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ORIGINAL ARTICLE

Physical performance tests are useful for evaluating and monitoring the severity of locomotive syndrome

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Abstract

Background The concept of the locomotive syndrome (LS), first proposed in Japan in 2007, has become widely accepted, and the 25-question Geriatric Locomotive Function Scale (GLFS-25), a quantitative, evidence-based diagnostic tool for LS, has been developed. However, the association between the GLFS-25 score and the outcome of physical capacity tests has never been investigated. Furthermore, which physical tests are good indices for evaluating and monitoring the severity of locomotive syndrome have not been identified. In addition, the impact of knee and low back pain on locomotive syndrome is unclear. The purpose of this study is to confirm the validity of GLFS-25 by demonstrating its significant correlation with the outcome of physical function tests and to determine which tests are good indicators for monitoring the severity of LS. The secondary aim of the project is to investigate how much influence knee and low back pain may have on the LS of the middle-aged and elderly.

Methods A total of 358 subjects were drawn from a general health checkup in a rural area of Japan. We measured back muscle strength, grip strength, one-leg standing time with eyes open, 10-m gait time, timed up-and-go test, maximum stride, functional reach, height, weight, % body fat and bone mineral density, and we obtained a visual analog scale of low back pain and knee pain. The degree of the locomotive syndrome was evaluated using the GLFS-25. Associations of all the variables with the GLFS-25 score were analyzed using both univariate and multivariate analyses.

Results The GLFS-25 score was significantly higher in females than in males in both the total and in the age older than 60 years groups. The GLFS-25 score showed a significant positive correlation with age ($r = 0.360$), knee pain ($r = 0.576$), low back pain ($r = 0.526$), timed up-and-go test ($r = 0.688$) and 10-m gait time ($r = 0.634$), and it showed a significant negative correlation with one-leg standing time with eyes open ($r = -0.458$), maximum stride ($r = -0.408$), functional reach test ($r = -0.380$), back muscle strength ($r = -0.364$) and grip strength ($r = -0.280$). Multiple regression analysis indicated that knee pain ($\beta = 0.282$), low back pain ($\beta = 0.304$), one-leg standing time ($\beta = -0.116$), timed up-and-go test ($\beta = -0.319$) and back muscle strength ($\beta = -0.090$) were significantly associated with the GLFS-25 score. Grip strength ($\beta = -0.99$) was a good substitute for back muscle strength in the multiple regression analysis.

Conclusions We confirmed the validity of GLFS-25 by demonstrating a significant correlation and association of its score with the outcome of a series of functional performance tests. One-leg standing time with eyes open, timed up-and-go test and grip strength proved to be easy, reliable and safe performance tests to evaluate and monitor an individual's severity of LS as a complement to the GLFS-25. We also proved that knee and low back pain significantly impact the degree of LS.

Introduction

With the aging of the population, rising disability rates are becoming an increasingly important issue because of increasing health care costs as well as the associated

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impairment in the quality of life (QOL) of the elderly [1]. A recent National Livelihood Survey by the Ministry of Health, Labour and Welfare in Japan ranks osteoarthritis (OA) fourth, and falls and osteoporotic fractures fifth among diseases causing disabilities that subsequently require support for individuals' activities of daily living (ADLs) [2]. This means that orthopedic problems are one of the main reasons people require long-term care. Measures to prevent disabilities of the locomotive organs are urgently needed. The Japanese Orthopaedic Association proposed a new concept, locomotive syndrome, to designate middle-aged and elderly people at high risk of becoming in need of care service because of problems of the locomotive components [3]. Locomotive syndrome (LS) is a socioeconomic concept rather than disease entity. Therefore, the diagnosis of LS is ambiguous. Recently, however, a precise, quantitative and evidence-based screening tool called the GLFS-25 has been developed to measure the degree of LS affecting an individual, and its validity and reliability have been confirmed [4]. It is a questionnaire composed of 25 questions regarding a person's difficulty in performing physical motions required for daily living, each of which is scored from 0 to 4 points, with the total score ranging from 0 to 100 points. A person with a GLFS-25 score of 16 points or higher is diagnosed as having LS. Its validity was confirmed by demonstrating significant correlation with the European Quality of Life Scale-5 Dimensions (EQ-5D), which was used as an external control in the study [4]. The EQ-5D is a five-dimension health state classification, considering the following areas: mobility, self care, usual activities, pain/discomfort and anxiety/depression; it is a representative instrument to measure health-related quality of life [5]. Attending physicians filled out the patient information sheet and judged the locomotive function of participants according to the modified six-grade scale proposed by the Japanese long-term care insurance system (Kaigo Hoken) [6]. The judged grade was then compared to the GLFS-25 score, and 16 was decided on as the cutoff point for having LS. Therefore, a limitation in developing the GLFS-25 score is that direct and objective information on the participants' actual functional capacity is lacking. Therefore, in this study we evaluated the correlation and association of the GLFS-25 score with the outcome of a series of physical performance tests to confirm the validity of the GLFS-25.

Knee pain and low back pain are major public health issues and important causes of physical impairment among the elderly populations of most developed countries [7, 8]. There is a high prevalence of knee pain and low back pain among elderly Japanese [7]. Few studies have assessed the association between knee pain and QOL, although there are reports on the association of low back pain and QOL issues [9, 10]. Our hypothesis is that knee pain and low back pain also have a great impact on LS in the elderly Japanese; however, there have not been any reports on this issue.

The purpose of this study is to confirm the validity of the GLFS-25 by demonstrating its significant correlation with the outcome of physical function tests and to determine which tests are good indicators for monitoring the severity of LS. The secondary aim of the project is to investigate how much influence knee and low back pain have on LS in the middle-aged and elderly populations.

Participants and methods

The subjects were healthy Japanese volunteers who attended a "basic health checkup" supported by the local government in 2011. This checkup has been held annually in Yakumo for 30 years and is well known among the local people. The current study involved 358 volunteers (128 men, 230 women) between the ages of 40–91 years (mean 66 ± 10 years). LS severity was evaluated using the GLFS-25 score [5]. We calculated knee and low back pain using a VAS of 10 cm from no pain to the worst possible pain. We defined the degree of osteoporosis as % YAM <70 % in the calcaneus measured by using an Achilles ultrasound bone densitometer (Lunar Corporation, Madison, WI, USA). The study protocol was approved by the Ethics Committee for Human Research of Nagoya University.

Back muscle strength and grip strength

We determined back muscle strength as the maximal isometric strength of the trunk muscles in a standing posture with 30° lumbar flexion using a digital back muscle strength meter (T.K.K.5102, Takei Co., Japan). The test was performed one time on 334 participants (124 men, 210 women). Grip strength was measured bilaterally in a standing position using a Toei Light handgrip dynamometer (Toei Light Co., Ltd., Saitama, Japan) in 358 participants (128 men, 230 women). Both hands were tested one time, and the average value was used to characterize the grip strength of the subject.

One-leg standing time with eyes open

One-leg standing time with eyes open was measured twice for each leg of 341 individuals (127 men, 214 women). The subject was timed starting from raising the leg until placing it back down on the floor for up to a maximum of 60 s [11]. We recorded the average value of the four measurements (two trials on each leg).

The 10-m gait time

We evaluated the 10-m gait time as a reflection of the mobility of 340 participants (127 men, 213 women). Walking time was the time required to complete a 10-m straight course. All participants walked the 10-m course once at their fastest pace.

Maximum stride

The maximum stride of 336 subjects (126 men, 210 women) was measured. A participant in standing position was told to put his/her right foot forward as far as he/she could, then to bring the left foot up to the right foot without touching the hands on the floor or on the knees. This was repeated with the left foot forward. The average value divided by the participant's height was used to characterize the maximum stride of the subject.

Timed up-and-go test (TUG)

The timed-up-and-go test was measured on 340 subjects (127 men, 213 women). We measured the time it took a subject to rise from a standard chair (46 cm seat height from the ground), walk a distance of 3 m, turn around, walk back to the chair and sit down [12]. Each subject performed the test two times, and the mean score was recorded.

Functional reach (FR)

Duncan first reported the method and meaning of measuring FR [13]. We measured FR using a functional reach meter (GB-200, OG Co., Japan) on 340 subjects (126 men, 213 women). The participant stood straight with both arms stretched out in front at 90° of shoulder flexion with wrists and fingers straight and palms facing down. The starting position was measured at the middle finger tip. The subject was instructed to reach either hand as far forward as possible without taking a step, and the position of the middle finger tip at the end of the reach was recorded. The distance between the starting point and the end point was the reach distance automatically measured in centimeters. The participant performed three trials on each hand with the average of the last two on both sides recorded.

Statistical analysis

All data are shown as means ± standard deviations (SD). We analyzed correlations between variables using Pearson's correlation coefficient and simple regression analysis. Further analyses using multiple regression were conducted to determine which variables best correlated with the degree of LS. We considered probability values of less than 0.05 as statistically significant. SPSS (version 18 for Windows, SPSS Inc., Armonk, NY, USA) was used for all statistical analyses.

Results

The mean values of the GLFS-25 scores of each age group are shown in Table 1. The older age group tended to have higher scores. The GLFS-25 score was significantly higher in females than in males in both the total and age older than 60 years groups. The mean values of age, pain scales and measured variables are listed in Table 2. The correlation between the GLFS-25 scores and the measured valuables are shown in Table 3. The GLFS-25 score had significant positive correlations with age ($r = 0.360$), knee pain ($r = 0.576$), low back pain ($r = 0.526$), TUG ($r = 0.688$) and 10-m gait time ($r = 0.634$). It had significant negative correlations with the one-leg standing time with eyes open ($r = -0.458$), maximum stride ($r = -0.408$), FR ($r = -0.380$) and grip strength ($r = -0.280$).

Based on these results, age, knee pain, low back pain, one-leg standing time, TUG, FR, 10-m gait time and back muscle strength were selected as independent variables in a multiple regression model for the GLFS-25 score. In this model, low back pain, knee pain, one-leg standing time, TUG and back muscle strength appeared to be significant contributors to the GLFS-25 score (Table 4). No other factors were significantly associated with the GLFS-25 score, including age. The coefficient of determination (R^2) in the multiple regression model was 0.637, indicating that 63.7 % of the variability in the GLFS-25 score could be explained by these variables.

There were significant correlations between back muscle strength and grip strength. Pearson's correlation coefficient was 0.787. When grip strength was applied as a variable instead of back muscle strength in the multiple regression model, grip strength became a significant contributor to the

Table 1 Mean values (standard deviation) of the GLFS-25 score classified by age and gender

Age strata (years)	*n*	Male	*n*	Female	*n*	Significance (*p*)
40–49	19	6.0 (4.6)	5	4.2 (4.3)	14	0.261
50–59	54	5.7 (8.0)	11	4.7 (4.0)	43	0.315
60–69	150	4.9 (6.8)	56	7.7 (8.7)	94	0.01
70–79	98	7.3 (10.0)	40	11.6 (11.2)	58	0.018
80 and older	37	14.9 (10.7)	16	21.7 (13.5)	21	0.048
Total	358	7.0 (9.0)	128	9.2 (10.2)	230	0.008

Table 2 Mean values, standard deviation, range of each variables of the participants

Variables	Male			Female			Total		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Age (years)	66.4	9.9	40–91	65.4	9.9	40–89	65.8	9.9	40–91
Low back pain (VAS)	14.0	20.6	0–75	14.0	21.0	0–96	14.0	20.8	0–96
Knee pain (VAS)	9.9	16.2	0–77	14.2	20.2	0–98	12.6	18.9	0–98
One-leg standing time (s)	35.8	20.4	2.6–60.0	34.2	21.3	2.4–60.0	34.8	21.0	2.4–60.0
TUG (s)	6.5	1.3	4.6–11.5	7.0	1.9	4.6–18.7	7.0	2.7	4.6–18.7
FR (cm)	35.5	6.0	16.3–48.3	33.1	5.2	17.2–46.7	33.7	6.3	16.3–48.3
Maximum stride (%)	0.78	0.12	0.47–0.99	0.79	0.12	0.4–1.2	0.79	0.12	0.39–1.16
10-m gait time (s)	5.1	1.1	3.5–10.3	5.7	1.5	3.5–13.4	5.5	1.4	3–13
Back muscle strength (kg)	94.1	28.4	27–202	51.4	15.8	11.5–108.5	67.3	29.7	12–202
Grip strength (kg)	38.1	7.9	10–66	23.7	5.1	6.0–39.5	29.4	9.5	6–66
% YAM (%)	82.8	16.7	52–146	76.8	16.3	35–134	79.0	16.7	35–146
Height (cm)	163.4	6.2	147.5–185.0	151.0	6.2	126.7–170	155.0	8.5	127–185
Weight (kg)	64.4	10.1	40.0–113.8	53.0	8.0	35.8–85.8	57.0	10.6	36–114
BMI (kg/m^2)	24.0	3.1	16.9–39.4	23.3	3.4	16.0–33.1	23.6	3.3	16–39.4
% Fat (%)	22.0	5.5	7.8–42.8	28.8	6.1	15.3–53.1	26.2	6.8	7.8–53.1

TUG timed up-and-go, *FR* functional reach, *% YAM* percent of young adult mean of bone mineral density, *BMI* body mass index

GLFS-25 score and did not substantially affect the results of other variables (Table 5).

Discussion

Recently, the GLFS-25 was developed to measure the degree of LS affecting an individual, and its validity and reliability have been confirmed [4]. Although its validity was confirmed by demonstrating a significant correlation with a representative generic health-related quality of life instrument, the EQ-5D, the direct evidence as to the association with an individual's functional capacity was lacking. This is the first study to reconfirm the validity of the GLFS-25 by demonstrating significant correlations of its scores with the outcome of physical performance tests.

The ICF uses the performance and capacity constructs to differentiate between patients' functional statuses [14]. Functional performance is related to what individuals can execute in their own natural environments. To assess the functional performance of patients with low back pain, for example, several instruments have been proposed in the literature, such as the Roland Morris Disability Questionnaire [15]. The capacity construct is used to describe an individual's ability to execute a task or an action in a standardized environment. To evaluate the capacity of patients with low back pain, a specific function test can be used, such as the sit-to-stand and timed up and go, among others [16]. Some authors insist on the importance of assessing both of these different aspects of functional status [16, 17]. The GLFS-25 is an easy and useful instrument for diagnosing and monitoring the LS. However, it is a self-reported, subjective questionnaire, and some objective physical function tests that correlate well with the GLFS-25 score are important as a complement to patient s' self-report. These performance tests are especially useful in monitoring the degree of LS and in developing a training program for overcoming LS, because people become more encouraged and motivated by improvement in the outcome of the actual physical capacity tests than improvement in the score of the questionnaire.

There have been reports on the reference value of physical function tests associated with LS [18, 19]. However, these reports lack information about which tests are more appropriate and important than others for evaluating LS. This is the first report to assess which specific physical performance tests are adequate for evaluating and monitoring the severity of LS.

A strength of this study is that we performed an extensive set of physical performance tests that are associated with QOL or ADLs [20, 21]. Another strength is that the coefficient of determination (R^2) in the multiple regression model was 0.637, indicating that two-thirds of the variability in the GLFS-25 score was explained by the variables used in this model. Therefore, this model fit well with the GLFS-25, and we found that musculoskeletal pain and physical performance explain a large part of what underlies locomotive syndrome.

There have been reports on the relationship between muscle strength and QOL. Hongo et al. [22] showed that back muscle strengthening resulted in a significant improvement in QOL in a randomized controlled study.

Table 3 Correlations between the GLFS-25 score and measured variables

Variables	Male Coefficients	Female Coefficients	Total Coefficients
Age	0.310***	0.415*****	0.360****
Low back pain (VAS)	0.441*****	0.581******	0.526******
Knee pain (VAS)	0.623******	0.552******	0.576******
One-leg standing time (s)	−0.469******	−0.460******	−0.458******
TUG (s)	0.528******	0.729******	0.688******
FR (cm)	−0.420*****	−0.343****	−0.380****
Maximum stride	−0.401*****	−0.430*****	−0.408*****
10-m gait time (s)	0.481******	0.674******	0.634******
Back muscle strength (kg)	−0.430*****	−0.421*****	−0.364****
Grip strength (kg)	−0.266**	−0.335****	−0.280**
% YAM (%)	−0.071	−0.300***	−0.236***
Height (cm)	−0.255**	−0.298***	−0.284***
Weight (kg)	−0.104	0.103	−0.042
BMI (kg/m^2)	0.036	0.270**	−0.182*
% Body fat (%)	−0.064	0.241**	−0.180*

Data are Pearson's correlation coefficients (r)

TUG timed up-and-go, *FR* functional reach, *% YAM* percent of young adult mean of bone mineral density, *BMI* body mass index

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.005$, **** $p < 0.001$, ***** $p < 0.0005$, ****** $p < 0.0001$

Table 4 Multiple regression analysis of factors associated with the GLFS-25 score

Variables	β	Significance (p)
		0.171
Age (years)	−0.009	0.845
Low back pain (VAS)	0.304	0.000
Knee pain (VAS)	0.282	0.000
TUG (s)	0.319	0.000
One-leg standing time (s)	−0.116	0.018
Back muscle strength (kg)	−0.090	0.032
10-m gait time (s)	0.055	0.398
FR (cm)	0.027	0.631
Maximum stride	−0.015	0.772

TUG timed up-and-go, *FR* functional reach

Table 5 Multiple regression analysis of factors associated with the GLFS-25 score

Variables	β	Significance (p)
		0.259
Age (years)	−0.021	0.652
Low back pain (VAS)	0.296	0.000
Knee pain (VAS)	0.265	0.000
TUG (s)	0.365	0.000
One-leg standing time (s)	−0.107	0.025
Grip strength (kg)	−0.099	0.020
10-m gait time (s)	0.047	0.484
FR (cm)	0.053	0.364
Maximum stride	−0.051	0.346

TUG timed up-and-go, *FR* functional reach

Our previous study showed that back muscle strength was significantly associated with QOL in middle-aged and elderly males [23]. Miyakoshi et al. [24] have shown that maintaining back muscle strength improves the QOL of postmenopausal women with osteoporosis. In the current study, back muscle strength was shown to be a good indicator of LS in both univariate and multivariate analyses; however, grip strength may be a safer measure for evaluating the degree of locomotive syndrome. Measuring back muscle strength requires participants to perform intense anaerobic exertion with the potential risk of acute low back pain or other medical accidents from an acute rise of blood pressure. Actually, we experienced two cases of acute low back pain after the back muscle strength test in this year's health checkups. Both participants were able to walk after a short rest. On the other hand, no such cases have been reported after the grip strength test in our health checkups. Although the best index remains controversial, grip strength has been found to be a good indicator of overall muscle strength [25] and an important predictor of disability [26]. In this study, grip strength had a weaker correlation with the GLFS-25 score compared to back muscle strength, but in the multivariate analysis, grip strength was comparable to back muscle strength. Therefore, we recommend measuring grip strength as a safe and reliable index for evaluating LS.

Balance impairment in older persons has been positively associated with measured parameters and their self-reported mobility disability [27, 28]. One-leg standing time with eyes open was significantly correlated with the GLFS-25 [5]; in one study, a one-leg standing time of less than 10 s indicated severe mobility disability [29]. The Japanese Orthopaedic Association recommends "standing on one leg with eyes open" as a beneficial exercise against LS [4]. In the current study, one-leg standing time with eyes open was shown to be a very good index for LS by both univariate and multivariate analyses.

The timed up-and-go test was found to predict ADLs disability [20]. The TUG is a reliable, safe, easy and functional measure for assessing mobility and predicting disability [14], making this test a very good candidate for standardized testing for LS. In the current study, both the TUG and 10-m gait time correlated significantly with the GLFS-25 score, but in the multivariate analysis, TUG proved to be a more significant contributor. This may be because TUG requires not only walking, but also complex components of physical movements that are important for ADLs, including standing up, turning, stopping and sitting down.

There have been no studies published to date focusing on the impact of knee pain and low back pain on the degree of LS. The results of our study revealed that knee and low back pain greatly impact the severity of locomotive syndrome. Systematic and comprehensive measures for the prevention and treatment of knee and low back pain are important to prevent people from experiencing locomotive syndrome. Although only 4 out of 25 questions in the GLFS-25 ask directly about physical pain, it is noteworthy that knee and low back pain correlate and affect the GLFS-25 score to such a great extent. Knee and low back pain significantly impact a person's ADLs, and the VAS scale of knee and low back pain may serve as an instant index for LS.

The GLFS-25 did not correlate substantially with an individual's physique. There was a weak negative correlation with height in both sexes and a weak positive correlation with BMI and % body fat in females. There was a also weak correlation with % YAM only in females. These results indicate that physique and bone mineral density (BMD) are not good indices for LS.

Several limitations of the study should be noted. First, the number of participants was not large enough to separately analyze the data according to sexes and age groups. However, the correlations of each variable with the GLFS-25 were not very different between sexes; therefore, in the multiple regression model, we performed the analysis with both sexes combined. Age correlated with the GLFS-25 score, but to a relatively small extent, and in the multiple regression model age was not a significant contributor. Therefore, it may not be a problem that the analysis was done with all ages combined. This means that, although it is true elderly people tend to be more dependent, it is not due to age per se, but rather due to any pain, muscle weakness, impaired balance or decreased walking ability. There are certainly elderly people without much pain who maintain muscle strength, balance and walking ability. Second, there may be additional physical performance measures that could be tested and used for assessing LS, for example, reaction time to evaluate agility and 30-s sit-ups for muscular endurance [18], but we were limited by time and personnel. Lastly, using the calcaneus for measuring BMD might be a limitation, but this was the only available method for the basic health checkup.

Conclusion

We confirmed the validity of the GLFS-25 by demonstrating the significant correlation and association of its score with a series of functional performance tests. A useful set of physical function tests that has good correlation and makes a large contribution to the severity of LS was identified. The one-leg standing time with eyes open, timed up-and-go test and grip strength are easy, reliable and safe physical performance tests to evaluate and monitor the severity of an individual's LS as a complement to the GLFS-25. We have also revealed that knee and low back pain significantly impact the degree of LS. Further study is needed to identify the cutoff value of each physical performance test that is indicative of LS.

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Conflict of interest The authors declare that they have no conflict of interest.

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