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Original article

Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ): part 4. Establishment of equations for severity scores

Subcommittee on Low Back Pain and Cervical Myelopathy, Evaluation of the Clinical Outcome Committee of the Japanese Orthopaedic Association

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Abstract
Background. To establish a patient-oriented outcome measure for cervical myelopathy, a subcommittee of the Japanese Orthopaedic Association (JOA) developed a new scoring system to evaluate the overall clinical status of patients, which could be completed by patients themselves. The subcommittee completed three large-scale studies to select and modify questions derived from various preexisting outcome measures including Short Form-36, and then finalized and validated the questionnaire, which comprised 24 questions.
Methods. The finalized questionnaire was administered to 369 patients with cervical myelopathy due to disc herniation, spondylosis, or ossification of posterior longitudinal ligament by randomly selected board-certified spine surgeons. Patients with different severities of myelopathy were included to insure accuracy and responsiveness of this questionnaire against patients' different neurological status.
Results. Data of 236 patients were employed and were subjected to rigorous statistical analyses. There was no question that was difficult to answer and distribution of answers for each question was not concentrated to one choice, indicating the appropriateness of all 24 questions. Results of factor analysis suggested that the 24 questions could be divided into five different factors or functional domains. The factors were defined as follows: factor 1, lower extremity function; factor 2, quality of life; factor 3, cervical spine function; factor 4, bladder function; and factor 5, upper extremity function. Finally, equations that would yield scores for the five factors were assembled. The score to be used to represent the degree of patients' disability or status in each domain can be calculated by multiplying prefixed numbers of selected answers to questions by preassigned coefficients. Coefficients were defined to make the minimum score 0 and the maximum score 100.
Conclusions. We have successfully established a questionnaire that is able to demonstrate the status of patients suffering cervical myelopathy from five different aspects represented by five intuitive numerical scores. The final issue to be confirmed is the responsiveness of this questionnaire to changes in patients' status after various surgical and nonsurgical treatments.

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Introduction

The Japanese Orthopaedic Association scoring system for the evaluation of cervical myelopathy (JOA score) was first established by a committee of the JOA chaired by Hirabayashi.[1] Since then, this scoring system has been accepted universally in Japan as a tool to measure the outcomes of surgical and nonsurgical treatments for various cervical spinal disorders that cause cervical myelopathy. The JOA score first appeared in the English literature in 1980 when Hirabayashi published an article describing surgical results in patients with ossification of the posterior longitudinal ligament of the cervical spine (OPLL) that underwent expansive open-door laminoplasty.[2] The JOA score underwent the first revision in 1994 to reflect the deficits in shoulder and elbow functions, which are often caused by cervical root lesions, and this revised version was officially translated into English.[3] Various modified versions of the JOA score have also been introduced in the western countries.[4–6] The JOA score is a disease-specific and physician-oriented system that mainly assesses the neurological status of the patient and enables surgeons to compare the changes in the neurological status of the patient before and after certain treatments. Due to emerging needs to evaluate the impairments in patients' activities of daily living (ADL), which is related directly to their quality of life (QOL), various patient-oriented outcome measures, for example, the Short Form (SF)-36, have been developed and adopted into clinical practices in different medical fields.[7] To take up such needs, the JOA together with the Japanese Society of Spine Surgery and Related Research (JSSR), formerly called the Japanese Spine Research Society (JSRS), has appointed several members of the Clinical Outcomes Committee of the JOA to organize a subcommittee, the aim of which is to develop a completely new patient-oriented scoring system for the evaluation of clinical results in patients with back pain and cervical myelopathy. The subcommittee decided to construct a self-rating questionnaire that could be filled out by patients themselves. Candidates of the questions to be included in the questionnaire were selected and modified from various preexisting outcome measures including the SF-36, the Rolland and Morris Disability Questionnaire, and the Oswestry Disability Index.[8,9] The subcommittee completed three large-scale studies to select and validate the questions that would ultimately become parts of the new JOA scoring system and as a result, the questionnaires including 25 and 24 questions for the evaluation of back pain and cervical myelopathy respectively were finalized.[10–12] In the present study, the cervical version of the finalized questionnaires was administered to patients with cervical myelopathy of different severity to insure the accuracy and responsiveness of this questionnaire and the obtained data were subjected to factor analysis in order to divide the 24 questions into different functional domains. The titles of the domains were designated according to the context of the questions in each domain. Finally, the equations that would yield scores based on the answers to the questions, selected by the patients, in the different domains were established. The scores would represent the degree of patient disability in the functional domains.

Table 1. Sex and age distribution of patients

Sex	Age groups (years)	Severity of myelopathy				Total
		Mild	Moderate	Severe	NA	
Male	20–29	0	0	1		1
	30–39	5	6	3		14
	40–49	5	5	8		18
	50–59	16	18	6	1	41
	60–69	24	26	9		59
	70–79	7	9	7		23
	80–89	3	1	2		6
	>90	0	0	0		0
	Total	60	65	36	1	162
Female	20–29	0	0	0		0
	30–39	2	1	0		3
	40–49	3	6	0		9
	50–59	4	8	2		14
	60–69	11	8	4		23
	70–79	5	8	7		20
	80–89	2	2	1		5
	>90	0	0	0		0
	Total	27	33	14		74
Total		87	98	50	1	236

Table 2. Distribution of scores for subdomains in original scoring system of Japanese Orthopaedic Association

Domain	Function	Score	Response number
Motor	Upper extremity: feeding		
	Impossible	0	5
	Severe	1	22
	Moderate	2	56
	Mild	3	92
	Normal	4	61
Motor	Upper extremity: shoulder and elbow function		
	Severe	–2	8
	Moderate	–1	14
	Mild	–0.5	45
	Normal	0	166
	Unknown		3
Motor	Lower extremity: gait		
	Impossible	0	9
		0.5	1
	Severe	1	26
		1.5	23
	Moderate	2	39
		2.5	20
	Mild	3	59
	Normal	4	59
Sensory	Upper extremity		
	Severe	0	9
		0.5	40
	Moderate	1	111
	Mild	1.5	60
	Normal	2	16
Sensory	Trunk		
	Severe	0	1
		0.5	5
	Moderate	1	39
	Mild	1.5	26
	Normal	2	165
	Unknown		
Sensory	Lower extremity		
	Severe	0	4
		0.5	24
	Moderate	1	69
	Mild	1.5	46
	Normal	2	93
Bladder	Urinary dysfunction		
	Severe	0	3
	Moderate	1	40
	Mild	2	55
	Normal	3	138
	Unknown		

n = 236

Materials and methods

The subcommittee randomly chose 369 out of 829 board-certified spine surgeons who were registered in the JSSR database and asked them to participate in the present survey. Each surgeon was asked to administer the questionnaire to patients with cervical myelopathy due to disc herniation, spondylosis, or OPLL. The surgeons were required to include at least one patient each with mild, moderate, and severe myelopathy according to the discretion of each surgeon. Patients with (1) myelopathy due to nondegenerative diseases, such as trauma, tumor, and rheumatoid arthritis; (2) other musculoskeletal diseases that would affect the evaluation of myelopathy; (3) difficulties filling the questionnaire due to their specific physical (e.g., defects or impairments in the limbs) or mental conditions (e.g., dementia, disorientation); and (4) a history of previous spinal surgery, were excluded from the analysis. Those who participated in our previous studies were also excluded. The surgeons were also asked to assess the neurological status of the patients using the original JOA scoring system. This study was approved by the Ethics Committee of the JSSR, and informed consent was obtained

Table 3. Distribution of answers for 24 questions

	Response				
Question	1	2	3	4	5
Q1-1	108 (45.8)	103 (43.6)	25 (10.6)		
Q1-2	171 (72.5)	56 (23.7)	9 (3.8)		
Q1-3	154 (65.3)	49 (20.8)	23 (9.7)	10 (4.2)	
Q1-4	107 (45.3)	82 (34.7)	24 (10.2)	15 (6.4)	8 (3.4)
Q1-5	107 (45.3)	72 (30.5)	57 (24.2)		
Q1-6	153 (64.8)	49 (20.8)	19 (8.1)	12 (5.1)	3 (1.3)
Q1-7	77 (32.6)	114 (48.3)	45 (19.1)		
Q1-8	127 (53.8)	83 (35.2)	26 (11.0)		
Q1-9	143 (60.6)	73 (30.9)	20 (8.5)		
Q1-10	120 (50.8)	86 (36.4)	30 (12.7)		
Q1-11	140 (59.3)	70 (29.7)	26 (11.0)		
Q1-12	161 (68.2)	53 (22.5)	22 (9.3)		
Q1-13	91 (38.6)	90 (38.1)	55 (23.3)		
Q2-1	6 (2.5)	14 (5.9)	87 (36.9)	100 (42.4)	29 (12.3)
Q2-2	48 (20.3)	113 (47.9)	75 (31.8)		
Q2-3	43 (18.2)	126 (53.4)	67 (28.4)		
Q2-4	46 (19.5)	98 (41.5)	92 (39.0)		
Q2-5	25 (10.6)	45 (19.1)	95 (40.3)	51 (21.6)	20 (8.5)
Q2-6	38 (16.1)	49 (20.8)	75 (31.8)	50 (21.2)	24 (10.2)
Q2-7	24 (10.2)	31 (13.1)	105 (44.5)	53 (22.5)	23 (9.7)
Q2-8	24 (10.2)	38 (16.1)	113 (47.9)	40 (16.9)	21 (8.9)
Q2-9	14 (5.9)	46 (19.5)	104 (44.1)	50 (21.2)	22 (9.3)
Q2-10	26 (11.0)	68 (28.8)	51 (21.6)	56 (23.7)	35 (14.8)
Q2-11	38 (16.1)	76 (32.2)	73 (30.9)	36 (15.3)	13 (5.5)

Numbers given in parentheses are percentages of the total response

from each subject. The completed questionnaires and the results of the original JOA scoring system were collected and sent to the independent central organization where biostatisticians compiled the results and input patient data into a spreadsheet. Rigorous statistical analyses including factor analysis were performed using SPSS software (Version 12, SPSS, Chicago, IL, USA).

Results

Three hundred and sixty-nine patients were initially recruited for this survey. Among them, 106 patients were excluded because they had other musculoskeletal disorders that could affect the evaluation of cervical myelopathy. Most of them had nonspecific low-back pain without neurological symptoms ($n = 70$) and mild knee joint pain due to osteoarthritis ($n = 22$). Twenty-six patients gave no answers to one or more questions and were also excluded. One other patient was excluded because of the discretion of the surgeon in charge. The data of the remaining 236 patients were employed. The sex and age distributions of patients and the distributions of the scores for different subdomains in the original JOA scoring system are given in Tables 1 and 2. Because the majority of the excluded patients were those having other musculoskeletal diseases due to spondylosis or osteoarthritis, the average age was significantly higher in the excluded patients than those that were included. The average scores for shoulder/elbow function and lower motor function in the JOA scoring system were significantly lower in the excluded patients than those for the included subjects.

The incidence of unanswered questions was less than 5%, indicating that there was no question that was difficult to answer. There also was no question for which the distribution of the answer was concentrated to one choice (Table 3), indicating the appropriateness of all 24 questions.

Results of factor analysis revealed that there were six common factors whose eigenvalues exceeded 1.0, which are thought to be the factor having significant contributions to the result. We decided to employ the first five factors because the cumulative contribution rate of the first five factors reached 60% and the contribution of the sixth factor was less than 5% (Table 4).

According to the calculation of the factor loadings after orthogonal rotation using the direct oblimin method with the Kaiser normalization, correlations among the 24 questions and the selected five factors were reexamined. When the maximum factor loading of a question exceeded 0.40, that question was supposed to be correlated with the factor. All 24 questions were judged to have correlation with at least one of the five

Table 4. Results of factor analysis

Factor	Eigenvalue	Contribution rate (%)	Cumulative contribution rate (%)
1	**8.86**	36.9	36.9
2	**2.02**	8.4	45.3
3	**1.56**	6.5	51.8
4	**1.36**	5.6	57.5
5	**1.20**	5.0	62.5
6	**1.08**	4.5	67.0
7	0.81	3.4	70.3
8	0.71	3.0	73.3
9	0.67	2.8	76.1
10	0.62	2.6	78.7
11	0.53	2.2	80.9
12	0.51	2.1	83.0
13	0.48	2.0	85.0
14	0.43	1.8	86.8
15	0.41	1.7	88.5
16	0.40	1.7	90.2
17	0.38	1.6	91.7
18	0.35	1.5	93.2
19	0.32	1.4	94.6
20	0.30	1.3	95.8
21	0.28	1.2	97.0
22	0.27	1.1	98.1
23	0.24	1.0	99.1
24	0.22	0.9	100.0

$n = 236$
Bold typeface indicates eigenvalues over 1.0

factors, except for Q1-4 and Q1-12. Q1-4 had relatively higher factor loadings for both factor 1 and 5 and this question was judged to be correlated with both factors. Q1-12 was first judged to be weakly correlated with factor 5 with a factor loading of 0.37; however, the committee decided to correlate this question also to factor 3 after reading the context of the question and given that the factor loading of 0.32 was also moderately high (Table 5).

According to the interpretations of the context of the questions that were divided into the five factors, each factor was categorized as follows; factor 1: lower extremity function; factor 2: quality of life; factor 3: cervical spine function; factor 4: bladder function; and factor 5: upper extremity function.

To establish an equation to calculate the individual score for each factor/domain that would intuitively indicate the status of a patient with regard to the designated function, the questions that had the maximum absolute factor loading value were used to calculate the score for the factor. For example, Q1-5 was used to calculate the score for factor 1 (lower extremity function), because the factor loading of this question for factor 1 was markedly larger (0.58) than those for the other four factors (–0.10, –0.14, –0.12, 0.11). As described above, Q1-4 and Q1-12 were used to calculate the scores for both factors 1 and 5, and 3 and 5, respectively (Table 5). The score was derived by multiplying the prefixed number of the

Table 5. Factor loading after orthogonal rotation

Question	Factors 1	2	3	4	5
Q1-5	**0.58**	–0.10	–0.14	–0.12	0.11
Q1-4	**0.55**	0.05	–0.08	–0.12	**0.40**
Q2-3	**–0.39**	0.25	0.16	0.18	–0.04
Q2-4	**–0.39**	0.24	0.10	0.33	–0.09
Q2-2	**–0.52**	0.20	0.13	0.24	–0.03
Q2-7	0.10	**0.79**	0.00	0.08	–0.01
Q2-8	0.14	**0.73**	0.06	0.12	–0.06
Q2-11	–0.01	**0.68**	–0.21	0.03	0.01
Q2-6	0.05	**0.55**	0.25	–0.06	–0.06
Q2-5	–0.27	**0.39**	0.19	0.04	–0.13
Q2-10	0.23	**–0.49**	0.08	–0.10	0.15
Q2-1	0.12	**–0.60**	–0.04	0.01	0.09
Q2-9	0.13	**–0.66**	–0.13	0.10	–0.06
Q1-11	–0.02	0.03	**–0.57**	–0.24	0.10
Q1-13	0.05	–0.06	**–0.75**	0.00	0.05
Q1-10	0.04	–0.01	**–0.87**	0.07	–0.06
Q1-12	0.10	0.04	–0.32	–0.21	**0.37**
Q1-9	0.08	–0.05	–0.07	**–0.43**	–0.01
Q1-7	0.14	–0.04	0.09	**–0.53**	–0.03
Q1-6	0.00	0.02	0.01	**–0.58**	0.03
Q1-8	–0.11	0.01	–0.06	**–0.61**	0.00
Q1-2	0.12	0.02	0.02	0.10	**0.73**
Q1-1	0.24	–0.13	0.01	0.02	**0.60**
Q1-3	–0.27	–0.11	–0.05	–0.11	**0.60**

Method of factor extraction: unweighted least-squares method. Orthogonal rotation: direct oblimin method with Kaiser normalization
Bold typeface indicates absolute value of the factor loading of more than 0.35

Table 6. Coefficients for calculation of severity score

	Factors				
Question	1 Lower extremity function	2 Quality of life	3 Cervical spine function	4 Bladder function	5 Upper extremity function
Q1-1					–10
Q1-2					–15
Q1-3					–5
Q1-4	–10				–5
Q1-5	–10				
Q1-6				–10	
Q1-7				–5	
Q1-8				–10	
Q1-9				–5	
Q1-10			–20		
Q1-11			–10		
Q1-12			–5		–5
Q1-13			–15		
Q2-1		–3			
Q2-2	15				
Q2-3	5				
Q2-4	5				
Q2-5		2			
Q2-6		2			
Q2-7		5			
Q2-8		4			
Q2-9		–3			
Q2-10		–2			
Q2-11		3			

Table 7. Equations to calculate scores for different factors

Factor	Equation
1 Lower extremity function	(Q1-4 × 10 + Q1-5 × 10 + Q2-2 × 15 + Q2-3 × 5 + Q2-4 × 5 – 45) × 100 ÷ 105
2 Quality of life	(Q2-1 × 3 + Q2-5 × 2 + Q2-6 × 2 + Q2-7 × 5 + Q2-8 × 4 + Q2-9 × 3 + Q2-10 × 2+ Q2-11 × 3 – 24) × 100 ÷ 96
3 Cervical spine function	(Q1-10 × 20 + Q1-11 × 10 + Q1-12 × 5 + Q1-13 × 15 – 50)
4 Bladder function	(Q1-6 × 10 + Q1-7 × 5 + Q1-8 × 10 + Q1-9 × 5 – 30) × 100 ÷ 80
5 Upper extremity function	(Q1-1 × 10 + Q1-2 × 15 + Q1-3 × 5 + Q1-4 × 5 + Q1-12 × 5 – 40) × 100 ÷ 95

answer, selected by the patient, by the coefficient that were defined to make the difference between the minimum and maximum scores to be approximately 100 points (Table 6). The additional coefficients were also assigned to adjust the minimum score to be 0 and the maximum score to be 100. The final equations for the scores for the five domains are shown in Table 7.

Discussion

In our previous studies, the questionnaires were constructed by referring to various preexisting outcome measures including the SF-36, the Roland and Morris Disability Questionnaire, and the Oswestry Disability Index,[7–9] which have commonly been used for patients with different spinal disorders. We also took extra care to maintain relevance to the original JOA scoring systems by carefully assessing the correlation between the new and original systems. The new questionnaires have been revised several times and underwent many validation processes using rigorous statistical analyses. As a result, 24 questions were selected as the items of the finalized questionnaires for back pain and cervical myelopathy.[10–13]

In the present study, patients with different severity of cervical myelopathy were examined using the cervical version of the questionnaires to insure the accuracy and responsiveness of this questionnaire against various neurological states of the patient. Factor analysis was used to divide the 24 questions into different factorial domains, and the domains were categorized by interpreting the context of the questions that were divided into each domain. The five domains into which the 24 questions were divided were designated as: (1) lower extremity function, (2) quality of life, (3) cervical spine function, (4) bladder function, and (5) upper extremity function. Then the equations to calculate the score for each domain were assembled in order to intuitively indicate the status of patients in the five different functional domains. The numbers prefixed to the answers chosen by the patients were multiplied by the coefficients so that the difference between the minimum score representing the worst condition and the maximum score representing the best condition would become 100. The equations were further manipulated by other supplemental coefficients so that the minimum score became 0 and the maximum score became 100 to make recognition of the status of the patient as intuitive as possible.

Because the previous JOA scoring system was a preference-based system, and the scores for different neurological functions (i.e., upper and lower extremity motor function, upper and lower extremity and trunk sensory function, and bladder function) were added up to represent overall status of the patients by one simple score, the new system was initially supposed to use a similar manner. However, because the five factors derived from factor analysis were completely independent statistically, and it was considered impractical to evaluate the multidimensional aspects of the patient suffering cervical myelopathy by one digit, we decided to use the scores in different domains independently without simply adding them.

We have successfully assembled the final questionnaire that is capable of demonstrating the status of the patient suffering cervical myelopathy in five different functional aspects with five intuitive numerical scores, after rigorous yet sophisticated statistical analyses. The remaining issue to be confirmed is the responsiveness of this finalized questionnaire against the changes in patient status after various surgical and nonsurgical treatments. We have investigated if the changes in the patient functional status after surgical treatment would be accurately reflected by the changes in the scores in the different domains. The results will be shown and discussed in part V of our study.

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