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Table 2. Profiles of LCS Patients and Control Subjects

	LCS Patients	Control	
No. Patients	120	370	*P*
Mean age	73.5 ± 8.0	75.6 ± 6.5	0.23
Gender			
Male	85	162	<0.001
Female	35	208	
Mean follow-up (yr)	3.6 ± 1.9		

Relationships Between Leg Cramps and Surgery in LCS Patients

In LCS patients, leg cramps improved after surgery in 18.2%, remained unchanged in 45.5%, and worsened in 26.1% (unknown, 10.2%) (Figure 1). Sixty-eight patients (56.7%) still had residual leg pain (mean VAS, 50.6 ± 3.3) and 81 patients (67.5%) had residual numbness in the legs. Forty-nine of the 68 patients with residual leg pain (72.1%) and 36 of the patients without it (69.2%) had leg cramps ($P = 0.84$), whereas 65 of 81 patients with residual leg numbness (80.2%) and 20 of 39 patients without it (51.3%) had leg cramps ($P = 0.002$). Leg cramps disturbed the subjects' ADL to various degrees in 47.6% of the patients (Figure 2). The patients with leg cramps (70.2%) and those without (57.1%) were satisfied with surgery ($P = 0.2$). There was no significant difference in RDQ scores, ODI scores, or

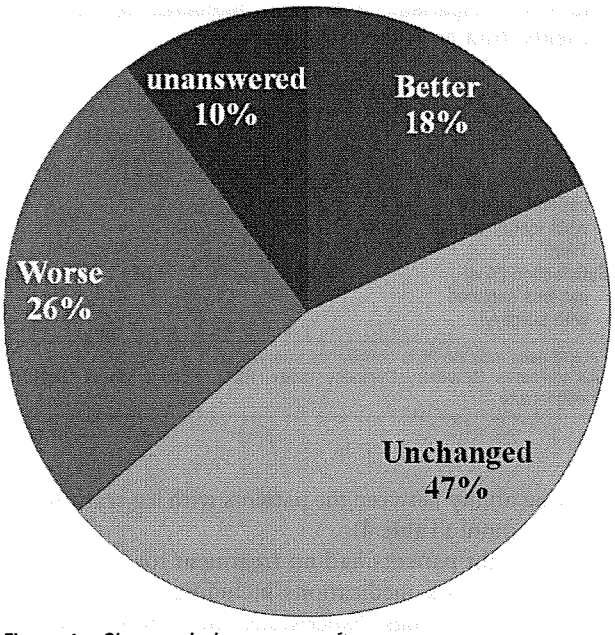

Figure 1. Changes in leg cramps after surgery.

Table 3. Comparison Between LCS Patients and Control Subjects on Leg Cramps

	LCS Patients	Controls	
No. Patients	120	370	*P*
Leg cramps			
Yes	85 (71.4)	137 (37.0)	<0.001
No	35 (28.6)	233 (63.0)	(Adjusted odds ratio 4.59, 95% confidence interval 2.87–7.35)
How often			
More than once a d	13 (15.1)	0 (0)	
Once a d	6 (7.0)	4 (2.9)	
Once a several d	30 (34.9)	17 (12.4)	<0.001
Once a several wk	20 (23.3)	49 (35.8)	
Once a several mo	16 (18.6)	61 (44.5)	
Once a yr	1 (1.2)	6 (4.4)	
When			
During sleep (midnight to dawn)	63 (73.3)	109 (91.6)	
In the morning	4 (4.7)	2 (1.9)	
In the afternoon	7 (8.1)	5 (4.2)	0.002
In the evening	12 (14.0)	3 (2.5)	
Where			
Calf	64 (74.4)	86 (64.2)	
Shin	6 (7)	7 (5.2)	
Anterior thigh	6 (7)	21 (15.7)	0.032
Posterior thigh	10 (10.6)	12 (9.0)	
Foot		8 (6.0)	
Which side			
Right	18 (20.9)		
Left	28 (32.6)		
Both	35 (40.7)	Not asked	
Unanswered	5 (5.8)		
Walking ability			
No limitation	36 (30.0)	184 (49.9)	
Longer than 1km	34 (28.3)	118 (32.0)	
500 m-1 km	14 (11.7)	31 (8.4)	<0.001
100–500 m	25 (20.8)	29 (7.9)	
Less than 100 m	11 (9.2)	7 (1.9)	
Comorbidities			
Hypertension	43 (35.8)	150 (41.1)	0.39
Diabetes	17 (14.2)	23 (6.2)	0.014

Parentheses indicate percentage.

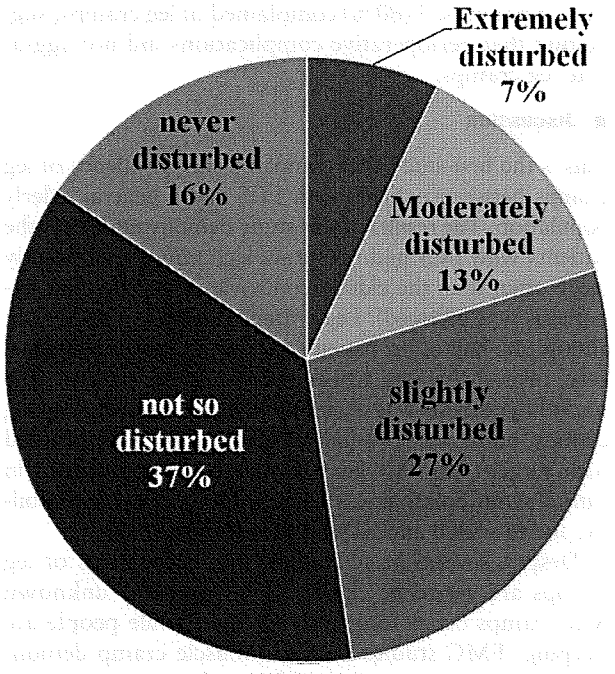

Figure 2. ADL disturbance by leg cramps.

Table 4. Comparison of Surgical Outcomes Between Patients With or Without Leg Cramps

	Cramp (+)	Cramp (−)	*P*
ODI	20.8 (17.8–23.8)	18.2 (13.0–23.5)	0.37
RDQ	7.7 (6.2–9.2)	5.2 (3.0–7.3)	0.53
Walking ability (% of patients able to walk longer than 1 km)	58.8	57.2	0.89
Satisfaction (% of patients satisfied with surgery)	70.2	57.2	0.83

Parentheses indicate 95% confidence interval.
ODI indicates Oswestry Disability Index; RDQ, Roland Morris Disability Questionnaire.

walking ability between the patients with leg cramps and those without (Table 4). T4

Fifty-eight patients had no treatment for leg cramps, and only 9 took medications including vitamin B and antispasmodic drugs (Esperisone, and others). Twenty-three patients had massage, acupuncture, and/or heat therapy at the time of the investigation.

Thirty-six patients (42.4%) with leg cramps and 15 patients (42.9%) without leg cramps took medications that have been reported to be related to the occurrence of leg cramps including diuretics, statins, steroid, and nifedipine, antidepressants, and/or β-blockers ($P = 1.00$). Thus, there was no statistically significant association between medication and incidence of leg cramps in the LCS patients.

Perioperative complications were observed in 5 patients including 1 hematoma, which required evacuation, 3 dural tears, which were treated with dural sutures with no serious sequelae, and 1 transient nerve root palsy. Of these 5 patients, 3 (60%) complained of leg cramps, suggesting that perioperative complications did not aggravate leg cramps.

■ Discussion

This is the first study that compared the prevalence of leg cramps between patients with LCS and a general elderly population. The results of this study demonstrated that the patients with LCS had nocturnal leg cramps significantly more often than the elderly control subjects (the first hypothesis was affirmed). Leg cramps disturbed the ADL in almost one-half of the patients, seldom improved after surgery, or even became worse in 26% of the patients (the second hypothesis was denied). However, regardless of leg cramps, more than one-half of the patients were satisfied with surgery, possibly because they had improvement in clinical symptoms that was suggested by good walking ability, and low ODI and RDQ scores after surgery.

Despite several basic studies, the mechanisms of leg cramps are yet to be clarified,[10–12] and it is unknown why cramps occur frequently at night while people are sleeping. EMG studies during a muscle cramp demonstrated involuntary repetitive firing of motor unit action potentials at a high frequency, and thus, abnormalities in the motor units including motor neurons, neuromuscular junctions, and muscles can cause cramps.[10–12] It is reported that elderly people lose motor neurons as a result of aging, making this population prone to muscle cramps.[13] It has been speculated that the nocturnal frequency of leg cramps is due to changes in hydrostatic pressure and ionic shift across the cell membrane in the calf muscles in a recumbent position, leading to hyperexcitability of the motor neurons.[10] The disturbing pain, which occurs during cramps, is the result of accumulation of metabolites and focal ischemia.

There are many diseases or disorders reported to be associated with cramps; lower motor neuron disorders including amyotrophic lateral sclerosis, poliomyelitis, peripheral neuropathy, and lumbar spinal radiculopathy; metabolic disorders including diabetes, pregnancy, uremia, liver cirrhosis, and hypothyroidism; acute extracellular volume depletion including excessive perspiration, hemodialysis, diarrhea, and diuretic therapy; hereditary disorders; and medications including diuretics, antidepressants, calcium blockers, β-blockers, statins, and steroid, and so on. In this study, we compared LCS patients with a general population as the control. Because the questionnaire for the control subjects did not include detailed comorbidities except for common diseases such as hypertension and diabetes, we included these 2 common diseases related to leg cramps as independent variables with age and gender for the logistic regression analysis. Because the adjusted odds ratio was as high as 4.87, exclusion of other rare pathologic conditions mentioned above from logistic regression analysis might not change the result of the analysis. In LCS patients, we filed all medications administered to the patients, and evaluated the prevalence of leg cramps with stratification by medications to investigate their possible association with leg cramps, but we found no difference in the prevalence between patients with such medications and those without. From these results, although there may be other confounding factors for leg cramps, we can conclude that LCS is definitely a causative factor of leg cramps.

The incidence of leg cramps was significantly higher in LCS patients than in the control population in this study. However, studies on the association between leg cramps and lumbar spinal diseases have been scarce. Rish empirically stated that leg cramps were frequently seen in patients with lumbar radiculopathy.[14] Haskell and Fiebach conducted a retrospective chart review of 50 elderly patients who took quinine sulfate for nocturnal leg cramps in comparison with age-matched controls.[15] They found that peripheral vascular disorders and peripheral neurologic deficits were more common in the patients than in the controls. Demircan *et al* reported the "cramp finding" in patients with lumbar disc herniation.[16] They held the leg of the patients against forceful knee flexion, and if they felt a disturbing cramp in the leg or thigh, the cramp finding was considered to be positive. They identified the positive cramp finding in 72% of the patients with surgically treated lumbar disc herniation. Such a high inci-

dence of leg cramps in patients with lumbar radiculopathy could be attributed to disturbance in the functions of the lumbar spinal nerves controlling the tonus of the muscles innervated by them.[12] In our study, however, decompression surgery did not improve leg cramps in more than a half of the patients although the lumbar spinal nerve roots were decompressed and, therefore, should have improved the leg cramps. Possible reasons are as follows: (1) The lumbar nerve roots were irreversibly damaged by long-lasting compression, which was suggested by the results of the study that leg cramps were more often observed in patients with residual numbness after surgery.[17] Kobayashi *et al* conducted an experimental study using a dog nerve root compression model, and found that dysfunction of the motor neurons is not confined to degeneration at the site of compression but also extends to the motor neurons within the lumbar spinal cord as a result of the axonal reaction, and they stressed that motor deficits would not resolve immediately after surgery; (2) after decompression, reinnervation of the affected muscles can enhance the hyperexcitability of the motor units[10,11,18]; and (3) most of the patients became able to walk farther than before surgery, which might have lead to muscle fatigue and accumulation of metabolites in the lower extremities, causing leg cramps.

Proposed remedies for leg cramps are stretching, massage, intake of vitamins B and E, magnesium, quinine, and anticonvulsants such as carbamazenpine.[10–12] Quinine is an antimalarial drug, and has been reported to be effective for leg cramps by decreasing the excitability of the motor endplate, thereby reducing the muscle contractility. However, the results of these treatment options for leg cramps varies among different studies, and efficacies of these treatment options for LCS patients remains unknown and needs to be clarified in further studies, taking into consideration the high prevalence rate of leg cramps and the associated disturbance of ADL.

This study has several limitations. First, this study was conducted retrospectively using the custom-made questionnaire, and the response rate was only 60%. Some of the questions were answered depending on patients' recall. These issues originated from the retrospective fashion of the present study might cause substantial bias in the results. Further prospective study is necessary using validated questionnaire on leg cramps to eliminate the bias. Second, the subjects of this study only included LCS patients who underwent decompression surgery alone, and we did not include LCS patients who were treated conservatively or treated by fusion surgery. Therefore, we could not evaluate the relationship between conservative treatments (or natural history) and leg cramps or the relationship among different surgical methods and improvement of leg cramps after surgery. In the present study, we only included patients who underwent decompression surgery alone to minimize the possible confounding factor and simplify the analyses. However, further study is necessary to elucidate the impact of conservative treatments or different surgical methods on improvement of leg cramps after surgery. Third, we chose an elderly general population who had participated in a general health checkup and asked them to fill in the questionnaire regarding leg cramps without any matching for age or gender. Therefore, age and gender distributions were different between the patients and the control. To adjust for these differences, we used logistic regression analyses using age, gender, and comorbidities as independent variables.

In conclusion, nocturnal leg cramps are more prevalent in LCS patients than in the general elderly population and should be recognized as one of the symptoms of LCS, which disturbs LCS patients' quality of life.

■ Key Points

- Questionnaire on leg cramps for patients with LCS and general elderly population.
- One hundred twenty patients who underwent decompression surgery without fusion (men 85, women 35, mean age 73.5, mean follow-up 3.6 years) and 370 senile town populations without history of back surgery (men 162, women 208, mean age 75.6) were enrolled in this study.
- Eighty-five (70.8%) patients with LCS and 137 (37.2%) control populations experienced leg cramps (age and sex adjusted odds ratio; 4.6, $P < 0.01$).
- Leg cramps improved after surgery in 18.2%, unchanged in 45.5%, and worsened in 26.1% of the patients, and disturbed activity of daily living in 47.6% of the patients with leg cramps.
- Leg cramps should be recognized as 1 of the symptoms of LCS which disturbs patients' quality of life.

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JOURNAL OF
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Review article

One-leg standing test for elderly populations

TAKEHIRO MICHIKAWA[1], YUJI NISHIWAKI[1], TORU TAKEBAYASHI[1], and YOSHIAKI TOYAMA[2]

[1]Department of Preventive Medicine and Public Health, School of Medicine, Keio University, 35 Shinanomachi, Shinjuku-ku, Tokyo 160-8582, Japan
[2]Department of Orthopaedic Surgery, School of Medicine, Keio University, Tokyo, Japan

Abstract

Background. The one-leg standing (OLS) test is one of the balance tests used to diagnose musculoskeletal ambulation disability symptom complex (MARS), a condition newly defined by three professional Japanese medical societies in 2006 to help identify the symptoms of motor organ deterioration and establish preventive strategies. Although many studies have used the OLS test, none has shown conclusively that the test can be used as a practical marker of frailty among elderly people, especially in community settings. Based on the type of epidemiological study — i.e., descriptive epidemiology and analytical epidemiology (observational and intervention studies) — we reviewed evidence on three fundamental issues related to the OLS test: (1) testing procedures and reference values; (2) the associations between the OLS time and negative events; (3) improvement of the OLS time by intervention. These issues are key to any discussion of whether the OLS test can be used as a practical marker for predicting frailty in community-dwelling elderly populations.

Methods. Articles were collected from MEDLINE databases using the search terms "one- leg standing" and the other names included in the same category.

Results. Because various procedures are used to carry out the OLS test, the measured values for the OLS time varied widely from study to study. Some observational studies showed that the OLS time is related to negative events such as falls, declines in activity of daily living, and other morbidity. OLS times could be improved by several interventions.

Conclusions. This review suggests that the OLS test can be a tool for predicting frailty in community-dwelling elderly populations. However, our review should be interpreted with caution because we did not confirm the evidence level of each of the studies we selected. Further research on this topic is needed.

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Introduction

The one-leg standing (OLS) test measures the time one is able to stand on one lower limb without support.[1,2] This test is a clinical tool to assess postural steadiness in a static position by quantitative measurement.[3] Not only the OLS test[4–8] but also the tests called one-leg stance,[3,9] one-leg balance,[10] one-legged stance,[11] one-legged balance,[12] one-legged standing,[13] unipedal stance,[14,15] unipedal balance,[16] unipedal standing balance,[17] standing on one leg,[18–20] one-foot standing,[21] single-leg standing,[22] single-leg stance,[2] single-limb stance,[23,24] balance on one foot,[25] and unilateral stance[26] are included in the same category. The test is easy to perform for both examiner and examinee, it correlates well with other balance tests, it is inexpensive and time-efficient, and it does not require use of special equipment.[27] The test–retest reproducibility and interrater reliability are acceptable.[11,28–30] It is also reported to be helpful in identifying elderly persons at increased risk of future functional dependence.[31,32]

In Japan, the OLS test has been adopted to diagnose musculoskeletal ambulation disability symptom complex (MARS), a condition newly defined in 2006 by three professional Japanese medical societies to help identify the symptoms of motor organ deterioration and establish preventive strategies.[33] In addition, the OLS test has become a tool for identifying people at high risk of requiring long-term care (*Tokutei-koreisha*).[34] Therefore, the test is presumably widely used not only in clinical settings but also in community settings. Although many studies have examined the use of the OLS test, none has demonstrated conclusively whether the test can be used as a practical marker of frailty among elderly people. Furthermore, no review articles summarizing the findings of epidemiological studies involving the OLS test are available. Efforts to reduce the number of people requiring long-term care should include a review of the use of the OLS test in commu-

nity settings. As one of the main causes of the need for long-term care in Japan is motor organ disorders,[35] preventing deterioration of motor function is an issue that needs to be addressed urgently from a public health viewpoint. This review focuses, therefore, on epidemiological studies of community-dwelling elderly populations. Based on the type of epidemiological study — i.e., descriptive epidemiology and analytic epidemiology (observational and intervention studies) — we reviewed evidence on three fundamental issues related to the OLS test: (1) testing procedures and reference values (descriptive epidemiology); (2) the association between the OLS time and negative events (observational study: analytical epidemiology); (3) improvement of the OLS time by intervention (intervention study: analytical epidemiology). These three issues are key to any discussion of whether the OLS test can be used as a practical marker for predicting frailty in community-dwelling elderly populations.

Methods

As OLS was not registered in medical subject headings, we searched MEDLINE databases for 1966–2007 on PubMed (http://www.ncbi.nlm.nih.gov/PubMed), using the following search terms: one leg standing, one leg stance, one leg balance, one legged stance, one legged balance, one legged standing, unipedal stance, unipedal balance, unipedal standing balance, standing on one leg, one foot standing, single leg standing, single leg stance, single limb stance, balance on one foot, and unilateral stance. The database search elicited 391 articles. To investigate the associations between the OLS time and negative events, we added "risk" or "predict" to the search terms (55 hits). PubMed's "Related Articles" function, along with hand researching of the references cited in all the retrieved articles, allowed us to identify relevant articles. Searches were restricted to English and Japanese language articles. Because the target of this review was the OLS test, balance test standing on two legs was not included. Bearing in mind the purpose of this review, we focused on evidence presented in community-based studies of subjects aged 65 years or older and selected 23 observational studies for further investigation.

We also looked for relevant studies of intervention — with "intervention studies" or "randomized controlled trial" as search terms — as with the descriptive and observational studies and identified 46 articles. In addition, we carried out hand searches of the references included in the articles identified through PubMed. We excluded studies involving institutionalized subjects or clinically based populations and came up with 15 studies that used randomized controlled trials of community-dwelling elderly people aged 65 years or older.

Results and discussion

Testing procedures and reference values

Test procedure

There is as yet no standardized procedure for administering the OLS test, and investigators have reported many slightly different methods for procedure components, such as opening/closing of eyes, leg selection, maximum time, number of times for repeating test. However, there are various essential similarities among most of these procedures, which can be summarized as follows. To ensure that testing conditions are the same for all subjects, the test is preferably performed on a smooth, hard wooden board with the subjects barefooted.[24,36] The examiner first asks the subjects to decide on which leg they would like to stand. The subjects are then asked to stand initially in a relaxed stance with their weight evenly distributed between both. With their eyes open, the subjects are instructed to stand on the leg they have selected, without using any assistive device, and keeping their arms by their sides. The test is over after 60 s has elapsed, when the stance foot shifts, or when the lifted foot is replaced on the board, whichever occurs first. To prevent falls or injuries, the examiner stands close to the subjects throughout the trial.[24] Ideally, the test is performed by two examiners, one acting as time keeper and the other as an assistant to prevent falls or injuries caused by loss of balance.[37] Subjects are given two trials unless they are able to complete 60 s on the first. The examiner records the better of the two trial times.

In most studies, subjects have undergone the OLS test with their eyes open, but in several studies the subjects were also tested with their eyes closed.[38–42] Because most of the participants completed the maximum time with their eyes open,[13] a study by Kuh et al. measured OLS time in subjects with their eyes closed. At present, there is no consensus on whether it is better to perform the test with the eyes open or closed. Stones and Kozma reported greater reliability and sensitivity to the aging process when the test was performed with the eyes open.[16] Potvin et al., on the other hand, reported the opposite and concluded that the test was more effective with the eyes closed.[28] In consideration of the risk of falls, however, we recommend that elderly subjects keep their eyes open.

There are also conflicting views on the question of whether leg selection affects the outcome. Netz and Argov recommended testing both legs separately, having found significant differences in the OLS time depending on which leg was used.[43] Conversely, another

report suggested that neither foot dominance nor the wearing of shoes during the test affects balance performance.[27]

We have adopted 60 s as the maximum time for the OLS test,[4,7,22,44–47] but other researchers have used 15 s,[48] 30 s,[27,36,49–51] 45 s,[15,27] or >60 s.[8,24,38] Some studies even used 5 s (with eyes closed test, presumably).[31,32,52–54]

Studies also vary on the number of times each subject is tested, ranging between one and five times.[1] In some cases, each subject's best OLS time is taken as the recorded value,[4,7,27,55,56] whereas in others the average of several trials is recorded.[20,36,57]

Reference value for OLS time in elderly subjects

Because various procedures are used to carry out the OLS test, the measured values for the OLS time varied widely from study to study,[1] with the mean reported OLS time of women aged 70–79 years ranging widely by as much as 6.9–32.9 s.[58,59] Naturally, this variation may be due to differences in the populations examined as well as procedural differences. Most studies give combined data on the OLS time for men and women, but the results should be separated according to sex, as muscle strength may differ between men and women.

We measured the OLS times of 544 community-dwelling elderly residents (252 men, 292 women) aged 65 years and older of Kurabuchi Town, Takasaki City, Gunma Prefecture, Japan, according to the method already described. The median OLS times (interquartile range) of the various age groups (65–69, 70–74, 75–79, and 80– years) by sex are shown in Table 1. If the aim of measuring the OLS time is to identify frailty among elderly people, we need to collect more data from local residents rather than rely solely on sample data obtained from patients in the clinic. Although Kita et al. proposed a maximum OLS testing time (with eyes open) of 15 s to screen frail patients with musculoskeletal disease in an orthopedic clinic,[10] this restriction is not necessarily appropriate for all elderly members of a given community.

Summary

Because there are variations in the procedure for administering the OLS test, it is difficult to establish a reference value for the OLS time. Therefore, it is essential that one pay attention to the details of the procedure when comparing studies.

Associations between OLS time and negative events

We assessed 23 observational studies to investigate the associations between the OLS time and negative events such as falls, decline in activities of daily living (ADL), and other morbidity among elderly people. If clear associations between OLS times and negative events could be demonstrated, the OLS test would certainly be a useful tool for screening elderly people, as it is easy to carry out in busy clinical settings and community settings. Descriptions of the study outlines are presented in Table 2.

Mortality

A 4-year cohort study of 697 residents (277 men, 420 women) aged 80 years or older of Fukuoka, Japan was performed to investigate the association between physical fitness, including OLS, and mortality.[8] Multivariate Cox analysis revealed that OLS time was not associated with total mortality or specific causes of mortality (cardiovascular disease, pneumonia, and cancer).

Falls

Although several studies have examined the relation between decreasing OLS times and falls, the findings are inconsistent. Of four cross-sectional studies carried out in the United States, two showed positive associations[37,60] and two showed negative results.[27,56] Gehlsen and Whaley reported shorter OLS times among fallers than among nonfallers: 10.9 vs. 18.7 s when tested with eyes open ($P < 0.001$); 3.6 vs. 5.2 s with eyes closed ($P < 0.05$).[60] In contrast, Briggs et al.[27] and Heitmann et al.[56] reported no difference in OLS times between fallers and nonfallers. We found two Japanese cross-sectional studies, both of which showed no difference in OLS times between fallers and nonfallers.[4,45] Interestingly, however, a study by Kim et al. of 669 women aged 70 years or older living in Tokyo showed that OLS times were significantly lower in the group of subjects with "falls + instrumental activities of daily living (IADL)

Table 1. Median OLS times (interquartile range) of the subjects

	Men ($n = 252$)		Women ($n = 292$)	
Age	No.	Median OLS times (s)	No.	Median OLS times (s)
65–69	77	60.0 (43.0–60.0)	95	60.0 (55.7–60.0)
70–74	78	60.0 (42.5–60.0)	85	60.0 (20.3–60.0)
75–79	54	42.2 (14.4–60.0)	58	27.8 (12.0–60.0)
80–	43	16.6 (10.1–60.0)	54	16.3 (4.4–55.7)

OLS, one-leg standing

Table 2. Associations of OLS test with negative events in community-dwelling elderly populations

Outcome Author	Year	Country	Population	Results	Comments
Mortality					
Takata et al.[8]	2007	Japan	697 individuals (277 men, 420 women) aged 80 years or older	The multi-adjusted hazard ratio of mortality from any cause was 0.99 (0.97–1.02) for 1-second increasing in OLS time	Cohort study for 4 years
Falls					
Kim et al.[4]	2007	Japan	668 women aged 70 years or older	OLS time was lower in the group with "falls + IADL decline" (19.7 s) than in the normal group (36.8 s) ($p < 0.05$)	Cross-sectional study limited to women
Kinugasa et al.[45]	1996	Japan	495 residents aged 65–89 years (253 men, 242 women)	There was no difference in mean OLS time: 38.3 seconds in the fallers; 38.7 seconds in the non-fallers	Cross-sectional study
MacRae et al.[37]	1992	U.S.A.	94 older adults (29 men and 65 women, mean age 73)	The association between OLS time and falls was statistically significant ($p = 0.001$)	Cross-sectional study
Gehlsen et al.[60]	1990	U.S.A.	55 elderly persons (19 men and 36 women, mean age 71)	A significant difference in OLS time (with eyes open) was observed between the fallers (18.7 s) and the non-fallers (10.9 s) ($p < 0.001$)	Cross-sectional study
Heitmann et al.[56]	1989	U.S.A.	113 healthy women (mean age 74)	No difference in OLS time was found between the fallers and the non-fallers	Cross-sectional study limited to women
Briggs et al.[27]	1989	U.S.A.	73 noninstitutionalized elderly women (mean age 72)	No difference in OLS time was found between the fallers and the non-fallers	Cross-sectional study limited to women
Suzuki et al.[61]	1999	Japan	685 elderly aged 65 years or over (278 men, 407 women)	The adjusted OR for experience of falls was not statistically significant related to OLS time (data not shown in the article)	Cohort study for 5 years
Hill et al.[66]	1999	Australia	96 community-dwelling women (mean age 74)	The OR of falls for a 1-second decrease in OLS time was 1.03 (95% CI: 0.99–1.08)	One-year cohort study limited to women
Vellas et al.[63]	1998	U.S.A.	482 volunteers (198 men and 284 women, mean age 74)	OLS was not a risk factor in a multivariate analysis of controlling confounders (OR of falls = 1.07, 95% CI: 0.85–1.35)	Cohort study for 2 years
Yasumura et al.[62]	1994	Japan	658 elderly aged 65 years or over (276 men, 409 women)	OLS time predicted the risk for falls in a univariate analysis. However, there was no significant association in a multivariate analysis	Cohort study for 1 year
Maki et al.[65]	1994	Canada	100 volunteers (17 men and 83 women, mean age 83)	OLS time (with eyes closed) was shorter for the fallers (1.6 s) than the non-fallers (2.2 s) ($p = 0.02$)	Cohort study for 1 year
Tinetti et al.[64]	1988	U.S.A.	336 elderly persons (151 men and 185 women, mean age 78)	The adjusted OR of falls was 1.9 (95% CI: 1.0–3.7) when 6–7 balance and gait abnormalities were compared with 0–2	Cohort study for 1 year. OLS was one item of balance tests used
Activities of dailry living (ADL) including instrumental ADL (IADL)					
Drusini et al.[32]	2002	Italy	102 elderly persons (29 men and 73 women, mean age 83)	Statistically significant difference in ADL were observed according to OLS categories ($p < 0.001$)	Cross-sectional study

Table 2. *Continued*

Outcome Author	Year	Country	Population	Results	Comments
Vellas et al.[31]	1997	France	512 elderly persons (147 men and 365 women, mean age 73)	Multivariate analysis revealed that having at least one IADL incapacity was related to having OLS abnormality defined as being unable to stand at least 5 seconds (OR = 1.85, 95% CI: 1.10–3.07)	Cross-sectional study
Lin et al.[67]	2004	Taiwan	1,200 older people (709 men and 491 women, mean age 73)	The adjusted OR of ADL decline was 0.98 (95% CI: 0.97–0.99) for a 1-second decrease in OLS time. No relationship between OLS time and falls was observed	Cohort study for 1 year
Shinkai et al.[68]	2000	Japan	748 people aged 65 years and older	The adjusted hazard ratio of functional dependence was 3.69 (95% CI: 1.87–7.26) among those aged 75 years or more when the worst quatile group was compared with the best	Cohort study for 6 years
Osteoporosis					
Lindsey et al.[70]	2005	USA	116 healthy Caucasian women (mean age 68)	OLS time correlated with femoral neck and whole body bone mineral density (BMD) ($P = 0.02$ and 0.03, respectively)	Cross-sectional study limited to women
Taaffe et al.[71]	2003	Australia	3041 healthy Caucasian and black subjects, aged 70–79 years (1471 men and 1570 women)	The OR of hip osteoporosis in the lowest quartile for balance among the Caucasian men was 1.81 (95% CI: 0.91–3.60) compared with the top quartile	Cross-sectional study. OLS was one of three balance tests used
Guillette-Guyonnet et al.[52]	2000	France	129 healthy women (mean age 81)	No positive association was recognized between osteoporosis (assessed from BMD at femoral neck) and OLS abnormality (defined as being unable to stand for at least 5 s) (OR = 1.27, 95% CI: 0.51–3.17)	Cross-sectional study limited to women
Lung function					
Jedrychowski et al.[72]	1990	Poland	559 male residents, aged 65–89 years	Multiple regression analysis revealed that a 100-ml increase in forced expiratory vital capacity was associated with elongation of OLS time by 1.40 s ($P < 0.01$)	Cross-sectional study
Physical activity					
Tanaka et al.[7]	2006	Japan	330 residents (196 men,134 women), aged ≥70 years	The results of stepwise regression analysis showed that OLS time was not associated with physical activity	Cross-sectional study
Body mass index					
Sergi et al.[20]	2007	Italy	2672 individuals (1436 men, 1236 women), aged 65–84 years	Compared with those showing good performance on OLS (≥2 s), the OR of severe obesity in those with poor OLS performance was 6.30 (95% CI: 1.70–21.33) among the men and 3.93 (1.87–8.27) among the women	Cross-sectional study

OLS, one-leg standing; OR, odds ratio; CI, confidence interval

decline" (19.7 s) than in the control group (36.8 s) ($P < 0.05$).[4]

No relation between decreased OLS time and elevated risk of falls was found in two Japanese population-based studies using a prospective longitudinal design,[61,62] or in a similar U.S. study.[63] However, in another three studies, the OLS time was found to predict future falls. Tinetti et al. reported that balance and gait abnormalities were associated with future falls: The adjusted odds ratio (OR) of falls was 1.9 [95% confidence interval (CI): 1.0–3.7] when six or seven balance and gait abnormalities were compared with none to two.[64] In their study, however, because balance and gait scores were calculated not only from OLS times but also from three other balance tests (sitting down, turning, gentle push on sternum) and three gait tests (trunk sway, pick up walking pace, path deviation), careful interpretation is needed. Two cohort studies involving 1-year follow-up in Canada[65] and Australia[66] also identified a relation between decreased OLS time and falls.

Declines in ADL

Several studies have shown that the OLS test can be used as a marker of a decline in ADL, including IADL. Drusini et al. divided 102 subjects into three groups according to OLS times: a "normal group," an "adaptive group," and an "abnormal group."[32] Members of the normal group (those with OLS times of ≥5 s) had IADL dependence scores 2.1 and 2.7 points lower than members of the adaptive group (those who stood for 5 s but had apparent difficulty maintaining balance) and those of the abnormal group (those unable to complete the test), respectively. Vellas et al. reported that the presence of at least 1 IADL incapacity was related to an OLS abnormality defined as being unable to stand for at least 5 seconds (OR = 1.85, 95% CI: 1.10–3.07).[31] The above studies were cross-sectional studies, but two cohort studies have also been carried out. Lin et al. recruited 1200 people aged 65 years or older in Taichung County, Taiwan, and monitored them for 1 year. They observed that a shorter OLS time predicted a decline in ADL, with an adjusted OR of ADL decline of 0.98 (95% CI 0.97–0.99) for a 1-s decrease in OLS time.[67] Shinkai et al. followed 748 people aged 65 years or older in Akita Prefecture, Japan for 6 years, and reported that the OLS test was predictive of the onset of functional dependence defined as a new disability in one or more of the five basic ADLs.[68] They divided men and women into quartiles according to the OLS time. The adjusted hazard ratio of functional dependence was 2.53 (95% CI 1.40–4.55) in the age group 65–74 years and 3.69 (95% CI 1.87–7.26) in those aged ≥75 years when the worst quartile group was compared with the best.

Osteoporosis

It is known that declining physical performance is related to lower bone mineral density (BMD),[69] so a relation between the OLS and osteoporosis can be predicted. Lindsey et al. recruited 116 healthy Caucasian women aged 57.4–88.6 years and found that the OLS times (with eyes open) correlated significantly with femoral neck and whole body BMD ($r = 0.21$, $P = 0.02$; $r = 0.22$, $P = 0.03$, respectively).[70] Taaffe et al. used the OLS test as one of three balance tests in a study of 3041 Black and Caucasian men and women aged 70–79 years.[71] The adjusted OR of hip osteoporosis in the lowest quartile for balance was 1.53 (95% CI 0.90–2.61) for the Caucasian women and 1.81 (95% CI 0.91–3.60) for the Caucasian men, compared with the top quartile. The balance test results, including those for OLS, were moderately related to BMD. In contrast, Gillette-Guyonnet et al. carried out a cross-sectional study of 129 French women aged 75–89 years to investigate whether they were able to stand on one leg for 5 s (presumably with their eyes closed); they found no association between the presence of osteoporosis and the OLS tests (adjusted OR of abnormal OLS = 1.27, 95% CI 0.51–3.17).[52]

Other points

Jedrychowski et al. have shown that a decreased OLS time reflects physical deterioration, and that a 100-ml increase in forced expiratory vital capacity was associated with elongation of the OLS time by 1.40 s ($P < 0.01$).[72] In the same study, the OLS time was also shown to correlate with the subjects' self-assessment of their health status. Another study of 2672 Italian men and women demonstrated an association between the OLS time and the body mass index (BMI). When the reference was good performance in OLS (≥2 s), the OR of severe obesity in those with poor OLS performance was 6.03 (95% CI 1.70–21.33) among the men and 3.93 (95% CI:1.87–8.27) among the women.[20] Tanaka et al. observed a relation between OLS time and physical activity in a univariate analysis, but the relation disappeared in a stepwise regression analysis.[7]

Summary

Overall, this section points to associations between OLS time and falls, declines in ADL, and other morbidity including osteoporosis. In particular, the relations of OLS time with falls and osteoporosis suggest that decreased OLS time is associated with an increased prevalence of fracture. Although additional evidence is needed, the OLS test appears promising as a screening tool to detect frailty among elderly people.

However, the inconsistent results do not allow us to conclude definitively that there is an association between OLS time and falls. The discrepancies in the results may

be partially explained by differential or nondifferential misclassifications caused by different individual interpretations of falls. Further longitudinal studies in which efforts are made to minimize the misclassification of falls are needed.

Improvement of OLS time by intervention

We also discussed whether the OLS time can be improved by intervention, such as balance exercises. Extension of OLS time is important because decreased OLS time may predict negative events, including falls and declines in ADL, as noted in the previous section.[73,74] Fifteen randomized controlled trials were reviewed (Table 3).

Interventions likely to be effective

There were seven trials where the intervention programs successfully extended the OLS time when compared to the reference groups. The programs used in the trials varied from study to study, but those typically used were balance exercises, resistance training, and strength and endurance training. The study populations, sample sizes, and durations of the training programs also varied from study to study.

Islam et al. reported a trial involving 29 elderly volunteers in Nagoya, Japan. The subjects were randomly assigned to two groups: a balance training group that participated for 12 weeks (two sessions per week) in a supervised exercise program that included balance training for the visual, vestibular, somatosensory, and muscular systems or a control group.[75] The OLS time was extended by 3.6 s (an 82% increase from the baseline measurement) in the training group ($P = 0.04$); no change was noted in the control group. Kalapotharakos et al. assigned 33 volunteers to one of three groups: a control group, a high resistance exercise group (80% of one-repetition maximum), and a moderate resistance exercise group (60% of one-repetition maximum) resistance exercise.[76] The 12-week resistance exercise program involved the major muscles of both the upper and lower body and was carried out on six home exercise machines. The resistance exercises improved the OLS time (with eyes open) from 50.9 to 85.4 s in the high resistance group and from 37.4 to 77.5 s in the moderate resistance group. Hu and Woollacott also reported effective balance training in a trial with 24 volunteers.[77] The training program involved the subjects standing barefoot on a platform system for 1 h per day for 10 days while sensory inputs affecting postural stability were systematically manipulated.

In addition to these three small-sample studies, several larger studies have been reported. Rooks et al. randomly divided 131 elderly persons living independently into three groups: a resistance training group, a walking group, and a control group.[47] The resistance training program, which was carried out three times per week for 10 months, was designed to strengthen hip and knee extension and ankle plantar flexion and dorsiflexion. The OLS time (with eyes open) was improved from 19.7 to 39.1 s (98% increase; $P < 0.001$) by resistance training and from 15.7 to 21.8 s (39% increase; $P = 0.04$) by walking; no significant improvement was noted in the control group (from 17.9 to 22.5 s, $P = 0.13$). Wolfson et al. recruited 110 healthy individuals residing in West Hartford, Connecticut (USA), randomly assigning them to one of four groups: a balance group, a strength group, a balance and strength group, and a control group.[78] The balance training consisted of equilibrium control exercises on firm foam surfaces and center-of-pressure biofeedback; the strength training included lower extremity weightlifting three times per week for 3 months. The adjusted mean change after intervention from baseline was 7.0 s ($P < 0.01$) in the balance group and 5.3 s ($P < 0.05$) in the strength group.

It is interesting to note that ancient conditioning exercises such as Tai-Chi and yoga improved OLS times. Li et al. recruited 256 community-dwelling adults in Portland, Oregon (USA) and designed a randomized controlled trial involving two intervention arms: Tai-Chi and stretching control; both were carried out three times per week for 6 months.[22] The OLS time (with eyes both open and closed) was roughly doubled in the Tai Chi group. A randomized controlled trial by Oken et al. demonstrated that Yoga intervention improved the OLS time (with eyes open) from 29.6 to 39.2 s ($P < 0.05$).[79]

Interventions unlikely to be effective

In eight of the trials we investigated, interventions seemed to be ineffective in improving OLS time. Obuchi et al. compared perturbed treadmill training, which involves simulated falling through sudden, random acceleration or deceleration of the treadmill belts, with ordinary treadmill training for 4 weeks and observed no differences.[80] A study by Shimada et al. indicated that neither balance exercise nor gait exercise two or three times weekly for 12 weeks was effective.[81] The balance training program consisted of 30 repeated forward reaching exercises, 10 min of center-of-mass movement using a balance board, 5 min of OLS, and 5 min of tandem standing. Other studies indicated no improvement in the OLS time as a result of strength and endurance exercises for 12 weeks[48] or 24–26 weeks,[82] general gymnastic and balance exercises twice a week for 9 weeks,[83] or wearing a body weight vest to gain lower extremity strength.[84]

Two larger studies also provided no evidence of improvement in the OLS time as a result of intervention. Jette et al. randomly assigned 215 older persons

Table 3. Effects of intervention programs on OLS time demonstrated in randomized controlled trials in community-dwelling elderly populations

Author	Year	Country	Subjects	Training program	Results
Likely to be effective					
Oken et al.[79]	2006	USA	135 healthy people (34 men, 101 women), mean age 72 years	Yoga for 6 months	OLS time (with eyes open) in the Yoga group significantly extended from 29.6 to 39.2 s
Li et al.[22]	2005	USA	256 people (77 men, 179 women), mean age 77 years	Tai Chi training for 6 months (3 times/ week)	The Tai Chi participants showed significant improvement in OLS time (both with eyes open and closed)
Islam et al.[75]	2004	Japan	29 volunteers (10 men, 19 women), mean age 76 years	12-week (2 days/week, 60 min/day) supervised balance exercises	OLS time increased by 3.6 s, an 82% increase from the baseline measurement
Kalapotharakos et al.[76]	2004	Greece	33 volunteers (12 men, 21 women), mean age 67 years	Resistance exercise (high and moderate) for 12 weeks (3 days/ week)	OLS time extended from 50.9 to 85.4 s in the high exercise group, and from 37.4 to 77.5 s in the moderate exercise group
Rooks et al.[47]	1997	USA	131 elderly persons (60 men, 71 women), mean age 74 years	Self-paced resistance training or walking exercise for 10 months	OLS time (with eyes open) improved from 19.7 to 39.1 s in the resistance group and from 15.7 to 21.8 s in the walking group
Wolfson et al.[78]	1996	USA	110 volunteers (64 men, 46 women), mean age 79 years	Balance and/or strength training for 3 months (3 days/ week)	OLS time was improved by both balance training (adjusted mean change 7.0 s) and by strength training (5.3 s)
Hu et al.[77]	1994	China	24 volunteers (7 men, 17 women), mean age 75 years	Multisensory training program for 10 h (1 h each day)	A significantly greater improvement in OLS time was observed in the training group than in the control group
Unlikely to be effective					
Obuchi et al.[80]	2004	Japan	29 persons (16 men, 13 women), mean age 69 years	Treadmill training with perturbation for 4 weeks (2 times/week, 15 min/time)	There were no improvements in OLS time (with eyes open or closed)
Shimada et al.[81]	2003	Japan	34 volunteers (5 men, 29 women), mean age 81 years	(1) Balance exercise or (2) gait exercise, each for 12 weeks (2–3 times/week, 40 min/time)	Although OLS time improved in both intervention groups, there were no differences compared with the control
Rubenstein et al.[48]	2000	USA	59 community-living men, mean age 74 years	Strength and endurance exercises for 12 weeks (3 times/week, 90 min/ time)	Exercise achieved no significant effect on OLS time
Greendale et al.[84]	2000	USA	62 volunteers (16 men, 46 women), mean age 74 years	Use 3% or 5% body weight vest for 27 weeks (2 h daily, 4 days/week)	Neither the 3% nor 5% weighted vest had any effect on OLS time
Jette et al.[26]	1999	USA	215 older persons (48 men, 167 women), mean age 75 years	Home-based resistance training for 6 months	No statistically significant difference in OLS time was detected between training and control groups
Buchner et al.[82]	1997	USA	105 adults (51 men, 54 women), mean age 75 years	Endurance training and/or strength training for 24–26 weeks (3 times/week, 60 min/time)	There were no effects of exercise on OLS time
Reinsch et al.[25]	1992	USA	230 volunteers (45 men, 185 women), mean age 74 years	Exercise and/or cognitive interventions for 1 year (1 h, 3 days/ week)	OLS time did not differ after 1 year for any of the intervention groups
Ledin et al.[83]	1990	Sweden	30 adults (14 men, 15 women, 1 unknown), mean age 73 years	Balance training for 9 weeks (twice/week)	No statistically significant difference in improvement of OLS time was detected between the training group and controls

OLS, one-leg standing

into two groups: (1) a home-based resistance exercise program comprised of 5 min of warm-up, 25 min of strengthening, and 5 min of cool-down; and (2) a waiting list for 6 months.[26] Reinsch et al. recruited 230 older adults, who participated in a 1-year exercise program consisting of strength and balance training, including stand-ups from a sitting position and step-ups onto a 6-inch high stepping stool.[25] In both studies, there was no difference between the intervention and control groups.

Preventing falls

In some of the articles taken up in this review, the effects of exercise intervention on preventing falls were examined. The Tai-Chi program used in Li's study reduced the frequency of severe falls requiring medical attention compared to the control group (relative risk for severe falls = 0.28, 95% CI 0.09–0.86).[22] The balance training in Hu's report successfully reduced the frequency of falls compared to the control group.[77] Although no effect on extending the OLS time was reported, Buchner et al.'s exercise programs produced a statistically significant effect on time to the first fall (relative hazard for the first fall in the exercise group = 0.53, 95% CI 0.30–0.91),[82] and Rubenstein et al.'s programs reduced the fall rate (6.0 falls/1000 h of activity in the exercise group compared to 16.2 falls/1000 h of activity in the control group, $P = 0.027$).[48] However, one intervention trial failed to show any decrease in the number of repeat fallers.[25] The proportion of repeat fallers was 45.5% in the exercise group, 52.9% in the cognitive group, and 30.3% in the exercise-cognitive group; the control group had the lowest proportion of repeat fallers (29.4%).

The OLS test has been also used as an intervention exercises in a randomized controlled trial to prevent falls and hip fracture carried out by the Japanese Orthopaedic Association's Osteoporosis Committee, although the participants were all nursing home residents.[17] After 6 months of OLS exercise, there were fewer falls in the intervention group (cumulative number of falls = 118, $n = 314$) than in the control group (cumulative number of falls = 121, $n = 212$) ($P = 0.006$).

Summary

Several intervention studies suggested that it is possible to improve elderly people's OLS times. Theoretically, extension of the OLS time by intervention could lead to the prevention of negative events including falls, declines in ADL, other morbidity, and even fractures.

However, much work is still needed to determine the appropriate types, intensity, frequency and duration of exercise to achieve this end. The effectiveness of intervention in ordinary clinical and community settings as well as in ideal experimental situations should also be investigated. In addition, evaluation of the cost-effectiveness of intervention is important from the public health perspective.

Methodological issues

To our knowledge, this is the first review article summarizing the findings of epidemiological studies concerning the OLS test in community-dwelling elderly populations. Despite this advantage, our review should be interpreted with caution because we did not confirm the evidence level of each of the studies we selected. Further research on this topic is needed.

Conclusions

We have summarized the findings according to the type of epidemiological study, both descriptive and analytical, on the OLS test. With respect to the descriptive studies, the measured values for OLS time varied widely from study to study owing to the various procedures used. Overall, the analytical studies carried out in community settings suggest that the OLS test can be used as a practical marker to screen the elderly for frailty and that the OLS time can be improved by various exercises.

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ORIGINAL ARTICLE

Clinical outcomes of microendoscopic decompression surgery for cervical myelopathy

Akihito Minamide · Munehito Yoshida · Hiroshi Yamada · Yukihiro Nakagawa · Kazuhiro Maio · Masaki Kawai · Hiroshi Iwasaki

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Abstract Retrospective study on the results of microendoscopic decompression surgery for the treatment of cervical myelopathy. The purpose of this study was to describe the microendoscopic laminoplasty (MEL) technique as the surgical method in the treatment of cervical myelopathy, and to document the clinical outcomes for MEL surgery. Endoscopic surgery poses several challenges for the aspiring endoscopic surgeons, the most critical of which is mastering hand–eye coordination. With training in live animal and cadaver surgery, the technical progress has reduced the problem of morbidity following surgery. The authors have performed microendoscopic decompression surgery on more than 2,000 patients for lumbar spinal canal stenosis. Fifty-one patients underwent the posterior decompression surgery using microendoscopy for cervical myelopathy at authors' institute. The average age was 62.9 years. The criteria for exclusion were cervical myelopathy with tumor, trauma, severe ossification of posterior longitudinal ligament, rheumatoid arthritis, pyogenic spondylitises, destructive spondylo-arthropathies, and other combined spinal lesions. The items evaluated were neurological evaluation, recovery rates; these were calculated following examination using the Hirabayashi's method with the criteria proposed by the Japanese Orthopaedic Association scoring system (JOA score). The mean follow-up period was 20.3 months. The average of JOA score was 10.1 points at the initial examination and 13.6 points at the final follow-up. The average recovery rate was 52.5%. The recovery rate according to surgical levels was, respectively, 56.5% in one level, 46.3% in two levels and 54.1% in more than three levels. The complications were as follows: one patient sustained a pin-hole-like dura mater injury inflicted by a high-speed air-drill during surgery, one patient developed an epidural hematoma 3 days after surgery, and two patients had the C5 nerve root palsy after surgery. The epidural hematoma was removed by the microendoscopy. All two C5 palsy improved with conservative therapy, such as a neck collar. These four patients on complications have returned to work at the final follow-up. This observation suggests that the clinical outcomes of microendoscopic surgery for cervical myelopathy were excellent or showed good results. This minimally invasive technique would be helpful in choosing a surgical method for cervical myelopathy.

Keywords Cervical spine · Clinical outcome · Endoscopic surgery · Laminoplasty · Myelopathy

A. Minamide (✉) · M. Yoshida · H. Yamada · Y. Nakagawa · K. Maio · M. Kawai · H. Iwasaki
Department of Orthopaedic Surgery,
Wakayama Medical University,
811-1 Kimiidera, Wakayama City,
Wakayama 641-8510, Japan
e-mail: minamide@wakayama-med.ac.jp

Introduction

Minimally invasive spinal procedures are currently being used effectively to treat a variety of commonly encountered degenerative conditions of the lumbar [7, 9, 13, 16], thoracic [10] and cervical spine [1, 4, 21]. These developments have led to surgical approaches to the spine that can result in less tissue trauma and reduce a patient's postoperative pain and discomfort, shorten hospital stays, and allow a quicker return to activities of daily living.

Endoscopic surgery poses several challenges for the aspiring endoscopic surgeons, the most critical of which is mastering hand–eye coordination. With training in live

animal and cadaver surgery, the technical progress has reduced some problems of morbidity following surgery, such as dural tear, neural deficit, and so on [5]. Recently, microendoscopic decompressive techniques have been developed and applied to various spine pathologies including lumbar spinal stenosis and cervical radiculopathy and myelopathy [1, 4, 7, 9, 13, 16, 21]. Over 2,000 patients of lumbar spinal canal stenosis have undergone the microendoscopic decompression surgery in authors' institution. The authors have been applying microendoscopic laminoplasty (MEL) as a minimally invasive strategy to cervical posterior decompression surgery. The purpose of this study was to describe the MEL technique (used in 51 patients) as the surgical method in the treatment of cervical myelopathy, and to document the clinical outcomes for MEL surgery.

Materials and methods

Surgical technique of cervical microendoscopic laminoplasty (C-MEL)

General endotracheal anesthesia was induced with adequate intravenous access and an intra-arterial monitoring catheter. The patient was secured in a Mayfield headholder, and was turned to the prone position. The neck was fixed in a neutral position. The fluoroscopic C-arm was brought into the surgical field so that real-time lateral fluoroscopic images could be obtained. The operator generally stood on the side of the approach and video monitors placed opposite to him. Under fluoroscopic guidance held laterally to the patient, the targeting level was marked on the side of the approach. A skin incision approximately 17 mm in length was made at the spinal level to be decompressed. The microendoscopic discectomy (MED) and instrumentation developed by Smith and Foley [16] for lumbar disc disease were used for this procedure. After splitting into paravertebral muscles, the set of serial dilators of the METRx endoscopic system (Medtronic Sofamor Danek, Memphis, TN, USA) was passed to gently dilate the cervical musculature. The 16-mm final working channel was then passed over the dilators and secured to the flexible-arm of the METRx retractor mounted to the table side rail. Final fluoroscopic confirmation of the working channel position was obtained, and the serial dilators were removed. The tubular retractor lay on the lamina and facet joints (Fig. 1), and was tilted parallel to the intervertebral disc (Fig. 2). The endoscope was then attached to the tubular retractor. Bipolar cautery was used to remove any residual muscular and soft tissues overlying the lamina and facet joint in the tubular retractor. With the bony edges well visualized, a small angled endoscopic curette was used

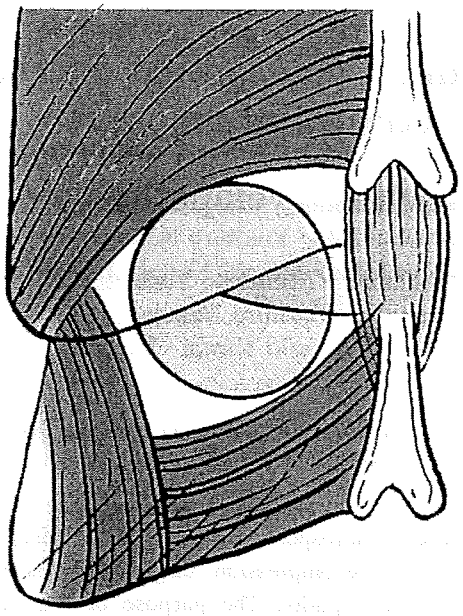

Fig. 1 The tubular retractor of microendoscopic system lies on the lamina and facet joint

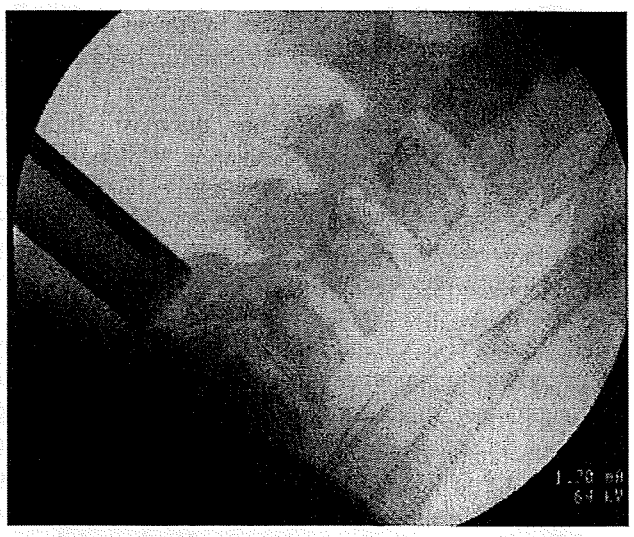

Fig. 2 The tubular retractor of microendoscopic system is tilted to the direction of the intervertebral disc. The setting position is confirmed by X-ray

to confirm the inter-lamina space and the medial edge of the fact complex. To begin the partial laminectomy (Fig. 3a), a high-speed drill with a long curved endoscopic bit (e.g., Midas-Rex) was used to thin the lamina near the attachment of ligamentum flavum. After adequate drilling, endoscopic Kerrison's rongeurs were used to continue the removal of the lamina. The superior attachment of ligamentum flavum was exposed, and the procedure was then continued to the superior portion of the inferior lamina. The inferior attachment of ligamentum flavum was

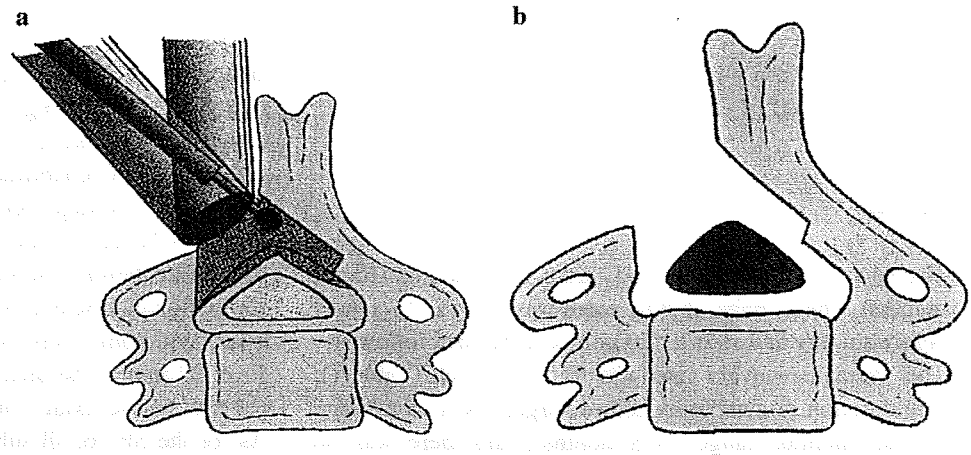

Fig. 3 The decompression surgery is preformed using a high-speed air-drill. **a** The hemilaminectomy is performed on the approaching side, and then the laminotomy on the contralateral side is done. **b** Finally, the laminoplasty is completed to enlarge the spinal canal

exposed. The endoscope was then swung medially and downward to obtain a contralateral view. After the basement of spinal process was drilled, the laminotomy was performed by a long curved high-speed drill with an endoscopic bit (Fig. 3b). The scope was rotated to a lateral position to make use of its 25° viewing angle. As a result of these maneuvers, an excellent viewing angle of nearly 60 to 75° was usually obtained with good contralateral visualization. It was important to continue the contralateral procedure without removing the ligamentum flavum to protect the spinal cord. When the spinal cord was completely decompressed, the floated ligamentum flavum was observed. Attention was directed to removing the ligamentum flavum. A small angled curette, nerve hook, or endoscopic Kerrison's rongeurs was used to gently dissect the ligament and to identify the plane between the ligamentum flavum and the underlying dura. When the ligamentum flavum was completely removed, the dural pulsation was observed. The C-MEL was completed (Fig. 3c). When the decompression surgery was needed for an adjacent level, the tubular retractor was inclined cranially or caudally. Then, the procedure as the above was added to the adjacent level. For more than three levels another skin incision was added. For example, in case of C3–C7 C-MEL, the skin incisions were made on C4 and C6 levels. A drain was placed at each level to prevent epidural hematoma after surgery. The tubular retractor and endoscope were removed, and the fascia and skin were closed using standard techniques. The drain was placed at the operative level(s) for 48 h to prevent the epidural hematoma after surgery.

Patient population

Between 2003 and 2008, a total of 51 patients with cervical myelopathy underwent this C-MEL at authors' institution. The criteria for exclusion were cervical myelopathy with tumor, trauma, severe ossification of posterior longitudinal ligament (OPLL), rheumatoid arthritis, pyogenic spondylitises, destructive spondylo-arthropathies, and other combined spinal lesion. There were 34 males and 17 females. The average age at the time of surgery was 62.9 years (range 24–85 years). All patients presented with symptoms of cervical myelopathy, such as clumsiness, numbness of upper and lower extremities, gait disturbance, and urinary disturbance. There were 44 patients with cervical spondylotic myelopathy (CSM), 4 patients with cervical myelopathy due to the calcification of ligamentum flavum (CLF), and 3 patients with cervical intervertebral disc herniation. The spinal cord compression was confirmed by magnetic resonance imaging (MRI), myelography and post-myelography computed tomography (CTM). The following items were assessed both pre- and postoperatively. A contributed lesion was reviewed by a symptom, neurological deficiency and imaging. As much as 26 patients suffered cervical myelopathy on one level, 17 patients on two levels, and 8 patients on more than three levels. These items evaluated were clinical outcomes including complications, neurological evaluation, and recovery rates, which were calculated following examination using Hirabayashi's method with the criteria proposed by the Japanese Orthopaedic Association scoring system (JOA score) [6, 22], blood loss during surgery, change of C reactive protein (CRP), visual analog scale (VAS) for assessment of treatment of axial pain, Short Form 36 (SF-36). The recovery rate was calculated as follows: recovery rate = 100 × (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score).

Statistical analysis

All parameters were analyzed statistically. Either nonparametric Kruskal–Wallis test or Spearman's correlation coefficient by rank test was used to test differences in the recovery rate of JOA score between groups. The Mann–Whitney *U* test was used to test differences in the SF-36

subscales between preoperative and the final follow-up. A probability level of <0.05 was considered significant.

Results

The mean follow-up period was 20.3 months (6–56 months). The average of JOA score was 10.1 ± 2.7 points before surgery and 13.6 ± 2.3 points at the final follow-up. The average recovery rate was 52.5 ± 20.3% (Table 1). The duration of symptoms before surgery was an average of 20.1 months (range 1–78 months), and there was no correlation between the duration of symptoms and recovery rates (Spearman's correlation coefficient by rank test; $p = 0.6$). As for the contributed levels, the recovery rate was 56.5% on one level, 46.3% on two levels, and 54.1% on more than 3 levels. There were no significant differences between the contributed levels and recovery rates (Kruskal–Wallis test; $p = 0.065$). Four patients had some perioperative complications. One patient sustained a pin-hole-like dura mater injury inflicted by a high-speed air-drill during surgery. There was little leakage of the cerebrospinal fluid. So, fibrin paste was wound up on dura mater. In another patient who had undergone the C-MEL on one level, although the postoperative drain was retained on the epidural space for 48 h, the spinal cord was compressed by the epidural hematoma 3 days after surgery. He had the progressive quadriplegia, and underwent the emergency surgery to remove the epidural hematoma using microendoscopy. His quadriplegia improved immediately after surgery. After the C-MEL surgery on two or three levels, there were two patients who had temporal C5 nerve root palsy. These two patients were not able to evaluate their upper extremity on the corresponded side to the opened lamina (hemilaminectomy). Their neurological symptoms improved with conservative treatment on a Philadelphia collar. Both patients were able to evaluate their upper extremity a few months later. One of the two patients improved to a full score in manual muscle testing (MMT) for both deltoid and biceps muscles.

The mean amount of blood loss in surgery was 35.4 ml on one level, 22.9 ml on two levels, and 44.4 ml on more than three levels. The surgical time was an average of 106 min on one level, 146.4 min on two levels, and 178.2 min on more than three levels. The mean value of CRP 3 days after surgery was 1.1 ± 1.4 mg/dl (normal: <0.3). All patients could get up after awakening from anesthesia immediately and participated in rehabilitation from an early postoperative period. The average period of hospital stay was 8.6 days (range 4–21 days). There was no correlation between the JOA score before surgery and hospital stay (Spearman's correlation coefficient by rank test; $p = 0.28$). The VAS of axial symptoms was 46 ± 45 mm before surgery and 15 ± 22 mm at the final follow-up. There was none of the patients whose axial symptoms worsened postoperatively. As for the SF-36, all subscales at the final follow-up have been improved. The scores of role physical, bodily pain, social functioning, and role emotional subscales at the final follow-up were significantly higher than that before surgery (Mann–Whitney U test; $p < 0.05$, Fig. 4). On the alignment of cervical spine after surgery, no patient changed to kyphosis postoperatively. The lordotic angle of cervical spine (C2–C7) was 13.1 ± 14.0° before surgery and 13.5 ± 14.9° at the final follow-up (Table 1). The local angle of the surgical level was 6.7 ± 10.4° before surgery and 6.7 ± 9.1° at the final follow-up.

Table 1 JOA score and cervical alignment after C-MEL surgery

	Pre-operation	Final follow-up
JOA score (points)	10.1 ± 2.7	13.6 ± 2.3
Recovery rate (%) (JOA score)		52.5 ± 20.3
Lordotic angle (degree) (C2–C7)	13.1 ± 14.0	13.5 ± 14.9

Case presentation

Case 1

A 59-year-old woman noticed clumsiness in her finger motions and numbness in both her hands. She attended the authors' clinic, where she presented in a wheelchair and revealed urinary disturbance. An MRI and CTM showed severe spinal compression caused by the calcification of

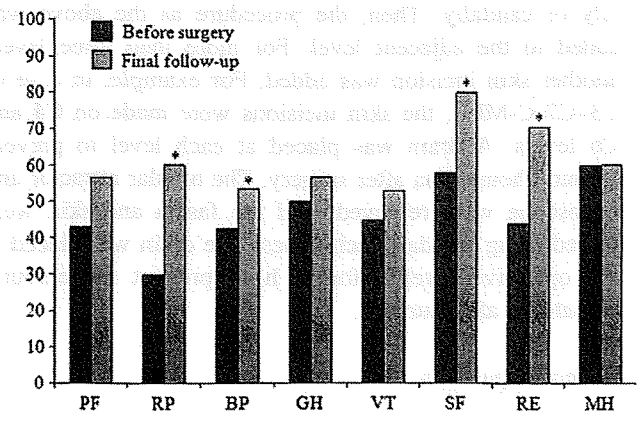

Fig. 4 All subscales at the final follow-up have been improved. The scores of RP, BP, SF, and RE subscales at the final follow-up were significantly higher than that before surgery. (*PF* physical functioning, *RP* role physical, *BP* bodily pain, *SF* social functioning, *GH* general health perceptions, *VT* vitality, *RE* role emotional, *MH* mental health) Significantly different from before surgery (Mann–Whitney U test, $*p < 0.05$)