed cycles in the G&R test decreased with age in the
106 CSM patients and asymptomatic subjects (Table 3). There was a difference in the 10-s G&R test
107 results between males and females. In the asymptomatic subjects, the number of completed
108 cycles in the G&R test in the females was less than that in the males (Table 4). The number of
109 completed cycles in the G&R test was significantly less in the CSM patients than that in the
110 asymptomatic subjects in each decade ($P < 0.01$) (Figure 3).

111 The number of steps significantly correlated with the total JOA score in the CSM
112 patients ($r = 0.6344$, $P < 0.0001$) (Figure 4). The results of the step test in the CSM patients to
113 assess motor function of the lower extremities are shown in Figure 5. The number of steps
114 significantly correlated with the motor function grading of the lower extremities assessed based
115 on JOA score ($r = 0.7207$, $P < 0.0001$). The number of steps decreased with age in the CSM

116 patients and asymptomatic subjects (Table 3). There was a difference in the 10-s step test results
117 between males and females. In the asymptomatic subjects, the number of steps was less in the
118 females than in the males (Table 4). The number of steps in the 10-s step test was significantly
119 lower in the CSM patients than in the asymptomatic subjects in each decade ($P < 0.01$) (Figure
120 6).

121

122 **DISCUSSION**

123 In this study, we compared the 10-s G&R and 10-s step test results by decade between
124 males and females in their 40s, 50s, 60s and 70s in a large series of CSM patients and healthy
125 subjects. Age-related differences in the results were observed. The number of completed cycles
126 in the 10-s G&R test and number of steps in the 10-s step test were significantly lower in the
127 CSM patients than in the asymptomatic subjects and decreased with age in both groups. A
128 sex-related difference in the results of both tests was observed. The 10-s G&R and 10-s step tests
129 are easily performed quantifiable tasks that are useful in detecting CSM assessing its severity.

130 These clinical variables include patient symptoms, physical findings and laboratory
131 investigations that are prone to reporting biases. A variety of traditional functional measures
132 have been reported in evaluating the severity of CSM.¹⁴⁻¹⁷ The most commonly used are the
133 Ranawat classification,¹⁴ Nurick classification¹⁵ and JOA score.^{16,17} The Ranawat classification
134 scale was originally devised to evaluate the neurological function of patients undergoing cervical
135 spine arthrodesis for rheumatoid involvement of the cervical spine.¹⁴ Nurick proposed a grading
136 scheme to measure the degree of walking difficulty in patients with myelopathy secondary to
137 cervical spondylosis.¹⁵ The JOA score is the most comprehensive of the traditional and available
138 measures in quantifying the degree of impairment secondary to myelopathy.^{16,17} However, JOA

139 score alone is not sufficient for effectively quantifying the severity of myelopathy.¹⁶ These
140 classifications are determined by questioning the patients and seem to lack the objectivity of a
141 clinical neurological examination. These measures are also poorly quantifiable, with very few
142 and largely arbitrary categories. The sensitivity to change is likely to be poor because one
143 category covers a wide range of clinical severity.¹⁶

144 Quantitative physical tests could be used as confidential objective assessment methods
145 for CSM. When they are combined with clinical tests, such as the JOA score, an even more
146 objective and quantitative evaluation of CSM could be achieved. A preferable assessment of
147 neurological impairment would be objective, quantitative and easy to use. Three quantitative
148 tests for CCM have been reported: the 10-s G&R test,⁸ 30-m walking test¹⁸ and 10-s step test.^{9,13}

149 The 10-s G&R test was introduced to evaluate myelopathy of the hand. The G&R test
150 can quantitatively reflect motor disability of the upper extremities and distinguish the laterality
151 of the symptom. This test is easily performed in clinics and wards.⁸ In this study, the number of
152 completed cycles in the G&R test significantly correlated with the motor function grading of the
153 upper extremities by JOA score. Therefore, this study demonstrated that the 10-s G&R test can
154 reflect and quantify the severity of CSM.

155 The 30-m walking test has been reported to be a suitable measure of the severity of
156 CCM.¹⁸ The test has been proven to be quantitative, reproducible and reliable in repeated trials.
157 However, it is fairly difficult to perform in an outpatient clinic and usually requires a relatively
158 wide space in addition to an examiner.

159 The 10-s step test as a quantitative measure of the severity of CCM was developed by
160 Yukawa et al.⁹ This test has been shown to not only be useful for assessing the severity of CCM
161 but also to have the significant advantage of being easier to perform for lower limb dysfunction

162 evaluation than the G&R test and 30-m walking test.¹⁹ The 10-s step test can be easily performed
163 anywhere and at any time without the requirement of a special instrument and can be repeated if
164 necessary because it is sensitive to neurological impairment, particularly the locomotor function
165 of the lower extremities.²⁰ The present study showed that the number of steps significantly
166 correlated with the motor function grading of the lower extremities assessed based on JOA score.
167 Thus, this study also demonstrated that the 10-s step test can reflect and quantify the severity of
168 CSM.

169 Especially, the G&R and step tests are access friendly and easy to use in clinical
170 practice. These tests are reproducible, comprehensively performed worldwide and not affected
171 by differences in language and life style.^{8,9,13} Therefore, we used the 10-s G&R and 10-s step
172 tests to quantitatively measure symptom severity in this study. These tests, as an access-friendly
173 form of screening, also have the potential to reveal undiagnosed patients who do not recognize
174 their own symptoms. The diagnostic accuracy of early myelopathy can be improved by
175 combining the two tests.

176 Usually, these functional tests are affected not only by the severity of locomotor disability but
177 also by age-related decline. There were some differences in the 10-s G&R and 10-s step test
178 results between the CSM patients and asymptomatic subjects in their 40s and 70s. The number of
179 completed cycles in the 10-s G&R test and steps in the 10-s step test decreased with increasing
180 age in both groups. Fewer than 20 in the 10-s G&R test were considered to be pathologic without
181 considering aging.⁸ Nakashima et al. determined a cut-off value of the step test to further clarify
182 the pathological findings without considering age.²⁰ Receiver operating characteristic curve
183 analysis showed that a cut-off value of 14.5 maximized the power of a step test result as a
184 predictor of effective clinical results assessed based on JOA score.²⁰ Because the age variation

185 was quite large, it was difficult to set up standardised border values between the patients and
186 healthy subjects.¹³ Additionally, there was a difference in the 10-s G&R and 10-s step test results
187 between the sexes. From the results of this study, the number of completed cycles in the G&R
188 test in the females was less than that in the males in the asymptomatic subjects. The number of
189 steps was also less in the females than in the males in the asymptomatic subjects. We speculated
190 that males had a greater physical ability for these tests than females in the asymptomatic subjects.
191 In the CSM patients, as for the reason why sex-related difference in the results of both tests was
192 observed, there may be differences in the severity of CSM in each decade between males and
193 females. Especially, elderly males might have more severe forms of CSM. At the evaluation,
194 age- and sex-related differences should be considered.¹³ In each decade, the performance in both
195 tests was lower in the CSM patients than in the asymptomatic subjects. Thus, the tests could
196 potentially be used as a screening examination for CSM.

197 One of the limitations in this study was that the patients with severe gait disturbances
198 could not perform the 10-s step test; therefore, their results were estimated to be zero. The 10-s
199 step test can estimate locomotor function of the trunk and bilateral lower extremities but cannot
200 assess the laterality of symptomatic severity, as can be estimated using the 10-s G&R test. The
201 other limitation is that the 10-s step test can be impaired by other medical conditions, such as
202 locomotor disorders. In this study, patients with rheumatoid arthritis, cerebral palsy, Parkinson's
203 disease, stroke, thoracic myelopathy, lumbar spinal stenosis and hip or knee osteoarthritis were
204 excluded. Patients with thoracic myelopathy can potentially show results similar to patients with
205 CCM. Patient-based objective questionnaires, such as quality of life determined using the
206 short-form health survey 36, were not used. However, our data set was sufficiently large for most
207 evaluations. All data in this study were derived only from Japanese patients and volunteers, the

208 majority of who belonged to a single race. Therefore, it may be difficult to apply these findings
209 to other races in a similar manner. However, Japan has the most advanced age society, and these
210 data should be useful for understanding age-related changes in other races in countries with
211 ageing populations.²¹ The strength of this study is that it included the largest number of CSM
212 patients and asymptomatic subjects reported in the literature on this subject till date. The
213 information obtained from this study might be important within the decision-making process
214 during treatment planning.

215

216 **CONCLUSION**

217 The 10-s G&R and 10-s step tests are useful tools for quantitatively assessing the
218 severity of CSM. When these quantitative tests are used to screen for CSM, age- and sex-related
219 differences should be considered.

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Table 1.
 Demographics of CSM patients and Asymptomatic subjects in each gender and each generation

CSM patients					
	40s	50s	60s	70s	ALL
Male	29	64	112	84	289
Female	4	29	58	74	165
Total	33	93	170	158	454
Asymptomatic subjects					
	40s	50s	60s	70s	ALL
Male	100	105	101	102	408
Female	100	102	106	102	410
Total	200	207	207	204	818

Table 2.

Evaluation of cervical myelopathy using the scoring system proposed by the Japanese Orthopaedic Association (JOA) score and recovery rate of the JOA score.

JOA score

I. Motor function of the upper extremity

0. Impossible to eat with chopsticks or spoon
1. Possible to eat with spoon, but not with chopsticks
2. Possible to eat with chopsticks, but inadequate
3. Possible to eat with chopsticks, awkward
4. Normal

II. Motor function of the lower extremity

0. Impossible to walk
1. Needs cane or aid on flat ground
2. Needs cane or aid only on stairs
3. Possible to walk without cane or aid but slowly
4. Normal

III. Sensory function

- A. Upper extremity
 0. Apparent sensory loss
 1. Minimal sensory loss
 2. Normal
- B. Lower extremity (same as A)
- C. Trunk (same as A)

IV. Bladder function

0. Complete retention
 1. Severe disturbance (sense of retention, dribbling, incomplete continence)
 2. Mild disturbance (urinary frequency, urinary hesitancy)
 3. Normal
-

Table 3.

Aging variation of the 10-s G&R test and 10-s step test in each patients and subjects

	10-s G&R test (right)	10-s G&R test (left)	10-s step test
CSM patients Male			
40s	18.7±5.3	19.8±5.2	16.4±2.3
50s	18.3±5.9	18.3±5.9	14.4±3.8
60s	15.2±4.4	15.5±4.5	12.1±4.4
70s	13.4±4.5	13.5±4.3	10.7±4.5
CSM patients Female			
40s	16.3±3.1	16.5±1.9	13.5±3.7
50s	16.3±4.2	16.3±3.8	14.9±3.6
60s	15.2±4.5	16.0±4.2	12.9±4.0
70s	14.4±3.7	14.8±4.3	9.3±5.2
Asymptomatic subjects Male			
40s	24.8±5.2	25.8±5.4	21.1±3.8
50s	21.6±4.1	22.7±4.2	19.7±2.9
60s	19.7±4.6	20.4±4.6	18.4±2.4
70s	17.4±3.7	18.1±3.9	17.5±3.0
Asymptomatic subjects Female			
40s	22.2±5.1	23.0±5.1	19.9±2.2
50s	19.4±3.4	20.2±3.6	19.1±2.7
60s	17.3±3.2	18.1±3.4	18.2±2.1
70s	16.1±2.9	16.9±3.1	17.1±2.2

mean ± standard deviation (SD)

Table 4.

Comparisons of 10-s G&R test and 10-s step test in each subjects and each generation

	CSM Male	CSM Female	Asymp Male	Asymp Female	P value
10-s G&R test (r)					
40s	18.7±5.3	16.3±3.1	24.8±5.2	22.2±5.1	<0.001
50s	18.3±5.9	16.3±4.2	21.6±4.1	19.4±3.4	<0.001
60s	15.2±4.4	15.2±4.5	19.7±4.6	17.3±3.2	<0.001
70s	13.4±4.5	14.4±3.7	17.4±3.7	16.1±2.9	<0.01
10-s G&R test (l)					
40s	19.8±5.2	16.5±1.9	25.8±5.4	23.0±5.1	<0.001
50s	18.3±5.9	16.3±3.8	22.7±4.2	20.2±3.6	<0.001
60s	15.5±4.5	16.0±4.2	20.4±4.6	18.1±3.4	<0.001
70s	13.5±4.3	14.8±4.3	18.1±3.9	16.9±3.1	<0.01
10-s step test					
40s	16.4±2.3	13.5±3.7	21.1±3.8	19.9±2.2	<0.001
50s	14.4±3.8	14.9±3.6	19.7±2.9	19.1±2.7	<0.01
60s	12.1±4.4	12.9±4.0	18.4±2.4	18.2±2.1	<0.01
70s	10.7±4.5	9.3±5.2	17.5±3.0	17.1±2.2	<0.001

mean ± standard deviation (SD)

Asymp: Asymptomatic subjects

r; right

l: left

FIGURE LEGENDS

Figure 1. The 10-s G&R test and total JOA score in CSM patients

In the CSM patients, the number of cycles completed in the G&R test significantly correlated with the total JOA score ($r = 0.5064$, $P < 0.0001$).

Figure 2. The 10-s G&R test in CSM patients for motor function grading of the upper extremities by JOA score

The number of completed cycles in the G&R test significantly correlated with the motor function grading of the upper extremities assessed based on the JOA score ($r = 0.4810$, $P < 0.0001$).

Error bar: Standard deviation

Figure 3. The 10-s G&R test in each generation of CSM patients and asymptomatic subjects

The number of completed cycles in the G&R test decreased with age in the CSM patients and asymptomatic subjects. In the asymptomatic subjects, the number of completed cycles in the G&R test in the females was less than that in the males. The number of completed cycles in the G&R test was significantly less in the CSM patients than that in the asymptomatic subjects in each decade ($P < 0.01$).

Error bar: Standard deviation

Figure 4. The 10-s step test and total JOA score in CSM patients

The number of steps significantly correlated with the total JOA score in the CSM patients ($r = 0.6344$, $P < 0.0001$).

Figure 5. The 10-s step test of CSM patients for motor function grading of the lower extremities by JOA score

The number of steps significantly correlated with the motor function grading of the lower extremities assessed based on JOA score ($r = 0.7207$, $P < 0.0001$).

Error bar: Standard deviation

Figure 6. The 10-s step test in each generation of CSM patients and asymptomatic subjects

The number of steps decreased with age in the CSM patients and asymptomatic subjects. In the asymptomatic subjects, the number of steps was less in the females than in the males. The number of steps in the 10-s step test was significantly lower in the CSM patients than in the asymptomatic subjects in each decade ($P < 0.01$).

Error bar: Standard deviation