*Article*

# A Simplified Screening Tool for the One-Leg Standing Test to Determine the Severity of Locomotive Syndrome

Takaomi Kobayashi [1] ![ORCID], Tadatsugu Morimoto [1,*] ![ORCID], Chisato Shimanoe [2] ![ORCID], Rei Ono [3], Koji Otani [4,*] ![ORCID] and Masaaki Mawatari [1]

[1] Department of Orthopaedic Surgery, Faculty of Medicine, Saga University, 5-1-1 Nabeshima, Saga 849-8501, Japan; takaomi_920@yahoo.co.jp (T.K.); mawatam@cc.saga-u.ac.jp (M.M.)
[2] Department of Pharmacy, Saga University Hospital, Saga 849-0937, Japan; chisatos@cc.saga-u.ac.jp
[3] Department of Physical Activity Research, National Institute of Health and Nutrition, National Institutes of Biomedical Innovation, Health and Nutrition, 1-23-1, Toyama, Shinjuku-ku, Tokyo 162-8636, Japan; ono@nibiohn.go.jp
[4] Department of Orthopaedic Surgery, Fukushima Medical University School of Medicine, Fukushima 960-1295, Japan
* Correspondence: sakiyuki0830@gmail.com (T.M.); kotani@fmu.ac.jp (K.O.); Tel.: +81-952-31-6511 (T.M.); +81-24-547-1276 (K.O.); Fax: +81-952-34-3157 (T.M.); +81-24-548-5505 (K.O.)

**Abstract:** This study determined the cut-off time for the one-leg standing test (OLST) to simply screen the severity of locomotive syndrome (LS). We conducted this cross-sectional study on 1860 community-dwelling residents (age, $70.5 \pm 9.5$ years old; males, $n = 826$; females, $n = 1034$) who underwent the OLST and completed the 25-question geriatric locomotive function scale (GLFS-25). Multivariate linear regression and multivariate logistic regression analyses were conducted to assess the relationship between the OLST and the GLFS-25 score and LS after adjusting for age, sex, and body mass index. A receiver operating characteristic (ROC) curve analysis was performed to calculate the optimal cut-off time of the OLST for determining LS severity. The multivariate linear regression and multivariate logistic regression analyses showed that the OLST was significantly associated with the GLFS-25 score and a diagnosis of LS. The optimal cut-off times of the OLST to screen LS-1, LS-2, and LS-3 were 42 s (sensitivity 65.8%, specificity 65.3%), 27 s (sensitivity 72.7%, specificity 72.5%), and 19 s (sensitivity 77.4%, specificity 76.8%), respectively. We developed a simplified screening tool for the OLST to determine LS severity.

**Keywords:** locomotive syndrome; one-leg standing test; screening; 25-question geriatric locomotive function scale

## 1. Introduction

With the aging of society, the Japanese Orthopaedic Association (JOA) has spread the concept of 'locomotive syndrome' (LS) and developed a diagnostic tool called the 25-question geriatric locomotive function scale (GLFS-25) [1–3]. The GLFS-25 includes 25 questionnaire items graded on a 5-point scale, for a total possible score of 0–100 (Figure 1); total scores of 0–6 points, 7–15 points, 16–23 points, and 24–100 points are defined as non-LS, LS-1, LS-2, and LS-3, respectively [2,3]. Locomotion training is encouraged to prevent exacerbating LS-1, orthopedic consultation is considered for the scrutiny and treatment of LS-2, and relevant surgical treatment is thought to be efficacious for the treatment of LS-3 [3].

However, despite the precision of the GLFS-25 and its management, its complexity remains a major limitation, especially for elderly individuals, and the response rate reportedly ranges from 50% to 70% [4,5]. Accordingly, the relationship between the GLFS-25 and various physical performance tests (e.g., grip strength, maximum stride, timed up-and-go, one-leg standing test [OLST], and gait speed) has been investigated [6–13].

## 25-QUESTION GERIATRIC LOCOMOTIVE FUNCTION SCALE (GLFS-25)

**BODY PAIN** — **POINT**

| | | | | | |
|---|---|---|---|---|---|
| 1. Did you have any pain (including numbness) in your neck or upper limbs? | 0 No pain | 1 Mild pain | 2 Moderate pain | 3 Considerable pain | 4 Severe pain |
| 2. Did you have any pain in your back, lower back or buttocks? | 0 No pain | 1 Mild pain | 2 Moderate pain | 3 Considerable pain | 4 Severe pain |
| 3. Did you have any pain (including numbness) in your lower limbs? | 0 No pain | 1 Mild pain | 2 Moderate pain | 3 Considerable pain | 4 Severe pain |
| 4. To what extent has it been painful to move your body in daily life? | 0 No pain | 1 Mild pain | 2 Moderate pain | 3 Considerable pain | 4 Severe pain |

**MOVEMENT-RELATED DIFFICULTY**

| | | | | | |
|---|---|---|---|---|---|
| 5. To what extent has it been difficult to get up from a bed or lie down? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 6. To what extent has it been difficult to stand up from a chair? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 7. To what extent has it been difficult to walk inside the house? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |

**USUAL CARE**

| | | | | | |
|---|---|---|---|---|---|
| 8. To what extent has it been difficult to put on and take off shirts? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 9. To what extent has it been difficult to put on and take off trousers and pants? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 10. To what extent has it been difficult to use the toilet? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 11. To what extent has it been difficult to wash your body in the bath? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 14. To what extent has it been difficult to keep yourself neat? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |

**SOCIAL ACTIVITIES**

| | | | | | |
|---|---|---|---|---|---|
| 12. To what extent has it been difficult to go up and down stairs? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 13. To what extent has it been difficult to walk briskly? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 15. How far can you keep walking without rest? | 0 More than 2-3 km | 1 Approximately 1 km | 2 Approximately 300 m | 3 Approximately 100 m | 4 Approximately 10 m |
| 16. To what extent has it been difficult to go out to visit neighbors? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 17. To what extent has it been difficult to carry objects weighing 2 kg? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 18. To what extent has it been difficult to go out using public transportation? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 19. To what extent have simple tasks and housework been difficult? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 20. To what extent have load-bearing tasks and housework been difficult? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 21. To what extent has it been difficult to perform sports activities? | 0 Not difficult | 1 Mildly difficult | 2 Moderately difficult | 3 Considerably difficult | 4 Extremely difficult |
| 22. Have you been restricted from meeting your friends? | 0 Not restricted | 1 Slightly restricted | 2 Restricted about half the time | 3 Considerably restricted | 4 Gave up all activities |
| 23. Have you been restricted from joining social activities? | 0 Not restricted | 1 Slightly restricted | 2 Restricted about half the time | 3 Considerably restricted | 4 Gave up all activities |

**COGNITIVE**

| | | | | | |
|---|---|---|---|---|---|
| 24. Have you ever felt anxious about falls in your house? | 0 Have not felt anxious | 1 Have occasionally felt anxious | 2 Have sometimes felt anxious | 3 Have often felt anxious | 4 Have constantly felt anxious |
| 25. Have you ever felt anxious about being unable to walk in the future? | 0 Have not felt anxious | 1 Have occasionally felt anxious | 2 Have sometimes felt anxious | 3 Have often felt anxious | 4 Have constantly felt anxious |

**NON-LS** (0–6 POINTS)　**LS-1** (7–15 POINTS)　**LS-2** (16–23 POINTS)　**LS-3** (24–100 POINTS)

TOTAL SCORE _____ POINTS

◆ Locomotion training is encouraged to prevent exacerbating LS-1.
◆ Orthopaedic consultation is considered for the scrutiny and treatment of LS-2.
◆ Relevant surgical treatment is thought to be efficacious for the treatment of LS-3.

**Figure 1.** The GLFS-25 questionnaire items. *GLFS*-25, 25-question geriatric locomotive function scale; *LS*, locomotive syndrome.

Among them, the OLST is one of the easiest physical performance tests to perform [6–12]. Furthermore, the OLST does not require special testing equipment and it can be performed easily by anyone. However, while some investigators have assessed the best cut-off times of the OLST for diagnosing LS-2 [6–8], the results have varied. Furthermore, the cut-off time of the OLST for screening LS severity (i.e., LS-1, LS-2, and LS-3) in community-dwelling residents remains entirely unexplored. These problems may hinder the clinical application of the GLFS-25. The present study explored the optimal cut-off times of the OLST for simply screening LS severity in community-dwelling residents.

## 2. Materials and Methods

### 2.1. Study Design

The study was approved by the institutional ethics committee. The description of this paper was followed according to the standards for reporting diagnostic accuracy (STARD) [14]. We conducted a cross-sectional study on Japanese volunteers (≥40 years old) who were living in their own houses and able to walk independently and attended a 'basic health checkup' in Minami-Aizu Town and Tadami Town in Fukushima Prefecture, Japan, in 2017. The exclusion criteria were as follows: (1) individuals who did not provide their written informed consent to be interviewed; (2) individuals who did not complete all questions of the GLFS-25; (3) individuals who had comorbidities (i.e., cerebrovascular diseases, cardiovascular diseases, pulmonary diseases, and/or renal diseases [15]); and (4) individuals without evaluable data.

Among 4012 potentially eligible participants, individuals who did not provide their written informed consent to be interviewed (*n* = 636), did not complete all questions of

the GLFS-25 (*n* = 567), had comorbidities (*n* = 432), and lacked evaluable data (*n* = 517) were excluded (Figure 2). Ultimately, 1860 (male, *n* = 826; female, *n* = 1034; mean age, 70.5 ± 9.5 years old) were considered eligible for this study.

**Prototypical STARD diagram to report flow of participants through the study**
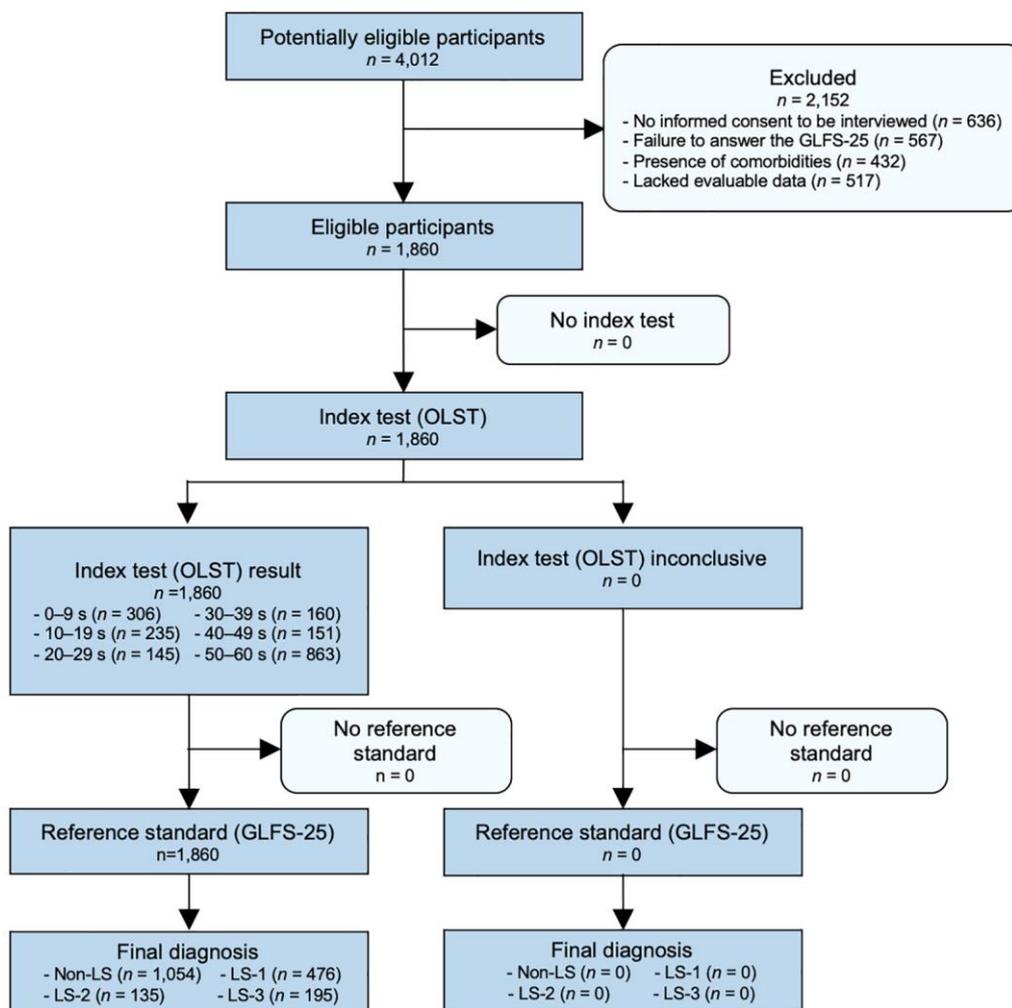


**Figure 2.** Prototypical STARD diagram reporting the flow of participants through the study. *STARD*, standards for reporting diagnostic accuracy; *GLFS-25*, 25-question geriatric locomotive function scale; *LS*, locomotive syndrome; *the OLST*, one-leg standing test.

### 2.2. GLFS-25

The GLFS-25 includes 25 questionnaire items, all of which feature a 5-point scale (Figure 1): no impairment—0 points, mild impairment—1 point, moderate impairment—2 points, considerable impairment—3 points, and severe impairment—4 points. The total possible score ranges from 0 to 100. The domain scores include body pain (items 1–4), movement-related difficulty (items 5–7), usual care (items 8–11 and 14), social activities (items 12, 13, and 15–23), and cognition (items 24 and 25). A GLFS-25 total score of 0–6 points, 7–15 points, 16–23 points, and 24–100 points were categorized into non-LS, LS-1, LS-2, and LS-3, respectively [2,3].

### 2.3. The OLST

The OLST was conducted with the patients' eyes open (and their hands on their hips) once for each leg. The test was continuously performed in the same time slot. The OLST was recorded with a stopwatch to measure the duration from when the subject raised

his/her leg until their leg was set back down on the floor (up to 60 s [s]). We recorded the average time of the two measurements., i.e., average OLST = (right OLST + left OLST)/2.

### 2.4. Statistical Analyses

We used the JMP® pro 16 software program (SAS Institute, Cary, NC, USA) for all analyses in this study. We set the level of significance (*p*-value) at 0.05. For assessments of the association between the GLFS-25 scores and the OLST, we conducted a simple regression analysis to calculate the crude regression coefficient (β) and a multivariate linear regression analysis with the ordinary least squares method to calculate the adjusted β controlled for age (years, continuous), sex (0: male, 1: female), and body mass index (kg/m², continuous). We used the GLFS-25 scores (points, continuous) as a dependent variable and the OLST (s, continuous) as an independent variable. For determinations of the association between the diagnosis of LS and the OLST findings, we conducted a univariate logistic regression analysis to calculate crude odds ratios (ORs) and a multivariate logistic regression analysis to calculate adjusted ORs that were controlled for age (years, continuous), sex (0: male, 1: female), and body mass index (kg/m², continuous). We used the LS (LS-1 or more [0: absent, 1: present], LS-2 or more [0: absent, 1: present], or LS-3 or more [0: absent, 1: present]) as a dependent variable and the OLST (s, continuous) as an independent variable. We conducted a receiver operating characteristic (ROC) curve analysis to calculate the optimal cut-off time for the OLST for identifying individuals with LS-1 or more, LS-2 or more, and LS-3 or more, with a preference for slightly higher sensitivity, as the tool is primarily intended for screening purposes. As in previous reports [7,8], a gender analysis was also performed. We assessed the discriminative ability of the model according to the area under the ROC curve (AUC). The AUC values of 0.50–0.59, 0.60–0.69, 0.70–0.79, 0.80–0.89, and 0.90–1.00 were classified as failure, poor, fair, good, and excellent, respectively [16].

### 3. Results

#### 3.1. Participants

Of the 1860 participants, 1054 (56.7%), 476 (25.6%), 135 (7.3%), and 195 (10.5%) were diagnosed with non-LS, LS-1, LS-2, and LS-3, respectively (Table 1). The median OLST was 45 s (interquartile range, 15–60 s).

**Table 1.** Clinical characteristics of the eligible participants in this study.

| Demographic | Overall (*n* = 1860) | Male (*n* = 826) | Female (*n* = 1034) |
|---|---|---|---|
| Age, years | 70.5 ± 9.5 | 70.9 ± 9.8 | 70.1 ± 9.1 |
| 40–70 years old | | | |
| Non-LS, *n* (%) | 655 (35.2) | 307 (37.2) | 348 (33.7) |
| LS-1, *n* (%) | 195 (10.5) | 64 (7.7) | 131 (12.7) |
| LS-2, *n* (%) | 31 (1.7) | 10 (1.2) | 21 (2.0) |
| LS-3, *n* (%) | 35 (1.9) | 11 (1.3) | 24 (2.3) |
| 71–75 years old | | | |
| Non-LS, *n* (%) | 183 (9.8) | 103 (12.5) | 80 (7.7) |
| LS-1, *n* (%) | 99 (5.3) | 37 (4.5) | 62 (6.0) |
| LS-2, *n* (%) | 28 (1.5) | 6 (0.7) | 22 (2.1) |
| LS-3, *n* (%) | 29 (1.6) | 2 (0.2) | 27 (2.6) |
| ≥76 years old | | | |
| Non-LS, *n* (%) | 216 (11.6) | 120 (14.5) | 96 (9.3) |
| LS-1, *n* (%) | 182 (9.8) | 91 (11.0) | 91 (8.8) |
| LS-2, *n* (%) | 76 (4.1) | 37 (4.5) | 39 (3.8) |
| LS-3, *n* (%) | 131 (7.0) | 38 (4.6) | 93 (9.0) |

**Table 1.** *Cont.*

| Demographic | Overall (*n* = 1860) | Male (*n* = 826) | Female (*n* = 1034) |
|---|---|---|---|
| Body mass index, kg/m$^2$ | 23.6 ± 3.3 | 23.8 ± 2.9 | 23.5 ± 3.6 |
| GLFS-25 total score, points | 5 (2–12) | 4 (1–9) | 6 (3–14) |
| GLFS-25 domain score, points | | | |
| Body pain | 2 (1–4) | 2 (0–4) | 3 (1–5) |
| Movement-related difficulty | 0 (0–0) | 0 (0–0) | 0 (0–1) |
| Usual care | 0 (0–0) | 0 (0–0) | 0 (0–0) |
| Social activities | 2 (0–6) | 1 (0–5) | 3 (1–7) |
| Cognition | 0 (0–1) | 0 (0–1) | 0 (0–2) |
| OLST, s | 45 (15–60) | 47 (17–60) | 43 (15–60) |

*GLFS-25*, 25-question geriatric locomotive function scale; *LS*, locomotive syndrome; *OLST*, one-leg standing test. The values represent the mean ± standard deviation or median (interquartile range). The classification of age and sex is the same as that used by Seichi et al. [6].

### 3.2. Regression Analyses

The univariate and multivariate linear regression analyses showed that the OLST had significant associations with the GLFS-25 domain scores (i.e., movement-related difficulty, usual care, social activity, and cognition) and the total score (Table 2). The univariate and multivariate logistic regression analyses showed that the OLST had significant associations with the diagnoses of LS-1 or more, LS-2 or more, and LS-3 or more (Table 3).

**Table 2.** Univariate and multivariate linear regression analyses on the relationship between the GLFS-25 and the OLST.

| Dependent Variable | Independent Variable | Crude *β* (95% CI) | *p*-Value | Adjusted *β* * (95% CI) | *p*-Value |
|---|---|---|---|---|---|
| GLFS-25 total score, points | OLST, s | −0.24 (−0.26 to −0.22) | <0.001 | −0.19 (−0.21 to −0.16) | <0.001 |
| GLFS-25 domain score, points | | | | | |
| Body pain | OLST, s | −0.03 (−0.04 to −0.02) | <0.001 | −0.02 (−0.03 to −0.02) | <0.001 |
| Movement-related difficulty | OLST, s | −0.02 (−0.03 to −0.02) | <0.001 | −0.02 (−0.02 to −0.01) | <0.001 |
| Usual care | OLST, s | −0.03 (−0.03 to −0.02) | <0.001 | −0.02 (−0.03 to −0.02) | <0.001 |
| Social activities | OLST, s | −0.13 (−0.15 to −0.12) | <0.001 | −0.11 (−0.12 to −0.10) | <0.001 |
| Cognition | OLST, s | −0.02 (−0.02 to −0.01) | <0.001 | −0.02 (−0.02 to −0.01) | <0.001 |

*GLFS-25*, 25-question geriatric locomotive function scale; *OLST*, one-leg standing test; *β*, regression coefficient; *CI*, confidence interval. * Adjusted for age (years, continuous), sex (0: male, 1: female), and body mass index (kg/m$^2$, continuous).

**Table 3.** Univariate and multivariate logistic regression analyses on the relationship between the LS and the OLST.

| Dependent Variable | Independent Variable | Crude OR (95% CI) | *p*-Value | Adjusted OR * (95% CI) | *p*-Value |
|---|---|---|---|---|---|
| LS-1 or more | OLST, s | 0.96 (0.96 to 0.97) | <0.001 | 0.98 (0.97 to 0.98) | <0.001 |
| LS-2 or more | OLST, s | 0.95 (0.94 to 0.95) | <0.001 | 0.96 (0.95 to 0.97) | <0.001 |
| LS-3 or more | OLST, s | 0.93 (0.92 to 0.94) | <0.001 | 0.94 (0.93 to 0.95) | <0.001 |

*LS*, locomotive syndrome; *OLST*, one-leg standing test; *OR*, odds ratio; *CI*, confidence interval. *Adjusted for age (years, continuous), sex (0: male, 1: female), and body mass index (kg/m$^2$, continuous).

### 3.3. ROC Analyses

In all participants, the discriminative ability of the OLST model was considered fair to good (AUC 0.71–0.86). The optimal cut-off times of the OLST to screen LS-1 or more, LS-2 or more, and LS-3 or more were 42 s (sensitivity 65.8%, specificity 65.3%), 27 s (sensitivity 72.7%, specificity 72.5%), and 19 s (sensitivity 77.4%, specificity 76.8%), respectively (Figure 3).
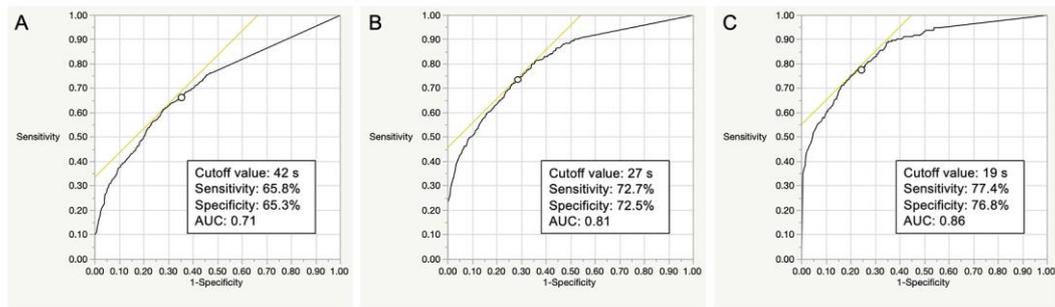
**Figure 3.** ROC analyses of the OLST to determine the optimal cut-off values for identifying LS-1 (**A**), LS-2 (**B**), and LS-3 (**C**) in the overall participants. *ROC*, receiver operating characteristic; *AUC*, area under the ROC curve; *OLST*, one-leg standing test; *LS*, locomotive syndrome.

In the male participants, the discriminative ability of the OLST model was considered fair to good (AUC 0.71–0.83). The optimal cut-off times of the OLST to screen LS-1 or more, LS-2 or more, and LS-3 or more were 42 s (sensitivity 64.2%, specificity 63.8%), 30 s (sensitivity 72.1%, specificity 69.5%), and 20 s (sensitivity 74.5%, specificity 72.7%), respectively (Figure 4).
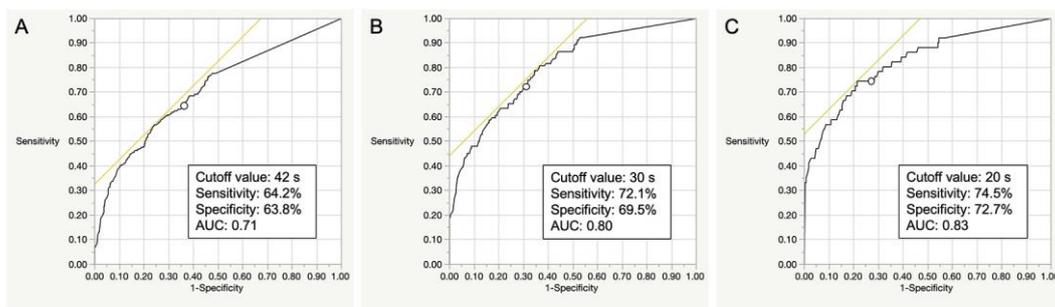


**Figure 4.** ROC analyses of the OLST to determine the optimal cut-off values for identifying LS-1 (**A**), LS-2 (**B**), and LS-3 (**C**) in the male participants. *ROC*, receiver operating characteristic; *AUC*, area under the ROC curve; *OLST*, one-leg standing test; *LS*, locomotive syndrome.

In the female participants, the discriminative ability of the OLST model was considered fair to good (AUC 0.71–0.87). The optimal cut-off times of the OLST to screen LS-1 or more, LS-2 or more, and LS-3 or more were 43 s (sensitivity 67.3%, specificity 66.0%), 26 s (sensitivity 74.3%, specificity 73.4%), and 19 s (sensitivity 78.5%, specificity 77.9%), respectively (Figure 5).
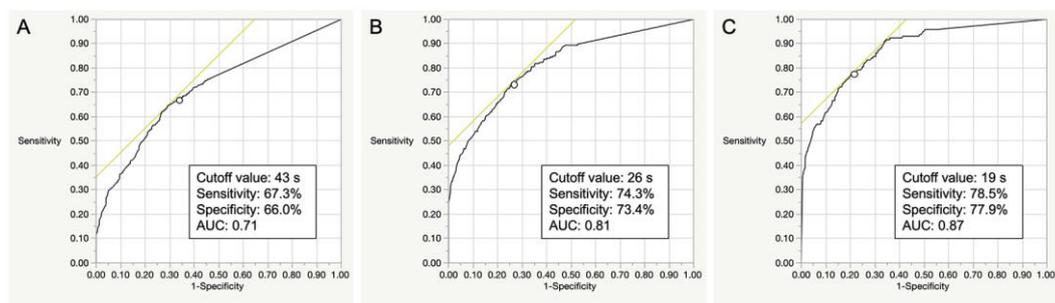


**Figure 5.** ROC analyses of the OLST to determine the optimal cut-off values for identifying LS-1 (**A**), LS-2 (**B**), and LS-3 (**C**) in the female participants. *ROC*, receiver operating characteristic; *AUC*, area under the ROC curve; *OLST*, one-leg standing test; *LS*, locomotive syndrome.

## 4. Discussion

To our knowledge, this is the first study to calculate the optimal cut-off time of the OLST for screening LS severity. Our main findings were as follows: (1) the OLST had significant associations with the GLFS-25 domain scores and the total score and the diagnoses of LS and (2) the optimal cut-off times of the OLST to screen LS-1 or more, LS-2 or more, and LS-3 or more were approximately 40 s, 30 s, and 20 s, respectively.

We found that the OLST had significant associations with the GLFS-25 domain scores and the total score and the diagnoses of LS. Similar to our findings, past studies observed a significant relationship between the OLST and the GLFS-25 total score [6–12]. Indeed, the OLST is thought to indicate both static (holding our body in a specific position) and dynamic balance function (maintaining balance while moving our body and walking– e.g., risk of falls [17–20]), a decrease in which leads to a decline in movement-related difficulty [21,22], usual care [21,22], social activity [21,22], and cognition [23]. Therefore, the OLST has significant associations with the GLFS-25 domain scores of movement-related difficulty (items 5–7), usual care (items 8–11 and 14), social activity (items 12, 13, and 15–23), and cognition (items 24 and 25), resulting in a clear association between the GLFS-25 total score and a related diagnosis of LS.

We found that the optimal cut-off times of the OLST to screen LS-1 or more, LS-2 or more, and LS-3 or more in community-dwelling residents (age, 40–96 years old) were approximately 40 s, 30 s, and 20 s, respectively. However, previous studies detected varied results (Table 4). Seichi et al. [6] found that the optimal cut-off times of the OLST to detect LS-2 or more were 19 s (sensitivity 69%, specificity 65%, AUC 0.73) in those 65–70 years old, 10 s (sensitivity 70%, specificity 71%, AUC 0.76) in those 71–75 years old, and 6 s (sensitivity 70%, specificity 67%, AUC 0.76) in those 75–96 years old. Muramoto et al. [7] found that the optimal cut-off times of the OLST to detect LS-2 or more were 21 s (sensitivity 71%, specificity 73%, AUC 0.75) in males and 15 s (sensitivity 69%, specificity 74%, AUC 0.78) in females. Nakamura et al. [8] found that the optimal cut-off time of the OLST to detect LS-2 or more was 15 s (sensitivity 57.1%, specificity 93.8%, AUC 0.74) in females.

**Table 4.** Summary of previous reports regarding cut-off values of the OLST for LS-2 or more.

| Study | Subject (Number of Subjects) | Body Mass Index (kg/m²) | Cut-off Time (s) | Sensitivity (%) | Specificity (%) | AUC |
|---|---|---|---|---|---|---|
| Seichi et al., 2014 [6] | Overall (*n* = 880) | NA | 9 | 71 | 72 | 0.79 |
| | 65–70 years (*n* = 142) | NA | 19 | 69 | 65 | 0.73 |
| | 71–75 years (*n* = 234) | NA | 10 | 70 | 71 | 0.76 |
| | ≥76 years (*n* = 504) | NA | 6 | 70 | 67 | 0.76 |
| Muramoto et al., 2013 [7] | Male (*n* = 167) | 24.0 ± 2.9 | 21 | 71 | 73 | 0.75 |
| | Female (*n* = 239) | 23.5 ± 3.4 | 15 | 69 | 74 | 0.78 |
| Nakamura et al., 2015 [8] | Female (*n* = 126) | 23.3 ± 3.0 | 15 | 57 | 94 | 0.74 |
| Present study | Overall (*n* = 1860) | 23.6 ± 3.3 | 27 | 73 | 73 | 0.81 |
| | Male (*n* = 826) | 23.8 ± 2.9 | 30 | 72 | 70 | 0.80 |
| | Female (*n* = 1034) | 23.5 ± 3.6 | 26 | 74 | 73 | 0.81 |

*OLST*, one-leg standing test; *LS*, locomotive syndrome; *AUC*, area under the receiver operating characteristic curve; *NA*, not available.

These inconsistencies may be multifactorial, with possible responsible factors including differences in the subjects, procedures, and statistical analyses. To be more detailed, the subjects were not unified, including the participants who attended a basic health checkup (age, 40–96) in this study, outpatients of clinics and hospitals (age, 65–96 years old) [6], the participants who attended a basic health checkup (age, 60–88 years old) [7], and the female participants who attended a basic health checkup (age, 34–84 years old) [8]. The measurements of the OLST were also not unified, including average time (once on each leg) [6], average time (twice on each leg) [7], and maximum time (once on each leg) [8].

Approaches to selecting a cut-off point on an ROC curve were also not unified, including a cut-off point where the sum of sensitivity and specificity was maximal [6], where sensitivity and specificity had similar values [7], and where false negatives and false positives had similar values [8]. Given the above, we recommend using our approach as a screening tool for community-dwelling residents.

To provide the Supplementary Information, we measured the cut-off time of the OLST according to age and sex (Appendix A, Figures A1–A6) in the same classification as Seichi et al. [6]. The optimal cut-off time differs among the age and sex groups. To be more precise, older age was associated with a lower cut-off time, and the cut-off time for the male participants was higher than that for the female participants in those ≥71 years old. Nevertheless, these results may be too complex to use in the clinical field. When we use the simplified screening tool (cut-off time of the OLST for identifying LS-1 or more, 40 s; LS-2 or more, 30 s; and LS-3 or more, 20 s) regardless of age and sex, LS severity may be underestimated in those 40–70 years old and overestimated in those ≥76 years old. Importantly, the rates of LS-1 or more increased with age (Table 1), with them being 261/916 (27.2%) in those 40–70 years old, 156/339 (46.0%) in those 71–75 years old, and 389/605 (64.3%) in those ≥76 years old. From the viewpoint of screening, the simplified screening tool may be clinically useful regardless of age or sex. However, 6.0% (60/1005) of the participants with an OLST of >40 s were diagnosed with LS-2 or more (Appendix A, Table A1), so we should bear in mind that further assessments with official diagnostic tools (i.e., the GLFS-25, the two-step test, and the stand-up test [3]) are necessary after using this simplified screening tool.

Several limitations associated with this study warrant being mentioned. First, we calculated only the average times of the OLST on both legs. It seems difficult to accurately evaluate body balancing by an evaluation at the maximum or minimum time. For instance, if one leg is normal and the OLST is 60 s while the other leg suffers from knee osteoarthritis and the OLST is 20 s, the evaluation at the maximum value overestimates to 60 s or at the minimum value, it underestimates to 20 s. Both legs are required for standing and walking, so the average time should be evaluated. Second, sample bias may have affected our results. All eligible participants were able to walk by themselves and answer the GLFS-25. Therefore, their physical performance tests may have been better than those of average elderly individuals. Third, the test–retest reliability and interrater reliability were not assessed in this study. However, in previous studies, these values were reported to be acceptable [21,24,25]. Fourth, 60 s was adopted as the maximum time for the OLST in this study, which led to a non-normal distribution of the parameter. However, this measurement method has been traditionally used in previous studies [6,26,27], and it is clinically difficult to test for more than 60 s on both legs from a simplicity standpoint. Finally, and most importantly, the present study developed a simplified screening tool without validation. Additional validation studies with a different population are therefore necessary.

## 5. Conclusions

We developed a simplified screening tool for community-dwelling residents (≥40 years old); the optimal cut-off times of the OLST to screen LS-1 or more, LS-2 or more, and LS-3 or more were approximately 40 s, 30 s, and 20 s, respectively. It is necessary to clinically apply this simple screening tool for the early detection, prevention, and treatment of LS.

**Institutional Review Board Statement:** All of the procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional review board of Fukushima Medical University School of Medicine (No. 2907) and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The datasets used during the current study are not publicly available because of patient confidentiality but are available from the corresponding author on reasonable request.

**Conflicts of Interest:** All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interests (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements) or non-financial interests (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this manuscript.

## Appendix A
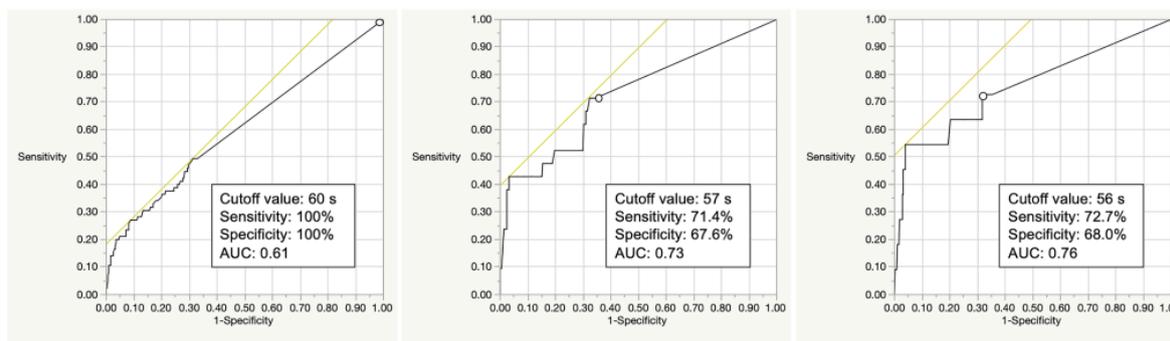


**Figure A1.** ROC analyses of the OLST to determine the optimal cut-off values for identifying LS-1, LS-2, and LS-3 in males 40–70 years old. *ROC*, receiver operating characteristic; *OLST*, one-leg standing test; *LS*, locomotive syndrome; *AUC*, area under the ROC curve.
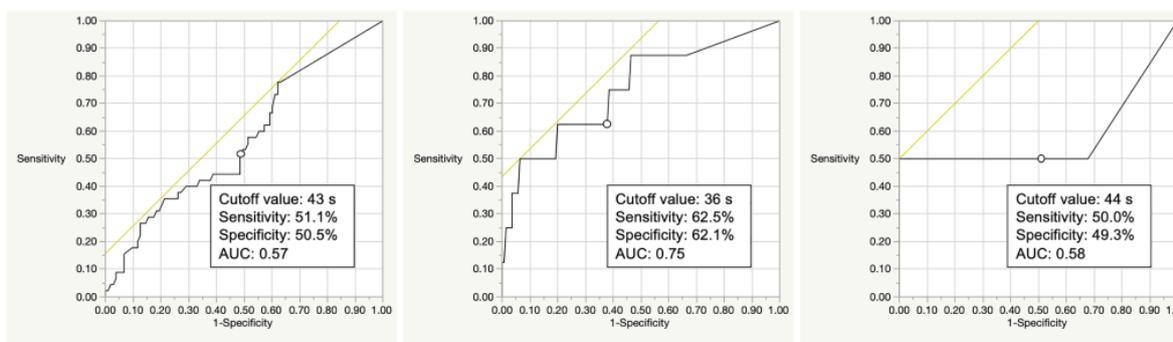


**Figure A2.** ROC analyses of the OLST to determine the optimal cut-off values for identifying LS-1, LS-2, and LS-3 in males 71–75 years old. *ROC*, receiver operating characteristic; *OLST*, one-leg standing test; *LS*, locomotive syndrome; *AUC*, area under the ROC curve.
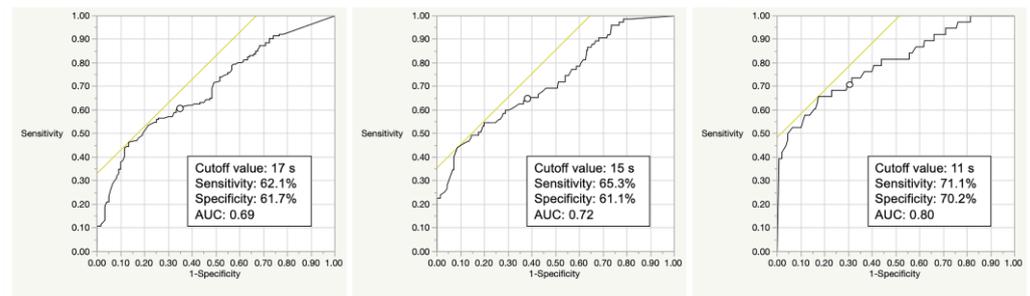
**Figure A3.** ROC analyses of the OLST to determine the optimal cut-off values for identifying LS-1, LS-2, and LS-3 in males ≥ 76 years old. *ROC*, receiver operating characteristic; *OLST*, one-leg standing test; *LS*, locomotive syndrome; *AUC*, area under the ROC curve.
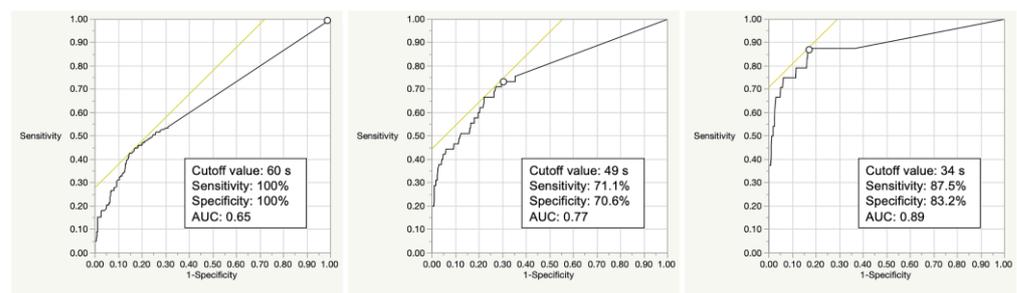


**Figure A4.** ROC analyses of the OLST to determine the optimal cut-off values for identifying LS-1, LS-2, and LS-3 in females 40–70 years old. *ROC*, receiver operating characteristic; *OLST*, one-leg standing test; *LS*, locomotive syndrome; *AUC*, area under the ROC curve.
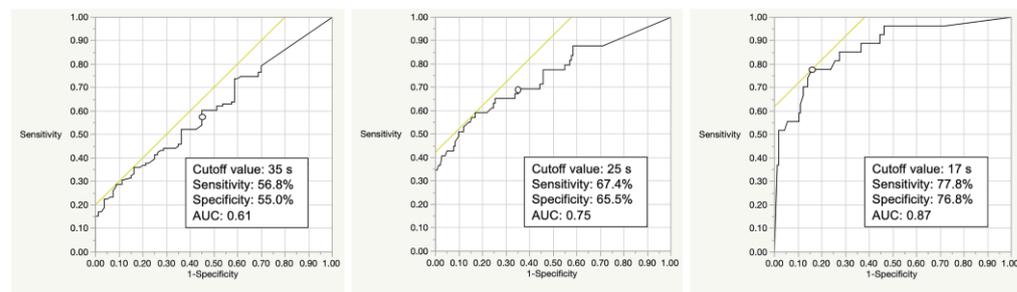


**Figure A5.** ROC analyses of the OLST to determine the optimal cut-off values for identifying LS-1, LS-2, and LS-3 in females 71–75 years old. *ROC*, receiver operating characteristic; *OLST*, one-leg standing test; *LS*, locomotive syndrome; *AUC*, area under the ROC curve.
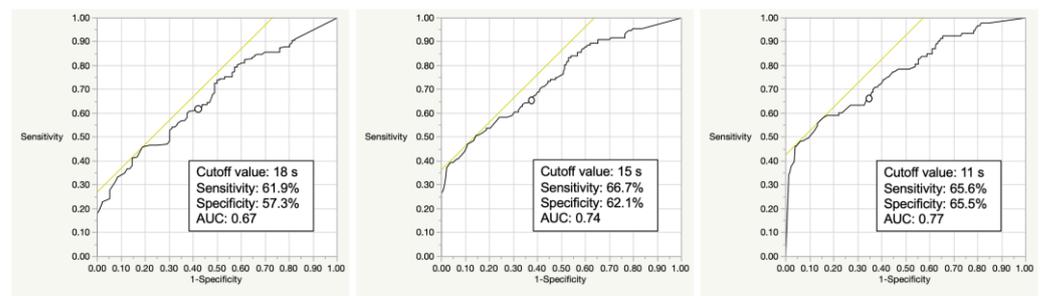


**Figure A6.** ROC analyses of the OLST to determine the optimal cut-off values for identifying LS-1, LS-2, and LS-3 in females ≥ 76 years old. *ROC*, receiver operating characteristic; *OLST*, one-leg standing test; *LS*, locomotive syndrome; *AUC*, area under the ROC curve.

**Table A1.** The relationship between the simple screening test of the OLST and the distribution of LS diagnoses.

| | OLST | | | |
|---|---|---|---|---|
| | 0–20 s (*n* = 556) | 21–30 s (*n* = 145) | 31–40 s (*n* = 154) | 41–60 s (*n* = 1005) |
| Non-LS (*n* = 1054) | 183 | 65 | 89 | 717 |
| LS-1 (*n* = 476) | 156 | 50 | 42 | 228 |
| LS-2 (*n* = 135) | 65 | 15 | 14 | 41 |
| LS-3 (*n* = 195) | 152 | 15 | 9 | 19 |

*OLST*, one-leg standing test; *LS*, locomotive syndrome.

**References**

1. Nakamura, K. A "super-aged" society and the "Locomotive Syndrome". *J. Orthop. Sci.* **2008**, *13*, 1–2. [CrossRef]
2. Seichi, A.; Hoshino, Y.; Doi, T.; Akai, M.; Tobimatsu, Y.; Iwaya, T. Development of a screening tool for risk of locomotive syndrome in the elderly: The 25-question Geriatric Locomotive Function Scale. *J. Orthop. Sci.* **2012**, *17*, 163–172. [CrossRef] [PubMed]
3. The Japanese Orthopedic Association Official Locomotive Syndrome Prevention Awareness Official Website. Available online: https://locomo-joa.jp (accessed on 28 August 2022).
4. Kobayashi, T.; Morimoto, T.; Shimanoe, C.; Ono, R.; Otani, K.; Mawatari, M. Development of a tool for screening the severity of locomotive syndrome by the loco-check. *J. Orthop. Sci.* **2022**, *27*, 701–706. [CrossRef] [PubMed]
5. Kobayashi, T.; Morimoto, T.; Shimanoe, C.; Ono, R.; Otani, K.; Mawatari, M. Development of a simple screening tool based on the 5-question geriatric locomotive function scale for locomotive syndrome. *J. Orthop. Sci.* **2022**, *27*, 913–920. [CrossRef] [PubMed]
6. Seichi, A.; Hoshino, Y.; Doi, T.; Akai, M.; Tobimatsu, Y.; Kita, K.; Iwaya, T. Determination of the optimal cutoff time to use when screening elderly people for locomotive syndrome using the one-leg standing test (with eyes open). *J. Orthop. Sci.* **2014**, *19*, 620–626. [CrossRef] [PubMed]
7. Muramoto, A.; Imagama, S.; Ito, Z.; Hirano, K.; Tauchi, R.; Ishiguro, N.; Hasegawa, Y. Threshold values of physical performance tests for lo-comotive syndrome. *J. Orthop. Sci.* **2013**, *18*, 618–626. [CrossRef] [PubMed]
8. Nakamura, M.; Hashizume, H.; Oka, H.; Okada, M.; Takakura, R.; Hisari, A.; Yoshida, M.; Utsunomiya, H. Physical Performance Measures Associated With Locomotive Syndrome in Middle-Aged and Older Japanese Women. *J. Geriatr. Phys. Ther.* **2015**, *38*, 202–207. [CrossRef] [PubMed]
9. Muramoto, A.; Imagama, S.; Ito, Z.; Hirano, K.; Ishiguro, N.; Hasegawa, Y. Spinal sagittal balance substantially influences locomotive syndrome and physical performance in community-living middle-aged and elderly women. *J. Orthop. Sci.* **2016**, *21*, 216–221. [CrossRef]
10. Ikemoto, T.; Inoue, M.; Nakata, M.; Miyagawa, H.; Shimo, K.; Wakabayashi, T.; Arai, Y.-C.P.; Ushida, T. Locomotive syndrome is associated not only with physical capacity but also degree of depression. *J. Orthop. Sci.* **2016**, *21*, 361–365. [CrossRef]
11. Nishimura, A.; Ito, N.; Asanuma, K.; Akeda, K.; Ogura, T.; Sudo, A. Do exercise habits during middle age affect locomotive syndrome in old age? *Mod. Rheumatol.* **2018**, *28*, 334–338. [CrossRef]
12. Taniguchi, M.; Ikezoe, T.; Tsuboyama, T.; Tabara, Y.; Matsuda, F.; Ichihashi, N. Additional file 1 of Prevalence and physical characteristics of locomotive syndrome stages as classified by the new criteria 2020 in older Japanese people: Results from the Nagahama study. *BMC Geriatr.* **2021**, *21*, 489. [CrossRef]
13. Kobayashi, T.; Morimoto, T.; Ono, R.; Otani, K.; Mawatari, M. Is grip strength useful in screening to predict the severity of locomotive syndrome? *J. Orthop. Sci.* 2022, in press. [CrossRef]
14. Bossuyt, P.M.; Reitsma, J.B.; Bruns, D.E.; Gatsonis, C.A.; Glasziou, P.P.; Irwig, L.; Lijmer, J.G.; Moher, D.; Rennie, D.; de Vet, H.C.W.; et al. STARD 2015: An updated list of essential items for reporting diagnostic accuracy studies. *BMJ* **2015**, *28*, 351.
15. Kobayashi, T.; Morimoto, T.; Shimanoe, C.; Ono, R.; Otani, K.; Mawatari, M. The association of comorbidities with the 25-question geriatric locomotive function scale and the diagnosis of locomotive syndrome. *J. Orthop. Sci.* **2022**, *28*, 453–459. [CrossRef] [PubMed]
16. Tavares, W.M.; Machado, A.G.; Matushita, H.; Please, J.P. CSF markers for diagnosis of bacterial meningitis in neurosurgical postop-erative patients. *Arq. Neuropsiquiatr.* **2006**, *64*, 592–595. [CrossRef] [PubMed]
17. Bongue, B.; Dupré, C.; Beauchet, O.; Rossat, A.; Fantino, B.; Colvez, A. A screening tool with five risk factors was developed for fall-risk prediction in community-dwelling elderly. *J. Clin. Epidemiol.* **2011**, *64*, 1152–1160. [CrossRef]
18. Kikuchi, R.; Kozaki, K.; Iwata, A.; Hasegawa, H.; Toba, K. Evaluation of risk of falls in patients at a memory impairment outpatient clinic. *Geriatr. Gerontol. Int.* **2009**, *9*, 298–303. [CrossRef] [PubMed]
19. Sakamoto, K.; Nakamura, T.; Hagino, H.; Endo, N.; Mori, S.; Muto, Y.; Harada, A.; Nakano, T.; Itoi, E.; Yoshimura, M.; et al. Effects of unipedal standing balance exercise on the prevention of falls and hip fracture among clinically defined high-risk elderly individuals: A randomized controlled trial. *J. Orthop. Sci.* **2006**, *11*, 467–472. [CrossRef]
20. Sakamoto, K.; Endo, N.; Harada, A.; Sakada, T.; Tsushita, K.; Kita, K.; Hagino, H.; Sakai, A.; Yamamoto, N.; Okamoto, T.; et al. Why not use your own body weight to prevent falls? A randomized, controlled trial of balance therapy to prevent falls and fractures for elderly people who can stand on one leg for ≤15 s. *J. Orthop. Sci.* **2013**, *18*, 110–120. [CrossRef]

21. Michikawa, T.; Nishiwaki, Y.; Takebayashi, T.; Toyama, Y. One-leg standing test for elderly populations. *J. Orthop. Sci.* **2009**, *14*, 675–685. [CrossRef]

22. Islam, M.M.; Nasu, E.; Rogers, M.E.; Koizumi, D.; Rogers, N.L.; Takeshima, N. Effects of combined sensory and muscular training on balance in Japanese older adults. *Prev. Med.* **2004**, *39*, 1148–1155. [CrossRef] [PubMed]

23. Veldema, J.; Jansen, P. The Relationship among Cognition, Psychological Well-being, Physical Activity and Demographic Data in People over 80 Years of Age. *Exp. Aging Res.* **2019**, *45*, 400–409. [CrossRef] [PubMed]

24. Giorgetti, M.M.; Harris, B.A.; Jette, A. Reliability of clinical balance outcome measures in the elderly. *Physiother. Res. Int.* **1998**, *3*, 274–283. [CrossRef] [PubMed]

25. Khanal, P.; He, L.; Stebbings, G.K.; Onambele-Pearson, G.L.; Degens, H.; Williams, A.G.; Thomis, M.; Morse, C.I. Static one-leg standing balance test as a screening tool for low muscle mass in healthy elderly women. *Aging Clin. Exp. Res.* **2021**, *33*, 1831–1839. [CrossRef] [PubMed]

26. Qin, X.; Mao, Y.; Wang, H.; Wu, H.; Xu, Y.; Zhao, J. Effects of the Otago Exercise Program in older hypertensive patients with pre-frailty. *J. Phys. Ther. Sci.* **2022**, *34*, 509–514. [CrossRef]

27. Li, F.; Harmer, P.; Fisher, K.J.; McAuley, E.; Chaumeton, N.; Eckstrom, E.; Wilson, N.L. Tai Chi and Fall Reductions in Older Adults: A Randomized Controlled Trial. *J. Gerontol. Ser. A* **2005**, *60*, 187–194. [CrossRef]